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UNITED STATES NUCLEAR REGULATORY COMMISSION

In the matter of:

EVIDENTIARY HEARING AT
SACRAMENTO MUNICIPAL
UTILITY DISTRICT
(RANCHO SECO)

DOCKET NO. 50-312

Place: Sacramento, Ca.

Date: Tues., Feb. 26, 1980 **Pages:** 165 - 279

INTERNATIONAL VERBATIM REPORTERS, INC.
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UNITED STATES

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Conference Room W-1150

U.S. Federal Building

2800 Cottage Way

Sacramento, California

Tuesday, February 26, 1980

The Atomic Safety and Licensing Board met, pursuant to recess, at 9:00 o'clock a.m., the Honorable Elizabeth Bowers, Chairman of the Board, presiding.

PRESENT:

ELIZABETH BOWERS, Chairperson

MR. FREDERICK J. SHON, Member

DR. RICHARD F. COLE, Member

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P R O C E E D I N G S

CHAIRPERSON BOWER: We would like to begin.

Now, I am going to repeat very briefly the introduction of the Board. Some of you, I am sure, have been here at other proceedings. You were here, perhaps, February 6, when we had a prehearing conference. But, for those of you who are attending for the first time, I will briefly introduce the Board and then, call for appearance of the parties.

My name is Elizabeth Bowers, I am a lawyer, and I am a Member of the Kansas Bar. I have been involved in Federal Administrative hearings for approximately 28 years. The first 15 years as Government Trial Counsel and the last 12 or so years as Presiding Officer for various departments. I have been in this program almost 8 years.

On my right, is Mr. Federick Shon. He is an engineer who is an expert in nuclear reactors. He has had a long and distinguished career in private industry and in Government. As I mentioned February 6, this is almost like coming home for him, because he spent a number of years at the Lawrence Livermoore Laboratory.

On my left, is Dr. Richard F. Cole, he is an environmental engineer. When he was on the faculty of the University of North Carolina Chapel Hill, he was asked to set up a special program in Guadamala on environmental concerns.

He spent 4 years there before returning to Chapel Hill. Both Mr. Shon and Dr. Cole have been with this program over 7 years.

Now, let me call for appearances the parties. Is the licensee present?

MR. BAXTER: Mrs. Bowers and Members of the Board, appearing on behalf of the licensee of Sacramento Municipal Utility District, I am Thomas A. Baxter and to my right is Lex K. Larson. We are of the firm Shaw, Pittmen, Potts & Trowbridge.

CHAIRPERSON BOWER: Is the NRC Staff present?

MR. LEWIS: Mrs. Bowers and Members of the Board, my name is Steven Lewis. I am accompanied by Richard Black, we are Counsel for the NRC Staff. We also have with us Mr. Robert Capra, who is the project manager for this proceeding.

CHAIRPERSON BOWER: Is the California Energy Commission Energy Commission present?

MR. ELLISON: Yes, Mrs. Bowers. My name is Christopher Ellison, I am Counsel for the California Energy Commission. On my right is Mr. Clifford Webb, who is the project manager for the Commission on this proceeding.

CHAIRPERSON BOWER: Now, at our prehearing conference on February 6, we were dismayed to learn that one of the public interest intervenor groups Hursh & Castro decided to withdraw from this proceeding.

A week ago, I had a phone call from public information specialist if our Bethezda, Maryland office telling me chat she had been informed by a Sacramento reporter that Friends of the Earth, FOE represented by Mr. Reme had scheduled a press conference for the next day and he understood that the purpose of the conference was to announce that they were withdrawing from the proceeding.

We have heard nothing from them. We did leave very early Monday morning to come here, and so, if something was filed we simply didn't receive it. Let me check with the parties.

Mr. Lewis, do you have any information on this?

Sir, are you part of FOE?

MR. VANDERVELDEN: As a matter of fact, yes, I am. We did on February 19 mail a letter to you indicating our position with regard to this and I think, I may address that letter when it is more appropriate during the limited appearance section.

CHAIRPERSON BOWER: But, you are no longer proceeding as a party, is that correct?

MR. VANDERVELDEN: Yes, I think we make that rather clear in the letter. I don't think that you probably did get the letter.

CHAIRPERSON BOWER: We didn't.

MR. VANDERVELDEN: I may have copies for you, if you would like?

I think I may have some copies.

MR. COLE: Is that a copy of the letter?

MR. VANDERVELDEN: Yes, sir.

CHAIRPERSON BOWER: It is a long letter, we don't want to take time now to read the whole thing, we can read it at the midmorning recess.

MR. VANDERVELDEN: I will summarize it.

MR. BAXTER: Mrs. Bowers, could we have an identification for the record of the person in the audience?

CHAIRPERSON BOWER: Sir, will you please identify yourself?

MR. VANDERVELDEN: My name is Mark Vandervelden, a Sacramento representative for Friends of the Earth.

CHAIRPERSON BOWER: Well, we mentioned February 6.

We would like to proceed. Now at our prehearing conference February 6, when the question of opening statements by the parties came up we said that we understood why the parties might feel it was appropriate to make an opening statement, but we want that to be very, very brief. We are here today and we will be here this evening and tomorrow to hear limited appearance statements from the general public.

But, before we actually start I would like to mention something briefly. This is not a town meeting hall. This is not forum where you show your support or your disapproval by applause or laughter or booing or whatever you think is appropriate at the time. There will be an opportunity at recesses and at the luncheon break to speak to those who have spoken that you wish to express your support or opposition.

This is a judicial proceeding. In all Federal Government departments and agencies, these administrative hearings are conducted by one person, a Federal Administrative Law Judge. Because of the technical questions in the matters that we consider, Congress decided in its wisdom many years ago that our proceedings should be conducted by a three-person Board. A lawyer who has had experience in Administrative hearings, and the appropriate technical people for the particular hearing.

I want to emphasize that this is a judicial proceeding, we want a verbatim transcript, we want to hear every word you have to say. The best way we can do that is for the audience to remain silent as if you were in a Federal Court.

Now, another point I would like to make, if there is any disruption of any kind, you are doing a disservice to those who wish to make limited appearance statements, because the time has been set for these two days. We want to hear from as many people as we possibly can.

Mr. Baxter?

MR. BAXTER: Mrs. Bowers, my opening remarks will be brief because we, too, are interested in proceeding with the limited appearance statements by members of the public.

I advised you at the prehearing conference on February 6,that licensee would like the opportunity to present an additional opening statement by a representative of the District's management. In order that we do not interfere with public statements today, however, we will defer with your permission the opening statement of John J. Mattimoe, Assistant General Manager and Chief Engineer of the District, until the afternoon session of tomorrow's hearing.

I have, however, distributed today to the Board and the parties copies of Mr. Mattimoe's remarks. In addition, copies of his statements are available on the side of the room and we invite members of the audience to have a copy.

First, I would like to briefly review the history of this case, because I feel it is important for members of the audience here to understand how we got here and why, in my view, there is integrity to this process in which we have all been so heavily engaged in recent months.

Immediately following the accident last year at Unit 2 of the Three Mile Island Nuclear Generating Station, the Nuclear Regulatory Commission became concerned with the capability of reactors designed by Babcock & Wilcox to respond to transients such as a loss of feedwater.

On April 28, 1979, the District shut down Rancho

Seco Nuclear Generating Station, another B & W reactor. On May 7, the NRC issued a number of orders confirming the shutdown of all B & W reactors. The order directed the District to undertake certain so-called short-term modifications at Rancho Seco before the plant could be returned to service.

The District implemented these modifications, the NRC Staff confirmed that they were completed satisfactorily, and Rancho Seco was returned to service of July 5, 1979.

In addition, the May 7 order directed the District to undertake certain long term actions not directly related to safety to enhance the plan's capability to respond to feedwater transients. Most of these long term actions have been completed and the remaider are well along in the implementation process.

The May 7 order was made effective immediately but the Commission provided that any person who's interest might be effected could request a hearing with respect to the order. Hearing requests were filed and on June 21, the Commission directed the establishment of an atomic safety and licensing board to rule on the hearing requests. Pursuant to standards set forth in the Rules of Practice and to conduct any hearing required.

The Commission also specified that three fundamental issues to be considered if the hearing were held. One, if the short term modifications provide reasonable assurance pending completion to the long term actions, that the facility will respond safely to feedwater transients.

Second, whether the licensee should be required to implement the long term actions as promptly as practicable.

Third, whether the long term actions provide continued reasonable assurance that the facility will respond safely to feedwater transients.

In addition, at an open meeting held last July, the Commission stated that the Board was not foreclosed from considering the question of licensee management competence.

There has never been any question that these issues specified by the NRC last spring define the scope of any hearing to be held as a result of the May 7 order.

Following a conference held here in Sacramento in early August, the Board determined that each of the requesting parties met the Commission standards for intervention in such proceedings and concluded that a hearing would be held. The Board also granted that a request by the California Energy Commission to participate in these proceedings as a representative of an interested state under provisions of the Commission's rules which afford an opportunity for such a representative to participate without taking a position on the issues.

In that capacity, the Energy Commission has raised certain questions to which we will respond here with evidence.

In early October, the Board issued a lengthy order ruling on the various contentions raised by the intervenors and admitted as matters in controversy to be decided here, those which were within the scope of the issues specified by the Commission.

Altogether, some 35 contentions and issues were raised and admitted. Later, the Board itself raised questions within the scope of these issues and contentions to which licensee and the NRC Staff are directed to respond with testimony.

These issues are broad in scope as well as many in number. They address many fundamental aspects of the B & W design and of the balance of plant design at Rancho Seco. The training and competence of Rancho Seco operaters and management, the adequacy of plant emergency and other operating procedures, the design and configuration of the control room, and the adequacy of the diagnostic information and controls available to the operators.

Virtually, the only significant issue which the Board decided not to hear, was offsite emergency planning. The Board rejected this issue because the Commission is addressing the adequacy of its emergency planning standards generically in a rule making proceeding.

At the same time, agencies of the State of California are conducting hearings on revisions to the State's emergency plans. One such hearing was held here in Sacramento earlier this month.

On the basis of the NRC's new rulemaking proceeding initiated in December the Energy Commission subsequently withdrew its appeal of the Board's ruling on this question.

From early October, when the contentions were defined, until mid January, the parties have been busy with the discovery process. Exchanging relevant information about the issues. During this period the District answered the questions posed by other parties. Made available drawers full of documents for inspection and copying and cooperated with requests for inspection of the plant itself.

In addition, three Rancho Seco operators voluntarily agreed to testify on their day off without the issuance of a subpoena at depositions called by the California Energy Commission.

So, from our standpoint, the development of the issues here and the exchange of information relevant to those issues, has been full, open, and vigorously pursued by the Board, the Energy Commission, the intervenors, and the licensee.

It does not detract from the integrity of this hearing that the Commission does not intend it to be another full scale investigation of the accident of Three Mile Island. This task was undertaken by the President's Commission, several committees of the Congress, the NR~'s own special inquiry group under the direction of Mitchell Rigovin, and several divisions of the Commissions Staff.

Neither is it appropriate or in the public interest for a hearing on this one plant to attempt to resolve the many important issues not unique to Babcock & Wilcox's reactors which are now being examined and acted upon by the nuclear industry and the NRC.

These are not being ignored. Proceedings to consider proposed rule changes will be initiated. The NRC Staff has presented the Commission with a proposed action plan to respond to and implement the recommendations of the various investigative groups I have mentioned.

Many of the short term recommendations of the TMI 2 Lessons Learned Task Force are being implemented right now at Rancho Seco during the current refueling outage as ordered by the Commission on January 2.

The testimony filed by the NRC Staff in this case provides the Board, the parties, and the public with a wealth of information on the status of these many activities as they apply to Rancho Seco.

This is not, however, a proceeding to determine the adequacy of or our compliance with the Lessons Learned Task Force recommendations.

Bulletins issued by the Office of Inspection and

Enforcement, or the wisdom of all of the actions under consideration by the Staff and licensee.

Certainly, these are to some extent relevant to the Board's assessment of the adequacy of the May 7, 1979 order but that finally is the job relegated by the Commission to this Board.

At this stage of the proceeding with testimony filed we are without any of the parties who originally requested this hearing.

Following the withdrawal of Mr. Hursh and Mr. Castro on February 6, the Board adopted 9 of their contentions as Board questions to be pursued at this hearing. Now, that Friends of the Earth at all have withdrawn we have essentially an uncontested case.

There are no allegations here that the May 7 order is inadequate in any respect. As you well know, the Board's role in the discretionary hearing such as this one, is to decide the matters in controversy among the parties and in the process pursue whatever questions it might have directed toward deciding the contentions raised.

We no longer have matters in controversy. Neither is this a show cause proceeding. Licensee has not been put on notice of any dificiency or violation of any Commission regulation or order to which it must answer.

It is clear, I believe, that this proceeding could not have been initiated without a qualified intervenor under 10 CFR Section 2.714. At this point, the Board would be acting within the scope of its delegated authority and the Commission's Rules of Practice if it terminated the proceeding.

There are, after all, no hearings being held on the other B & W reactors except for Three Mile Island, because none were requested.

The District recognizes, however, the substantial public interest in this hearing as well as the importance of the questions raised by the California Energy Commission and by the Board itself.

Consequently, we are prepared to perceive to hearing to answer these questions. In fact, we intend with your permission to offer our testimony on the Friends of the Earth contentions even though they have been withdrawn.

Licensee has filed three pieces of testimony. The testimony of Bruce Kerish and Robert Jones from Babcock & Wilcox addresses the questions raised with respect to the B & W nuclear steam supply system.

The testimony of Robert A. Dieterich, Senior Nuclear Engineer in the District's generation engineering department responds to the questions raised on aspects of the Rancho Seco design.

Finally, the testimony of Ronald J. Rodriguez, the District's Manager of Nuclear Operations, will address the competence of Rancho Seco facility management and operators, the emergency and other operating procedures employed at the plant, controlroom configuration and instrumentation of the plant, and the actual performance of systems in response to feedwater transients.

The California Energy Commission filed to date four pieces of testimony. Dr. Harold Lewis of the University of California at Santa Barbara, concludes in his testimony that what hardware problems there were had been largely remedied by the series of orders that have been mandated by the NRC in the aftermath of Three Mile Island. He suggests that particular attention be given to operators at this point.

The testimony of Mr. Webb and Mr. Mann, both of whom are Members of the Energy Commission Staff suggest the need for further studies some of which are already actively underway,

Finally, the testimony of Mr. Minor and Mr. Bridenbaugh questions the adequacy of operator training at Rancho Seco and proposes the installation of three instruments, one of which is being installed during this refueling outage.

We believe at the conclusion of the hearing, the record will show that this testimony is contradicted by substantial evidence.

The record will also show, we believe, that the short and long term actions and modifications directed by the Commission in its order of May 7, 1979, were adequate to provide reasonable assurance that Rancho Seco will respond safely to feedwater transients.

In conclusion, I would like to mention, Mrs. Bowers, the we have also provided for members of the audience to pick up a copy of each of the three pieces of licensee testimony that I discussed in my opening statement. These are on the side of the room.

Thank you very much.

CHAIRPERSON BOWERS: They are in the boxes on the side of the room.

Mr. Lewis, has California Energy Commission and the Staff decided the pecking order, who goes first?

MR. LEWIS: Well, with respect to the general course of the proceeding normally, I believe that California Energy Commission would conduct cross examination and put on their case prior to the NRC Staff.

So, if Mr. Ellison wants to speak first, he may.

CHAIRPERSON BOWERS: Fine. Mr. Ellison?

MR. ELLISON: Thank you, Mrs. Bowers.

The California Energy Commission has filed --

CHAIRPERSON BOWERS: Will you please pull the mike up a little closer?

MR. ELLISON: Is that better?

CHAIRPERSON BOWERS: Fine.

MR. ELLISON: The California Energy Commission has filed a brief opening statement explaining our interest in this proceeding, listing the witnesses that we intend to produce to assist the Board in its inquiry. I am not going to repeat that statement here although we do have some extra copies available.

However, I would like to emphasize that we believe the importance of this hearing is to decide whether Rancho Seco can safely respond to feedwater transients today and although, this proceeding was initiated in response to the Commission's May 7 order, as we have stated previously in this proceeding, we believe it is very important for the Board to consider the actions which have been taken at Rancho Seco, subsequent to that order in evaluating whether it can safely respond to feedwater transients.

We do not believe that this inquiry would prove fruitful if the Board were to examine only the May 7 order. We also believe that the actions taken at Rancho Seco to enhance the ability of the facility to respond to feedwater transients demonstrate that in the view of the NRC, the May 7 order by itself was not sufficient to assure the safety of Rancho Seco.

CHAIRPERSON BOWERS: Thank you, Mr. Ellison.

Mr. Lewis?

MR. LEWIS: Mrs. Bowers, we would reserve our right to make a brief opening statement at the time that we commence the presentation of our direct case.

At this time I would simply note that myself and my associates are available at the break to talk to anybody who has questions of us today and tomorrow and also that during the break I will set out extra copies of our testimony which will be available to anybody who might want to pick them up.

CHAIRPERSON BOWERS: Mr. Lewis, you are volunteering to make an opening statement Thursday morning. It is very significant to the Board. We were going to put you on notice that we are directing the Staff to respond to the motion for consideration of the CEC 5-2 contention. Now, one of the primary questions there is whether it does or does not challenge the regulations. We want the Staff to respond to the motion for reconsideration at the opening Thursday morning. So, maybe you can include this in your opening statement.

Let me back up half a minute here. On January 24, the Board issued an order scheduling an evidentiary hearing and that was published on Friday, February 1, 1980 in the Federal Register by a 45 page 7356. We recited the issues that will be heard when the evidentiary hearing starts. The last two paragraphs pertain to our limited appearance statements. The public is invited.

The first two days, February 26 and 27 will be set aside for limited appearance statements.

There will be an evening session on Tuesday, February 26, from 7 to 10 p.m. to hear limited appearance statements.

Oral statements will be limited to five minutes each but written statements without limitation and length may be submitted.

Now, this morning the Board was asked for us to wave our five minute rule. We said no. If you waive it for one you have to waive it for everybody and the whole idea is for us to hear from as many people as we can as to what your position is, what your concerns are in this matter.

Now, let me check and see if there are any other preliminary matters. We would like to go right in to the limited appearance statements.

MR. ELLISON: Mrs. Bowers, pardon me?

CHAIRPERSON BOWERS: Yes, Mr. Ellison?

MR. ELLISON: I do have one procedural preliminary matter.

As you recall at the prehearing conference, the parties agreed that the testimony on CEC Issue 5-2 would be filed today. Since that time, the licensee has filed a motion for reconsideration of the Board's ruling on motion for summary judgment on that issue. We have responded. You have this morning directed the Staff to respond to that on Thursday morning. In addition, the Staff has also filed a motion to postpone the filing of that testimony apart from the controversy that I just mentioned and in that regard we do not intend to file our testimony today as we had previously planned. We have agreed with the Staff that the simultaneous filing of that testimony a week from today, I believe it was, is that correct Steve -- is acceptable to us, and provide that the Board so directs, we will assume that all parties will file testimony on this issue one week from today, unless the Board pursuant to the motion for reconsideration by the licensee directs otherwise.

CHAIRPERSON BOWERS: You can't hear, is that the problem?

MR. SHON: I believe you have a telephone call. Is that right, sir?

CHAIRPERSON BOWERS: You can't hear.

MR. SHON: You can't hear.

MR. COLE: Can you hear Mr. Ellison?

CHAIRPERSON BOWERS: You have to pull the mike a little closer, Mr. Ellison.

We recognize in considering the matters pending before us that this filing scedule, of course, was based on other than having a motion of reconsideration in front of us and then, go back. We will give our determination on the motion for consideration as soon as we can this hearing. We want to hear from the Staff first, on this.

MR. ELLISON: Mrs. Bowers, just to clarify, I presume there is no need for parties to file their testimony today.

We will hold our testimony in advance.

CHAIRPERSON BOWERS: Now, we have been given a few names of people who are signed up to give limited appearance statements.

Mr. Hamilton, can you?

This is Mr. Paul Hamilton from our Staff, he is the one who has been getting the names of people who would like to make limited appearance statements. So, if you will just contact him, then, he will pass the information on to us.

Now, the first name we have -- let me check, any other preliminary matters?

Mr. Baxter?

MR. BAXTER: No, Mrs. Bowers.

CHAIRPERSON BOWERS: Mr. Ellison?

MR. ELLISON: Well, Mrs. Bowers, there is a possible preliminary matter which I would like to raise at this time.

This morning Mr. Baxter suggested to me that if a limited appearances statements do not encompass the entire day today, then, he would like to proceed with the evidentiary portion of the hearing. We would object to that.

We understood the schedule to allow for the commencement of the evidentiary hearing on Thursday, and we are not prepared to begin cross examination of Mr. Kerish and Mr. Jones today or tomorrow. In addition, I would like to point out that the Staff has presented us just this morning with a document entitled "Generic Evaluation of Small Great Loss of Coolant Accident Behavior" from Babcock & Wilcox design 177 FA operationg plants, otherwise known as NUREG 0565 which is a document that we have been waiting for for sometime and we believe to the cross examination that Mr. Kerish and Mr. Jones. So, for that additional reason we would not be prepared to go forward with that cross examination today.

CHAIRPERSON BOWERS: Mr. Lewis, does the Staff have a position on this matter?

MR. LEWIS: The Staff might be prepared to proceed with cross examination of B&W panael by tomorrow, we wouldn't be prepared to do it today. We had understood that if the limited appearance statements did not require all of tomorrow, there would be a commencement of the evidentiary portion of the hearing.

So, we would be prepared to begin that cross examination tomorrow.

CHAIRPERSON BOWERS: For the whole idea -- Mr. Baxter?

MR. BAXTER: I simply wanted to add that we would just like you to know that we have the panel here and if it is convenient to make the maximum use of our time, we would be prepared to proceed with them, if the Staff has its cross examination ready or if Members of Board have questions that they are ready to ask the panel even in the absence of Mr. Ellison's cross examination, we would be ready to put them on today or tomorrow. Whenever you find it convenient.

CHAIRPERSON BOWERS: We don't think it is appropriate to break into the limited appearance statements by putting on piece meal, the expert witnesses for the evidentiary hearing. It does not give us a continuity. Of course, the whole idea of setting aside two days, and only two days, was so you could schedule your expert witnesses and they would not be here over an extended period of time while we were hearing limited appearance statements without a date certain.

Well, what we would like to ask, the first one on the list here is Mr. Harold Crary, and the second name, if you come up, these are our microphones.

Are you Mr. Crary?

MR. CRARY: Yes.

CHAIRPERSON BOWERS: The second name is Mr. Russ Minor, if you could come up, and there is an extra chair so you would be ready.

Will you please for the reporter, please spell your name, and if you would like to give your address.

Remember, five minutes.

SC SC

TAPE 2/1

MR. CRARY: The reporter has my name and my address.

CHAIRPERSON BOWERS: Can you hear?

They can't hear, you need to pull the mike closer.

MR. CRARY: The reporter already has my name and address and she will have a copy of this written report that I am about to make.

According to what you just said, I cannot limit this to five minutes. It is a written report that I want to read.

CHAIRPERSON BOWERS: Can you summarize?

MR. CRARY: No.

I can possibly get it out in ten minutes.

CHAIRPERSON BOWERS: Mr. Crary, why don't you start out and give us as much as you can in five minutes, and then, we will have the essence of the report in the written document.

MR. CRARY: My name is Harold Crary and I live in Sacramento and I am so old that I can remember when there was a Republican in the White House in Washington.

A remarkable man was Herb Hoover. He learned how to run an Earthmover. He went around damming rivers in his overgrown Flivvers. I wish he had been here when they started building Auburn dam. The dam wuld have been done fifteen years ago and would have been producing cheap electricity years ago, and SMUD wouldn't be raising their rates the first of this coming month.

We can't complain. Here we are, living in California where we are enjoying the best of all possible f rms of govern ment. The best form of government is no government at all. For the last six or eight months, that is the kind of government we have had.

Were any of you folks at the last USNRC meeting on February 6? If you were, you heard a report form one of the crunch-bunch in regard to two horrible devestating compounds found near Rancho Seco nuclear plant.

One of these was Krypton. The way the man said that word, sent shivers up and down your spines, and made your heart palpitate. You just knew by the way he said that word it must be something pretty awful.

He went on to tell about the devestation this dire element would cause if it were spread all over Sacramento. I encountered the word in comic books years ago. It seems that some super person arrived here from a planet beyond the farthest star and went around doing incredible feats of strength and being mistaken for a plane and a bird and finally for a man flying through the air with the speed of light.

Super guy had one weakness. Every six months he would run out of his miraculous power and have to go back to his home planet and have his fuel tank filled up with

Krypton.

I never bothered to look the word up until I heard it again at the last meeting on February 6. Until then, I thought it was a word made up by the comic book author. To my surprise I did discover it in a dictionary. Here is what I found out.

Krypton is a colorless, odorless, inert gas found in the air. On e part per million parts of air by volume. If you go higher, there is a little more Krypton. It is also found in greater concentration around Thermal Springs, and in the vacinity of natural springs, and sometimes in the runoff from such natural springs.

So, if you happen to be down around Rancho Seco and were looking for it, I don't know how you would tell it because it is colorless. If you were looking for it, you would be pretty sure to find it and you couldn't smell it.

It is inert. Now if anybody know what that means when it comes in contact with another element, it doesn't do anything, it just lays there. It just stays still. Inert, it minds its own business.

We all know that air is the mixture of several gases and when air is cooled minus something or other, and then compressed under terrific pressure, it becomes liquid air. From the liquid air it is possible to extract the Krypton.

It is used in high intensity lamps, where a brilliant illumination is desired. Now, you can buy one of these high intensity lamps in any chain drug store for $10 or $12 and take it home and enjoy all the Krypton radiation you want to right in the privacy of your own living room.

Krypton radiation is harmless and quite benign and it is very useful to us all. It enables people to read in the dark by flipping the switch.

I should warn you, however, that these high intensity lamps can be hazardous to your health. If you eat too many of them.

No wonder they found Krypton at Rancho Seco. You could find it anywhere on earth in up to 10 or 20 miles in the air above the earth to the edge of the atmosphere.

The second terrible discovery, according to this young person was Potassium iodide. The way he pronounced that it made strong men shudder and women moan and wring their hands. If that stuff could get loose, it would do away with fertility in people.

Not only in all the people, but all their sons and their grandsons even to the third or fourth generation. Besides, it would give them all cancer.

Potassium Iodide according to this Chicken Little, had been discovered in cow's milk on the Garcia Ranch, near the Rancho Seco site. I've seen the cows grazing in the pasture so near the plant, that when the wind was right, their bodies would be wrapped in the steam from the cooling towers. These people took samples of milk from several cows, and discovered Potassium Iodide in every sample.

I will guarantee you that every cow on that ranch near Rancho Seco has Potassium Iodide in its milk. I will also grarantee you that every dairy critter in the United States and probably Canada, too, will have Potassium Iodide in its milk.

Do you know what Potassium Iodide is? Le me explain it to you so you can stop shivering. A long time ago people ate Sodium Chloride on their food. Common ordinary table salt. And then the American Medical Association found out that sodium caused hardening of the arteries, which in certain circumstances could lead to heart attack.

Consequently, there are probably millions of people right here in California who are on low sodium diets. Human beings being human like salt on their food, SOME ARE sodium dieters and I happen to be one of them, switched to salt containing potassium iodide. You can buy it in the fad food stores in nice little glass bottles with shaker tops, and pay around, oh, about $2, for a four ounce bottle of it. You can buy the same potassium iodide salt in any grocery store for 60¢ for a four ounce package. For the last 20 years or more, you can buy it in one pound pachages for the same price that sodium chloride salt cost. I buy mine by the pound and put it in my own salt shaker and I have eating around a half an ounce of this stuff every day for the past 10 years.

According, to the Chicken Little at that meeting a couple weeks ago, there is enough potassium iodide in a pound of salt to make eunuchs of all the male population of California overnight, and put the business of pro-creation out of business. Besides giving them all cancer, and probably measles, whooping cough and chichen pox. It would wipe out the entire human race in less than 30 days.

Now, we have a group of people in America called dairy famers. They aren't supermen, or eve pretend to be, but they aren't dummies either. Wehn sodium chloride salt was all they could get, they fed it to their cows for the same reason that human beings ate it. It made the cow feed taste better, the cow would eat more food and she would give more milk. When potassium iodide came out, it was as cheap as the sodium chloride salt, those dairymen fed it to their cows for the same reason that human beings ate it. A cow with hardened arteries would be more apt to suffer a heart attack. By giving it the potassium iodide salt, it prolonged the cow's life which more milk fro;m each cow.

And these comic book educated ninnies tried to scare me to death by warning us about haveing Krypton and iodide at the Rancho Seco site. If any of you are worried about it you better go home and eat some potassium iodide salt and get rid of your tension or your ateries are going to harden.

So, I tell you folks, Egoism is the asperin people use to ease the pains of stupidity.

Today, I bring you news and some of it is good and some of it is bad. I am going to give you the bad news first.

Item one: Auburn dam is still half done and nobody knows when it will be producing electricity. Item two: the archealogy team scraping up old pottery shards at the New Melone reservior-to-be ran out of funds last week. A bill is stalled in Congress to raise more money to complete the digging so that the dam can go into production. Well, youknow how these Congressmen can stall and stall and stall. Federal officials say that raising of that money would delay using the dam another year or so, or so, or so.

CHAIRPERSON BOWERS: Mr. Crary, you are up to your five minutes. Will you please what you have and we will see that it goes in the docket.

MR. CRARY: Can I have just another minute?

CHAIRPERSON BOWERS: We told you five and that is what we are telling --

One minute can you summarize?

MR. CRARY: I think so.

The New Melone Dam was completed in 1978 at a cost of $430 million , and with the rain we've had since then, should have been full and slopping over by now and the dynamoes humming and the ozone oozing, and the electricity flowing out all over the community. If Auburn Dam and New Melone Dam were in operation today, SMUD wouldn't have raised their rates, they would have lowered them.

That is the bad news and now for the good news. Last week 2700 members of the California Medical Association of San Diego and did an about-face on their "Go Slow" policy regarding building more nuclear plants in California.

According to the report on that meeting, they had found out that any other method of producing electricity is no more hazardous than is nuclear. The report wound up with the words a complete flip-flop on their former attitude and they say it is symtomatic of the American concern for its self sufficiency in the matter of producing energy and especially with the buying of oil from foreign countries. You know what that means, it means they like as near as I can understand it it means that if gasoline at the pump price goes up much more people won't have enough money to buy gas to get to the doctor's office.

CHAIRPERSON BOWERS: Mr. Crary, we must stop you now. I think you have given us the idea of your thinking on this matter, and we must go on to other people.

If you would like to hand us the ribbon material, if there is anything further, then, we will consider.

HAROLD E. CRARY
P.O. Box 214601 - Phone 922-7440
Sacramento, CA 95821

USNRC 2 26 80 FedBldg 1140 9:45

Aren't you glad I'm here?

I'm glad you're here, too!

If you weren't all here I would be talking to myself and people would be pointing at me, and saying: "Hey, Look. That guy ain't all there!

My name is Harold Crary. I live in Sacramento. And I'm so old I can remember when there was a Republican in the White House in Washington.

A remarkable man was Herb Hoover. He learned how to run an Earthmover. Went around damming rivers in his overgrown Flivvers. How we wish he'd been here when we first started building Auburn dam. The dam would have been done fifteen years ago and would have been producing cheap electicity years ago, and SMUD wouldn't be raising their rates the first of next month. That raise is going to hit us right in our pocketbooks.

But we mustn't complain. Here we are, living in California where we are enjoying the best of all possible forms of government. The best form of government is no government at all, you know. And for the last six or eight months, that's the kind of government we've had. Things have actually improved in that time, too. When Jerry does come back to Sacramento he will find that inflation has had no effect on the price of alfalfa sprouts......or bubble gum either. Mickey Mouse can have his hat back then and get off Welfare and go back to work again.

Were any of you folks at the last USNR C meeting on Feb. 6th? If you were you heard a report from one of Tom and Jane's crunch-bunch in regard to two horrible, devastating compounds found near the Rancho Seco Nuclear Plant.

One of these was KRYPTON. And the way the little Prophet of Doom pronounced that word sent shivers up and down your spines, and made your heart go pitter-pat. You just knew, by the way he said the word that it must be something pretty awful. And as he went on to tell us what devastation this dire element would cause if it were spread all over Sacramento. I'd encountered the word in comic books years ago. It seems that some Super-Person arrived here from a planet far beyond the farthest star, and went about doing incredible feats of strength and being mistaken for a plane, a bird, and finally for a man flying through the air with the speed of light. Super-guy had one weakness. Every six months he would run our of his miraculous power, and have to go back to his home planet and have his fuel tank filled up with KRYPTON. I never bothered to look the word up in a dictionary until I heard it again at the last meeting on Feb 6. Until then I'd supposed it was a word made up by the comic book author. But to my surprise I did discover it in the dictionery a couple of weeks ago.

And here's what I found out about it. KRYPTON is a colorless, odorless INERT gas found in the air. One part per million parts of air by volume at sea level. If you go higher, it is a little more up there. It is also found in greater concentration around Thermal Springs. And in the vicinity of natural springs, and in the runoff from such natural springs. So if you happened to be down at Rancho Secco and were looking for it, you'd be pretty sure to find it, if you could see it, which you couldn't because it's colorless. You couldn't even smell it. And it is also inert, which anyone knows means that when it comes in contact with other elements, it doesn't do anything. It just stays still, inert, and minds its own business.

We all know that air is a mixture of several gasses. When air is cooled to minus something or other, and then compressed under terrific pressure it becomes liquid air, just like you or I would if they did that to us. And from the liquid air it is possible to extract the Krypton. It is used in high intensity lamps where a brilliant illumination is desired. You can buy one of these high intensity lamps in any chain drug store for ten or twelve dollars, and take it home and enjoy all the Krypton radiation you want to, right in the privacy of your own living room. Krypton radation is harmless, and quite benign, and it is very useful to us all. It enables people to read in the dark by just flipping a switch. I should warn you. However that these high intensity lamps can be hazardous to your health ....if you eat too many of them.

No wonder they found Krypton at Rancho Seco. You could find it any where on earth, and anywhere up to ten or twenty miles in the air above the earth to the edge of the atmosphere.

The second terrible discovery, according to this young person was POTASSIUM IODIDE. Again, the way he prounounced it made strong men shudder and women moan and wring their hands. If that stuff should get loose, it would do away with all fertility in people. And not only in all people, but their sons, and their grandsons even to the third or fourth generation. And besides that it would give them all cancer.

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The New Melone Dam was completed in 1978 at a cost of $340 million dollars. and with the rain we've had since, should have been full and slopping over by now, and the dynamoes humming and the ozone oozing, and the electricity flowing in a steady stream all over the community. If Auburn Dam and the New Melone Dam were in operation today, Smuc wouldn't have raised their rates, they would have lowered them. So who's really responsible for the energy shortage?

That's the bad news, and now for the good news. Last week 2,700 members of the California Medical Society met in San Diego, and did an about-face move on their "Go Slow" policy regarding building more nuclear plants in California. According to the report on thatmeeting, they had found out that producing energy in nuclear plants was no more hazardous than producing electricity by any other method, including coal. The report wound up with the words: the move was a complete flip-flop on their former attitude and is symtompatic of the American concern toward self sufficiency in the energy producing area, especially with the buying of oil from foreign countries. Well, you know how doctors are. They like to use big words. As near as I could understand it, it means that if gasoline at the pump goes much higher nobody will have enough money to buy gas to get to a doctor's office, and you know how they feel about making house calls.

So you see, folks, you may not win 'em all, but you sure ain't going to lose 'em all either.

The second good news was the announcement by the Friends Of The Earth weren't going to be at this meeting today. Mark Vandervelen who calls himself the main spokesman in Sacramento for the group said there wasn't any use for them to be here. Because this meeting is so narrow in scope, and of a format that requires the Friends of the Earth to prove that the rancho Seco plant is dangerous, as opposed to the Nrc and Smud to prove that it is safe. This should give them time to go back to their Comic Books and come up with something even more dire and threatening than Krypton and Potassium Iodide.

How nice it is here today, not to have to listen to the Freakish Feathered Friends, the Chicken Littles who dash about, hither and yon cackling The Sky is Falling. Run for your lives, the Sky is falling. Look out.....Look look look look out. Was a time when a fool was born every minute, but now it seems to happen to everybody.

I have one more piece of good news. Some of you may have noticed that it has been raining a ~~little~~ here in California. Now California needn't be called the land of fruit and nuts any more. We can call it the Cleanest State in the Union. Stop and think. You've never seen a fish with dirty feet, or ring-around the collar, now have you.

The older a man gets the quieter he becomes. Maybe because he has more to be quiet about. And I'm older than I was when I got up here to talk, so now I'm going to be quiet.......

POOR ORIGINAL

Mr. Minor, are you ready to proceed?

Is E. A. Combatalade in the audience?

Sir, will you please come forward?

Alright, we will have the speaker stay on the seat on the left. This is better for the reporters. I am sorry could you gentlement trade, now?

These extra microphones tie in with the T.V. and also with the reporter.

Mr. Minor?

MR. MINOR: Thank you, my name is Russ Minor, I live at 4707 Illinois Avenue in Fair Oaks. I am appearing here today as a private concerned citizen who is deeply concerned about the energy future of this State, both for the other people living here and the people that reside in my household, my family.

I have been analyzing the energy demand and supply situation in California for the last 10 to 12 years. While working for a major utility, while working with the State Energy Commission, and with two consulting firms. I have been analyzing the demand in the State as well as the risk and benefits of various supply alternatives for meeting demand.

I am a professional engineer in California.

The major thrust of my statement today, is to request that you carefully weigh the risk of shutting down the Rancho Seco plant even if for a short time.

The Rancho Seco plant must not be shut down for any period of time unless their is a bonafide showing that such a temporary shutdown is needed to correct a safety problem.

By bonafide showing I mean that this would require analysis by either the NRC Staff of an industry technical group that has the capability of making such an assessment.

There are several important risks which need to be examined in the decision to shut down Rancho Seco even if for a temporary period.

First, the margin of energy supply demand is getting alarmingly thinner each year in California. The State's Energy agencies are again taking their annual hearings to find out how bad things might be this summer. Particularly, if Rancho Seco was shut down and Diablo Canyon 1 and 2 in the PG & E service area is not licensed.

If both Rancho Seco and Diablo Canyon 1 and 2 are not on line this summer, Northern California will have a negative reserve margin of about 2.4 percent, that is the available capacity would be less than the keep low demand by about 400 megawatts. I believe that these figures are consistent with those that have recently been put forth by the California Energy Commission.

The only way to rectify the situation is for PG & E and for Sacramento District to try to ge emergency imports. The good hydro year in California may help. This will require more analysis.

However, since the Pacific Northwest hydro-year is less than average, capacity and energy help will to a large extent come from Southern California's oil fired power plants, This brings three addional risks into focus.

Additional oil comsumption, additional cost to the consumer, and additional pollution. Let's quickly examine the consequences of not having the 3100 megawatts from Diablo Canyon 1 and 2 and Rancho Seco on line this summer.

Concerning the additional oil comsumption, approximately 80 thousand barrels per day additiona oil consumption would be required to replace the energy lost from these 3000 plus megawatts of nuclear power.

Additional cost to the consumer, if we assume that the average cost at the utility bears when he burns a barrel of oil is about $30 a barrel which is actually a little bit low and it is going up. There would be an additional 40 mills per kilowatt hour, that is above and beyond what it would have cost to operate the existing nuclear plants, 40 mills per kilowatt hour for the consumer.

This translates to about $6 million per month additional cost of having to displace nuclear energy with oil energy.

Let's consider very briefly the additional pollution.

For 3100 megawatts of nuclear power displaced by oil we have approximately 90 tons per day of NOX that is nitrogen oxide, approximately 90 tons per day of sulfur oxides. approximately 15 tons per day of particulates being distributed to the atmosphere.

The ARB testify, that is the Air Resources Board in California testified in December of 1975, that replacing natural gas in Southern California with low sulfur oil of about .5 percent sulfur, would cause many premature deaths and many additional asthma attacks. I won't go into the figures in the interest of time.

Secondly, the American Medical Association, in a study two years ago, found that oil plants would cause about 24 to 90 times the deaths as in nuclear plant when provideing the equivalent unit of power.

I would like to be able to share more on the various risk and the benefits but I think you have been able to gain the thrust from the summary that I have given.

In closing, I would like to say, that for reason of potential capacity and energy shortages, for reasons of decreasing oil consumption, which this State is already overrelying on. for reasons of pollution control, and for reasons of cost that the State absolutely cannot tolerate a shut down of its existing nuclear facilities or any delay in the licensing of Diablo Canyon unless there is a valid overriding reason that a temporary closing be done in order to correct a safety problem.

So, the thrust of my statement, again, is to request that this Board carefull weigh the risk of what happens if we are not generating the nuclear power but we are using oil power.

Thank you, very much.

CHAIRPERSON BOWERS: Thank you.

Herb Silvius, if you will switch over beyond that, please.

MR. COMBATALADE: Madame Chairman, my name is Ed Combatalade, I have given it to the young lady with my address.

I want to welcome you to Sacramento and hope that you will stay to see the opening of our 26th annual festival this Saturday. I know you will enjoy it.

We have several people in the audience that are a little shy on microphones but they are supporting Rancho Seco and Nuclear energy. Is it permissable for me to ask them to stand, Madame Chairman?

CHAIRPERSON BOWERS: You will be taking your five minutes.

MR. COMBATALADE: Hurry up, stand, please.

Thank you.

Now, we all agree that we need energy in this industrialized nation of ours. We all agree that it must be "safe". We also want safe automobiles, safe aircrafts, safe coal mines, and if there is such a thing safe drugs.

A major concern to me for the need of energy in addition to maintaining our standard of living and even improving it, is this. We are being surrounded by a philosophy that has as its major objective the acquisition of this great country of ours.

We are being surrounded by this philosophy day by day as you know by reading your papers and taking cognizance of the events that are going on around this wall. The world is getting smaller everyday. We are outnumbered and we need our big muscle energy to maintain what this country stands for.

I have had the experience in 31 years of military life, not all active of course, to talk to many knowledgable military people that have told me that we could have easily have lost World War II had we been without the big muscle energy to out produce our opponents.

It behooves us, then, to develop all the energy that we can and I think and I am sure that the facts and figures will show you that nuclear energy is what we now have available to us and we should develop it quickly.

I, for one, am for building Rancho Seco tomorrow.

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This energy is essential, for our lifestyles, for our preservation, and I hope we can build not only Rancho Seco but many others. We have never had any real problems with it and the problems we have had have been problems not of nuclear energy but problems of human failures.

Thank you, Madame Chairman, for the opportunity to appear.

CHAIRPERSON BOWERS: Thank you.

Will Mr. Roger K. Seal please come forward?

MR. SILVIUS: Madame Chairman, my name is Herb Silvius, I am one of these unusual persons in town here that was born here. I have seen progress go by leaps and bounds and I am convinced as many of you are that there is a real need for generation of energy. I am not limiting that comment to just nuclear energy, because I realize that studies are being made to determine the proper use of not only oil, gas, chemical, coal, nuclear, windmills, shale, and even geothermal generation of energy.

I do believe that the years I have been in this City, I am convinced that there are three steps to follow in solving a problem. First, and most important, is to analyze the problem thoroughly and always detail with expert Counsel, in determining exactly a complete analysis.

Second, consider alternatives, many alternatives.

Third, adopt and implement the one deamed best in the interest of the people as a whole.

We have heard a lot about the operation of our business world, the cost benefit basis for determining whether decisions should be made one way or another.

I would suggest that the greatest benefit to most people and the least detrimental effect of the people should be the basis upon which their problems should be solved. And that goes for the nuclear energy and all energy.

Let us not close our eyes to the experience of other countries, which countries have shown a very high degree of safety. Let us come closer to home and study the results and experiences of our nuclear powered submariines and aircraft carriers.

I believe that nuclear energy is best developed any of these methods of creating energy with the least detrimental effect. We have coal miners problems, black lung. We have smog problems,just to cite two of them.

So, I don't want to be too redundant but let's consider and I am sure that your Board will, the two methods of solving the problem and I fell confident that the development of nuclear energy from where we are now, will go a long ways toward solving the energy problem. Unless, and until something is proven beyond all reasonable doubt to be superior to what we have. I suggest we waste no more time in our competition for world position and delay no further.

Thank you for the opportunity.

CHAIRPERSON B)WERS: Thank you.

Mr. Seal?

Could D. Price please some forward?

MR. SEAL: My name is Roger Seal, I live at 2390 Oakmont Street. I am here today to speak in the hope that I can get one person here to open their eyes.

As I understand it the purpose of this hearing is to determine whether Rancho Seco is dangerous. I feel that the fact that all nuclear power plants must now have emergency evacuation plans, should be proof enough.

The burden of proof should be on SMUD and the NRC to prove that Rancho Seco is safe and that no evacuation plan is necessary.

There is not enough known about the low level radiation to be able to say that it is of no harm to people. If the money that has been spent on building nuclear power plants had been put into research on solar, nuclear fusion, and other alternatives, many of our energy problems that we had today probably could have been solved.

The risk and cost to human life is much too high. No amount of money or energy from nuclear fission can ever replace the value of a human life. It is very easy for many people to dismiss those who speak out against nuclear fission as radical revolutionaries. Just let me remind you that people such as Thomas Jefferson, George Washington, and Martin Luther King were also considered radical revolutionaries in their time.

Thank you.

CHAIRPERSON BOWERS: Thank you.

Mr. Vandervelden?

MS. PRICE: My name is Anna D. Price and I have been a resident of Wilton, California sicne 1959 and my husband, Joe Price, has been a resident of that community since 1939.

Our small ranch is located about 6-6 1/2 miles from the Rancho Seco site, and my husband's family have been ratepayers to SMUD since its beginning.

At the time Rancho Seco was proposed for construction, I much more than my husband opposed its construction. We were concerned about the Folsom South Canal taking Northern California water to Southern California and I was most certainly not pro nuclear.

After attending a meeting in Sacramento, I felt that we should build a bomb shelter, but with this plant being constructed in Mather Air Force Base in the other direction, I was concerned about the explosion of one or the other.

My husband had worked in engineering at Aero-jet General Corporation for over 11 years and was then laid off.

Four years later, June, 1974, he was accepted for employment by this utility. I was very pleased until I learned where he would be working.

Many discussions ensued and I do remember informing him " you are not going to work at that place and bring that stuff home to us". I told this to let you see how very ignorant I was about nuclear power.

My husband has now been at Rancho Seco for almost 6 years. His employment did little to change my mind or ease my fears. He brought home training materials to study which I read and then became thoroughly convinced that he was being totally brainwashed by the utility.

Along came California's proposition 15, the nuclear initiative and I was given a small handbook about nuclear power. After reading the booklet twice, I started doing some checking because it became rather apparent that I had received a dose of radiation in excess of what my husband could be allowed while working at Rancho Seco.

I was alarmed and angry to say the least. I wondered why someone wasn't making a big stink about this source of radiation. Why not scare people with exrays, attack radiologists and the rest of the medical profession? Why, indeed.

In both instances the radiation is being used for the good of mankind while I personally do not approve of nuclear weapons, I certainly, endorse the peaceful uses of the atom.

Since 1975, I have been involved with several pro energy groups and done a great deal of studying of the issue both technical and ethical. I have read and read and read until it is now done with glasses.

While I can empathize with the anti-nuclear people who are truly concerned citizens and who have not yet learned more of the facts. I have no sympathy for their leaders. Many of them do have the facts and still pursue the issue.

We have had SMUD directors, Gary Hursh and Rick Castro, friends of the Earth, et al, and our own publically financed California Energy Commission. We all pay for the California Energy Commission and that is their tax charge on our utility bills make contentions and allegations against the operation of Rancho Seco. This was done in a rather sophisticated langurage that the general public would probably not fully understand. These charges were made and then the accusers withdrew from the hearing when it became necessary for them to prove the charges.

In my opinion, these people were not just asking for a public hearing, they wanted to publicize and air a public debate on nuclear power. We welcome the public hearings here in Sacramento. We want critical issues addressed so that the public will know that Rancho Seco is being operated in a safe manner and that these hearings are not a "sham and

and white wash".

I have a vested interest in this plant being operated in a safe manner. The constant charge is whether or not SMUD and its management is competent to operate a nuclear facility. This is an area of scrutiny by NRC and rightly should be.

However, the operators and personnel of Rancho Seco are often spoken of as if they were the incompetents. The people who work at the plant have families, live near the plant or in the surrounding Sacramento area. They own homes, the spend their paychecks in the Community just like any other worker, they teach sunday school, lead boyscout troops, participate in PTA's, work as volunteer firemen and yes, they, too, have a vested interest in this plant being safely operated.

I have not said anything in this presentation that this Board has probably not already heard but I want the community to hear it this time.

I think the time has come for all Rancho Seco employees to let the community know that they are concerned, responsible citizens, and that Rancho Seco will continue to operate safely to provide this community with jobs and energy.

Thank you.

CHAIRPERSON BOWERS: Stan Van Vleck, please?

MR. VANDERVELDEN: Mrs. Bowers, Mr. Shon, and Dr. Cole, my name is Mark Vandervelden and I am a Sacramento Representative of Friends of the Earth. I am somewhat sorry that you haven't had the benefit of reviewing the letter that we sent on February 19, indicating our position with regard to these hearings, so what I would like to do is briefly summarize the content of that letter and also make some additional comments relative to the position that we have taken with regard to these hearings.

I will read to you the first paragraph or so of the letter that we sent. The letter starts out quoting Emery Lovintz who is Friends of the Earth's British representative and who is also internationally recognized as an energy analyst.

He has commented the following, he said, " When the history of the nuclear controversy comes to be written those who killed nuclear technology will be seen to have been its most avid promoters who systematically missed to copes for facts, advocacy for analysis, commercial zeal for national interests, expertise for truth, and the people for fools."

When the chapter on the accident of Three Mile Island and its aftermath is written it will be recognized as the critical and decisive turning point in nuclear development.

Three Mile Island will not simply be remembered as possibly the worst accident in the history of commercial nuclear power. It will also be remembered as one part of purvasive and disquieting pattern of arrogance by an industry and an agency which has engendered in the public mind the deepest possible feelings of mistrust, anger, and cynicism.

Victor Gilinsky who is one of the NRC Commissioners has said, "Certain things it appears to me are clear right now. The significance of the accident lies not in the extent of public exposure radioactivity, but rather in the exposure of flaws in the system we have depended on to assure the public health and safety. The fact that things happended at Three Mile Island that weren't supposed to happen sent shock waves through the industry and the regulatory agency."

He concludes by saying, " The public's less than enthusiastic acceptance of nuclear power has been ascribed variously among other causes to an anti-technology movement, to a loss of nerve of Western civilization, and even to the generation gap." And Gilinsky goes on and says, " The explanation seems to me to be simpler. The problem is chiefly that the public has not yet been convinced that the regulators can be counted on to do their jobs. Althoughm it is not the NRC's job to foster public enthusiasm for nuclear power, it is the Commission's responsibility to regulate it in such a way as to dispel doubts about its performance."

Now, let me give you a different feeling for the scenario events that led to this hearing. a scenario that is little different from Mr. Baxter's.

Rancho Seco was shut down by the utility on April 28. It must be noted that this shutdown came after extensive discussions between the NRC Staff and the utility.

NRC Staff documents essentially disclose that the NRC assumed a diagnostic role and left it essentially up to the utilities to determine the remedies at least in the short term.

This they did and the NRC came along on May 7 and essentially confirmed that that the utilities had shut down and that they would be allowed to resume operation pending the completion of certain items.

There was an offer in the May 7 order for public hearings and after talking to technical people and so forth our concern was not that that order was not adequate. That it did not deal with emergency planning, that it did not deal with generic issues and, in fact, it did not provide for an explicit determination prior to resumption of operations that the plant was, in fact, safe to operate.

It is because we felt that those assurances were absolutely necessary. Reasonable assurances that that plant could be operated safely. We decided to go ahead and embark on this process.

We asked for these hearings prior to the resumption of operations. We had support for that position from the City Counsel, from the County Board of Supervisors, from some 40 or 45 assembly members. We has support form the

B, we had support from 10 thousand people who signed petitions and who repeatedly requested that the Sacramento Municipal Utility District conduct hearings. Three separate times those requests were denied.

Sacramento B commented in an editorial just prior to the resumption of operations that " the danger lies not only in the loss of public confidence and in the warping of the priorities that must be maintained when technical concerns in the public interest conflict, but also as we have learned in the record of the NRC dangerous mistakes have been made when protesting voices were silenced or ignored."

Now, I would like to emphasize that the political tentions generated by Three Mile Island are very real. They are not just words on paper, they are not just posturing for the cameras, they are many, many real people with very valid concerns about the safety of Rancho Seco.

These are people who aren't necessarily committed to shutting it down. They are people who recognize that an investiment has been made in a facility and that that facility is going to continue to operate. Their concern is that the plant be operated safely. But, there is also another concern and this is also one of the major lessons learned from Three Mile Island and this is something that I hope you listen to.

There are political lessons. Lessons related to the legitimacy of the political process itself. The faith the public has in the regulatory agencies in the utilities acting in the public's behalf to protect them.

Part of what makes for legitimacy in a political process is full and open discussion of issues that bear significantly on people's vital interest: their health and their safety, their economic situation, their piece of mind.

In the letter I go on to say, even more important than whether these people are right, is that they have a right to influence and tangibly effect major decisions about their lives.

Denying them that right is a sure road to a system of government that few of us would want to live under nor care to defend.

Indeed, if the process is designed merely to diffuse controversy without legitimately resolving conflict, without seeing to do justice, it will only make the conflict worse and radicalize previously placid onlookers.

A process designed to probe the merits of controversy in order to examine real and acknowledged problems can add great power, flexibility, validity and legitimacy to the decision making process.

A process designed to suppress such examination or to rob it of its effectiveness or forego these advantages and gain in their place the anomity citizens concerned only with the particular safety issues but with the integrity and the legitimacy of the process as well.

I go on to say that legitimacy is seen by anyone whether a minority or not as a precious gift that should not be lightly hazard.

To presume the superior wisdom of a few appointed or non appointed officials betrays an astonishing contempt for the painstaking efforts to develop self processes and principals in our society.

We feel that there has been some contempt for some of these legitimate concerns that have been expressed not only by Friends of the Earth, Hursh and Castro and by the public at large that hasn't had a voice in this proceeding to this point, we point to one of the major more outstanding findings of the Kemeny Commission in which they conclude, "Fundamental changes must occur in organizations, procedures, and above all in the attitudes of people. No amount of technical fixes will cure this underlying problem. We are convinced that unless portions of the industry and its regulatory agency undergo fundamental changes, they will over time totally destroy public confidence and hence they will be responsible for the elimination of nuclear power as a viable source of energy."

One of the things that Peter Bradford who is also a Commissioner has pointed out is that there are problems that an agency that is in the business more of reassuring then -- well, let just sort of -- it says"The essential element, it seems to me in any regulatory system that it reassures more than it regulates, is that it has immense capacity for self dillusion."

He goes through and identifies a number of these elements of self dillusion which he feels are significant. I pointed these out in this letter, it is a lengthy quote, because I think a number of these items bear on this process and let me just sort of comment on one or two of them.

The fourth item he says is "The system should deal with its critics, more or less, the way the tar baby dealt with Fraer rabbit. It should have an almost infinite capacity for repressive tolerance, the extending of exquisite procedural courtesy to participants who are never, in fact, allowed to get their hands on anything vital. This can be expected to frustrate critics to a point in which they become obsessed or shrill, or demagoguic, or a little crazy. Then again, their arguments are more easily dismissed as obsessed shrill, demogoguic, or crazy especially if others had these characteristics all along have at some point been attracted into the fraer. I think we have seen some of that already.

Since May 15, 1979 when we sent a letter to the NRC indicating our intention to have some of these issues aired, Friends of the Earth has attempted in a good faith way to try to get some of these vital questions answered.

We were denied our requests for hearing prior to reopening, but there seemed to be broad community support, broad poliitcal support for holding hearings in spite of the fact they are occurring after the plant was going to be allowed to resume operation.

So, we went on with the process.

MR. CRARY: Madame Chairman, I thought we were going to hold these for five minutes.

MR. COLE: You are considerably past the five minutes. It might very well be though that we could consider this not an opening statement but a closing statement for FOE which was a party in this proceeding. So, because of that I recommend we give him some additional time.

CHAIRPERSON BOWERS: Actually, I think it is too bad, Mr. Vandervelden, that you chose to go this route because you certainly would have had unlimited time to have made a closing speech in the opening speech time.

Perhaps, you could summarize.

MR. VANDERVELDEN: Mrs. Bowers, there is no one who regrets that more than I do.. I promise you that, there is no one who wanted these hearings more than I did. There is no one who has been as frustrated with this process as I have been. There is no one that I know of in the public sector that has tried and invested as much blood, sweat, and tears into this as I have.

I am not trying to make -- I wish I could be in these proceedings instead of a very poor second sitting right here making testimony that isn't even on the record, as far as I know.

I would appreciate having additional periods to comment if I may.

CHAIRPERSON BOWERS: Can you wrap it up pretty soon? We do have your 9-page letter.

MR. VANDERVELDEN: Yes, for the benefit of those who don't have it, I would just like to highlight some of the other points that I made.

In the last few months, we have tried to engage in this process, as parties are expected to. We have tried to meet all of our substantive and procedural obligations. We have tried to file documents on time, we have undertaken discovery. We have responded to inquiries ourselves and we have tried to, but a combination of factors have compelled us to withdraw from this proceeding.

I just want to make it very clear why we have decided to do that.

We have concerns related to the scope of the proceeding. I think that other parties don't feel that that is quite the problem that we felt it was. It was clear from the rulings of the Board at the February 6 meeting, that some of the matters that we had inquired into during our discovery process with the NRC were deemed by the Board to be not relevant to this proceeding. Central to this were the issues related to the Lessons Learned Task Force recommendations, their implementation and criteria for determining compliance and the adequacy of those measures to provide for the public health and safety.

A lot of money is being spent right now, as the plant is being shut down to implement those items that do go beyond the question of whether the plant can go beyond the question of whether the plant can respond safely to feedwater transients. We felt that that was a legitimate area of inquiry.

We are concerned about emergency planning as many people are. We are concerned about the loss of offsite power and a number of other things. But, I think the most difficult impediment to our pursuing this proceeding, was our feeling that the burden of proof essentally the burden of moving forward our contentions and moving forth through the evidence was extraordinarily difficult task.

First of all, because like Peter Bradford suggests, intervenor parties are only able to get only a limited amount of information out of that process. We are only able to get what we can get from discovery. There is an entire universe of information related to Three Mile Island and Babcock & Wilcox plants. Most of that information is husband by the NRC and the utiility.

There is an infinite amount of information on the subject on this subject. We are essentially in the position of having to show why that plant is not safe to operate, what has to be done to make that plant safe, and on what criteria in order to prevail on our contentions?

Now, it seems to me that fairness would dictate that the burden should be on the utility or on the agency to show why what they did is adequate.

Now, at the end of this process, it may very well be established that without any adversarial relationships in the proceeding, of course, may well be established that they probably can respond safely to feedwater transients but to say -- the important part I want to make is who is going to believe that?

I honestly don't believe that there is a whole lot of --SMUD has a whole lot of credibility in this community. I certainly believe that the NRC has very little credibility in this community and I think the way that this proceeding is going to be conducted is going to eliminate whatever shreds of credibility the Board may have.

I am saying that is the real danger here, not whether the plant's going to melt down. The real danger is that from a political standpoint, there is a crisis of legitimacy here, a crisis of confidence, and this proceeding is not going to allay those fears.

That is where the real problem lies.

The final paragraph in the letter is just rather harsh I am afraid. It is written I have to admit out of a considerable amount of frustration. Trying to keep pace with this process, trying to deal with all the paperwork, trying to raise the money. I don't think you understand what a public intervenor has to go through to participate meaningfully in this kind of process.

I don't think there is a real appreciation for that. We cannot possibly afford spend maybe a quarter of a million dollars that SMUD spent or maybe an equal amount that the NRC has spent. It is very much like being a gnat on a windshield.

The final paragraph goes, under these conditions, Friends of the Earth can no longer participate in this proceeding. To do so would perpetuate a cruel hoax that is being foisted down in threats to the public.

It would create an illusion that the public's health and welfare are being tended to. Finally, the truth would be the ultimate casualty.

To continue to participate in these proceedings would confirm more legitimacy to a white wash. I hope that that is not true. I hope that is not true. I hope that this Board undertakes a rigorous hard examination of the issues that you have before you.

What is at stake here, honestly, is not just simply the safety of that plant, but the legitimacy of that process which is under attack and it is under attack because people like myself who have valid concerns find themselves fighting and almost impossible to participate in a meaningful way.

We have public hearings with no public intervenors, no adversarial relationships and that in itself is creating a cloud of suspicion over the nature of these proceedings.

Just as a final note, the other frustrating part of this is that we had hoped that the Board would stay the operation of that plant pending the completion of this review. It is ovbious, apparent that the Board has absolutely has no intention of doing that. To me that seems to indicate that there has been a predisposition on the part of the Board to presume the plant innocent until proven guilty.

I am saying that now, since Three Mile Island things have changed. The plant in my mind is guilty until proven innocent and the charge for this Board ought to be to not simply vindicate SMUD and the NRC but to honestly inquire into some very real outstanding problems.

I know I took a long time. It has been 9 long hard months for me and I want to thank you for allowing me the time to make my presentation.

MR. COLE: Thank you for your statement, Mr. Vandervelden. I personally think it is regrettable that it is associated organizations and parties chose not to proceed on an evidentiary basis in the proceeding.

I think it is a shame I think it would have -- I personally would have liked to have you assist us in our hearing. I think it makes our job harder. Again, it is truly regrettable to the Board's viewpoint.

Thank you.

MR. VANDERVELDEN: I know what you all put into this also.

CHAIRPERSON BOWERS: We need to take a mid morning recess not only for some of us but for the hardest worker in the room, our reporter. So, we will take ten minutes.

(Whereupon a ten-minute recess was taken.)

AFTER RECESS

CHAIRPERSON BOWERS: May I have your attention, please?

Is Mr. Keogh here, please? And we are ready to hear from Mr. VanVleck.

Reporter ready? Fine.

MR. VANVLECK: The Chairman and Members and the people present.

The first thing I am going to say is that number one, I am a rancher, and I am not a public speaker and by the time I get finished you will know that.

The reason I am here is that I traveled around to agriculture meetings and throught California I am a good listener and I became aware of the fact that there just was not anyone hardly in agriculture opposed to the generation of nuclear energy. But there were not any of us attending hearings, we were the silent majority that were sitting on our butt. So, it got me off of mine this morning and I came down here.

We ranch rather close to Rancho Seco downwind from the prevailing wind.

We have approximately five thousand acres that I guess this radiation has fallen all over, but during that time our cattle still keep having calves in fact our calf crop has gotten better, our sheep still have lambs, and our lamb crop has gotten better, except when the coyotes work

SACRAMENTO MUNICIPAL UTILITY DISTRICT

July 5, 1979

Mr. Chair,an and Members:

For the Record, I am Herman Grabow.

This Cow Bell is over one hundred years old. I was the Champion Hand Milker at the State Fair - over 80 years old!

Let's talk common sense and placeethings in their proper perspective. Property lost by Storms, Floods, Fire or even a Nuclear Plant Phase-Out is Replaceable.

Life is irreplacable - there was no loss of Life from the so called "Three Mile Island" Nuclear Disaster!

So,let's use Common Sense when evaluating Nuclear Reactor Problems! Lets place Values in Persoective!

THERE IS NOTHING THAT IS ONE THOUSAND PER CENT DANGER FREE!

Let's look at the Recoed.

MAN. In the beginning, muscle was his only energy!

HORSE. So, He advanced his power thru the HORSE! This new energy created problems! They,"Balked,kicked,ran away causing injuries and even DEATHS!

TRAINS. They moved goods and materials,faster,cheaper and to various sections of the Nation - yet, they too had accidents, collisie ons and DEATHS!

TRUCKS. They had mobility, speed and are economical - yet they too had wrecks - caught on fire -Overturned and caused DEATHS!

TRACTORS. They had more Horse-Power,did more work,accidents and DEATHS!

AUTOMOBILES. More power -Speed - Injuries and DEATHS!

on them pretty bad.

Recently, I attended California cattleman's association meeting in Palm Springs and at that meeting I heard all the people there unanimously approve a resolution to Governor Brown's office. After being here today, it was probably totally wasted asking his good office to do all he could to see the Diablo Canyon got onstream as quickly as possible as well as New Malone's to produce energy as cheap as possible.

We are the largest industry in California that is agriculture and we use tremendous amounts of power, we have to pump. We have to get our produce to the market. We have to do it competitively, not just competitively with the United States but competitively with the world.

As you know, agriculture products are what has made the difference in the balance of payments. It is sad, but it would be a lot sadder if it was not for agriculture exports.

The reason they buy our exports is because we produce cheaper than anybody else in the world. That is the only reason, and as long as we can do that, they will keep buying, when we stop doing that and one of the reasons we can do it is because of energy. It takes tremendous amounts of it to produce. To produce good agriculture products.

We would even like to see you go further because there has been concerns expressed about twenty years down the road running out of uranium. We do not really know how much uranium we really have. When we look around the world and find France and West Germany and Russia using the breeder reactor plants, we think perhaps there should be some advancement in those areas because in order to stay in the forefront in the World it takes energy to do it.

Now, I am going to tell you that I have some concerns about Rancho Seco. I am downwind and my concerns are the day I look over and old huff-and-puff is not putting out any steam. Thank you.

CHAIRPERSON BOWERS: Thank you.

Mr. R. A. Caples? -

MR. KEOGH: Madam Chairperson. I am John Keogh the Executive Vice-President of the Sacremento Metropolitan Chamber of Commerce and I would like to welcome all of you to Sacremento and I know Ed Combatalade has given you the buttons and this is a beautiful time of year in Sacramento.

My concern in being here is to raise the Chamber of Commerce concern over the progressive growth of our Community.

The Chamber of Commerce has been in existence since 1895. It has been a strong advocate of preserving the values of our community and insuring that our community has the economic stregth to maintain itself in the future.

I know that we have made a close study of a report which was done in 1962 by the California Group on the preservation of some of these values and we supported such as the American River Parkway. We have supported the Municipal Utility District in its effort to have electrical energy to meet our construction and our economic needs.

Immediately following the emotional reaction to the Three Mile Island situation, we are a sensitive area to Community alarms and the bells that went off following that were very minimal from the standpoint of the community.

In fact, a survey which was taken by our energy task force indciated an 80% support of the people this community for the Municipal Utility District, Sacramento SMUD and PG&E which was not associated at that point because they haven't a nuclear plant in the Sacremento area, but 80% of the people were supporting the managers and engineers in what they had from the standpoint of their professional expertise.

I think it is a high degree of arrogance for those of us who are laymen in the area of nuclear science to preempt those who are devoting a life to this particular area and I think the Nuclear Regulatory Commission should be applauded this morning on the decision which has been made to move the moratorium nationwide because as Mr. VanVleck stated, [illegible], and the Soviet Union and West Germany are [illegible]ing this form of energy production to maintain the momentum of productivity of their societies and their people.

When it comes to Sacramento, we are a Government community with jobs as a key issue. We haven't much private sector development. We have on the horizon a threat to the State jobs because of the taxpayer's anxieties over something called Jarvis 2.

We have to insure in the eighties having the jobs to meet the demands of our people.

We at the Chamber were very saddened that a major firm Signetics chose not to locate in Sacramento because we could not assure the electrical power needed. That would be four thousand jobs in the private sector.

The State Energy Commission has to be a villain in this particular situation because of their knee jerk reaction to the criers of gloom and doom they have not chosen to effectively plan for the future of electrical power needs of our people.

Therefore, the Chamber of Commerce has taken a policy to support conservation as a number one need to support both the Sacramento Municipal Utility District and Pacific Gas and Electric and developing predictable electrical power for the 1980's and the third part of this program is to applaud the efforts to seek new technological developments the alternate energy sources that will be assuring the future of this community.

On that note, I thank you very much for the opportunity to testify and again, welcome.

CHAIRPERSON BOWERS: Thank you very much. Miss Virginia Moose, is that correct?

MR. CAPLES: Madam Chairman, my name is Al Caples, I represent the building and construction trades counsel for organized labor and it is rather ironic that you scheduled me to speak right behind my very dear friend with the Chamber of Commerce and in this particular case, organized labor in the Chamber of Commerce is set in the same particular spot.

We are both in support of the continuation of Rancho Seco. We are both concerned about the safety of Rancho Seco and we know that you people are also.

We are in full support of continued growth in this area.

This area is probably one of the faster growing areas in the United States today.

We need further electrical energy and if Rancho Seco is shutdown or closed down, in any way it will damage, in our estimation a considerable amount of people.

My people representing approximately twenty thousand construction workers in this area is depending upon their livelihood for construction, and without electrical energy we are not going to have a job.

So, quite frankly we are in full support of the continuation of Rancho Seco.

Thank you.

League of Women Voters of Sacramento
2206 K Street, Suite 2 • Sacramento, Ca 95816 • 443-3678

February 26, 1980

TO THE ATOMIC SAFETY AND LICENSING BOARD OF THE NUCLEAR REGULATORY COMMISSION

After a two-year evaluation of energy sources, the League of Women Voters of the United States adopted a position which calls for increased reliance on conservation and renewable resources and no increase in nuclear energy. While this position recognizes that nuclear power has a place in the energy mix, it assigns it the lowest priority because of long-term waste disposal and safety problems.

The League, both on a national and a state level, has called for openness on the part of the nuclear community and for "prompt public disclosure" of findings resulting from investigations of nuclear power safety matters by the NRC and any other public body.

Phyllis Price, State Energy Director for the League of Women Voters, stated in a letter to the NRC dated August 9, 1979: "The League of Women Voters of California urges the Nuclear Regulatory Commission to conduct <u>full</u> public hearings in Sacramento on the operation of the Rancho Seco Nuclear Plant. We feel the citizens living in the Rancho Seco area must be given an opportunity to hear the findings of the investigations into the Three Mile Island incident. These citizens also deserve full access to the NRC in order to ask questions regarding the operation of Rancho Seco."

The Sacramento League of Women Voters does not have a statement to make regarding the safety or lack of safety of Rancho Seco. We do wish, however, to address ourselves to the way in which the nuclear community has treated the subject of safety as it concerns the general public, and by "nuclear community" we mean both industry and government.

Peter Bradford has been quoted as saying that the first casualty of atomic energy was the truth. Whether or not the nuclear community deserves this, the public's perception is that it has not been told the truth, that it has been given a sales pitch instead of the facts, and that, in fact, much time and effort has been expended on keeping information from the public.

A week or so ago, a nuclear expert on a San Francisco talk show came out with that same cliche about the Three Mile Island accident proving how safe nuclear power is because no one was killed. This is not the kind of thing the public wants to hear from the nuclear community. Nor does it want to hear that nuclear plants are failsafe when no allowance is made for human error, or that there will be no harmful effects from low level radiation when the scientific community is sharply divided on that issue, or that the chances of being injured by a nuclear reactor accident are as remote as being hit on the head by a falling meteorite. Nor do people want safety hearings which are so narrow in scope that they become meaningless to the public in general.

This tendency to deal with the public via cliches instead of with real information has resulted in a tremendous loss of confidence by the public in the nuclear industry and in the nuclear regulatory agency. The public has a need and a right to know. No significant headway can be made in solving our energy problems if we are not working together, and right now an enormous gap exists between nuclear advocates and nuclear critics with the general public caught somewhere in the middle.

Both nuclear advocates and nuclear critics have some changes to make. It is incumbent upon nuclear critics not to blow up out of proportion expressions of scientific caution on the part of nuclear advocates as admissions that nuclear power is unsafe. Critics must also deal realistically with the consequences of shutting down producing nuclear power plants. Nuclear advocates, both industry and government, must stop impugning the competence and motives, and even the right, of outsiders to question their judgements.

Give the general public the facts. Let us, especially those of us who live within a few miles of a nuclear plant and who use the electricity produced by that plant, weigh whatever risks exist against the consequences of doing without that electricity. It may be too late for candor, but, at least, let us give it a try.

Goldie Hall

Goldie Hall, President
League of Women Voters of Sacramento

Virginia Moose

Virginia Moose, Energy Consultant
League of Women Voters of Sacramento
1312 ROBERTSON WAY
SACTO. 958[illegible]

MS. MOOSE: My name is Virginia Moose, I am here on behalf of the Sacramento League of Woman Voters and I have given my address to the young lady.

I have a statement to read which has been signed by Goldie Hall, the President of the Sacramento League, and by my self.

After a two-year evaluation of energy sources, the League of Women Voters of the United States adopted a position which calls for increased reliance on conservation and renewable resources and no increase in nuclear energy. While this position recognizes that nuclear power has a place in the energy mix, it assigns it the lowest priority because of long-term wase disposal and safety problems.

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Phyllis Price, State Energy Director fo the League of Women Voters stated in a letter to the NRC dated August 9, 1979, and I am quoting now;

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These citizens also deserve full access to the NRC in order to ask questions regarding operation of Rancho Seco."

The Sacremento League of Women Voters does not have a statement to make regarding the safety or lack of safety of Rancho Seco. We do wish, however, to address ourselves to the way in which the nuclear community has treated the subject of safety as it concerns the general public, and by "nuclear community" we mean both industry and government.

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As week or so ago, a nuclear expert on a San Francisco talk show came out with that same cliche about the Three Mile Island Accident proving how safe nuclear power is because no one was killed.

This is not the kind of thing the public wants to hear from the nuclear community. Nor, does it want to hear that nuclear plants are failsafe when no allowance is made for human error, or that there will be no harmful effects from low level of radiation when the scientific community is sharply divided on that issue, or that the chances of being injured by a nuclear reactor accident are as remote as being hit in the head by a falling meteorite.

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This tendency to deal with the public via cliches instead of with real information has resulted in a tremendous loss of confidence by the public in the nuclear industry and in the nuclear regulatory agencies.

The public has a need and a right to know. No significant headway can be made in solving our energy problems if we are not working together, and right now an enormous gas exists between nuclear advocates and nuclear critics with the general public caught somewhere in the middle.

Both nuclear advocates and nuclear critics have some changes to make. It is incumbent upon nuclear critics not to blow up out of proportion expressions of scientific caution on the part of nuclear advocates as admissions that nuclear power is not safe.

Critics must also deal realistically with the consequences of shutting down producing nuclear plants.

Nuclear advocates, both industry and government, must stop impugning the competence and motives and even the right of outsiders to question their judgments.

Give the public the facts. Let us, especially those of us who live within a few miles of a nuclear plant and who use the electricity produced by that plant weigh whatever risk exists against the consequences of doing without that electricity.

It may be too late for candor, but please let us give it a try. Thank you.

CHAIRPERSON BOWERS: Thank you. Herman Grabow?

MR. GRABOW: Madam Chairman and Members. For the record, I am Herman Grable known as a cow commentator.

This bronze cow bell is 101 years old. I was a legislator representative for the California State grains for 18 years.

For the past eight years on my birthday, January 11th, I have passed out butter to the legislators, the secretaries and my many friends. I have butter labels for you. It is too late, January 11th is long gone.

I understand, according to the publicity in the newspapers that today is set aside for testimony covering broad aspects of the safe operation of Rancho Seco.

This is the way I see it. The cow commentator has lived in the Florin area just a few miles from Rancho Seco for twenty years. So, let us regurgitate a few facts.

One, I have never seen anything that is invisible, have you? Nor, have I ever seen two gases that unite to create rain nor do I know exactly what causes pain, nor can I or anyone else predict exactly Rancho Seco's reign. Nor, there is nothing in this world that is permanent forever, actually the only permanent thing is change, and safety is no accident.

You can have ultimate safety at Rancho Seco through a complete shutdown forever. Rancho Seco cannot be operated without potential danger because everything has an ultimate potential danger.

Maybe Friends of the Earth misspelled the words friends. Do they really want to protect people? Well right here in Sacramento there are stabbings, purse snatchings, robbery, holdups, arson almost every day. So, Sacramento is a fertile field for the good intentions and efforts to help and protect humanity.

My question is, how many deaths or crime in Sacramento can Friends of the Earth name are caused by Ranco Seco? My answer, is none. The way I see it, the Three Mile Island Accident, as far as animals and humans are concerned is a safe, harmless kind of accident. Just hope and pray that trains, plances, autos, guns, knives, bicycles, and earthquakes has as safety as safety record as Three Mile Island had.

Chairman, I have here a copy of Hoards Dairyman, June 10, 1979 that has a picture of the Richard Alwine Dairy located near Three Mile Island. No adverse effect on the animals, the milk, or man. I request permission to read my previous testimony of July 5, 1979 .

I ring this bronze cow bell in support of Rancho Seco.

Now, whatever time I have left, this is what I read on July 5, 1979.

Here is a picture of a Three Mile Island and here is Richard Alwine's Dairy, and I called him Saturday and he said nothing has ever happened to the milk to the animals, to his family, nothing at all.

This Cow Bell is over a hundred years old. I was a Champion Hand Milker at the State Fair over 80 years old.

Let's talk common sense and place things in their proper perspective. Property lost by storms, floods, fire, or even a nuclear plant phase-out is replaceable.

Life is irreplacable. There was no loss of life from the so-called Three Mile Island nuclear disaster.

So, let's use common sense when evaluating nuclear reactor problems.

Let's place values in perspective. There was nothing that is a thousand percent danger free. Let's look at the record.

Man. In the beginning, muscle was his only energy.

NUCLEAR REGULATORY COMMISSION

Feb, 26, 1980

NCR Atomic Safety and Licensing Board:

Mr. Chairman and Members:

For the Record, I am Herman Grabow, known as the "Cow Commentator". This Bronze Cow Bell is 101 years old. I was the Legis lative Reprsentative for the California State Grange for Eighteen years. The past eight years,(on my Birthday,Jan.11, I have passed out Butter to the Legislators,Secretaries and my many Friends.

Mr. Chairman: I have Butter Labels for you and Members.

I understand, according to the publicity in the newspapers, that, today is set aside for testimony covering broad aspects of the "Safe Operation" of Rancho Seco.

THIS IS THE WAY I SEE IT.

The Cow Commentator has lived in the Florin Area, just a few miles from Rancho Seco, for twenty years - so let's "Regurgiitate" a few Facts.

1. I have never seen anything that is invisible, Have You?
2. Nor have I ever seen the two "gases" that unite to create rain.
3. Nor do I know exactly what causes pain!
4. Nor can I or anyone else predict exactly Rancho Seco's reign!
5. There is nothing in this World that is permanent forever.
6. Actually, the only Permanent thing is Change!
7. Safety is no accident!
8.

two Rancho Seco

8. You can have Ultimate Safety at Rancho Seco thru a complete "Shutdown Forever". Rancho Seco can not be operated without Potential Danger - because, everything has an ulrimate Potential Danger!

Maybe, "Friends of the Earth" dispelled the word "Friends". Do they really want to protect people? Well, right here in Sacramento there are: Stabbings, Purse snatching, Robbery, Hold-ups, Arson almost everyday. So Sacramento is a fertile field for their good intentiond and efforts to help and protect humanity. My question is: "How many Death's or any crime in Sacramento can the Friends of the Earth name caused by Rancho Seco?

My answer is "NONE".

The Way I See It - The Three Mile Accident - as far as animals, and Humans are concerned, is a Safe, Harmless kind of an Accident. Let us Hope and Pray that Trains - Planes - Autos - Guns - Knives - and Bicyles and Earthquates have as SAFEty RECORD as THREE MILE ISLAND HAD!

Mr. Chairman , I have here a copy of Hoards Dairyman, June 10. 1979 that has a picture of the Richard Alwine Dairy located near THREE MILE ISLAND. NO ADVERSE EFFECT ON THE ANIMALS, MILK, or MAN! I request permission to read my previous testimony of July5, 1979

I RING THIS BRONZE COW BELL IN [illegible]ORT OF RANCHO SECO!

Herman Grabow
"Cow Commentator"

Herman Grabow

Horse. So, he advanced his power through the horse. This new energy created problems. They balked, kicked, ran away causing injuries and even deaths.

Trains. They moved goods and materials faster, cheaper and to various sections of the nation. Yet, they too had accidents, collisions and deaths.

Trucks. They had mobility, speed and are economical yet they too had wrecks, caught on fire, overturned and caused deaths.

Tractors. They had more horse power, did more work, accidents and deaths.

Automobiles. More power, speed, injurie and deaths.

Oil. Drilling for oil is dangerous, fires, injuries, price is sky high and there are deaths.

There is nothing one thousand percent danger free.

Let's look at the record.

Every day in California, in fact here in Sacramento County, there are auto accidents with bodily harm even deaths, do we : op driving autos? No, we don't.

There are fires in homes, schools and apartments with uge losses both material, physical and even deaths. Do . stop building? We do not. Why then, when there are no serious problem caused from minor problems at the nuclear power plant: and without deaths do some individuals want to forbid the operation of those energy saving electric providing power plants? Since we do not stop building homes, churches, schools, auditoriums, what should we do? Do we improve their fire resistance and try to eliminate the causes of these fires. Smoking, add sprinkler systems and try to catch any arsonists.

The above covers what has happened in the past to man. To man himself, horses, trains, autos, tractors, trucks, fires, which have a record of destruction practically every day of the year.

What about nuclear power? Do we have a record there? Yes, there is such a record. Three Mile Island the one that shook the world. The one that demonstrated how safe nuclear power is for everyone in the area where the problem existed.

Mr. Chairman, permit me to quote from the June 10, 1979 issue of Hoards Dairyman by Dieter Krieg on Three Mile Island --

CHAIRPERSON BOWERS: Mr. Grabow, looking at your document, which if I understood you correctly, you did read at the July 5 pre-hearing conference; is that correct? So it is already in the docket and you do have considerably more so we would like to pass on to the next person if we may.

MR. GRABOW: Be happy to do that.

CHAIRPERSON BOWERS: Mr. Whitecloud.

MR. WHITECLOUD: I took some notes from some of the other people while some of the other people were speaking and I would like to address some of those things first.

I guess the first thing is that your comment that you would like to have seen Mark stay in the hearings, well, you are getting paid to be here, we are not. If you pay us, we will be here and conduct legitimate hearings.

If you will support us, not even pay us, just feed us, take care of us. We will conduct legitimate hearings.

You are getting paid to be here, we are not. I think you should keep that in mind.

The second thing was the comment on the potential loss of generating capacity from Rancho Seco and Diablo Canyon of -.24% or something like that.

All of the energy experts agree our largest energy resource right now is conservation. Look at the lights in here, half of them would be enough. That is where we can do away with Rancho Seco.

The need is not there. There is the comment that other things are dangerous and have caused deaths as well. Coal, oil, those things need to be dealth with too, we are not denying that. We are just saying that we feel the nuclear threat is the most dangerous one right now.

So, we are not denying that all of these other things need to be dealt with right now.

Fourth was the comments on potassium iodide and crypton in the milk I do not really know where he got those.

The things that were in the milk were iodine 131, and stronium 90, so that I do not understand -- the potassium iodide is one of the things that people to take to help them after a nuclear accident to help ward off the radiation, by the way it is beneficial.

Iodine 131 is one of the main things that was released. There were over 14 curies of iodine 131 released from Three Mile Island during the first two days of that accident, not peco curies, as is normally measured, but curie. This is from the utilities own documents and records of the gases releases after that accident.

This is significant in that iodine 131 concentrates in the thyroid gland and especially in the thyroid gland of the fetus.

In doing so it retards the development of the fetus and the babies are born premature, that babies effected are born premature with under developed lungs and other organs and just are incapable of surviving and they die.

Dr. Ernest Sternglass did research into the infant mortality rates after Three Mile Island and in some areas the infant mortality rate increased 100% in the months immediately following the accident and then dropped off again after aboud a four or five month period of time.

This is explainable because iodine 131 has a very, very short half flight, eight days and does not stay around long.

Babies who were in pre-thyroid development at the time of the accident were not affected, they were born normal because they did not have a thyroid gland for it to be effective.

The next thing is we have done a little bit of research around Rancho Seco. Not enought, but again, we are not a a paid staff, we are people working giving up our jobs and lives to do the work that we feel that the government and this board and the NRC should be doing and are not.

We found that when Rancho Seco was lid off and went on line for a matter of just a few months and then back off line for eight, when in went on line the first four months there was a 25% increase in infant mortalities in the areas around the plant.

Average over the years time, for the first year of operation considering that the next eight months of operation were down time the infant mortality rate had decreased.

This is exactly the same pattern as after the Three Mile Island Accident, only on a slightly reduced scale but the pattern of infant mortality is bare around Rancho

Seco. The idea that people supply and demand that we need the electricity is only valid to the point that we start saying that it is okay to kill our babies to get the electricty

We cannot do that, we cannot allow that. It is murder and it is suicide.

To maintain a faith of our own moral consciousness, we have to do everything in our power to prevent these murders from continuing. We are duty bound and law bound to try to prevent this from continuing to happen.

If people did not know the effects of Rancho Seco when they built it and when they let it off, that is understandable, but now you know, you know the effects of radiation, you know that that plant will start killing people when it goes back on line again and if you allow that to happen, you are allowing murder to happen.

You are, because you here have the power to stop it at a minimum. At a minimum you can demand that it not go on line until after the safety hearing. That is the minimum that you can morally responsibly do and call these hearings anything at all but public hearings.

I have got two pages of notes out of the standard California Codes, 1980 edition. They address the first note is from Article 187 and it constitutes murder. It describes what murder is.

Murder is the unlawful killing of a human being or a fetus with malice aforethought.

We feel that we can prove that babies are dying at Rancho Seco, if it is necessary for us to take it to Court. We do not want to do that. Be reasonable people, we do not want to take you to Court on murder charges. That is a very heavy thing to do. But you are leaving us no options.

If you allow that plant to go online, we have no choice, we must pursue every legal non-violent option available to us to protect the lives of our children and ourselves.

You must do it or we must act. It is your choice. You can either shut it down or face the possiblity of criminal charges of conspiracy to commit murder.

CHAIRPERSON BOWERS: Whitecloud and is Will in the audience, W-I-L-L? Okay fine.

MR. WHITECLOUD: I am Whitecloud, and I am not a town, I am a country, America.

I have no organization or group that I belong to.

My mongrel spirit transcends those tribal limitations. My tribe is the whole of humanity and that humanity that tribe is in the process of confronting nuclear disaster.

I have a responsiblity for your lives. You are responsible for mine. I do not come here this morning attack because to attack is to attack myself since I am part of that whole.

I come only to inform you that I am effecting, introducing you to a curative, concentric circle of magic.

I gathered that magic together this morning and released it the moment I entered this room.

It is now in operation. It began with the people around me and it surrounded this room and it is now a circle around this entire building.

If you close your eyes, you might be able to see it. That circle is designed to spread over a 150 mile radius and to expand continuallys and concentrically for as many thousand miles as I can send it.

I am not the only person involved in creating those circles. There are people all over the country and the world who are effecting those circles.

At the risk of stretching political credibility, those people are generally called psychics and mystics.

The origin of the word, India, the original meaning was land of the actor, Columbus was right. We all have roles to perform in this theater of God. Let it not be our part to profane something which she has made sacred, and that is the earth and that is human life. The perpetuatin to which I am dedicated.

CHAIRPERSON BOWERS: Thank you.

Will, you will be next and Mary Moore.

SC SC

TAPE 5/1

MR. WILL: I have been involved in questioning the validity of many activities our society has decided to do in nuclear being one of them.

In my pursuit something really started to bother me, I found the underlining theme that is most discerning to many of the activities that we now accept in our society today. Most of our industries are set up in pattern to have allowable deaths.

What safety has become to us is whether the nunber of allowable deaths we can tolerate for what we are willing to pay for and we all, every one of us have accepted this for all these years. Now, it is the same story with nuclear power. We are asking to define safety as the number of people we are willing to allow to die for the benefit of producing electricity.

I can't consciensiously believe that any human being has been given the authority to make that decision. I would get very frustrated about this and the people that I thought were promoting nuclear power, I conceive them to be enemies and demons and just vicious, bad people. I realize what I was doing was actually attacking their activities. Now I can honestly sit here and say I love these people and everybody here for being human beings but I hate and I feel really regretful that we have allowed ourselves to take part in the activities that now we all take part in. We are all in this together. We have to mutally begin to work together to come up with new and creative ways of dealing with our own destructive tendencies. If we don't we are going to exterminate ourselves.

The NRC people have been used by these arbitrary authorities we have set up to be whipping boys and whipping persons and we failed to realize the human beings there, and today that is all I want to address.

I plan to do a silent visual with the Members here of the NRC today.

CHAIRPERSON BOWERS: Lauren Bodi, please?

This will be -- Ms. Bodi will be the last speaker before we break for the lunch in one hour and then after that Mrs. E. J. Leshan and Helen Hubbard and Diane Hughes after lunch.

Sorry.

MS. MOORE: My name is Mary Moore. I didn't come here prepared to say anything. I came here and I thought I would just see what felt right to me in my five minutes. Just since I got up here looking at the people that are sitting here at this table, all men sitting at the table all in their ties, which is the acceptable mode of dress. I would like to ask each one of you individually how many ever thought of not wanting to put on your tie? I see a few smiles of recognition.

You do it to conform, you do it to be accepted. There are people in the audience who aren't dressed quite as acceptably, it is a suit and tie but maybe a little different style.

I am saying that because I want to make the point that new ideas are difficult to accept, you know, the mainstream we all about the mainstream and the outsiders. Whenever there is a new idea, it merges on the consciences of people and this has gone throughout history, you all know of this.

It is usually done by people who are not accepted at first, little by little that idea gains acceptance, seem in radical sheak, seem in county when the rich people and the poor people. Seen in large numeration, you all know what I am talking about.

So, there are a few people here, that are saying so many far out things, and probably some of you don't even want to hear. On some level, as you know, what we are saying is true..

All of you have your jobs and your lives are depended onthem. So, you don't want to let it in.

The second thing I want to make is about vested interest. Vested interest don't want to let in new ideas. If I were the wife of a worker who was going to work at Rancho Seco I wouldn't want to believe that radiation might kill my husband. If I were a rancher around Rancho Seco and my whole life depended on it, I certainly would not want to believe that radiation could effect me, my family, and I wouldn't want to let that idea in. That is what I heard happen this morning. I have heard a lot of people being used to the old ways who didn't want to let in new ideas.

I just want to back up what was said before. The three of you have the opportunity and are paid to do it, to examine all the evidence. I know what I would do if I was in your shoes, there wouldn't be any question about it. Because, I deep down with all the evidence unless you are engaging in real massive denial.

I don't need to go into all that. Since Three Mile Island was not the first accident, it was the first widely publicized accident. There has been a lot of accidents and there have been people killed on nuclear power.

I am a member of a group, but we are all speaking for ourselves today, but a member of a group that has an office at 1414 16th Street, called People United Against Rancho Seco. We invite any of you to come down and talk for linger than 5 minutes if you really want to know what we are talking about. Rather than sit here and try to tell it to you in 5 minutes which you all know is limiting.

Come on down we will talk to you. We will show you what we have got. We have got 3 large shelves full of evidence. I invite the three of you, too, if you are going to be here. Come on down we will be willing to talk to you on our turf just as we always come and talk on your turf, with your rules and regulations. I dare you. Any of you, come on down, you, too, Mark.

CHAIRPERSON BOWERS: Thank you.

Warren Bodi, please?

MR. BODI: Yes. First of all, I would like to say that I have no dislike for the Nuclear Regulatory Commission, that is sitting up here. I have great compassion for the Nuclear Regulatory Commission. I have been in the anti-nuclear movement for quite a while now and was at hearings on about Diablo Canyon. Where we presented all kinds of evidence. Part of that evidence was about an earthquake that sits under Diablo Canyon that has the potential of up to 7.9.

At Lawrence Livermoore Lab there was recently an earthquake that was recently 5.6, that damaged the structure of the Lawrence Livermoor Labs. Now, 7.9 is at least 25 times stronger. You take a sound and you tap and you magnify the sound 25 times and that intensity is going to strike Diablo Canyon.

Now, I am using that as a point that you all have no validity anymore. YOu all have no credibility. I have compassion for you. I do not feel like you are evil. Not at all. I feel like we are dealing with acute psychosis, I feel like we are dealing with acute insanity.

Insanity relative to what it means to see life as a sacrament.

I am not approaching any more. This whole nuclear thing from a technical point of view. You all know all the technical arguments we have given you. Your ears have remained deaf to it.

I am not approaching this anymore on a political point of view. You all have been pressured by political people. You see our own Governor is trying to pressure you to deaf ears. I am pressuring you out of a spiritual more of a psychic type level.

Your spirit has gone astray. You are rationalizing to yourself genicide. The people that work at Rancho Seco I believe have been brainwashed. They are not at fault. They are brainwashed thinking nuclear power and nuclear weapons can be made safe. You know yourself they cannot be made safe.

I cannot assume that you a scientist telling us constantly things like an earthquake that is 20 times stronger than one we experienced at Lawrence Livermoore Lab is safe. I cannot assume that there is sanity or you are so corrupt by the greed of money.

A friend of mine, Brad, a little while ago, talked about bringing up judicial papers to more or less a citizens arrest of you all because it would be next to impossible to get most government officials to take a risk. They are a all too scared about losing their jobs or being reelected. We have the intent in Sacramento, we have the intent as spreading this idea throughout the country of confronting directly not each individual nuclear power plant, not the governments, well, yes, the government, but directly the utilities, directly the people that sit on the Nuclear Regulatory Commission and directly the Government, and directly the military industrial complex.

You all have violence. We seen what has happened in the past to dissent, in this world. YOu have violent ways of dealing with it potentially. There is now too many of us. Too many people are aware of what is happening.

Is our intent non violently to resist you all spiritually? Basically, if you want can even potentially kill members of our group. There have been members of anti-nuclear groups in Austin, Texas who have been murdered.

There have been native American Indians like John Trudeau who have been murdered because of their resistance to uranium mining at Indians land.

But, you cannot kill millions and millions of people in good faith. You saw what happened after Kent State, when you killed four people you talked out against genicide in Viet Nam. I am talking about genicide in America.

We are going to confront you with love so you can't just turn to us and say " Boy, these people are weird you know, they hate us." I do not hate you. I love you. I love your spirits. That is why we are addressing this to you. In this moment you can repent your evils, and return to some sanity and as far as I am concerned it is over. You made your apologies to society. There is no reason to punish. I don't believe in punishing people. I am asking people resist now, we are asking you all, the three of you up their for Nuclear Regulatory Commission to join us. I am asking the people in the audience to join us in non-violent resisting genicide.

Genicide when it comes to nuclear power, genicide when it comes to nuclear weapontry, genicide when it comes to uranium mining, and genicide in any form.

Basically, what we are dealing with is pain. When you die of something like cancer if you are a child, when you die of something like lung disease from uranium mining, it basically, is very, very painful. It is conceptual to say it isn't connected to that, but you all are scientists and you know it is.

There is not that many of us who are this persistently saying this, because we are wrong. We are like the people that confronted the third right. You can stop as of now, your allegience to nuclear authority. Resist.

I appeal to you to resist. I appeal to everybody in this room to resist.

Thank you.

MR. GRABOW: Madame Chairman, I inadvertently left

left c 't two short paragraphs to Three Mile Island, it is ver, important.

Could I put them in now?

CHAIRPERSON BOWERS: Can't you give us a copy of that? We will be here for a couple of weeks so if you could run off a copy, we will put it in the record.

Fine.

We would like to remind all of you in the room that there will be a session for limited appearances this evening beginning at 7:00 p.m..

We hope those who are planning to come, can come at that time or soon after because if we find ourselves here and there is simply no people to take their limited appearance statements, we will assume that those who have been interested in speaking have attended.

Mr. Vandervelden?

MR. VANDERVELDEN: Some people work and can't make it.

CHAIRPERSON BOWERS: You might they couldn't come this evening?

MR. VANDERVELDEN: I might very well be able to come this evening. What time are you going to --

CHAIRPERSON BOWERS: 7 to 10 p.m. I would say by 8:30 or 9:00 if we have no one to listen to we will assume that people have -- everyone has come that is interested in coming.

Alright, we will have a luncheon break and plan to resume as close to 1:00 p.m. as possible.

I don't know what the situation is as far as getting something to eat.

(Whereupon the Board recessed for lunch at 12:00 p.m..)

AFTERNOON SESSION 2:00

CHAIRPERSON BOWERS: May I have your attention, please? Are you Mrs. E. J. Leshan?

MRS. LESHAN: Yes, I am.

CHAIRPERSON BOWERS: Would you like to proceed please?

MRS. LESHAN: Yes. I have something prepared in answer to the gertlemen who spoke about his cows and his butter. Buc, I feel at this point that I should make it more personal and I should tell you that I am the widow of Edward J. Leshan who was a very fine theoretical physicist trained at Cornel with great potential who preferred to be known by his work and not because he had a Phd but for people to wonder why he did not have a Phd and who in nine-teen hundred and sixty-one gave his life at the age of 34 for the complete abolition of nuclear energy. He left five children and incidentally, Mrs. Bowers, I am French I am not an American and I had to raise those five children alone in this country and I did it with one thing in mind.

That is that they should be aware of who they were as individuals and not as society necessarily defined them.

My oldest daughter is graduating from Medical School. She is deeply aware of what took her father's life. She knows very well the work of Dr. Ernest Sternglass and Dr. Helen Kalcut and I have become increasingly aware as a scientist. I was myself going into medicine. I went into cultural anthropology instead that those people whom are in authoratative positions on your Nuclear Regulatory Commission are by and large not any of them interested or trained in the biological sciences and I have made it my business to take the work of Dr. Ernest Sternglass on Three Mile Island to those that I know at U.C. Medical School at Stanford Medical School and at Doner Laboratory the information on Three Mile Island and what has happened at Three Mile Island.

I hope that any of you in any life are presented with the difficulties I had in raising five children alone as a widow. But I hope that you are presented in your lives the opportunity to grow so that you define yourself and that you do not allow yourself to be defined by outer exterior conditions. That you have the courage and bravery to face life as Edward Leshan's five children are facing it and as his widow is facing it.

I feel that what happened as Will stood behind you in silent prayer because he held in his hand the prayer book that was used by the early Quakers in this country

I brought it and gave it to him. As he was made a laughing stock in today's society as the early Quakers were in the early history of this nation and which incidentally founded this nation on its ideals of freedom that you become aware of his sacrifice for you.

Now, as a scientist, and a trained scientist and a good scientist, all I can say is that since Galielo and Copernicus limited the area of science to the laboratory it has still and consistently and will always be the perogative of science to say what is new that I cannot control in this environment. That is the definition of science. What are the sufficient and necessary conditions for something to occur. Thus far, the instrumentation of science is not capable of measuring this new element and we are dukes and prisoners of that which we felt constituted since the 15th our freedom.

I am only pleading with you members of the Nuclear Regulatory Commission to begin to not close your eyes to that which is new which thus far you have not been able to measure, which is radiation, man-made radiation as contrasted and different from cosmic radiation.

If I could have a moment. I have a statement here written for People United Against Rancho Seco. Other than that I would like to introduce it into the body of this documentation.

CHAIRPERSON BOWERS: We have been given a copy. It will go into the transcript. Does the reporter have a copy? Okay, fine.

MRS. LESHAN: Incidentally, if you would permit me to use the statement that the gentlemen made who talked about butter.

The cows are known nowadays to become very

TRANSCRIPT

PEOPLE UNITED AGAINST RANCHO SECO

c/o P.O. BOX 160334
SACTO.; CALIF. 95814
916/448-5071

26 February 1980

TO: NUCLEAR REGULATORY COMMISSION
ATOMIC LICENSING AND SAFETY BOARD

HEARINGS ON RANCHO SECO NUCLEAR FACILITY
26 FEBRUARY 1980
SACRAMENTO, CALIFORNIA

FROM: PEOPLE UNITED AGAINST RANCHO SECO (PU..S)
1414 16th St.
Sacramento, California

Although the following communication is addressed specifically to those persons of the Nuclear Regulatory Commission (NRC), it applies equally to all government and utility officials who have the power to shut-down Rancho Seco nuclear facility.

We must first inform you that our own investigations agree with the finding of the Kemeny Report on the Accident at Three Mile Island which indicates that the NRC has promoted nuclear power rather than to regulate it. It is as if the NRC has pursued a policy of "safety first, unless it costs too much to fix". However interpreted, the end result is that we the people cannot have trust that the NRC has as its first priority the health and safety of our people.

In the above respect we note our technical task force report "Imminent Peril at Rancho Seco" which notes the Kemeny Report's admission that, for example, generic design defects exist which have never been corrected either for the Three Mile Island nuclear facility, and we would note, for its twin, the Rancho Seco nuclear facility.

In view of the above facts, we must duly note that these present hearings cannot be considered valid with regard to protecting the safety of our people with regard to Rancho Seco nuclear facility.

The obvious failure of responsible officials to duly protect the life and safety of our people, and the ever present threat of a nuclear disaster—a disaster which would be worse than the gas ovens of World War II—requires us, the People United Against Rancho Seco, to declare in public forum the following declarations of conscience:

(1) That in order to maintain faith with our own principles of conscience, it is our moral duty to do everything in our power via nonviolent means to prevent the continued indiscriminant murder of ourselves and our children by nuclear facilities. That the dangers of low level radiation, the unsolved problems of nuclear waste disposal, and the ever present threat of the tragedy of a nuclear accident go beyond reasonable standards of moral principle.

We note with regard to nuclear accidents that (1a) THE TECHNICAL SAFETY OF NUCLEAR FACILITIES HAS NOT AND CANNOT BE MADE 100% PERFECT. THEREFORE, NUCLEAR ACCIDENTS ARE INEVITABLE. (1b) HUMAN ERROR IN THE ONGOING OPERATION OF NUCLEAR FACILITIES HAS NOT AND CANNOT BE 100% ELIMINATED. THEREFORE, NUCLEAR ACCIDENTS ARE INEVITABLE.

(2) That as the public becomes more and more aware of the facts, that it appears that nuclear energy at best is a terrible mistake, and appears now to be the moral equivalent of murder.

That if Rancho Seco nuclear facility is allowed to resume operation, it is our moral obligation to determine if criminal charges should be filed against those officials who are responsible.

THAT EACH AND EVERY PERSON MUST NOW BE HELD NOT ONLY MORALLY RESPONSIBLE, BUT ALSO MUST BE HELD LEGALLY ACCOUNTABLE FOR HIS OR HER ACTIONS OR INACTION AND THE RESULTS THEREOF. THE EFFECTS OF "LOW LEVEL" RADIATION FROM OPERATING A NUCLEAR FACILITY AS WELL AS A NUCLEAR "ACCIDENT" MUST NOW DEMAND ACCOUNTABILITY FROM RESPONSIBLE OFFICIALS.

(3) We the People United Against Rancho Seco, put the NRC and the other responsible officials on notice of our intention to pursue fully the applicability of criminal charges to all responsible officials with the power to protect our people from Rancho Seco nuclear facility, and who fail to do so.

We will explore the following criminal charges in accordance with the California Penal Code:

CHAPTER 1, section 189-	Murder of First or Second Degree.
CHAPTER 1, section 192-	Manslaughter. (Voluntary or Involuntary).
CHAPTER 8, section 182-	Conspiracy. According to this section of the California Penal Code, conspiracy occurs when two or more persons conspire "To commit any act injurious to the public health, to public morals, or to pervert or obstruct justice, or the due administration of the laws."

(4) We of PUARS declare our intention to pursue fully all legal avenues in order to fully protect our people and our children's children from a nuclear mistake. We regret that as citizens we are forced to intercede in what should have been work already done by our government and by the corporations and utilities responsible for the nuclear threat.

As the facts warrant it, we will demand that appropriate legal charges be applied and be pursued fully in a court of law wherein the facts can speak for themselves.

WE OF PUARS HAVE AGREED TO THE POSSIBLE NEED TO PERFORM CITIZEN'S ARREST IF REQUIRED TO INSURE A FULL LEGAL AIRING OF THE CHARGES AGAINST RESPONSIBLE OFFICIALS IF THEY FAIL TO ADEQUATELY PROTECT OUR PEOPLE FROM RANCHO SECO NUCLEAR FACILITY.

(5) We, the People United Against Rancho Seco, deeply regret the serious and grave nature of this communication. We regret that the original hopes of "atoms for peace" now appears to be a scientific, technical, business, financial, and medical nightmare. A tragic mistake.

BUT TO NOW PERSIST IN NUCLEAR POWER WITH FULL KNOWLEDGE THAT IT HAS NOT YET BEEN PROVEN SAFE, INDEED THE EVIDENCE INDICATES THAT IT IS CLEARLY UNSAFE, IS TO RAISE THE QUESTION NOW OF BOTH MORAL AND LEGAL CULPABILITY OF THE NRC, OF OTHER RESPONSIBLE GOVERNMENT OFFICIALS, OF UTILITY OFFICIALS, AND INDEED THOSE WHO WORK IN NUCLEAR FACILITIES.

(6) We ask you, or should we say invite you, to examine your motives and your values, to question whether or not you must personally be involved in a pledge of allegiance to a nuclear authority whose calling card appears to be genocide and the threat of the extinction of our planet and its people?

We are all victims now of constant nuclear stress. The challenge to each of us is to remove nuclear stress from our lives both here in America, and throughout the world so that we, and our children, can once again live without fear.

Respectfully,

PEOPLE UNITED AGAINST RANCHO SECO

wild as a result of being milked with electrical milking machines.

I wonder if Dr. Marvin Goldman who was used as your authority -- he will be here this evening -- I wonder if since he is in veternary science if he has measured this electrical impulse on the tits of the cows to see why it is that they become so wild or if he is willing to use this as part of his scientific documentation as a scientist that is not as a paid politician.

Thank you very much.

CHAIRPERSON BOWERS: Now, is Helen Hubbard here, please?

MRS. HUBBARD: Good afternoon. My name is Helen Hubbard and I live near Livermore in Alameda County.

Just as an aside from the Miss Moos who spoke this morning I am also a long-time member of League of Women Voters and with the general public, all league members do not agree with Miss Moos and I am one of them.

I am also aware of the ASLB's position in these proceedings, so please bear with me it is going to be quite short.

I am here today because no one is representing my point of view and I too am part of the public.

Since a portion of my electricity is supplied by SMUD I do not intend to sit idly by while my lights are in danger of being turned out.

Those who so vociferously protest against nuclear energy and use the Courts to further their objectives, whatever they might be have seemed to me to have bastions in inviolate and proclaim that they alone care about the unborn generations and the pristine planet.

Well, I am a wee bit tired of that fantasy and more and more I have grave doubts about their altruistic motives.

I think I know what they want. They want the total shutdown of all nuclear facilities in the United State, and now I will tell you what I want.

I want a future. A future that is not sopped and barren and second rate and unemployed and defenseless.

They seem to want their children to wander through the wilderness communing with nature.

I want mine to build, repair, to research, develop, produce and protect this country militarily if need be.

The need for electricity will continue to grow no matter how much they wish it wouldn't.

Electricity can be created by spinning turbines powered by expensive crude oil by natural gas as long as it lasts, by falling water where circumstances permit and by water held back where environmentalists permit and it can be created by burning coal.

Each of these methods have caused deaths and disaster and damage to the environment, or we can produce electricity by using the nuclear fission process. There is no way to get around the fact that this method has not killed or injured one person nor has it contaminated the environment.

While the protestors posture before the nation's media, the Courts and Federal and State Commissions and Boards, honest, caring, knowledgeable people such as the operators of Rancho Seco work in the nuclear energy field.

This is their country also and their beliefs deserve equal weight.

As a fellow citizen, I dislike the protestors' plan for my future and I protest actions which assure me of a chronic energy crisis.

We are a proud, industrious, innovative society and no matter what the theory, we have come a long way from flying kites.

It is time that those who would shut off the nuclear option realized our predicament and grew up to face the responsibilities we all must face as a nation.

I am very concerned about their constitutional rights but I am even more concerned about the survival of the free world.

Therefore, I would urge to consider this message prosperous.

Indeed, abundant energy is the economic basis fc ırvival.

This brings me to the heart of the matter which is electrical generation.

Presently, Rancho Seco is shutdown for refueling. Hopefully, this Board will find that it is safe enough to start up again.

In my opinion, nuclear generated electricity is one of the best hopes of mankind to provide clean, safe, economical and abundant electricity.

If one is to believe the energy commission in their recent letter Docket Number 80-EA-4, on the matter of the adequacy and reliability of California's electrical supplies in the summer of 1980, which states that "California nuclear power plants that currently provide electricity to California may be unavailable during the summer of 1980 if the NRC requires shutdown for changes in the design and operation of such facilities..."

Surely they are referring to Rancho Seco. Just as surely the Commission is instituting hearings to solve th. problem that it allowed to happen.

The Commission is just as surely spending more of the ratepayers' money.

As a ratepayer, supporting the California Energy

Testimony of Helen Hubbard before:

The United States Nuclear Regulatory Comm.
Atomic Safety + Licensing Board

Subject: In the Matter of:
The Sacramento Municipal Utility District
(Rancho Seco Nuclear Generating Station)

Date: February 26, 1980

Place. Federal Building, Sacramento, Ca.

Good Morning.

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not m[illegible] nergy

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Well, I'm sick and tired of that fantasy and MORE + MORE I have grave doubts about their avowed altruistic motives.

I think know what they want, the total shut down of all nuclear facilities in the United States. Now I'll tell you what I want. I want a future, a future that isn't sapped + barren, and second rate, and unemployed and defenseless.

POOR ORIGINAL

They want their children to wander

thru the Wilderness communing with nature, I want mine to build & repair, to research, develop, ~~and~~ produce and protect this country militarily if need be.

The need for electricity will continue to grow no matter how much they wish it wouldnt.

Electricity can be created by spinning turbines powered by expensive crude oil, by natural gas as long as it lasts, by falling water where circumstances permit and by water held back where environmentalists permit, and it can be created by burning coal. Each of these methods have caused deaths and disaster and damage to the environment.

Or we can produce electricity by using the nuclear fission process. There is no way to get around the fact that this method has not killed or injured one person nor has it contaminated the environment.

While PROTESTERS ~~they~~ posturing before the nations media, the courts + federal + state commissions + boards, honest, caring, knowledgeable people (~~your~~ SUCH AS OPERATORS OF RANCHO SECO ~~neighbors~~) and mine work in the nuclear energy field.

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As a fellow citizen I dislike ~~their~~ the protestors ~~their~~ plan for my future and I protest ~~their~~ actions which assure me of a

(6)

seem and lets get on with the job of producing sufficient electricity for this state and the nation.

Thank You for
Your kind attention.

Helen Hubbard
3401 Little Valley Rd. Box 63
Sunol, Ca. 94586

Member: Citizens for Total Energy

De centralization opposed centralization

of a chronic energy crisis

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however unimportant or emotional it may seem, and in the name of reason and logic, let us get on with the job of producing electricity sufficiently for this State and the nation.

Thank you.

CHAIRPERSON BOWERS: Diane Hughes and the next person, it looks like V-E-A Callahan.

MS. HUGHES: Good afternoon. My name is Diane Hughes and I am here from San Jose in Santa Clara County, California.

It is a privilege here to be here today before the NRC Atomic Safety and Licensing Board, whose responsibility it is to insure safe operations of Rancho Seco.

The reason I am here is to express my confidence in the ability of the operators to run this plant in a safe manner, and in accordance with all the NRC safety regulations.

I am here also to protect my interests and the interest of all Californians to have an adequate electrical energy supply.

I live in an electric house and depend PG&E for my electricity. They purchase a portion of their electricity from Rancho Seco. So, therefore, it is in my best interest to see that Rancho Seco operates safely so that I may operate my house. Not only is the electricity important to maintaining a home, but it is essential to operating the highly electrically intensive computer industries which keep Santa Clara

Commission, I resent the Commission's expansion into an enormous paper shuffeling factory which has yet to create one single new electric generating plant.

I resent their apparent talent to obstruct what generating plants we do have. In fact, it actually seems to me that the Commission has an uncanny ability to act against nuclear power generation.

In my opinion, an attack against one nuclear facility is an attack against all nuclear facilities.

This therefore, constitutes an attack against energy and an attack against energy raises the spector of an enforced change in my life and stand..rd of living.

After all, electricity is the slave of mankind, operating at about 5¢ a kilowatt hour. I do not wish to become the slave to some il concieved, over safety conscious, elitist, arrogant anti-nuclear factions plan to save the world. For whom are we saving the world?

Personally, I believe the safety licensing board is empowered to save Rancho Seco from oblivion by finding that it is indeed compentently run utility, needed by the State of California.

I thank you for your kind attention.

CHAIRPERSON BOWERS: Thank you. Is there is Vea Callahan in the audience?

(No response)

TESTIMONY OF DIANE HUGHES BEFORE: UNITED STATES NUCLEAR REGULATORY COMMISSION ATOMIC SAFETY AND LICENCING BOARD
SUBJECT: IN THE MATTER OF SACRAMENTO MUNICIPAL UTILITY DISTRICT(RANCHO SECO NUCLEAR GENERATING STATION)
DATE: FEBRUARY 26, 1980
PLACE: FEDERAL BUILDING, SACRAMENTO, CALIFORNIA

GOOD MORNING, I AM DIANE HUGHES, FROM SAN JOSE IN SANTA CLARA COUNTY, CALIFORNIA. IT IS A PRIVELEGE TO BE HERE BEFORE THE U.S. NRC ATOMIC SAFETY AND LICENCING BOARD, WHOSE RESPONSIBILITY IT IS TO INSURE SAFE OPERATIONS OF RANCHO SECO. THE REASON I'M HERE IS TO EXPRESS MY CONFIDENC[illegible] IN THE ABILITY OF THE OPERATORS TO RUN THIS PLANT IN A SAFE MANNER, AND IN ACCORDANCE WITH ALL NRC SAFETY REGULATIONS. I AM HERE, ALSO TO PROTECT MY INTERESTS, AND THE INTERESTS OF ALL CALIFORNIANS TO HAVE AN ADEQUATE ELECTRICAL ENERGY SUPPLY. I LIVE IN AN ELECTRIC HOUSE, AND DEPEND ON PG&E FOR ELECTRICITY, AND THEY PURCHACE A PORTION OF ELECTRICITY FROM RANCHO SECO. THEREFORE, IT IS IN MY BEST INTEREST TO SEE THAT RANCHO SECO OPERATES SMOOTHLY, SO THAT I CAN OPERATE MY HOUSE.

NOT ONLY IS ELECTRICITY IMPORTANT TO MAINTAINING A HOME, BUT IT IS ESSENTIAL TO OPERATING THE HIGHLY ELECTRICALLY INTENSIVE COMPUTER INDUSTRI[illegible] WHICH KEEP SANTA CLARA COUNTY PROSPEROUS. INDEED, ABUNDANT ENERGY IS THE ECONOMIC BASIS FOR SURVIVAL.

THIS BRINGS ME TO THE HEART OF THE MATTER WHICH IS ELECTRICAL GENERATION. PRESENTLY, RANCHO SECO IS SHUT DOWN FOR RE FUELING. HOPEFULLY, TH[illegible] BOARD WILL FIND IT SAFE ENOUGH TO START UP AGAIN. IN MY OPINION, NUCLEAR GENERATED POWER IS ONE OF THE BEST HOPES OF MANKIND TO PROVIDE CLEAN, SAFE, ECONOMICAL, AND ABUNDANT ELECTRICITY. THIS OPINION MAY EVEN BE SHARED BY THE CALIFORNIA ENERGY COMMISSION, IF ONE IS TO BELIEVE THEIR RECENT NEWSLETTER, DOCKET #80-EA -4, ON THE MATTER OF THE "ADEQUACY AND RELIABILITY OF CALIFORNIA'S ELECTRICAL SUPPLIES IN THE SUMMER OF 1980" WHICH STATES THAT "NUCLEAR POWER PLANTS THAT CURRENTLY PROVIDE ELECTRICITY TO CALIFORNIA MAY BE UNAVAILABLE DURING THE SUMMER OF 1980, IF THE NRC REQUIRES SHUT-DOWNS FOR CHANGES IN THE DESIGN AND OPERATIONS OF SUCH FACILITIES......"

SURELY THEY ARE REFERRING TO RANCHO SECO. JUST AS SURELY, THE COMMISSION IS INSTITUTING HEARINGS TO SOLVE THE PROBLEMS IT ALLOWED TO HAPPEN. THE COMMISSION IS JUST AS SURELY SPENDING MORE OF THE RETEPAYERS MONEY. AS A RATEPAYER, SUPPORTING THE C.E.C., I RESENT THE COMMISSIONS EXPANSION [illegible] TO AN ENORMOUS PAPER SHUFFELING FACTORY WHICH HAS YET TO CREATE ONE SINGL[illegible] NEW ELECTRIC GENERATING PLANT. I RESENT THEIR APPARENT TALENT TO OBSTRUCT WHAT GENERATING PLANS WE DO HAVE. IT ACTUALLY SEEMS TO ME THAT THE COMMISSION HAS AN UNCANNY ABILITY TO ACT AGAINST NUCLEAR POWER GENERATION. IN MY OPINION, AN ATTACK AGAINST ONE NUCLEAR FACILITY IS AN ATTACK AGAINST ALL NUCLEAR FACILITIES. THEREFORE, THAT CONSTITUTES AN ATTACK AGAINST EN[illegible] AN ATTACK AGAINST ENERGY RAISES THE SPECTRE OF AN ENFORCED CHANGE IN MY LI[illegible] AND STANDARD OF LIVING. AFTER ALL, ELECTRICITY IS THE SLAVE OF MANKIND, OPERATING AT ABOUT 5¢ A KWH. I DO NOT WISH TO BECOME THE SLAVE TO SOME ILL CONCIEVED, OVER SAFETY CONSCIOUS, ELITIST, ARROGANT PLAN TO SAVE THE WORLD. FOR WHOM ARE WE SAVING THE WORLD?? ANTI-NUKE FACTIONS

PERSONALLY, I BELIEVE THE SAFETY LICENCING BOARD IS EMPOWERED TO SAVE RANCHO SECO FROM OBLIVION BY FINDING THAT IT IS A COMPETENTLY RUN UTILITY, NEEDED BY THE STATE OF CALIFORNIA.

THANK YOU FOR YOUR KIND ATTENTION,

DIANE HUGHES, 20845 SCENIC VISTA DRIVE, SAN JOSE, CA. 95120
MEMBER OF "CITIZENS FOR TOTAL ENERGY", A GRASS ROOTS ENERGY EDUCATIONAL ORGANIZATION

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Now, I do not really believe that there is somebody in the audience by the name of I. Ratepayer, but did someone sign to speak using that name?

(No response)

Is there a K-A-R-M-A-K-A-N-I-C in the audience?

(No response)

Well, let me ask, do you have any more names?

Dr. Rodger :otila?

Well, if he was here, then I will go back to check in a few minutes for that.

Now, let me check is there anybody else in the audience at this time who would like to make a limited appearance statement who has not done so today? Sir, would you come forward and give your name, so the reporter will have it.

MR. HILL: My name is Warner Hill.

I just want to clear up one thing that keeps coming up at these hearings and I can understand why it has come up because people have not gotten the quality information.

The old argument that no one has died from nuclear power and I just want to bring out that three people died in Idaho in '67. Some of you may know about this but if I hear one more person say that nobody has died from nuclear power, I am going to be forced to do my imitation of a groaning dying, a person dying of cancer, and I do not want to do that.

Aside from the three people that died in the explosion in Idaho as Dr. Sternglass and others have pointed out, the main danger of nuclear power is not what we see right in front of us. It is a long-range contaminatin of the gene pool and the deaths are not -- the deaths are estimated to come within twenty to forty years after the contamination and we all know how long nuclear power has been with us now.

So, the point is if we say there are no deaths, it is very obviously who we are thinking about and I think everyone should be aware that if you are not concerned about the deaths, it is a real selfish outlook. It is like one generation and that -- one generation is about all the nuclear plant -- that is as much uranium as there is and we all know, well, I hope most people know that thirty years is about the ultimate life span of a nuclear power plant.

So, after thirty years, okay the pro-nu people got what they wanted and it is all over. Noboday can go near the power plant for two hundred fifty thousand years and the waste would be left with future generations. So, I think it is really important that people understand that the deaths are not deaths that will -- you won't have to suffer the deaths, it is our children and our children's children, it is the contamination of the gene pool and any one who has not seen the evidence now I would recommend stopping by the office, People United Against Rancho Seco.

Dr. Sternglass and others have done research regarding the fallout and the infant mortality related to Thre Mile Island Accident. So, this is starting to come out in the light now. Admittedly the explosion in Idaho in '67 which killed three people was pretty well covered up and I am sure that accounts for a lot of people no knowing about that.

I just want to do one more little thing. This is my imitation of John Wayne.

Well, kids, remember your grandparents cause we are the ones that made manifest our destiny.

Invest in future generations, no way, I'll put my money with Great Western.

CHAIRPERSON BOWERS: Now, let me check and see if Dr. Rodger Kotila has returned yet. Okay, fine. You left for two minutes and we called your name.

MR. KOTILA: My name is Dr. Rodger Kotila. I am a Clinical Psychologist and I live in Mill Valley, California.

I am a member of the People United Against Rancho Seco and I wish to make a couple of comments part of which will come from a written statement from People United

Against Rancho Seco that brings some very, very serious and grave issues to bear.

Addressed to the Nuclear Regualtory Commission and to all Government and Utility Officials.

The obvious failure of responsible officials to duly protect the life and safety of our people and the ever-present threat of a nuclear disaster, a disaster which would be worst than the gas ovens of World War II requires us, the People United Against Rancho Seco to declare in public forum the following declarations of conscience. I am only going to read one of these.

We note with regard to nuclear accidencts that la, the technical safety of nuclear facilities has not and cannot be made 100% safe.

lb, the paper follows that nuclear accidents are inevitable.

lb, human error in the ongoing operation of nuclear facilities has not and cannot be 100% eliminated. Therefore, once again, nuclear accidents are inevitable.

I wish to make a couple of comments on the human error issue as a psychologist most of which to insure you that we cannot 100% eliminate human error.

There is no way, and any psychologist would safely make that statement.

I think that that is an important issue.

The second comment I would like to make has to do with the notion of nuclear stress.

I think the Country now has to start considering what is happening to us with regard to the emotional and psychological pressures that are being brought to bear. I refer to this as nuclear stress and would simply like to point out to this Board that in Northern California, I as a psychologist, see more and more people who are reacting to nuclear stress, chronic and constant, background, apprehension and worry that something bad might happen. It is the "what if" problem.

Well, what if, there is an accident and I do not believe that this body and others relating to nuclear issue in this Country are adequately facing now the problems of nuclear stress.

People and their children are starting to have nightmares. People, in my opinion, are starting to show psychiatric disorders related to worry. Worry in regard to the "what if" question. What if there is an accident?

Any of you sitting here, including myself, who has read extensively much of the data on nuclear power has to conclude that if there is a so-called accident which our logic shows to be inevitable, it will be quite a tragedy. So, we cannot even reassure our children and I would like to personally appeal to you to please, please, look into your hearts now when we are at the crossroads in America at a time when we must question our basic value system and mine is an appeal to look into your heart that now is the time.

America is at a crossroads. People United Against Rancho Seco means no harm to anybody. We want to see Northern California safe for our children.

Thank you.

CHAIRPERSON BOWERS: Thank you. Is there anyone else in the audience who would like to make a limited appearance statement at this time?

(No response)

MRS. LESHAN: I had intended to bring you --

CHAIRPERSON BOWERS: Please identify yourself.

MRS. LESHAN: Yes, I am Mrs. Edward J. Leshan. I had intended to bring you documentation that Dr. Ernest Sternglass had left with me, but I had intended to bring it tonight because I did not have an opportunity to get hold of it before coming -- I just came from San Francisco, directly here -- I wondered if it would be possible to make provisions that this be part of your material --

CHAIRPERSON BOWERS: Yes, it can be handed in.

MRS. LESHAN: May I hand that in?

CHAIRPERSON BOWERS: Yes, fine. Thank you.

MR. BAXTER: While we have a pause, Mrs. Bowers, could I make an announcement for the record that at the pre-hearing conference on February 6th, when the Board adopted some of the Hurst Castro contentions as its own questions, we expressed the possibility there might be a need to supplement our testimony in some way after we saw your written pre-hearing conference order with your re-formulation of those issues.

I would just like the record to reflect that I have distributed to the Board and the parties this after-noon, two pieces of supplemental testimony by a Licensee, one by Robert A. Dietriech in response to Board question Hurst Castro, 20 and another by Bruce Carish and Robert Jones in respone to Board question Hurst Castro 22 and we would intend to present that supplemental testimony at the same time those witnesses present their main testimony distributed on February 11th.

CHAIRPERSON BOWERS: Just a matter of curiosity, you know, we were very late getting our transcript from that pre-hearing conference.

Now, the pre-hearing was February the 6th which was what on a Wednesday and we were a week getting our transcript. We did not get it until the close of business on Tuesday which created a real problem for us.

Do you have any idea when you got your copy, Mr. Baxter?

MR. BAXTER: Well, I had extra problems because I stayed out here.

CHAIRPERSON BOWERS: Mr. Lewis, do you recall when you got your copy on that transcript.

MR. LEWIS: Not specifically.

CHAIRPERSON BOWERS: Well, because we were delayed in getting it and we recognize the urgency of getting the order to the parties, we worked out a special messenger service now it was supposed to be hand carried to the plane in the Washington area and hand carried in Sacramento to the California Energy Commission and Friends of Earth. Do you have any idea -- did you get that Friday?

MR. BAXTER: I am sorry, Mrs. Bowers, I am not sure when.

CHAIRPERSON BOWERS: Well, anyway we are going to improve the situation that created a problem for us because we knew the parties who were not only interested in getting that post pre-hearing order, but were entitled to it and we simply could not get a hold of the transcript until what we considered to be too late.

Well, we are kind of puzzled actually we expected to have many more people here today to give statements and it might be a number of people here this evening, it is hard to know.

Is there anyone in the audience who knows of someone who plans to come shortly, because we could take a recess -- someone is indicating -- do you have information about people who are planning to appear this afternoon?

MS. PRICE: I know of one who was planning to be here this afternoon.

CHAIRPERSON BOWERS: Well, we could take a -- let me check and see with the parties to see if there are other matters to be considered, Mr. Baxter?

MR. BAXTER: I have none, Mrs. Bowers.

CHAIRPERSON BOWERS: C. E. C.?

MR. WEBB: None for us.

CHAIRPERSON BOWERS: Mr. Lewis?

MR. LEWIS: No.

MS. PRICE: I will call my party.

CHAIRPERSON BOWERS: Could this person come tonight?

MS. PRICE: That is what I am going to suggest.

CHAIRPERSON BOWERS: Okay, then what we will do is take a 15 minute recess now and Mr. Hamilton, will you please remain in the room so that if people come to let them know that we will come back and see if there are others and it may be too the person making the phone call will have some information. So, we will recess for 15 minutes.

(Whereupon the Board took a 15 minute recess.)

(Whereupon the Board returned from the recess.)

CHAIRPERSON BOWERS: May we have your attention, please. Mr. Hamilton, do you have any additional names for limited appearance statements?

MR. HAMILTON: No.

CHAIRPERSON BOWERS: Let me check with the audience. Is there anyone in the audience who has not given a limited appearance statement who would like to do so at this time?

(No response)

Well, what we will do is simply adjourn until 7:00 and we will ask Mr. Hamilton to put some signs on the doors that we waited and that we had no one to listen to.

So, we will return at 7:00.

(Whereupon the Board adjourned until 7:00.)

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EVENING SESSION 7:00

CHAIRPERSON BOWERS: May I have your attention, please. We are here to hear limited prepared statements and we have one information names, Dr. William Schuster who wants to make a limited prepared statement. Dr. Schuster, will you come forward please?

DR. SCHUSTER: Well, my statement is based upon my decision that after examining evidence for and against nuclear energy, I have made what I feel is a rational decision that nuclear energy is the only feasible current source of adequate energy and politically and economically we must not only maintain the energy resources we have now but we must expand our energy resources because the trouble in the Middle East cannot only decrease our supply of fossil fuel but could terminate it completely.

In which case I think that we would be helpless economically and that would be connected with failing military and national stregth.

I would like to offer the fact that based on a meeting of environmental scientists early this year, there was a very responsible group of scientists certainly as capable as any opponents of nuclear energy, maybe they do not have as many credentials but they certainly have respectable ones in my opinion.

They went on record during this meeting in supporting as a matter of organizational policy, the continued use of nuclear energy. The reason was based on the fact this was post Three Mile incident that in all the recorded use of nuclear energy, including the naval use and there had never been one life taken by an accident involving nuclear energy.

There have been accidents but these accidents seem to have been reasonably controlled by the safety systems. For example, there was an accident today in Florida and the current report is that there were no injuries and that the emergency cooling system served its purpose.

The only other comment I can make is that opponents of nuclear energy undoubtedly are sincere but in approaching an analysis of the issue they seem to leave a position of rationality and go to a position of extremeism which in the law would be characterized as going into ad hominem argument, that is they attack the integrity, the responsibility, and the morality of the pro-nuclear position.

In the meantime, of course, the enshrine their negative position with all kinds of sanctity.

There is no doubt danger in nuclear energy because there is danger in every kind of energy production even a friendly camp fire may spread and unless regulated may dessemate a forrest. A friedly fire in our home that we have in a fireplace can expand its energy and consume our home.

In a coal mine accident site some where in Virginia there was a loss of 14 lives and the media did not even report that tragedy.

So, in making a rational decision on this important issue, we must consider always the fact that the people who report the nature of pro-nuclear energy seem to seize on the melodramatic aspects of it and that is bound to effect public awareness and it is bound to turn a lot of the people off on nuclear energy and perhaps it would be better for all of us if the debate were continued on extremely rational basis with all of us continually digging for more facts before we make a decision.

Do you have any questions?

CHAIRPERSON BOWERS: Just one question, Dr. Shoster?

DR. SCHUSTER: Schuster.

CHAIRPERSON BOWERS: CSUS?

DR. SCHUSTER: California State University of Sacramento.

CHAIRPERSON BOWERS: Thank you and the doctorate is in what?

DR. SCHUSTER: Law, J. D. juris doctor.

CHAIRPERSON BOWERS: I know that. Thank you.

Who else in the audience would like to make a limited appearance statement? Anyone?

MR. HILL: Madam Chairman, I know that Dr. Goldman from the University of California said he would be here and it is about 35 miles away and if we can wait a few minutes I think he will be here. Also, Dr. Whalen from the California State University is supposed to be here also.

I hoping that they are not too late.

CHAIRPERSON BOWERS: Well, we will recess for 20 minutes and then come back to get these people because we are interested in hearing from those people who are interested in the Sacramento area so we will be here in 20 minutes, at some point we go home.

(Whereupon the Board took a 20 minute recess.)

(Whereupon the Board returned)

MR : These roses are from the people in jail to the NRC with love.

CHAIRPERSON BOWERS: We are in session and we have had a request from Warner Hill to make a statement. Is this your statement Mr. Hill?

MR. HILL: Will and Whitecloud were arrested today and they are members of People United Against Rancho Seco and that is their request.

CHAIRPERSON BOWERS: Let me check with Mr.

Hamilton and also with the audience. Are there any people in the audience who have not made limited appearance statements who would like to make limited appearance statements at this time?

I am just amazed. I thought there would be hundreds at the evening session and that simply is not true.

DR. COLE: Well, I think if anybody planned to be here they should be here by now. We announced the time as 7:00 so I am going to confer with my colleagues now and we will tell you what we are going to do.

MR. SHON: I might say I am very surprised to in my own experience the evening sessions have drawn far more people than this and I rather thought that this was an area that was very, very interested in saying their peace both pro and con, it is surprising.

CHAIRPERSON BOWERS: We thought that we would have many people here this evening and that is why we gave up the evening to -- yes, mam?

MRS. LESHAN: Perhaps what we make up in quantity can be made up in quality in as much as you have the statement from Dr. Ernest Sternglass and the University of Heidelberg. I think that they are very exact and very appropriate and I am sorry that we cannot do more but I think that that will speak to your conditions.

MR. SHON: Mrs. Leshan, just out of curiosity, did your husband work at the radiation laboratory?

MRS. LESHAN: Yes, he did. At Lawrence Livermore Laboratory.

MR. SHON: As sort of a little aside, his name sounds very like mine and I think I have often answer his pages and he mine on the public address system.

MRS. LESHAN: Well, God Bless you, I am glad that you are a live.

MR. SHON: I am glad too.

CHAIRPERSON BOWERS: Well, we have checked with the audience and let me check again.

Anyone in the audience who would like to make a limited appearance statement who has not done so already?

No response, negative.

We will adjourn and resume at 9:30 tomorrow morning and tomorrow we will also call for a limited appearance statement.

(Whereupon the Board was adjourned at 7:30 to resume again at 9:30 at the same location.)

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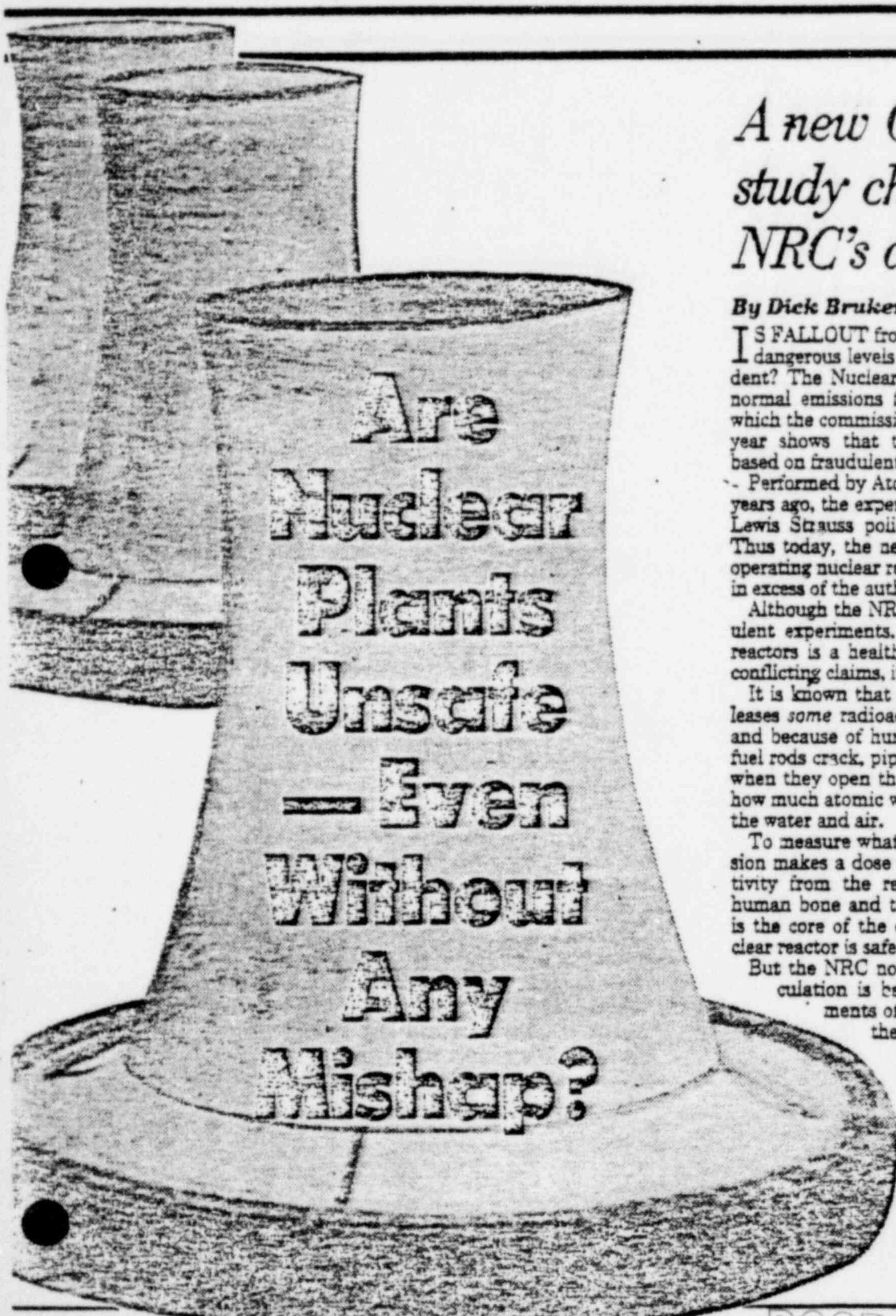
The Washington Post
Washington, D.C.
SUNDAY, NOVEMBER 11, 1979



A new German study challenges the NRC's assurances

By Dick Brukenfeld

IS FALLOUT from nuclear reactors exposing people to dangerous levels of radiation — even without an accident? The Nuclear Regulatory Commission claims that normal emissions from reactors are safe. But a report which the commission has been sitting on since early this year shows that these government safety claims are based on fraudulent research.

Performed by Atomic Energy Commission scientists 20 years ago, the experiments demonstrate the Eisenhower-Lewis Strauss policy of making fallout look harmless. Thus today, the new report says, fallout from normally operating nuclear reactors is exposing people to radiation in excess of the authorized limits.

Although the NRC admits the charge about the fraudulent experiments, it denies that fallout from nuclear reactors is a health hazard. To find the truth in these conflicting claims, it helps to begin with what is known.

It is known that each of this country's 72 reactors releases *some* radioactive waste. This happens by design and because of human and mechanical flaws. Uranium fuel rods crack, pipes leak, filters fail and so do workers when they open the wrong valve. Thus the NRC limits how much atomic waste each reactor may discharge into the water and air.

To measure what this is doing to people, the commission makes a dose calculation. This tracks the radioactivity from the reactor through the food chain into human bone and tissue. The resulting "dose estimate" is the core of the claim that a normally operating nuclear reactor is safe.

But the NRC now acknowledges that this safety calculation is based in part on the dubious experiments of the 1950s. The problem begins with the conviction that atmospheric nuclear testing was essential to national security.

See FALLOUT, Page B4

Dick Brukenfeld, a New York-based freelance writer, started following the nuclear power story as a reporter for the Lowell (Mass.) Sun in 1956.

Are Nuclear Plants Unsafe *Without* Accidents?

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FALLOUT, From Page B1

To quiet the Nervous Nellies who wanted a test ban, the old AEC took steps to show it was keeping on top of fallout. One such step was a program of experiments to find whether food crops would take up dangerous levels of fallout from the soil. More than just looking for results that would make fallout appear safe, most of the scientists rigged their experiments to produce the desired reassurance.

In measuring how much fallout plants would pick up from the soil:

- The AEC scientists made preliminary tests on a variety of soils. They chose for their experiments those soils which absorbed the least amount of fallout.
- It was known that plants have difficulty assimilating many fallout ingredients until they are acted upon by soil bacteria. To prevent this, the scientists cooked their soil in ovens and killed its bacteria.
- Then they added the radiotoxic substances to the soil shortly before the plants were harvested. This avoided the conditions of reality, where the plants would grow from seeds in the contaminated soil.

Not surprisingly, these experiments showed hardly any fallout was getting into crop plants.

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The report which reveals this information breaks new ground. It's the first time independent scientists have dug into the NRC's safety assurances to expose their foundations. Written by a team of 14 West German scientists — agricultural biologists, physicists, chemists, a mathematician, a physician and a veterinarian — from the University of Heidelberg, it applies directly to this country. Not only does Germany build its reactors from American designs but it proves their safety with the same set of calculations the Nuclear Regulatory Commission uses for that purpose here.

As performed by the NRC or the utilities, these calculations show a reactor giving little radiation to a person living within 10 miles — a fraction of a millirem to less than 5 millirems yearly. (Current estimates peg a chest X-ray between 15 and 30 millirems.)

But the German scientists say that in measuring fallout's journey from reactor to residence in the body, the NRC figures are "either at the lower end of the range given in the literature or far below the values that may be regarded as realistic. It follows that the results of these assessments are unrealistically low."

They say, for example, that NRC judgments on how much plutonium, cesium and strontium crops pick up from the soil are "between 10 and 1,000 times too low."

The Heidelberg group reached its conclusion after digging through 25 years of scientific journals to find what experiments had been done on how much fallout was getting to people. They then compared the results of these other experiments with the NRC figures — eight other experiments in the case of cesium, 11 others in the case of strontium.

After examining the NRC safety estimates, the report scores another first. It calculates the dose from a nuclear reactor, using figures chosen by independent scientists. What the German scientists did was feed their figures into the NRC computer model.

They found that a pressurized water reactor planned for the town of Whyl on the Rhine could be expected to expose people to a yearly dose of 1,071 millirems of whole-body radiation. The major part of this dose would come from radioactive substances taken into the body with food and drink. The reactor's exhaust air is the principal source of this contamination, with its waste water playing a significant but lesser role.

The exposure limit in the United States is 170 millirems of whole-body radiation yearly from all nuclear facilities. On Dec. 1, the Environmental Protection Agency will reduce this limit to 25 millirems.

But it would be inaccurate to transfer the 1,071-millirem result from the Whyl study to a reactor in this country or anywhere else. Conditions specific to each power plant's site, such as wind patterns, nearness of farmland, size and type of reactor could bring these figures up or down.

Still, the study strongly suggests that realistic safety calculations would show each of this country's 72 reactors burdening people with more radiation than the new 25-millirem limit. Since the NRC uses these dose estimates as its basic yardstick for licensing and regulation, it would have cause to act against all the country's nuclear plants in more than a cosmetic way.

But this is not likely to happen, for more than economic reasons. Just as the Heidelberg group calls the NRC figures too low, the commission replies that the German scientists' figures are too high. "Their literature search was not comprehensive," an NRC spokesman comments. "They looked for experiments that would support their conclusions."

More importantly, Dr. Frank Congel, leader of the NRC's radiological impact section, says that "real measurements" by the utilities show that radiation emitted by nuclear plants is well within current safety limits.

Can the utilities be trusted to monitor how much radiation their own plants are giving off? Asked whether the NRC had assigned the fox to guard the chickencoop, Dr. Congel responded that the NRC "reviews the records and procedures of each plant on an average of twice a year." The commission also "spotchecks seven or eight plants each year."

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But these "real measurements" by the utilities fail to answer the Heidelberg report. The German scien-

. . . In certain areas near nuclear plants the level of strontium 90 in milk has at times risen higher than it was at the height of atmospheric nuclear testing.

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tists are attacking not the utilities' emission figures but the set of calculations used to estimate what dose these releases give to human beings. To verify the Heidelberg report would require monitoring food from farms and dairies near reactors, a step which the NRC calls unnecessary and expensive.

Yet both the Environmental Protection Agency and the states monitor milk for radioactivity. Although milk from dairies near reactors often shows high levels of strontium 90, both the utilities and the NRC claim this contamination comes from atmospheric fallout. They blame this partly on the residue left in the atmosphere from old U.S. and Soviet tests, but mostly on the more recent Chinese bomb testing.

Since strontium 90 lacks a label of origin, no one can know for sure. But state and EPA monitoring shows a pattern. After the U.S.-Soviet test ban in 1963, strontium 90 milk levels remained high across the country for two or three years. Then the average dropped from roughly 25 picocuries per liter to 4 picocuries, where it remains. After a Chinese test, these levels jump briefly, then go back to what is now normal.

But in certain areas near nuclear plants the level of strontium 90 in milk has at times risen higher than it was at the height of atmospheric nuclear testing. Such readings were found in milk from dairies in Waterford, Conn., near the Millstone nuclear plant, when that facility was experiencing high radiation releases in 1976.

In Wisconsin, South Carolina and other states, rises in strontium 90 milk levels from dairies near reactors have also been recorded after releases of radiation from those facilities. Still, NRC and utility officials insist the strontium 90 comes from Chinese tests. This presents a picture of an America covered by a huge umbrella in the sky with holes punched over certain reactors.

This is less ridiculous than it sounds, since our technical institutes teach fledgling physicists that reactors do not give off strontium 90. Dr. Bernard L. Cohen, director of the Scaife Nuclear Laboratories at the University of Pittsburgh, writes in "Nuclear Science and Society" that "strontium 90, which has received wide publicity for its importance in bomb fallout, is removed in the chemical purification and hence is of little consequence here." (That is, it is removed by a filter within the reactor.)

Unfortunately, what's written in textbooks does not always happen in reality. Not only can filters be less than perfect, but the largest portion of radioactivity released from reactors, which is in the form of gases, presents special problems. These gases decay into radioactive particles, including strontium and cesium. Nuclear plants are designed to hold these gases long enough so that the decay takes place within the plant, where the particulates can be filtered out.

But if the gases leave the plant before they have had time to mellow, rather than floating away harmlessly, they deposit strontium, cesium and other isotopes in the environment. These gases can be released prematurely due to plant emergencies. Or, according to the Heidelberg report, significant quantities of the gases often leak out of the plant before they reach its filtering system.

□ □

Further, a Wisconsin investigation based on 14 years of milk monitoring by state officials supports the validity of the Heidelberg report, giving evidence that reactors are indeed releasing strontium 90.

America's dairyland state is bordered on three sides by a Big Dipper-shaped chain of 14 nuclear reactors. Wary of safety assurances, a Wisconsin environmental foundation asked the State Radiation Section to prepare a dose estimate based on the official milk sampling program, started in 1963. The state refused. So this concerned group of middle-aged, middle-class professionals — Land Educational Associates Foundation Inc. — took on the project with the assistance of a University of Minnesota biology professor. To insure credibility, they chose to use data only from state monitoring records.

The chain of reactors around Wisconsin grew from two to 14 between 1970 and 1976. State records show milk strontium 90 levels jumping in 1973 from just below to more than twice the national average, and staying there at least three years. (The study had to close with 1976, since state officials were more than two years late in supplying records which are supposedly public.)

The largest increases of strontium 90 came in a Wisconsin area 50 miles downwind, and downriver, from Minnesota's Monticello reactor, and in the Green Bay area around the Point Beach nuclear plant. Both high readings of strontium came and persisted during the year that Monticello was leading the nation in gaseous releases of radioactivity, and Point Beach was tripling its allowed emissions.

Showing instance after instance where nuclear plant releases were followed by high radioactivity in milk, the study points to reactor fallout as the major source of contamination.

In calculating its dose, the Heidelberg report judges the impact of a large reactor on people living in a small area — roughly within a 10-mile radius, making a circle around the plant of 314 square miles. But the Wisconsin study judges the impact of 14 smaller reactors on people spread across a territory of 54,000 square miles. Thus exposure for each person will be smaller.

Since they based their study on just the three radioactive poisons monitored by the state — strontium 90, cesium 137 and iodine 131 — the Wisconsin investigators label their "Total Fission Dose" findings as "not the whole dose."

Using government formulas, they find the average yearly dose to Wisconsin citizens from nuclear waste in food and the environment is 33 millirems of whole body radiation for an adult, and 67 millirems for a growing child. The yearly dose to the bones is 76 millirems for an adult and 174 millirems for a growing child. The study says this "extra" radiation has more than doubled the risk of blood cancer for Wisconsin 14-year-olds.

They caution that this radiation comes from more than milk. Although ideal for monitoring, milk is one of the least radiotoxic foods. It contains only 10 percent of the radioactivity found in the grass eaten by the cow, which filters out the rest. As foods high in fallout radiation, the investigators note potatoes, whole wheat, leafy vegetables, soybeans, berries, venison, nuts, cabbage and cheese, which multiplies the milk dose times six.

The NRC rejects the Wisconsin

study, even though it is based on verified state milk records and calculated with EPA and NRC formulas. The NRC's Dr. Congel states the Wisconsin study "showed extreme bias in its data and its presentation when we reviewed it."

□ □

At the same time that the EPA is establishing the new 25 millirem exposure limit, the NRC is stopping the monitoring of strontium 90 at nuclear plants. The reason given is that the utilities, assigned by the NRC to monitor themselves, aren't finding much. But like most manufacturers, utility executives want responsibility to end at the front gate. The public can't see the strontium 90 leaking out of the plant. Why should the utility? More importantly, why should nuclear plant owners be responsible for monitoring themselves?

The agency responsible for protecting the environment has given some indication of what its new 25 millirem limit means. One of its radiation officials explains, "The EPA does not have any regulatory requirement to monitor the environment around nuclear power plants; this monitoring is required by the NRC of their licensees."

When told of high strontium 90 levels being monitored in milk and fish from the area near the three Oconee reactors in South Carolina, another EPA radiation official responded that the 25 millirem limit applies to "planned discharges of radioactive materials." It does not apply, he said, "to background or fallout radiation in the vicinity of nuclear power plants." Chinese fallout again, and a large loophole for the many unplanned releases which reactors experience.

Both EPA and NRC plan to enforce the new limit by letting the utilities tell them what radiation is being released. From this they will estimate the dose to the public, using that same set of calculations which the Heidelberg report examined.

Both agencies have copies of the Heidelberg report. The NRC translated and printed it last spring (NRC translation 520: "Radioecological assessment of the Whyl Nuclear Power Plant.") Its distribution has been delayed while the German authors made some revisions. But Bernd Franke, one of the Heidelberg scientists, told this writer they had changed nothing of substance.

The significance of the report is that it indicates there is a great range of uncertainty in what is known about the impact of nuclear plants on human beings. The only way to determine whether the official dose estimates have validity is by a rigorous and continuing program of food monitoring performed by an independent agency.

NUCLEAR STRESS AND PSYCHOLOGICAL DEFENSE MECHANISMS

by Roger Kotila Ph.D.

The nuclear accident at Three Mile Island, coupled with more and more information which is finally becoming available to the American public concerning the dangers of nuclear energy, has created new levels of anxiety about nuclear power in increasing numbers of people: Citizens, government officials and corporation executives, the scientist and technocrat, even our children must somehow cope with the big "if"--if there is a full-blown accident...

Psychologically, the dangers of holocaust from atomic warfare on the one hand, and now the addition of radiation poisoning from reactor plants on the other hand, pose a severe strain on our collective psyche. I refer to this psychological form of severe stress as "nuclear stress" to designate the type of psychological and emotional strain to which we are being submitted by this hard-to-comprehend threat to our life and health.

Nuclear stress is unique by virtue of its insidious nature with effects sometimes not apparent for years later, and by the fact that the nuclear threat is so great as to essentially ask us to imagine the unimaginable.

In a word, we are being asked to accept the "unbelievable", and to acknowledge a danger which defies our everyday experience and common sense.

It is akin to asking us to accept as reality the idea that invisible rattlesnakes have been placed in each of our backyards, posed and ready-to-strike. Or worse yet, have already bit but we don't know it until twenty years later when the cancer surfaces. Such delayed cause and effect relationships are hard to believe, since most of our everyday experience is more accustomed to more immediate cause and effect: When we cut our finger we see the blood immediately.

Seeing clearly the hazards of nuclear use is made even more difficult, aside from the "delayed effects" problem, by the fact that the form of harm may itself be subtle. Recently, for example, a study by Dr. Ernest Sternglass of the University of Pittsburg School of Medicine found a correlation between declining Scholastic Aptitude Test scores and A bomb fallout in the 1950s and 1960s. Sternglass, who urged evacuation from Three Mile Island, gave this ominous warning: "We aren't aware of the damage being done, because these children look normal and seem normal. But hidden damage to the thyroid--where radioactive iodine accumulates--slows growth, physical and mental growth."

So now, we must add to the list of dangers. To cancer and birth defects we must add the possibility that radiation reduces intelligence. It is little wonder that most people find it difficult to admit fully to these dangers--the anxiety aroused might be overwhelming.

And how do we protect ourselves from being overtaken by worry? How do we cope with this nuclear stress? By the use of psychological defense mechanisms which serve the purpose of "defending" us from too much emotional stress, and thereby helping us keep our psychological equilibrium.

A description of some of the typical defenses from nuclear stress follows. Keep in mind that we may use more than one of these mechanisms. Also note that defenses are a two-edged sword, that is, although they can help us to maintain tolerable anxiety levels, they can also trick us into a false sense of security. Since defense mechanisms are used by everybody, and since they can mislead us into false beliefs and perceptions of reality, it is imperative that those persons most closely linked to nuclear power--corporate executives, government officials, scientists and stockholders in the nuclear industry--take an extra careful look at themselves psychologically since they are under more stress than the ordinary citizen, having the more direct responsibility for the advocacy of nuclear power. Nuclear power advocates therefore, face added nuclear stress which in turn can produce even stronger defenses to keep anxiety levels down. In short, they have the added background worry of "What if I am wrong about nuclear power, and there is a catastrophe?"

DEFENSE MECHANISMS TO REDUCE NUCLEAR STRESS

(1) One way to cope with nuclear stress is by denial.

In this type of defense, we simply deny that there is any nuclear danger, refuse to acknowledge to ourselves that there ever will be an accident. The Three Mile Island accident led to the interesting reaction of officials declaring, in essence, that the accident would insure that there wouldn't be another. This form of denial is a form of magical thinking wherein the officials wanted to believe its truth so much that they denied the possibility of another "accident". From the psychological point of view this is understandable. To admit that it could happen again would be to create tremendous anxiety which would be impossible to tolerate either by the officials themselves (who have to worry not only about their personal safety from radiation, but also the guilt of being incorrect), or by the citizenry who are within 150 miles of a nuclear plant.

Magical thinking (if I say it, it is true)can be a real problem for the government and corporate officials who are responsible for nuclear power. Faced with the facts that technology can never be 100% safe, and that one can never eliminate human error completely, one is faced with the logical conclusion that an accident is inevitable. For government and corporate officials, the inevitable "accident" would mean incredible amounts of anxiety and guilt, as well as loss of self-esteem always associated with making a mistake. Since these officials are committed to nuclear power, denial helps them maintain their psychological equilibrium and keeps them from being overwhelmed by the anxiety of nuclear stress.

In addition to the stress that there might be an accident, for the nuclear proponent there is the added stress of ego involvement. One veteran scientist, an outspoken proponent of nuclear power, felt compelled to appear in a Wall Street Journal ad after Three Mile Islànd to proclaim nuclear power still safe, and to declare the nuclear waste problem a "political" problem, not a technical one. This rather hysterical reaction to a controversy which scientists themselves disagree, reflects well the type of denial used to keep nuclear stress at a tolerable level. Better to deny the danger than to admit that one was wrong; to admit error would be to feel anxious since self-esteem would be threatened.

Scientists, government and corporate officials must be the most careful to insure that they are not simply denying danger via magical thinking--since many peoples' lives and health are at stake. And that is the obvious problem with denial because we become the proverbial ostrich who buries its head in the sand. If in our minds a problem doesn't exist, why change doing what we are doing?

(2) Rationalizing is another frequently used type of defense against nuclear stress whereby we give seemingly logical "reasons" to explain why there is not nuclear danger, or why we are not taking constructive action to eliminate the danger. To justify our lack of action, rationalizations serve to provide to our fellow citizens socially-approved reasons unconsciously designed to help us avoid being critized.

Rationalization helps us maintain our self-esteem and our public image. Few of us would want to be seen as the type of person that would endanger other peoples' health or lives.

Thus we see the nuclear scientist, the government and corporation official, the nuclear proponent argue that there is an "energy shortage" and that's why we need nuclear power, despite evidence that the so-called shortage could be put to rest almost immediately by conservation and by use of soft, renewable energy sources. Or rationalizations that nuclear power is "cheap", despite evidence that the costs of nuclear power keep rising and are completely beyond initial estimates of cost, and evidence that alternative energy sources which are renewable (sun, wind, etc.) would in the long run be much cheaper.

Most of us have experienced the anxiety of finally admitting we were wrong, that we made a mistake. Perhaps our ego's felt bruised since we tend to psychologically equate being wrong with being dumb, and our self-esteem suffers. No wonder then, that nuclear proponents desperately hang on to outdated beliefs despite the ever-increasing influx of contrary evidence.

For the ordinary citizen, the "sweet lemon" rationalization keeps anxiety down. Rather than admit that the nuclear reactor plant is the nuclear industry's version of the ill-fated Corvair, it is argued that reactors "aren't all that bad," and that since the plants are already giving energy, why not keep them? In similar fashion, many Corvair owners continued to drive them even after informed of the safety hazards; after all, they did provide transportation.

(3) If we do not use the defenses of denial or rationalization, we may use other defenses to protect ourselves from nuclear stress. One such defense is escapism wherein we distract ourselves from stress by "keeping busy" in other seemingly important activities such as our job, our hobbies, or a busy social life.

Preoccupation with these other activities may merge into preoccupation-with-self, and then we may react to nuclear danger by escape-into-decadence. The net effect is the same, to avoid the anxiety of nuclear stress, and to fail to take action to prevent a nuclear disaster.

A somewhat different type of escapism is procrastination, putting off until later facing the unpleasant reality of nuclear danger. Here, we may admit that nuclear danger (the rattlesnake) exists and could bite at any time, but put off trying to get the snake defanged. Many activists of the 1960s are using this type of defense, knowing full well that sooner or later they must get involved once again, and overcome their "burned-out" attitude toward renewed political action.

(4) If our actual behavior fails to live up to our standards of conscience, we may reduce our guilt by lowering our standards of conscience, rather than living up to them. Thus, one divorced man with children explained his failure to take action against nuclear threat by saying, "I can't babysit my children all their life. They have to be on their own sooner or later. I can't be responsible for what happens to them thirty years from now (referring to the delayed effects of getting cancer from radiation)."

(5) Much like a rabbit who fears for its life and reacts by becoming immobilized and trembling, some people react to nuclear stress with passivity and withdrawal, in this way shutting off the fright of possible nuclear disaster. One woman's underlying feelings of hopelessness and helplessness to prevent nuclear poisoning led her to the ultimately nihilistic view: "There's nothing I can do. There's nothing you can do. There's nothing anybody can do," she said, resigned to inevitable fate.

Her fatalistic and powerless view is sometimes supported by those who cite the Bible as predicting the end of the world. It is almost as if they deal with the anxiety of nuclear stress by saying to themselves, "If it (nuclear holocaust) is going to happen anyway, why worry about it?" a sure prescription for eventual extinction of our human race.

(6) Growing emotionally detached from nuclear stress can take the form of spiritual resignation ("The End is the will of the Lord."), or take the form of being overly cynical. Being cynical is a way to shut off emotions from our ideals. "Everybody dies sooner or later," is one example of a way of thinking to shut down the fear, and to stop ourselves from taking constructive action.

One cynic reacted to the danger of nuclear poisoning by comparing humans to roaches. Resigned to eventual extinction or radiation mutation, this young punk rock singer comforted himself by arguing, "The roaches that do survive DDT are the stronger and better for it!" So here we humans are, according to this young man, in a future which envisions those who survive nuclear poisoning to be the proud mutated winners of survival of the fittest, as able in our mutated forms to deal with radiation as the new generation roaches handle DDT!

A final example of the emotional detachment from nuclear stress through a form of cynicism is the dreamy lady whose comment about nuclear threat was that "Well, you know, everything happens for the best!"

(7) In these days of ever-increasing nuclear stress, you may hear somebody adopt the views of the nuclear industry itself, for example, that "economically, nuclear power is a necessity," or that "some risk is necessary in order to have the energy that we need." Unconsciously such a position may be a reflection of an attitude of " if you

can't beat 'em, join 'em," in short, an attitude of helplessness and powerlessness which can take the form of "What other choice do we have?"

During World War II prisoners in concentration camps sometimes adopted the value system of their captors. The prisoner <u>identified</u> with, or <u>introjected</u> the value system of the other side, the enemy. In these modern times, the proliferation of nuclear facilities throughout the United States may leave many people feeling they are in prison--or perhaps in the gas oven and just waiting for some fool, by accident or design, to turn the gas on. Certainly it could be argued that the nuclear danger is similar in America today to being in the gas ovens of World War II.

In any event, to handle such tremendous stress emotionally, we may not only identify with the proponents of nuclear power, we may <u>overidentify</u> with the other side. Here we may take the other's loss personally, as our own. Some people, for example, may feel very anxious about the idea of the corporation losing money if nuclear reactors are shut-down immediately and permanently, as if they themselves are losing the money from a bad investment. Any of us who have lost money in a poor investment can certainly sympathize with this type of hidden stress. Yet bad financial investments are a fact of business life for any of us at one time or another, and the anxiety of "losing money" should not detract from the more basic issues of life and health. Otherwise, we are put in the position of lowering our standards of conscience wherein "not losing money" becomes more important than birth defects, cancer, or lowered intelligence--not to mention massive outright death to the unfortunate victims of a nuclear accident.

Since psychological defense mechanisms are used by everybody--citizen, government and corporate official and scientist--it is critical that all become more psychologically aware of the defenses used against nuclear stress. This is because defenses, although they help keep anxiety at tolerable levels and maintain psychological equilibrium, also lead to misperceptions of reality and to a false sense of security.

Nuclear stress cannot be removed by wishful thinking, by rationalizations, or by escapism. It can only be eliminated by removing the source of the underlying problem itself. To stop nuclear stress we must stop nuclear power. Only then will the stress and anxiety which we all experience on a daily and chronic basis be eliminated from our collective psyche, and will we be able to truly relax once again.

NOVEMBER 19, 1979
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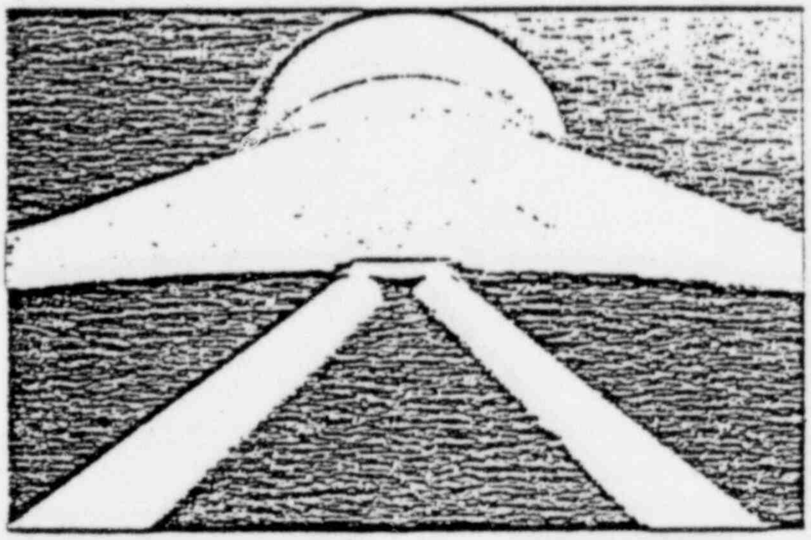


HOW SAFE IS RANCHO SECO?

By Judith Coburn

DOES AN NRC WHISTLE-blower have evidence that Rancho Seco is unsafe? Can anyone—including the people who built it—prove that it *is* safe? Or is the whole situation so complex that independent evaluation is impossible? No one knows the answers, but meanwhile, Rancho Seco keeps operating, protected by economic pressure and bureaucratic inevitability.

A VERY SIMPLE ERROR

IT BEGAN WITH A QUESTION about a decimal point. A simple mathematical error: an infinitesimal dot amid a swarm of square roots, variables and subtractions that add up on millions of sheets of paper to a nuclear power plant. The Rancho Seco nuclear power plant.

The mistake was so tiny on the "calc" sheet that Ron Clary had to squint to pick it out. It was early one morning in 1972, and Clary, a structural engineer for the Bechtel Power Company, was helping wrap up paperwork on Rancho Seco, which Bechtel was building for the Sacramento Municipal Utility District (SMUD).

But there it was, on the bottom of page 10. A decimal point, clearly in the wrong place. A dumb little goof in arithmetic. The kind anybody could make in a checkbook. But to an engineer, "an order of magnitude," one that could throw off a whole set of calculations by a factor of 10. And this was not a checkbook, but a nuclear power plant.

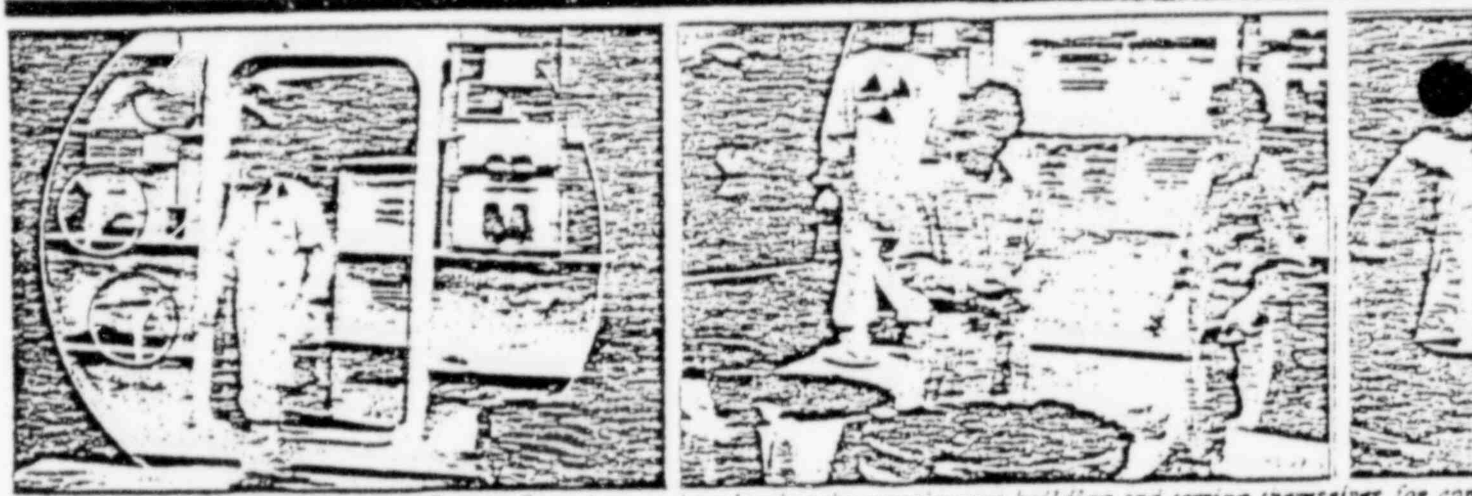
Clary moved his pencil once more over the numbers, and the mistake leapt up again. He walked across the office and pulled the "as-built" drawings, which detail every tiny change in the plant's design during construction. Skipping back and forth between the drawings and the "calc" sheets, Clary saw that the mistake was in the equations used on the building in which highly radioactive "spent" fuel, once it is removed from the reactor core, is stored. The decimal point error, Clary realized, could mean that Bechtel had built the spent-fuel storage building substantially less strong than it should be. To survive an earthquake or . . .

Clary rushed to show the mistake to his boss, project engineer William Brandes. Brandes listened to Clary argue that

Photographed by Robert Christopherson

POOR ORIGINAL

There it was, at the bottom of the page, a decimal point in the wrong place.



Exclusive photographs taken inside Rancho Seco show workers leaving the containment building and testing themselves for con

something had to be done. Then he took out a sharpened pencil and simply moved the decimal point over.

"That was it. I was supposed to forget it," remembers Clary.

THE BASEMENT PAPERS

IT IS 2 A.M. ON A RAINY, WINDY night in August, 1979, in the Maryland suburbs, and Ron Clary is still up, shuffling through papers in his wreck of a half-converted basement. Hastily hammered together bookshelves lean against the walls, crammed with boxes of Rancho Seco design code computer cards, random volumes of PSARs (preliminary safety analysis reports) and FSARs (final of same) of various American nuclear power plants, and rows of books on everything from nuclear terrorism to missile systems to nuclear space ships. Memos, documents, reports, computer print-outs, transcripts, letters, hearing records, newspaper clips and faded Xeroxes are piled, strewn and filed in bursting cardboard cartons, on the floor and on every reasonably level surface from there up to the ceiling.

Because Ron Clary is in a war. And because he used to work for the Nuclear Regulatory Commission and is locked in combat with it, the war is on NRC terms and NRC turf—suburban Bethesda, far from nosy congressmen and a worrisome White House. And it's in their common language, a tongue so complex and arcane that neither code breakers nor linguists, let alone the public (mere civilians all), know this war is going on.

Of all the questions that skeptics raise about nuclear power (concerning catastrophic accidents, disposal of wastes, safeguards, worker safety, low-level radiation, economics, inadequacy of NRC oversight and reactor safety), it is "reactor safety"—the nuts and bolts, pipes and valves of whether a plant is designed and operating safely—that is the most troublesome in terms of public accountability. There is simply an inverse proportion between the amount of technical detail needed to prove a nuclear power plant safe and the number of people ready, willing and able to grapple with such a mass of complex scientific data. (The public is also closed out of the controversy over "safeguards"—the necessary protections against sabotage of nuclear facilities or theft of bomb-grade material. But that is because of secrecy, not a barrier of technical complexity.) Nuclear reactor experts (let alone reporters, politicians or consumers) aren't even in full command: Nuclear physicists defer to seismologists on earthquakes, geologists to structural engineers on the strength of the containment's walls, and nuclear chemists to human-factors engineers on control room design. As a result, it is a rare reactor safety issue that is as stark and simple as what Karen Silkwood or *China Syndrome*'s Jack Godell uncovered.

The basement is too distracting.

Clary leads a visitor up the stairs past the bedrooms of his sleeping wife and four kids into the living room of his small tract house. Giving his guest a can of his beloved Stroh beer, Clary sinks back in his armchair to tell why he can't forget that decimal point and what it has led to.

"For one thing, we're talking about my town—Sacramento—where I grew up."

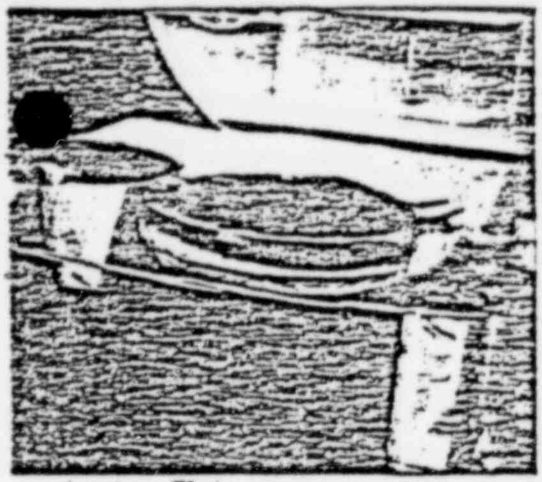
Ron Clary is no ideologue. He isn't even against nuclear power. What he is is an ex-marine (Korea) with twelve years of engineering in nuclear and another four at the Nuclear Regulatory Commission. He plays by the book. He's a structural engineer who thinks he's good, a detail man who thinks too many folks take short cuts. He's a religious man who has Scotch-taped handwritten homilies like "Thank God, because He is good and His mercy endures forever" and "There are no strangers here, only friends we haven't met" on the walls of his breakfast nook. He's a short man with a solid pot, the physique of a bulldog and the determination to match. A bulldog with an extremely large bone to pick.

Clary, whose father also was an engineer, grew up in Northern California, in Selma and later in Sacramento. "The family didn't have two nickels to rub together," remembers Clary. After four years in the marines, it was back to Southern California, "where the engineering action is," to work his way through school at UCLA and USC. Stints at Rocketdyne and Parsons designing missile silos. Just about the time he got his M.S. and his engineering license, Bechtel offered him a job on a new multimillion-dollar air force contract for "hardened" missile silos. "They didn't even have a design for it yet," recalls Clary, starting on a new beer. "So we got that out of the way: I wrote the whole damn report that came out of it. But I can't brag about it—top secret from front to back."

Then, says Clary, things got a little slow on the military side. Bechtel, one of the world's largest builders of nuclear power plants, transferred him to the reactor side. "I didn't know a damn thing about reactors and wasn't interested," says Clary with an amused bark. "I wasn't an antinuclear type, though. I knew they were dangerous. That just meant they had to be designed right."

Clary was assigned to Rancho Seco after the foundations had been poured and Bechtel had started to build. There were problems from the word go between the cheerfully dogged Clary and his co-workers. Engineering is a team sport. A good engineer, unlike a good scientist, is valued less for original thinking than for the fact that he can make a building stand up with as few original embellish-

This article was written with the assistance of Michael Singer and David Weir of the Center for Investigative Reporting.



tamination. Their garments are later sorted.

ments as possible. But from the start, Clary says, his idea of what was proper and safe differed from that of the other Bechtel engineers: Clary was branded "too conservative," meaning he wanted more things like reinforcing steel to strengthen concrete buildings and more bracing of walls and vents. "There were a whole raft of design decisions I questioned," claims Clary, still incredulous even after all the years.

There was the decimal point.

But it was the San Fernando earthquake on February 9, 1971, that caused the biggest seismic shift in Ron Clary's thinking, and, to hear him tell it, at Bechtel as well. By anybody's standards it was a big guy—6.4 on the Richter scale, killing 64 people, injuring hundreds, and causing $500 million in damage. But two things had seismologists from all over the world hopping planes to Caltech: First, the San Fernando caused much more "ground acceleration," or shaking, than expected, even for that size of a quake; and, second, because it had happened so close to Caltech's instruments, it was the most carefully recorded earthquake in history.

Here's Ron Clary's account of the San Fernando aftermath at Bechtel: In less colorful language, it is the substance of his complaint to the NRC about Rancho Seco's cooling towers. "There was a lot of thrashing around. Bechtel had always been concerned about the cooling towers at Rancho Seco [giant cooling towers like Three Mile Island's, and the first "natural draft" towers on the West Coast]. These huge structures were supported on these tiny, spindly little legs. The water comes in hot from the heat of the core. The sides of the towers don't rest on the earth, so the natural draft'll draw in the cool air from outside and push the heat out. Some of the computer guys there said that after San Fernando they cranked in these new numbers, the ground acceleration and all, through the computers and BOOM—the cooling towers fall down," hoots Clary. "So naturally, what do they do? Do they rebuild those towers? Hell no, they keep refining the computer model and cranking in new numbers until they get 'em to stay up. 'Course, whether that model represented the structure by the time they got finished is another question." (In signed statements to the Nuclear Regulatory Commission and in an interview with *New West*, Bechtel engineers, including seismologist Asadour H. Hadjian, say the San Fernando earthquake has no application to Rancho Seco, and that no such computer runs were necessary. William Brandes, in the same interview, denied moving the decimal point.)

Clary remembers it was hard to get a grip on it at the time. "Nobody knew, except the guys working on the modeling. They parcel everything up, give everyone a little piece of a job, and you have no idea how it's related to the rest of the plant or even an adjoining system. You just crank up the numbers and then go off to the next job on another side of the plant. The effect of it is to keep people from raising professional concerns." Clary says he doesn't remember the cooling towers being talked about as a safety issue. "The way I heard about it was from a staff guy bragging about how he'd been right all along—even before San Fernando—about the cooling towers being unsound. But it was just a big ego thing. It was much easier to get credit for good engineering savvy than to take responsibility for trying to fix it. Besides, he knew like all of us it was too expensive to fix once it was up. You'd just get yourself in Dutch."

In 1972, Ron Clary left Bechtel. In 1975, after other engineering jobs on the West Coast, he moved his family to Gaithersburg, Maryland, and went to work in the NRC's Bethesda headquarters. It was a job that would finally give him a sense of the big picture. A picture that wouldn't let him forget Rancho Seco—the cooling towers, the decimal point error—because they fit so neatly into it. Rancho Seco would appear in Clary's mind again and again once he saw how fragile nuclear safety was, how vulnerable to thousands of tiny errors, like the decimal point mistake. More mistakes than any man, even a man with a basement full of papers, could ever possibly master.

NOTHING SUCCEEDS AS PLANNED

ON APRIL 21, 1978, RON Clary sent a memo about nuclear safety problems to Donald A. Nussbaumer, assistant director of material safety and licensing at the NRC. Although Clary's cover letter gave a polite nod to Nussbaumer's "concern about safety," the document is stunning evidence of how disillusioned and suspicious Clary had become about the NRC and the nuclear industry. The memo's style reeks more of a smuggled message from a political prison or a microdot communication from a mole deep within enemy territory than of a report from a concerned bureaucrat to his superiors. Here's how the memo described Clary's own experience with the decimal point error, in order to protect his identity:

Incident: Falsification of records considered the basis of an OL [operating license for a nuclear power plant] application.

Players: Mr. A. Doe—a corporate officer of the XYZ Company responsible for the task of engineering project manager . . . on nuclear reactor "Zebra." Mr. B. Doe—a design engineer subordinate to Mr. A. Doe also an employee of the XYZ Company.

Background: Reactor "Zebra" was nearing the completion of construction. The XYZ Company was under intense pressure to finalize its design basis in support of an OL application. Various design calculations, constituting the basis for drawings of structures and equipment already built or in place, had to be "signed off" by an engineer not involved in the original design.

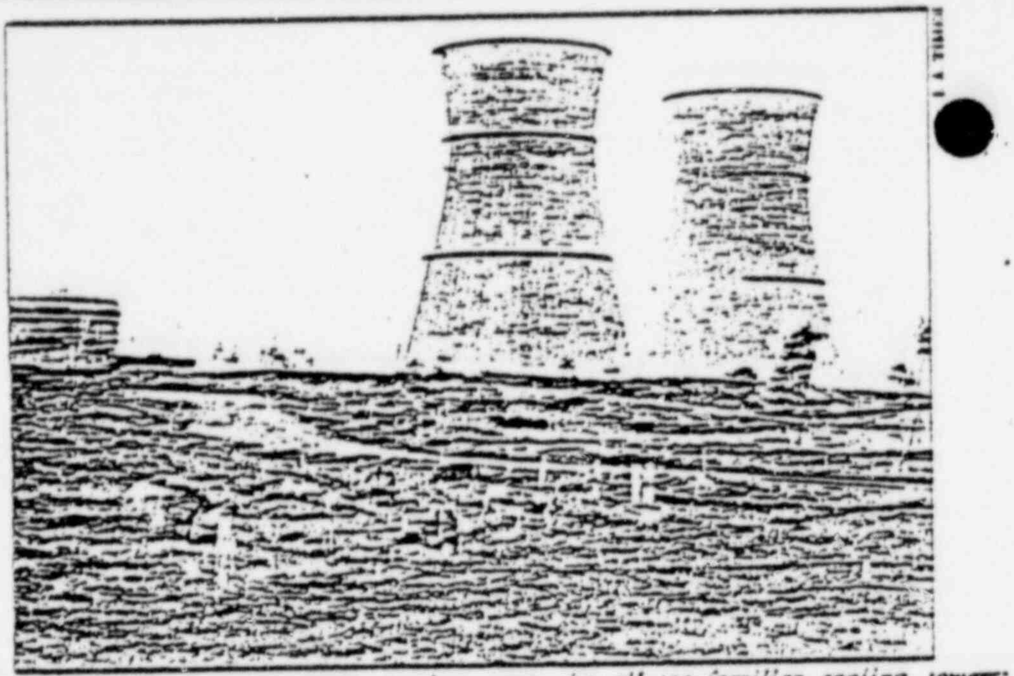
Events: Mr. B. Doe reported to Mr. A. Doe that, as a result of his check, he concluded that 1) the numeric results of the calculations were unconservative by an order of magnitude (decimal error at key step); 2) the drawings were consistent with the erroneous calculations; and 3) the structure had been built based upon erroneous drawings.

Action: Mr. A. Doe corrected the results sheets (in pencil) of the calculations by moving the decimal point over one place throughout. No other corrections or remedial actions are known or reported to have taken place.

Under pressure from top officials of the NRC's Office of Inspection and Enforcement (I&E) at two charged meetings on April 28 and 29, 1978, Ron Clary admitted that *he* was "Mr. B. Doe," that "reactor Zebra" was Rancho Seco, and that the "XYZ Company" was Bechtel. (And that "Reactor Vega," "Messrs. C. Doe, D. Doe, etc.," and seismic event "Surprise," mentioned later in the same document, involved his charges about the cooling towers at Rancho Seco and the San Fernando quake.)

Rancho Seco was not Clary's only concern. As president of local 2195 of the American Federation of Government Employees, Clary was a conduit for NRC employees' job complaints. Many were the kinds of grievances any white-collar bureaucrat has. Others were like Clary's own at Bechtel (and later at the

One year, 250 NRC inspectors made 3,000 visits to operating reactors.



Scenes from Rancho Seco: Popcorn in the control room; cows grazing near the all-too-familiar cooling towers.

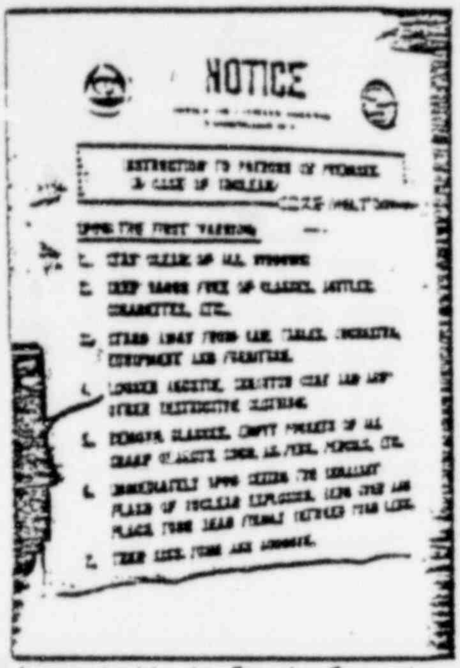
NRC): problems with supervisors over matters the employee believed to pose, in NRC bureaucratese, "health and safety issues." Still other reports, many of them on a rumor level, hinted of darker things, like bribes of NRC inspectors to overlook safety violations at nuclear power plants. In his four years at the NRC, Clary had seen scores of issues raised by whistle-blowers there; few of the issues were resolved, and most of the men were fired, transferred or persuaded to shut up. One of the biggest crusades Clary had joined was the case of Jim Conran, an NRC employee who blew the whistle on lax NRC safeguards. (Conran had stumbled across the sensational story of the disappearance of 200 kilos of bomb-grade plutonium from a nuclear processing plant in Apollo, Pennsylvania, had fought for tougher safeguards and was transferred for his trouble.)

The April 21 memo and the meetings on April 28 and 29 were Clary's shot at putting it all together. To him, the Rancho Seco problems he'd directly witnessed, the Conran case and the suppression of safety concerns raised by other whistle-blowers added up to a frightening picture "that could affect the health and safety of the American public." Already taking shape in Clary's basement was what came to be known in certain circles as The Clary File. The file is a six-foot-high mound of paper (indexed and reindexed so users have to be trained in the use of the index of the index) composed largely of Clary's union paperwork, furious correspondence with superiors about his own job performance, memos from other whistle-blowers and newspaper clips about everything from nuclear reactors and nuclear weapons to the nuclear fuel cycle.

But Clary was in a bind. The charges were all over the map, too many for even the most dogged of bureaucratic memo freaks, like Clary, to ride herd on. More tricky: Many of the NRC employees who had come to him with tips about things like bribery and intimidation of inspectors had done so in confidence, and did not want to come forward. Other allegations were just rumors, rumors his gut told Clary were true, but rumors just the same. So NRC investigators seized on the Rancho Seco charges, which Clary had witnessed himself. (NRC investigators did not explore until later another Clary charge which he had been pursuing simultaneously through his own office in the transportation division. But on July 22, 1979, the *Washington Post* reported that Clary had evidence that if the 250-ton casks the navy uses to ship reactor cores are damaged in a particular way, "the result could be an intense burst of radiation from the reactor's core like that of a neutron bomb." The newspaper quoted NRC officials as admitting that Clary had "a valid concern.")

The NRC's investigation of Ron Clary's allegations about Rancho Seco was stamped by its basic attitude toward nuclear power, best expressed perhaps in the mode of Joseph Heller. In his satire of Washington life, *Good as Gold*, Heller's slogan for the ambitious bureaucrat is "nothing succeeds as planned." NRC critics point to the agency's roots in the Atomic Energy Commission, which was established in 1954 to promote nuclear energy to a gun-shy public and energy industry. In the haste to go nuclear, regulation was an afterthought. In 1964, there were no nuclear power plants on order in the U.S. By 1966, 43 percent of all new generating capacity on order by American utilities was nuclear. By the early 1970s, the NRC was reaping that whirlwind in an overwhelming number of unanticipated and unresolved safety issues: defects in emergency core-cooling systems, leaking steam generators, cracking pipes, newly discovered earthquake faults under reactors, to name a few. (In 1978, NRC files contained 2,335 cases of what the bureaucrats reassuringly call "reportable occurrences": violations of NRC regulations ranging from a serious malfunction in the cooling system all the way to burned-out batteries in a security guard's flashlight. That year, more than 250 inspectors made 3,000 visits to operating reactors; 40 percent turned up health and safety violations.)

In the year and a half since Ron Clary made his charges to the NRC, three events lent weight to Clary's worries about Rancho Seco. In 1978, the General Accounting Office (GAO), Congress's investigative arm, issued a report criticizing the NRC for failing to test properly the quality of construction work on nuclear power plants. The GAO charged, among other things, that the NRC relied too heavily on assurances from the utilities and construction companies that work was proper, that the NRC often failed to make required inspections of nuclear power plant construction, and that the agency keeps practically no documentation to support its inspection reports. In addition, two spectacular examples of how tiny technical errors can affect the safety of a whole nuclear plant turned up.



black humor inside the Rancho Seco plant.

One—the discovery of a mistake in a computer code used to analyze earthquake hazards—led to the shutdown of five nuclear plants in the East. And in Oregon it was discovered that Bechtel had made a crucial mathematical error in the design of Portland General Electric's Trojan plant. As a result, the walls of the control building must be reinforced, and the utility and Bechtel are locked in litigation over liability.

Bob Pollard, an ex-NRC staffer who is now with the Union of Concerned Scientists, says the NRC's feeling is, "We think everything's okay and eventually we'll prove it." Pollard cites a 1972 reply from NRC Chairman Joseph Hendrie (then an NRC staffer) to a suggestion that a dangerous type of pressure-suppression containment system be eliminated by the NRC. Hendrie wrote: "Reversal of this hallowed policy ... could well be the end of nuclear power ... and would throw into question the continued operation of licensed plants ... and would generally create more turmoil than I can stand thinking about." Critics point to more rigorous requirements for new plants and the grandfathering of old plants, and to the fact that no nuclear power plant has ever had its license revoked. Once a safety violation is discovered, NRC reaction is astoundingly blase: Of some 1,200 safety violations found by NRC inspectors last year, only six civil penalties or fines were levied.

As soon as NRC investigators tackled Clary's concerns, they built a fence around them. The investigation was handled by the NRC's western (Region V) headquarters in Walnut Creek, California. In a May 3 memo from E. L. Jordan, a top official of the Office of Inspection and Enforcement, Walnut Creek was ordered to: "1) review the structural adequacy of fuel pool design and construction; 2) review adequacy of seismic design criteria used in structural calculations for natural draft cooling towers; and 3) if discrepancies are identified in the design of safety-related structures, an investigation into alleged falsification or withholding of information would necessarily follow."

But further telephone calls between Bethesda and Walnut Creek investigator W. G. Albert resulted in a decision to drastically limit the probe. What this meant was that the NRC only investigated whether the decimal point error was made and not whether the spent-fuel pool itself was unsafe. And secondly, this decision meant that no serious attention would be given to the cooling towers, which under NRC regulations are not part of the plant's "vital" nuclear operations. (They are not "class one" structures, the parts of a nuclear power plant without which the reactor cannot be shut down safely.)

The investigation took nine days. It consisted solely of interviews with Bechtel and SMUD employees, all of whom would share responsibility if Clary were right. Albert reviewed the Final Safety Analysis Report and several Bechtel documents. He never visited Rancho Seco to examine the cooling towers or the spent-fuel storage pool building. Ron Clary was never contacted by the Walnut Creek investigators or asked to provide his own documentation. Nor did Walnut Creek get a copy of the transcript of the April 28 and 29 I&E meeting, in which Clary expanded on the anonymous, truncated charges in his first memo. No independent seismologists or structural engineers were consulted; and Walnut Creek has no such experts on its own staff. (NRC documents refer reassuringly to "independent" seismic analyses and calculations. In a May 26 memo from R. H. Engleken, Region V director, to Jordan, Engleken assures headquarters: "We understand it was not your intent to *review* the adequacy of structural design and seismic criteria. However, during the course of investigating the substance of the allegations, we did find considerable evidence of the adequacy of the structural design and seismic criteria." All this "independent" verification was actually done by Bechtel employees "independent" of those who did the original calculations, George Spencer, Albert's boss, told *New West*.)

On May 30, 1978, the NRC report was finished. Basing their decision solely on Bechtel data, the NRC concluded there was no truth to Clary's allegations. Clary had never worked on the spent-fuel storage building or the "calcs" for that building, the NRC said. On the cooling towers, the NRC said that they were designed to withstand a greater force from winds than an earthquake and that the San Fernando earthquake did not apply to Rancho Seco. As if that were not enough, the NRC said that if the cooling towers *did* fall down, it wouldn't make any difference because they wouldn't fall on the rest of the plant.

When Ron Clary got the report, he went down into the basement to The Clary File and pulled his own copies of the "calcs" that show the errors and the place where the decimal point was moved. He took them to I&E headquarters. The next day, the NRC reopened its investigation. On June 19, the NRC found that the mistakes Clary alleged had, indeed, been made, but that they did not affect the overall design of the building. But the second NRC report never mentioned the evidence Clary had of the decimal point being changed to cover up the mistakes in the calculations. Instead, the report concluded mildly, "The finding regarding the revised calculations not being checked indicated a soft spot in QA [Quality Assurance] practices at the time. Bechtel stated that practices in this regard had been tightened during the past eight years." In the absence of any absolute proof on paper from Clary about the cooling towers, that part of the original investigation was not reopened.

HOW SAFE IS SAFE ENOUGH?

PEOPLE WHO WORK AT THE Nuclear Regulatory Commission and in the nuclear industry rarely, if ever, talk about a nuclear power plant being "safe." The operative phrase is "safe enough." The critical distinction might be illustrated in this way: An amendment to Rancho Seco's official file at the NRC contains the statement, "The cooling towers *are not expected* to fail on any critical equipment." When asked why the hedge "not expected" was used rather than "will not," Paul Narbut, an NRC inspector in Walnut Creek, chuckled. "Well, that's the scientific method. The problem is to express it in words. If you say 'will not,' it's not scientific—a whole host of 'what ifs' comes in there. At that point, it's the will of God."

As for the here and now, the NRC hope has been that the public will leave it up to "the nuclear priesthood," those highly trained, crack nuclear industry experts overseen by the dedicated, technically sophisticated men of the NRC.

The best and the brightest, if you will.

Then there was Three Mile Island. The experts learned a lot of things about nuclear power reactors from TMI, most of them too complicated to explain to anyone without a degree in nuclear engineering. Gone forever, though, for the public was what nuclear engineer Dale Bridenbaugh calls "the myth of the scientist in the white coat." "The public's perception of how a nuclear power plant is designed and constructed and operated," he explains, "is that they think of scientists running around in white lab coats in laboratories knowing exactly what they're doing, dedicated to their jobs and some higher, scientific truth. What they don't understand is that the guys running this thing are the same kind of guys who're screwing the bolts into the Pintos up the road a piece." Bridenbaugh, along with colleagues Richard Hubbard and Greg Minor, quit General Electric in 1976 because they were appalled by the number of technical nuclear safety problems ignored by the industry and the NRC.

Bridenbaugh, holed up in the documents room of MHB Technical Associates, the San Jose consulting firm he started with Hubbard and Minor, continues: "What Three Mile showed is a great gap in the public's notion of what is an 'acceptable risk' and what people who are in the engineering world think is an acceptable risk. Engineers never expect anything to be perfect. They know there are risks and mistakes made in every structure you build."

What frightened the technical community about Three Mile Island is that it showed that it didn't take a big mechanical disaster like the bursting of a major pipe to cause a major nuclear accident. Three Mile Island was an unlucky collection of tiny mishaps: a sticky valve, a mistaken reading of gauges on the control panel, faulty maintenance that left other crucial valves turned off. All the kinds of picayune little details (tiny as a decimal point error) that seem only too human, and only too ridiculous, to matter much.

Even more chilling was the picture of experts, the ones who had cautioned the public to "leave the driving to us," confused about technical matters. Henry Myers, nuclear expert for the House Interior Committee, for example, was told by one NRC official during the hydrogen bubble scare that there was no valve on top of TMI's pressure vessel. It took a General Electric man, called in for the emergency, to ferret out the valve on a drawing of the pressurizer. Another Capitol Hill nuclear expert says, "When the news came out that the NRC had four schemes about how to get rid of the hydrogen bubble—raise the pressure inside the reactor, lower the pressure, flood the reactor or restart it: *four mutually exclusive ideas*—I knew blind luck was all we had going for us."

The accident at Three Mile Island ended April 2. But the aftermath of the accident was to prove just as chilling to those who were concerned about the safety of Rancho Seco: people like Ron Clary, activists from Friends of the Earth, experts from the California Energy Commission and the MHB engineers. For one thing, Xeroxed copies of an internal B&W account of a serious accident on March 20, 1978, at Rancho Seco, an accident in which operators were described as having "extreme difficulty in controlling the plant," had begun circulating in Washington. Other documents also making the rounds in Washington showed that a host of experts—NRC inspectors, B&W engineers and nuclear experts at the Tennessee Valley Authority—had tried to bring a range of safety questions about B&W plants to the attention of the NRC and top officials at B&W. They had no success. The President's Commission on Three Mile Island, headed by Dartmouth president John Kemeny, made the suppression of dissenting safety concerns by the industry and the NRC a major theme of its hearings.

In Sacramento, Governor Jerry Brown, two SMUD board members—Rick Castro and Gary Hursh—and environmentalists were arguing that Rancho Seco should be shut down until the jury was in on Three Mile Island and the safety of the B&W reactor system. How the NRC handled the other B&W reactors and its critics is a direct parallel to how the agency dealt with Ron Clary's safety concerns. At first, the NRC refused a shutdown. But by late April, NRC staff experts were having second thoughts.

On April 23, the NRC staff told the commission that it had decided to recommend a shutdown of the B&W plants so that more extensive modifications in equipment could be made and so that control room operators could receive TMI training on a B&W reactor simulator. But Chairman Joseph Hendrie and the two other most pronuclear commissioners pressed to postpone the vote until the next meeting. Before that meeting, *New West* has learned, Hendrie's assistant told other members of the commission that Hendrie wanted Bill Lee, the president of the powerful Duke Power Company, which owns B&W reactors, to speak at the meeting. Commissioners Peter Bradford and Victor Gilinsky objected, pointing out that non-NRC staffers were never permitted to formally address the NRC in its meetings. But at the meeting, Hendrie gave Lee the floor anyway, and the Duke Power president raised specters of rolling blackouts and financial ruin if the NRC voted to close the B&W plants. But the NRC technical staff held firm, and the commission agreed to recommend the shutdowns. Even so, the NRC did not actually *order* the plants to shut down, the course Gilinsky and Bradford pushed for. Instead, the utilities agreed to shut down voluntarily, and Bill Lee closeted himself with NRC staffers "to negotiate what changes had to be made."

When the list of fixes came out, it was clear to many in Sacramento, especially Friends of the Earth lobbyists, Gary Hursh and Rick Castro, and some of the experts at the California Energy Commission, that Bill Lee had done his work well. MHB's Greg Minor, who spent weeks in Washington reviewing all the technical documents, is critical. "They're not asking the really hard questions. They've asked the short-term, finger in the dike-type questions only." Minor points out that three of the NRC's own in-house reviews of the accident (the "short-term, lessons-learned study," the review by the Advisory Committee on Reactor Safeguards, and the probe by the NRC's Inspection and Enforcement office) demonstrate the existence of many more safety flaws in B&W reactors than were ordered fixed at Rancho Seco before the plant was allowed to go back on line.

In late June, the NRC announced that Rancho Seco had successfully completed the TMI fixes. But the NRC refused to grant public hearings on the safety of Rancho Seco—as it had on TMI-1, the twin of damaged TMI-2—before the plant was to be reopened. As a result, Friends of the Earth went into court to block the reopening of Rancho Seco. FOE wanted the plant to shut down until a court ruled that the measures required by the NRC after Three Mile Island guarantee that Rancho Seco is safe.

On July 5, the U.S. Ninth Circuit Court of Appeals heard the eleventh-hour plea, and turned it down. But the critics got a surprise from Judge Walter R. Ely Jr., the presiding justice, who said he hadn't slept for two nights because of the gravity of the decision. When SMUD attorney John F. Downey argued that Rancho Seco should be kept open because of heavy summer peak loads, Judge Ely snapped, "That fact doesn't appeal to me *at all* if there are human lives at stake." But finally, Ely said, the court had no recourse other than to "defer to the expert judgment of the Nuclear Regulatory Commission." Although the court refused to block Rancho Seco's reopening, it did not dismiss the part of the suit which challenged the adequacy of the NRC-ordered safety measures; FOE is continuing to contest those in court.

None of this was anything new to Ron Clary. It confirmed everything he'd learned already about Rancho Seco, Bechtel and the NRC. He started a new file in his basement of nothing but TMI clips, which he sent copies of to interested parties. He could even chuckle at [illegible] Catch-22s: The NRC postponed sa[illegible] hearings until after Rancho Seco was re-opened, then presumed it was safe because it was operating.

But on July 13, Clary was to discover the price for his disaffection: He was fired by the NRC. And so stacks and stacks of bitter correspondence between Clary, his union and his bosses at the NRC were added to The Clary File. A proper epitaph for the whole affair might be the reaction of one ex-NRC staffer: "At the NRC, first they drive you crazy; then they say your safety questions can't be taken seriously because you're crazy."

THE UNCERTAINTY PRINCIPLE

THERE IS A PRINCIPLE OF quantum mechanics called "Heisenberg's law" that holds that the accurate measurement of either of two related quantities—say, of energy and time, or of position and momentum—makes the measurement of the other uncertain. In the debate over reactor safety, a kind of technological and political Heisenberg law can take over: As more and more technically accurate evidence is gathered to test safety allegations, the prospect of independently and scientifically measuring the safety of a nuclear power plant can grow more uncertain, not less so. By the fall of 1979, the technical complexity involved in proving Ron Clary right or wrong or Rancho Seco safe or unsafe had defeated scores of intelligent investigators. Friends of the Earth staffers had first tackled The Clary File back in the fall of 1978, when FOE's Jim Harding had gotten a copy from Clary in Washington. At that point Clary still wanted anonymity. Harding, who is respected enough as a technical expert to be appointed to the citizens' advisory committee to the Kemeny Commission, felt that the material was too complicated to corroborate. Harding did pass it on to Mark Vanderveiden, FOE's lobbyist in Sacramento. Clary's charge then surfaced in January, 1979, in a question from the floor at a SMUD meeting. SMUD general manager William Walbridge had an immediate attack of forgetfulness. Walbridge said he'd never heard about Clary's charges or the NRC investigation. Later Walbridge admitted that he had, in fact, received and initialed the NRC report.

The sheer complexity of Clary's charges alone created a separate issue of cognitive dissonance in the Clary affair. When Gary Hursh and Rick Castro tried to ask SMUD officials about the charges at a meeting, they had many of the details mixed up, allowing SMUD officials the easy out of denying them. Capitol Hill investigators have shied away from Clary's obsessively voluminous files, and the complexities of the reactor safety issues imbedded in them; he has never been called upon to raise his concerns with anyone higher at the NRC than the I&E investigators. Paul Barnes of the *Sacramento Union* tried to pursue the Clary matter beyond the questions raised at the SMUD board meeting, but the pressures of daily journalism and the complexity of Clary's battle with his bosses over his firing discouraged Barnes. The complexities of the case threatened to wash over even the NRC at one point. In a three-hour interview with George Spencer, W. G. Albert's boss (Albert now works in the Philippines and was unavailable for comment), there was a 45-minute exchange between Spencer, *New West* and NRC staffer Paul Narbut about exactly which decimal error it was that the NRC had found didn't matter. Mounds of papers, this time in triplicate, were consulted. Breaks had to be taken to confirm that everyone was talking about the same set of calculations. Finally, Spencer, reading from a March 2, 1979, internal Bechtel report, written after Clary's charges surfaced at the SMUD board meeting, was able to recapitulate how the NRC had reached its conclusions.

New West's three-month investigation, including consultations with seven different nuclear and structural engineers and hundreds of interviews with experts on reactor safety, was unable to prove definitively whether Ron Clary is right or wrong about Rancho Seco. The investigation did confirm that Clary's charges are serious, and that the NRC's sole documentation for its dismissal of Clary's charges comes from the very company it was investigating. In the course of the investigation, SMUD assistant general manager John Mattimoe refused to allow *New West* to inspect the nuclear portions of Rancho Seco, including the spent-fuel storage pool building. (Mattimoe said his ban was based on NRC policy; but NRC headquarters in Washington, D.C., later confirmed that the NRC has no policy banning reporters from any portion of a nuclear power plant.) However, a visual inspection of other parts of the plant, including the cooling towers, showed that Walbridge's statement in an interview that "the cooling towers are too far away from the rest of the plant to do any damage" is questionable. Clary's description of how, if the towers were to list to one side or the other, they could damage parts of the piping into the containment and the emergency core cooling system was confirmed. Corroboration of Clary's charges about the seismic safety of the plant are impossible without a full-scale re-analysis of the seismic and design criteria used to build the plant.

IS RANCHO SECO SAFE?

IN A HEARING BEFORE THE California Energy Commission on July 2, 1979, the NRC tried to reassure the commission about the accident at Three Mile Island and the safety of Rancho Seco. The hearing was marked by the same morass—of technical complexity and infinitesimal detail adding up somehow to maddening inexactitude—that characterizes most reactor safety controversies. At one point, this colloquy took place between CEC commissioner Ron Doctor and the NRC's Denny Ross:

Doctor: How can you recommend to the NRC that they reopen Rancho Seco and then tell them there are still outstanding safety defects?

Ross: The level of safety at any given instance or nuclear power plant, if one could calculate it, would undoubtedly be a point value. I'm not sure how you would measure it, but the acceptable level of safety is not a point . . .

Doctor: Then it becomes a judgment on your part—the NRC's—as to how much safety is safe enough.

Ross: Right.

Is Rancho Seco safe? On November 27, the Nuclear Regulatory Commission will open hearings on Rancho Seco in Sacramento. Ron Clary has not been asked to testify. In lengthy litigation with FOE, the NRC has limited the hearings to the technical reactor safety issues arising from Three Mile Island. "The hearings won't cover a lot of our concerns, especially the absence of evacuation plans," says Mark Vanderveiden. "And as usual, the burden of proof is on us to prove Rancho Seco's unsafe—and they can run technical rings around us—not on them to prove it's safe."

Is Rancho Seco safe? "Safe enough," says the NRC. But should the company that built the plant and the utility that runs it be the sole source of data for that guarantee? Can the NRC's judgment, after Three Mile Island and its handling of the Clary investigation, be trusted? The Kemeny Commission's recent report has two shocking answers: "We have not found a magic formula that would guarantee no serious future nuclear accidents" and "there is no well-thought-out, integrated system for the assurance of nuclear safety within the current NRC."

Is "safe enough" safe? People who want to answer that question for themselves are in a terrible bind. Given the complexity of nuclear reactor issues, can outsiders—Congress, the press, whistle-blowers or environmentalists—without access to internal documents, unlimited resources and technical expertise, prove themselves whether a Rancho Seco is safe?

Is Rancho Seco safe? Because in the end, what the Clary affair raised is a possibility even more disturbing than an absolute answer to that question. It posed a law of uncertainty of life in a high technological society of no small order of magnitude. It asked this question: Could it be possible for a Ron Clary to be right about a Rancho Seco and for no one to be able to prove it? ■

STATISTICAL STUDIES OF THE EFFECT OF LOW LEVEL RADIATION FROM NUCLEAR REACTORS ON HUMAN HEALTH

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1. Possible effects of nuclear reactors

Government policy with regard to the construction and operation of nuclear power plants is of great public concern, not only because of the possibility of a serious accident at one of these plants, but also because of the possibility that radioactive discharges from these plants during their routine operation may affect the health of nearby populations. In particular, because of the vulnerability of the human fetus, it is possible that exposure of a population to these discharges may be reflected in the infant mortality rate, the fetal death rate, the prematurity rate, and similar health indices of the population.

Since several nuclear reactors have been in operation in the United States for at least five years, and some for more than ten years, the relevant data for a statistical study of this problem are largely available in published records. A study of this type would necessarily be retrospective in nature and confined to short term effects of low level radiation. If these effects are discernible, then they should be reflected in certain relationships between the health indices mentioned above for a given population and various measures of radioactivity in the environment.

2. Populations to be considered

Annual infant and fetal mortality rates, as well as prematurity rates, are typically available on a county by county basis in the published vital statistics of each state. It is suggested for simplicity, therefore, that counties form the basic units of population to be considered. Thus, for a given reactor, annual health indices for the county containing the reactor and for nearby counties would be investigated over a period both before and after the reactor became critical for possible relations with measures of the total annual radioactive

This research was supported in part by the National Science Foundation under grant GP-23708.

discharges from the reactor. Obviously, the counties that might be affected by a given reactor can lie in more than one state.

Furthermore, the health indices for a given county containing or near a reactor can be compared with the corresponding indices in certain "control" counties which are located far from the reactor but which are similar to the given county with regard to other characteristics.

3. Variables to be considered

The basic purpose of the type of study being discussed here is to relate health indices such as the annual infant mortality, fetal mortality, prematurity, and fertility rates for a given population to measures of the annual amounts and compositions of radioactive gaseous and liquid discharges from a given nuclear reactor. It is clear, however, that many other variables besides the radioactive discharges from the reactor can affect these health indices.

Some of the variables which ideally should be included in the study are the distribution of the population by age, sex, and race; meteorological data pertinent to the times of discharge of gaseous effluents and to the geographic distribution of the population; socioeconomic indices such as income, housing, education, and the quality of medical care; the sources of food and water; natural background radiation levels; radioactive fallout from bomb tests; levels of air pollution, both SO_2 and particulate matter; and personal characteristics, such as smoking and dietary habits. Obviously, the list could be extended almost indefinitely and, equally obviously, it will be very difficult to obtain the relevant data for many of them.

In addition, besides simply looking at the overall infant mortality rates for a given population and its various stratifications, it would be valuable to look at these rates for various specific causes of death. Although certain causes of death can more easily be associated with radiation effects than others, this analysis may not be as straightforward as it might at first appear. For example, it is possible that an infectious disease could cause the death of an infant whose susceptibility has been increased by exposure to low level radiation, but not cause the death of an infant who has not been so exposed. Even accidental deaths must be considered. One great hazard of being rushed to the hospital with an acute respiratory ailment is the high speed and often reckless ambulance or automobile ride that one must undergo.

Clearly, when analyzing data of the type being discussed here, one must always interpret changing rates with caution. Although there has been a general decrease in the infant mortality rate in the United States during the period from 1952 to 1967, there has also been a general increase in the prematurity rate over that period. This increase might reflect the increasingly deleterious effects of radiation, air pollution, or other environmental agents, or of changing practices of prenatal care. On the other hand, it might merely reflect changing practices in the reporting of birth weights, or even the beneficial effects of changing medical practices which convert potential fetal deaths into premature live births and consequently also bring about a decrease in the fetal death rate.

4. Results of preliminary regression analyses

In order to get a feeling for the possible magnitudes of the effects of radioactive wastes from nuclear reactors on infant mortality, and for the relative difficulty or ease with which these effects can be identified, some preliminary multiple regression analyses were carried out for the following four reactors: (1) the Dresden reactor in Grundy County, Illinois; (2) the Shippingport reactor in Beaver County, Pennsylvania; (3) the Indian Point reactor in Westchester County, New York; and (4) an experimental reactor at Brookhaven National Laboratory in Suffolk County, New York. In these regression models, the infant mortality rate in a given county containing or near a nuclear reactor, or the logarithm of this rate, was regressed on the amounts of radioactive gaseous and liquid wastes from the reactor and on either the infant mortality rate in a specified reference population or simply on a general linear trend in time. It must be emphasized that none of the multitude of other environmental agents and relevant variables listed earlier in this paper were specifically included in the models.

The general outcome of these preliminary studies is the only one that could have been anticipated, in view of the smallness of the effects and the simplicity of the model. Namely, the studies are inconclusive. They neither establish nor disprove the existence of an effect. They do, however, lead to the inescapable recommendation that more comprehensive and detailed studies of these questions are urgently needed.

The regressions that were carried out will briefly be summarized here. Time series of annual infant mortality rates for the United States as a whole, Illinois, Pennsylvania, New York, and the counties containing or near the four reactors studied are readily available from the published vital statistics of the federal government and the individual states, and will not be reproduced here. Time series of annual gaseous and liquid discharges from Dresden, Shippingport and Indian Point were obtained from the report "Radioactive Waste Discharges to the Environment from Nuclear Power Facilities" by Joe E. Logsdon and Robert I. Chissler, March, 1970, Bureau of Radiological Health, Environmental Health Service, Public Health Service, U.S. Department of Health, Education, and Welfare, Rockville, Maryland 20852. The time series of annual sand filter bed discharges and background radiation levels for the Brookhaven reactor were obtained from a report entitled "Background Radiation Levels in Brookhaven National Laboratory" by Andrew P. Hull, which was presented in March, 1970, at licensing hearings for the Shoreham nuclear power station on Long Island. None of these data are included in this paper because they are available in the sources cited and because the primary purpose of my reporting on these regression studies here is not to convince the reader of the validity and strength of particular conclusions that are reached. Rather, the purpose is to indicate that it is not possible to derive strong conclusions about either the existence or the nonexistence of an effect from the simple regression models used here, and to urge that a full scale statistical study of these problems be carried out.

5. Dresden

The Dresden reactor is located in Grundy County, Illinois, and began emitting radioactive discharges in 1960. Infant mortality rates in Grundy County were studied from 1950 to 1967, the most recent year for which these rates have been published, in order to include a relatively modern time period of reasonable length in which the reactor was inoperative as well as a time period of reasonable length in which it was active.

A relation of the following form was studied:

$$M_t = \beta_0 + \beta_1 t + \beta_2 X_{2t} + \epsilon_t. \tag{1}$$

In this relation, the index t represents the particular year being studied in the period from 1950 to 1967. For simplicity, only the final two digits of the year were used for identification, so that the year 1958, say, would be represented by the value $t = 58$. The interpretation of the other variables is as follows: M_t is the infant mortality rate in Grundy County in the year t (that is, the number of infant deaths per 1000 live births in that year), and X_{2t} is a two year moving average (for the years t and $t - 1$) of the liquid discharge (less tritium) from Dresden measured in curies. It was originally intended also to include the yearly gaseous discharges from Dresden in equation (1), but the gaseous and liquid discharges were highly correlated over the entire period. Hence, only the liquid discharges were used in this model.

The least squares estimates of β_0, β_1, and β_2 turn out to be $\hat{\beta}_0 = 55.4$, $\hat{\beta}_1 = -0.606$, and $\hat{\beta}_2 = 1.59$. Their estimated standard deviations are 30.6, 0.546, and 0.943, respectively, which yield the following t-statistics: 1.81, -1.11, and 1.68. Each of these t-statistics has 15 degrees of freedom. Thus, one might find in these values mild evidence of a positive relationship between liquid discharges and infant mortality superimposed on a general downward trend. The peak liquid discharge from Dresden was more than ten curies in 1966 (two year moving average), and it is seen by using the least squares estimate $\hat{\beta}_2$, that this value corresponds to an infant mortality rate of 15.9 deaths per 1000 live births above the overall linear trend.

It must be emphasized that none of these estimates are very reliable. Grundy County has a population of only 22,000 and the average number of infant deaths per year during the period being studied was only 11.4. Furthermore, it must be kept in mind that even if a definite relationship between infant mortality and radioactive discharges was established by these techniques, one would still be unable to conclude definitely that by actually reducing the discharges in future years, the infant mortality rate would be reduced. In fact, the discharges may simply be surrogates for some other variables which are the actual causative agents. However, it is fair to state that each scientist would regard such statistical evidence as at least favoring to a certain extent the hypothesis that the discharges are affecting the infant mortality rate.

When a similar analysis is carried out for LaSalle County, which is directly to the west of Grundy and has a population of 110,000, no evidence of a relationship is found. The least squares estimates are $\hat{\beta}_0 = 24.3$, $\hat{\beta}_1 = -0.029$, and $\hat{\beta}_2 = -0.222$. The corresponding t-statistics are 1.95, -0.13, and -0.58, respectively.

The next step was to replace M_t in (1) by $\log M_t$, since it is generally believed to be more appropriate to try to fit a linear trend to $\log M_t$ rather than to M_t itself. The results obtained were little changed from before. The t-statistics corresponding to $\hat{\beta}_2$ for Grundy and LaSalle Counties became 1.42 and -0.63, respectively. These values are not much different from their previous values.

Here, the fitted value of M_t is equal to the product of a factor $\exp\{\hat{\beta}_0 + \hat{\beta}_1 t\}$ representing the general trend in time, and a factor $\exp\{\hat{\beta}_2 X_{2t}\}$.

For Grundy County, we now have $\hat{\beta}_0 = 4.26$ and $\hat{\beta}_1 = 0.022$, and the least squares estimate of the general trend factor for 1966 is therefore 16.6. Also, we now have $\hat{\beta}_2 = 0.061$. Thus, the effect of the factor due to the liquid discharge of 10 curies in 1966 (two year moving average) is to multiply the estimated infant mortality rate for that year by $\exp\{0.61\} = 1.84$. This factor therefore corresponds to an infant mortality rate of 13.9 deaths per 1000 live births above the general trend for that year. This estimated increase is not much different from the estimated increase of 15.9 found from the linear model without logarithms.

One important consideration that makes an analysis of this type somewhat questionable, is that although the radioactive liquid discharge from Dresden was 0 for each year in the 1950's and only began to be positive in the 1960's, the populations of Grundy and LaSalle Counties may have been exposed to relatively large levels of radiation during the 1950's from bomb tests that were not present in the 1960's. Thus, in fact, the exposure of the population to radiation may actually have decreased when the bomb tests of the 1950's ceased and the Dresden reactor became active in the 1960's, rather than having increased, as is implicitly assumed in the models being used here.

In order to overcome this difficulty, the linear trend $\beta_0 + \beta_1 t$ in (1) was replaced by $\beta_0 + \beta_1 X_{1t}$, where X_{1t} is the infant mortality rate in the entire United States for the year t. In other words, it was felt that the ups and downs in the infant mortality rate in the United States through the years would reflect the general exposure of the population to radioactive fallout from bomb tests as well as other pollutants and other transient and sporadic effects. Thus, rather than assuming a linear trend, we assume that the expected infant mortality rate in Grundy County is a linear function of the infant mortality rate in the United States plus a multiple of the discharges from the Dresden reactor.

The model used is therefore

$$M_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + e_t. \tag{2}$$

Regressions were also carried out in which X_{1t} was (i) the infant mortality rate in Illinois, rather than in the United States as a whole, (ii) the infant mortality rate in Illinois minus Cook County, since Chicago forms most of Cook County and was thought to have its own special characteristics; and (iii) the total infant mortality rate in Boone, DeWitt, Logan, McDonough, and Warren Counties in Illinois, which were chosen because they matched Grundy County to some extent with regard to their rural nature and their size, and were not near the reactor.

When X_{1t} is the United States infant mortality rate, the least squares estimates of β_0, β_1, and β_2 in (2) are $\hat{\beta}_0 = -28.4$, $\hat{\beta}_1 = 1.85$, and $\hat{\beta}_2 = 1.57$. Their estimated standard deviations are 45.8, 1.70, and 0.938, respectively. The t-statistic calculated from $\hat{\beta}_2$ is therefore 1.67. It is curious to note that this value is almost identical to the value found from equation (1).

When X_{1t} is the Illinois infant mortality rate, we find $\hat{\beta}_0 = -87.1$, $\hat{\beta}_1 = 4.36$, and $\hat{\beta}_2 = 0.937$, with estimated standard deviations 71.1, 2.85, and 0.552, respectively. The t-statistic calculated from $\hat{\beta}_2$ is therefore 1.70, again almost identical to the previous values.

When X_{1t} is the infant mortality rate in Illinois minus Cook County, we find $\hat{\beta}_0 = -51.6$, $\hat{\beta}_1 = 3.04$ and $\hat{\beta}_2 = 1.46$, with estimated standard deviations 39.9, 1.65, and 0.651, respectively. The t-statistic for $\hat{\beta}_2$ is therefore now 2.24.

When X_{1t} is the infant mortality rate in the group of matched counties, we find $\hat{\beta}_0 = 20.6$, $\hat{\beta}_1 = 0.0393$, and $\hat{\beta}_2 = 0.758$, with estimated standard deviations 16.5, 0.644, and 0.627, respectively. The t-statistic for $\hat{\beta}_2$ is now 1.21. It is interesting to note that the infant mortality rate in Grundy is almost totally unrelated to the infant mortality rate in the matching counties.

Finally, when M_t in (2) is replaced by the infant mortality rate in LaSalle County, we find that $\hat{\beta}_2$ is again negative in each of these regressions.

In summary, regardless of which regression model was used to study the infant mortality rate in small Grundy County, where the Dresden reactor is located, the coefficient $\hat{\beta}_2$ of the amount of radioactive liquid discharge was always found to be positive although the corresponding t-statistics were of modest magnitude. In neighboring LaSalle County, $\hat{\beta}_2$ was always found to be negative.

6. Shippingport

The Shippingport reactor, which is located in Beaver County, Pennsylvania, started up and began discharging tritium in 1958. It began emitting measurable radioactive gaseous and other liquid discharges the following year. The infant mortality rate in Beaver County, which has a population of 206,000 was also studied for the period from 1950 to 1967. The following regression model was used:

(3) $$M_t = \beta_0 + \beta_1 t + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \epsilon_t,$$

where X_{2t} is a two year moving average of the gaseous discharges from Shippingport, X_{3t} is a two year moving average of the liquid discharges (less tritium), and X_{4t} is a two year moving average of the tritium discharges. Both X_{2t} and X_{3t} are measured in millicuries and X_{4t} is measured in curies.

No evidence of a positive relationship between the discharges and the infant mortality rate was found, and some of the estimated coefficients are negative. In particular, the least squares estimates are $\hat{\beta}_0 = 55.0$, $\hat{\beta}_1 = -0.569$, $\hat{\beta}_2 = -0.0093$, $\hat{\beta}_3 = -0.0023$, and $\hat{\beta}_4 = 0.032$. The corresponding t-statistics, each with 13 degrees of freedom, are 5.28, $-$5.02, $-$0.57, $-$0.24, and 1.13, respectively.

When equation (3) is applied to Allegheny County, Pennsylvania, which is directly to the southeast of Beaver and has a population of 1,628,000, including Pittsburgh, the estimates are $\hat{\beta}_0 = 38.1$, $\hat{\beta}_1 = -0.239$, $\hat{\beta}_2 = -0.0060$, $\hat{\beta}_3 = 0.0050$, and $\hat{\beta}_4 = -0.021$. The corresponding t-statistics are 12.6, $-$4.37, $-$1.26, 1.79, and $-$2.60. The stability of the infant mortality rates in Allegheny County, because of its large population, is reflected here in the relatively large magnitudes of the t-statistics. Among the coefficients, $\hat{\beta}_2$, $\hat{\beta}_3$, and $\hat{\beta}_4$ of the discharges, however, the t-statistic with the largest magnitude corresponds to the negative coefficient $\hat{\beta}_4$ of the tritium discharge. Thus, evidence of a positive relationship is again lacking.

Similar results were obtained when the linear term in time in (3) was replaced by the infant mortality rate in either the United States or Pennsylvania.

7. Indian Point

The Indian Point reactor, which is located in Westchester County, New York, started up and began emitting radioactive liquid discharges in 1962. The infant mortality rate in Westchester County, which has a population of 853,000, was studied for the period from 1950 to 1967 and regression analyses were carried out similar to those described for the Dresden reactor. Equation (1) was studied first with M_t denoting the infant mortality rate in Westchester and X_{2t} denoting the two year moving average of liquid discharges (less tritium) from Indian Point measured in curies. The gaseous and liquid discharges were again highly correlated (both were 0 over much of the period and then they rose together), so only liquid discharges are included in the regression equation. The least squares estimates of β_0, β_1, and β_2 are $\hat{\beta}_0 = 31.7$, $\hat{\beta}_1 = -0.178$, and $\hat{\beta}_2 = 0.059$, with estimated standard deviations 3.51, 0.062, and 0.028, respectively. Thus, the value of the t-statistic corresponding to $\hat{\beta}_2$, with 15 degrees of freedom, is 2.11.

The liquid discharges from Indian Point were more than 35 curies in both 1966 and 1967, and it is seen by using the least squares estimate $\hat{\beta}_2$ that this value corresponds to an infant mortality rate of 2.03 deaths per 1000 live births above the overall linear trend.

When a similar analysis is carried out for smaller Rockland County, which is across the Hudson River from Westchester and has a population of 192,000, the results are $\hat{\beta}_0 = 25.9$, $\hat{\beta}_1 = -0.064$, and $\hat{\beta}_2 = -0.037$, and the corresponding t-statistics are 1.75, -0.25, and -0.32, respectively.

When M_t is replaced by $\log M_t$ in (1), the results are little changed. The t-statistics corresponding to β_2 for Westchester and Rockland Counties are 2.14 and -0.25, respectively. These values are not much different from their previous values. For Westchester County we now have $\hat{\beta}_0 = 3.54$, $\hat{\beta}_1 = -0.0081$, and $\hat{\beta}_2 = 0.0028$. For 1966, the factor of the fitted infant mortality corresponding to the general trend is therefore $e^{3.00} = 20.1$. The factor corresponding to the liquid discharge of 35 curies in that year (two year moving average) is $\exp\{0.098\} = 1.10$. Thus, the estimated increase in the infant mortality rate corresponding to the liquid discharge for that year, above the general trend, is 2.01 deaths per 1000 live births. Again, this value is in close agreement with the value found from the linear model without logarithms.

Next, equation (2) was studied for models in which M_t is the infant mortality rate in Westchester County and X_{1t} is the infant mortality rate in the United States. The least squares estimates are $\hat{\beta}_0 = 6.395$, $\hat{\beta}_1 = 0.571$, and $\hat{\beta}_2 = 0.065$, and the values of the corresponding t-statistics, again with 15 degrees of freedom, are 1.12, 2.68, and 2.11, respectively.

When X_{1t} is the infant mortality rate in New York State, the estimates are $\hat{\beta}_0 = 2.231$, $\hat{\beta}_1 = 0.802$, and $\hat{\beta}_2 = 0.045$, and the corresponding t-statistics are 0.13, 1.14, and 1.05, respectively.

When M_t is taken to be the infant mortality rate in Rockland County in these two models based on equation (2), the estimates of β_2 are $\hat{\beta}_2 = -0.046$ and $\hat{\beta}_2 = 0.055$. The corresponding t-statistics are -0.37 and 0.37.

Although these data can perhaps be interpreted as evidence at least mildly favoring the existence of a positive relationship between radioactive liquid discharges from Indian Point and the infant mortality rate in Westchester County, it must be emphasized that these discharges were 0 until 1962 and then increased monotonely from 1962 to 1967. Clearly then, this simple pattern might be present in the corresponding time series of many other environmental agents, one or more of which might actually be affecting infant mortality in the magnitude being attributed here to the Indian Point reactor. The fact however that these effects seem to be slightly more established in Westchester County than in Rockland County does provide some evidence, albeit weak, against this possibility.

8. Brookhaven

The final reactor to be studied was an experimental reactor at Brookhaven National Laboratory in Suffolk County, New York, for the period from 1951, the year that radioactivity was first used at the Laboratory, to 1968. The population of Suffolk County is 666,000. The following model was used:

$$M_t = \beta_0 + \beta_1 t + \beta_2 X_{2t} + \beta_3 X_{3t} + \epsilon_t, \quad (4)$$

where M_t was the infant mortality rate in Suffolk County in year t, X_{2t} is the two year moving average of the concentration of the sand filter bed discharge in picocuries per liter, and X_{3t} is an average of two offsite background radiation measurements made in year t and the two measurements made in year $t - 1$, measured in milliroentgens per week.

The least squares estimates turn out to be $\hat{\beta}_0 = 27.6$, $\hat{\beta}_1 = -0.142$, $\hat{\beta}_2 = 0.015$, and $\hat{\beta}_3 = -0.265$. The corresponding t-statistics, with 14 degrees of freedom, are 7.89, -2.19, 4.17, and -0.30. The striking aspect of this relation is the large t-statistic corresponding to the coefficient $\hat{\beta}_2$ of the concentration of the liquid discharge from the sand filter bed. From this relation it is found that an increase in the gross beta concentrations of the liquid releases of 300 pCi/liter, the observed value for 1961 (two year moving average) corresponds to an increase in the infant mortality rate of 4.5 deaths per 1000 live births.

These figures must again be interpreted with the greatest caution since the total amount of radioactivity in the liquid releases from the Brookhaven reactor is small, the maximum value being 219 millicuries in 1961. One interesting possibility suggested by this observation is that the actual composition of these releases may be as important as their total amount in affecting health.

It should also be noted that the background radiation levels bear essentially no relation to the infant mortality rates in Suffolk County.

When M_t is the infant mortality rate in Nassau County, which is to the west of Suffolk County on Long Island and has a population of 1,300,000, the estimates of the regression coefficients are $\hat{\beta}_0 = 24.9$, $\hat{\beta}_1 = -0.148$, $\hat{\beta}_2 = 0$ (to six decimal places), and $\hat{\beta}_3 = 1.66$. Only the years from 1951 to 1967 were included in this analysis, since the infant mortality rate in Nassau County in 1968 was not immediately available. The values of the t-statistics, with 13 degrees of freedom, for these four coefficients are 9.34, -2.79, -0.13, and 2.46, respectively. Thus, there is no evidence whatsoever of a relation between the filter bed discharge and the infant mortality rate in Nassau County, but there is now a relation in the observed data between off site background radiation levels and the infant mortality rate.

As before, when M_t is replaced by $\log M_t$ and the above analyses are carried out, the results are little changed.

9. Summary

It should be emphasized again that the results of these preliminary regression studies are inconclusive. They do not present strong evidence that there is a relationship between the exposure of a population to low level radiation from nuclear reactor discharges and the infant mortality rate in the population, and they do not present strong evidence that there is no such relation. The four reactors studied have different designs, and the inconclusive nature of these studies perhaps suggests that the actual composition of the discharges might be important, as well as whether and how these discharges enter the food chain. Some of the many other variables mentioned earlier in this paper, but not included in the regression models, are likely to be very influential.

The simple studies carried out here and their inconclusive results do lead, therefore, to a very strong and important recommendation. A large scale statistical study is urgently needed to aid in resolving this vital issue. Of course, statistical analysis can neither strictly prove nor disprove the hypothesis that exposure of a population to low level radiation increases the infant mortality rate. However, these analyses can substantially raise or lower the probability that the hypothesis is correct. Indeed, a large scale statistical study, such as the study of the effect of smoking on human health, could go far toward bringing the scientific community into agreement on this question.

In my classes, I usually define a scientist to be a person who can keep clearly in mind the distinction between the subjective utility that he assigns to any specific hypothesis and the subjective probability that he assigns to that hypothesis. In other words, a scientist must never let his hope or desire that there is no relation between low level radiation and infant mortality affect his professional evaluation of the probability that such a relation might exist. Statistical studies performed by interdisciplinary teams of scientists, in this strict sense, could provide information that will be of great help in reaching decisions regarding nuclear reactors that might critically affect large segments of the world's population.

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I am indebted to Dr. Ernest J. Sternglass, who initially stimulated my interest in this topic, for many helpful conversations. I am also indebted to Dr. Lincoln J. Gerende for his kind permission to use freely material he had prepared for a research proposal submitted jointly by him, Dr. Kenneth D. Rogers, and myself to the office of the Attorney General of Pennsylvania. I am further indebted to Dr. Gerende and Dr. Floyd H. Taylor for several valuable discussions of this project. Finally, I am indebted to William J. Franks, Jr., who did most of the groundwork and all of the computations for this paper, and whose assistance has been of great value.

Discussion

Question: P. Armitage, London School of Hygiene and Tropical Medicine, London

Isn't the analysis very sensitive to the true nature of the time trend? If the trend is really quadratic (as might be expected) with the curvature, may not the X factor be taking the place of the quadratic term?

Reply: M. DeGroot

The possible effects of the curvature of the trend were investigated by fitting a linear model to the logarithm of the infant mortality rate, a model for which there is some theoretical justification, as well as to the infant mortality rate itself. As I describe in this paper, the results for the two models were in close agreement and the magnitude of the effect of the radioactive discharge was almost the same for both models. The effects of trend curvature are also greatly reduced in those models where the rate in a given county is regarded as a linear function of the rate in some control population such as the state.

Question: V. L. Sailor, Brookhaven National Laboratory

It should be pointed out that the data used by Dr. DeGroot in his analysis of the Brookhaven Laboratory situation (liquid waste) does not have a plausible connection with infant mortality. The liquid waste flows into a stream which flows to the east through a completely uninhabited area to Peconic Bay away from the high density of population. The magnitude of the emissions are so small that they can no longer be detected a few miles off site, nor do the biota show activity. The total amount released over a period of twenty years was about 1¾ curies. During the same period Suffolk County had more than 100,000 times as much radioactivity deposited on it from weapons tests fallout. Gaseous radioactive release from Brookhaven was far greater (millions of curies per year), but these releases do not correlate with infant mortality since when the gaseous releases were high, the mortality rate was dropping. When gaseous releases were reduced, the mortality rate increased.

Reply: M. DeGroot

It is true that the total amount of liquid waste from Brookhaven National Laboratory was small compared to other contaminants. It is possible, therefore, that this discharge, which was zero until 1951, built up to its peak in 1961, and then steadily diminished, is simply acting as a surrogate for some other factor which seriously affects infant mortality but which was not explicitly identified in the analysis. On the other hand, it may well be true that the important consequences of radioactive discharges are derived not simply from the total amount, but rather from the actual composition of the effluent and the way in which various elements enter the food chain or otherwise reach the embryo.

Furthermore, the effect of radioactive releases on infant mortality cannot be measured simply by noting whether infant mortality went up or down in a given year, since there are obviously many other factors affecting infant mortality. The relevant measure of the effect of radioactive releases must be given in terms of whether or not infant mortality was higher in the given year than *it would have been* if these releases were not present but all the other factors were. It is this type of measure that the statistical methods described in this paper attempt to evaluate.

Question: J. Neyman, Statistical Laboratory, University of California, Berkeley

I am curious about the possible change in the socioeconomic composition of the population in a given county that might have occurred after a nuclear facility went into operation.

Also, how variable were the year to year numbers of live births in a given county. Did these numbers exhibit some temporal trend, and could there be any danger of some spurious correlations?

Reply: M. DeGroot

Dr. Neyman has raised two very interesting questions about my paper. First, he is quite correct that the construction of a nuclear reactor at a given site might well lead to changes in the socioeconomic composition of the population near that site which in turn lead to changes in the infant mortality rates. It is difficult to check this possibility because the relevant census data are published only every ten years. My own guess is that although there might be such changes in the immediate vicinity of the reactor (say within a few blocks), it is less likely that the composition of the county as a whole will shift because of the reactor. Of course, it may shift for other reasons in accordance with certain population trends or patterns, which is equally damaging to the analysis. However, I should think that the particular counties considered in my paper, rural Grundy as well as relatively populated Beaver, Westchester, and Suffolk, retained their same general character over the entire period studied. This question clearly requires further and more careful investigation.

Second, Dr. Neyman is again completely correct that a regression analysis based on rates is a tricky business when both the numerators and denominators are random variables, especially if the distribution of the number of live births in the denominator may be changing with time. Here, however, the yearly time series of the number of births and deaths in the various counties do not reveal any "substantial" changes over the period studied. Perhaps more reassuring, a glance at the graph of the time series of the infant mortality rate for each county seems to indicate that the variability of the annual rate remains roughly the same over the entire period.

COMMENTS OF MORRIS H. DeGROOT

In my view there were two important and distressing facts which emerged from the Committee's investigation. First, we learned that the area near the Shippingport reactor, there has been no regular reliable monitoring of radiation in the environment. Therefore, it is not now possible to determine whether or not there were unreported large releases of radioactivity from the reactor in 1972 or earlier, nor is it possible to determine the amounts of radioactivity from the reactor and other sources to which the populations of nearby communities have been exposed.

Second, the anomalous levels of radioactivity found by the NUS Corporation in their pre-operational monitoring program for the Beaver Valley Power Station seem to have been accepted without further investigation by the Duquesne Light Company and the Atomic Energy Commission until Professor Sternglass publicized these findings. A reanalysis was then carried out in an attempt to discredit the findings. However, because of the tendentious nature of this reanalysis, it must also be regarded as unreliable.

Thus, in the matter of low-level radiation, the people living in the Shippingport area have been forced to rely on, and to trust their health to, agencies which have been distressingly derelict in their duties. These agencies have not provided the people with the protection and safety that they assumed they were getting. Professor Sternglass is to be commended for bringing to the attention of the general public this significant shortcoming of the nuclear energy program.

It does not seem possible to ascertain on the basis of published data whether or not the operation of the Shippingport reactor, or of other nuclear reactors, has had an adverse effect on our health. Professor Sternglass has been critized for basing his allegations only on crude published mortality data, but those are the only data available. The criticism here should more properly fall on the public agencies that have neither collected nor published the detailed health and radiation data that are necessary for a careful statistical analysis of this problem. It would be a mistake for us to reject Professor Sternglass' allegations simply because we find his statistical methods inadequate.

There are two types of errors that we could make in our public policy. On the one hand, we could assume that the routine low-level releases from nuclear reactors are relatively harmless when, in fact, they pose a health hazard to infants and other susceptible groups. On the other hand we could assume that the routine low-level releases are harmful when in fact they are relatively harmless. The consequences of this type of error would be for our society to forego unnecessarily the great benefits of nuclear energy.

We face here a problem of public decision making under uncertainty in which both types of errors have serious consequences. I propose a full scale interdisciplinary study of low-level radiation and health, to be carried out by an independent commission appointed at the federal level. A study of this kind could provide information that would significantly reduce the probability of our making either type of error. It could go far toward bringing the scientific community and the general public into agreement about the risks and the benefits of nuclear reactors.

FALLOUT AND THE DECLINE OF SCHOLASTIC APTITUDE SCORES

by

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Presented at the 1979 Annual
Meeting of the American Psychological
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September 3, 1979

Despite a major effort to identify the causes of the significant decline in the Scholastic Aptitude Test (SAT) scores in the United States that began in the 1960s (Wirtz, 1977), no single factor or combination of factors has so far been identified that could adequately explain the observed pattern of temporal and geographic changes.

Among the psycho-social causes considered by the Wirtz Report, the following are believed to have played a part in the decline:

a. Changes in the mix of students taking the tests, more blacks and more women, and more individuals intending to go to less prestigious colleges

b. Changes in curricula and standards in response to the changing type of student

c. Diminished seriousness of purpose and reduced attention to the mastering of basic skills and knowledge

d. A gradually increasing grade inflation

e. Excessive television viewing

f. A rising number of broken homes

g. A general reduction in student motivation

h. Growing national turmoil associated with the urban ghetto riots and the Vietnam war

On the other hand, the various studies commissioned by the Wirtz Committee concluded that the following factors are not likely to have played a significant part in the decline:

a. Cultural bias

b. Differences in predictive ability of the tests for whites and blacks

c. Changes in the difficulty of the test

d. Tests getting out of line with secondary or post-secondary school practices and standards

One other possible cause was briefly considered but rejected: a medical reason (Arnold, 1977) resulting from some change in delivery practice during the birth of the test-takers such as increased use of induced labor that might have caused sufficient brain damage to be a factor in the decline of SAT scores some seventeen to eighteen years later.

However, the paper by Arnold did suggest the possibility that the observed pattern might be explained if there had been a wide-spread ecological factor that began to have an effect on the infant in utero or the newborn in the early post-war years that increased during the following fifteen years. If so, the article spelled out the conditions that it would have had to meet:

a. It would have had to act during early development or childhood and be "sub-clinical" in nature so as to escape early detection.

b. It would have had to be very widely distributed throughout the United States.

c. It would have had to be introduced in 1945-46 in order to explain the decline that began in 1962-63 some seventeen years later.

d. It would have had to increase gradually in its action to explain the accelerating decline during the 1970s.

e. It would have to be of such a nature as to affect test-takers in the most recent years less severely than in earlier years, and it would have to affect present students in grades 3 to 11 less than in the past.

The article considered such factors as pesticides, herbicides, food-additives, drugs, changes in dietary habits, alcohol, cigarettes or diagnostic x-rays during pregnancy, all of which are known to be capable of producing adverse effects on the developing infant in utero.

Largely because these environmental factors continued to act essentially unchanged throughout the late 1950s and the early 1960s when the most recent test-takers were born, Arnold concluded that none of the known biological or environmental factors met the criteria listed by him, leading him to the conclusion "that the decline in SAT scores is not likely to result from physical environmental factors".

However, one widely distributed environmental factor introduced at the end of World War II in 1945 was not considered by Arnold, namely fallout from nuclear weapons tests. Furthermore, unlike all other physical factors, it ceased to be introduced into the environment at the end of the 1950s when a temporary moratorium on all nuclear testing began in 1959, followed by a permanent end to all atmospheric tests by the United States, Russia and the United Kingdom in 1963. It is therefore the purpose of the present paper to investigate the hypothesis that this neglected physical agent in the environment may have played a major role in the decline of SAT scores.

If radioactive fallout from nuclear bomb-testing was indeed a primary yet hitherto unsuspected environmental agent involved in the decline of the SAT scores, then it must meet all five conditions spelled out by Arnold.

First, since the radiation doses to critical organs of the infant just before and after birth have generally been of the order of the relatively small doses received in the course of diagnostic examination of the abdomen in the course of pelvimetry (Lapp, 1962), (Sternglass, 1963), their effect would indeed be subtle and therefore "sub-clinical" so as to escape early detection.

Secondly, atmospheric fallout was a world-wide phenomenon and therefore meets the requirement of wide distribution.

Thirdly, since nuclear fallout began with the first detonation of a nuclear bomb in Alamogordo, New Mexico on July 16, 1945, followed by the detonation of two more bombs in Hiroshima and Nagasaki in August of 1945, fallout meets the criterion of introduction in the time-period 1945-46, needed to explain the decline of test scores beginning in the early 1960s.

Next, the concentration of fallout in the environment increased gradually throughout the post-war period as the total kilotons detonated rose steadily throughout this period until the test-ban came into effect in 1963. In particular, the total amount introduced into the world's atmosphere rose more rapidly with the beginning of hydrogen bomb tests in the Pacific and Siberia beginning in 1952-53 (U.N. 1959, 1962, 1969).

Finally, it meets the requirement that the most recent test-takers as well as young children in the lower grades during the last few years were less seriously affected. The reason is that world-wide levels of fallout began to decline steadily shortly after the test-ban treaty ended atmospheric bomb tests by all nations except France and China, with French atmospheric tests ending in the mid-70s.

Although nuclear fallout meets all the minimum conditions laid down by Arnold, it is desirable to refine these criteria further in order to separate nuclear radiation from the effect of all the other possible physical and psycho-social environmental factors that have been suspected to play a role in the decline of the test scores. The more specific requirements that must be met by this hypothesis are the following:

1. There should be a delay of 17 to 18 years between the onset of a major nuclear bomb test series and a decline in SAT scores, and similarly the same delay must exist between the end of a major nuclear test-series and leveling off in the decline of the scores.

2. Geographically, the greatest declines in SAT scores should have occurred in areas that received the largest fallout doses. These would be either areas closest to the test-sites in Nevada, the Pacific or Siberia, or areas of heavy rainfall in the path of fallout clouds since about 90% of world-wide distance fallout is brought down by precipitation (U.N. 1959). Since rainfall is enhanced by the presence of air pollution (Changnon, 1979), urban areas would in general be expected to be more strongly affected than nearby rural areas in the path of the fallout clouds, quite aside from the compounding effect of other socio-economic factors and chemical agents present in heavily urbanized areas that would be expected to act synergistically with the biological effect of radioactive fallout.

Turning first to an examination of the change of SAT scores with time, (Table I), Fig. 1 shows the trend of the mean verbal SAT scores in the United States for the birth years 1940 to 1960 (SAT years 1958 to 1978), together with a plot of the cumulative external gamma radiation dose from fallout as measured in New York for the period 1949 to 1969 (Hull, 1970), plotted according to birth-year of the test-takers. Since Table I shows that the mathematical scores follow the same general pattern as the verbal scores, the subsequent discussion can be simplified by focusing on the latter set of data.

Inspection of Table I and Figure 1 shows that during the period 1940 to 1945 when there was no fallout, the verbal SAT score remained essentially constant between 472 and 478, fluctuating by only ± 3 points around a mean of 475. Beginning in 1946, there was a steady decline in every year until the testing year of 1976, when the test-score suddenly leveled off at 429.

It is also seen that the rate of decline sharply accelerated in the birth years 1953 and 1954, following the detonation of the first large hydrogen weapons in the Pacific and Siberia, as well as the detonation of a series of small tactical A-bombs at the Nevada test-site beginning in the period 1951-53.

The largest drop in SAT scores is seen to have occurred for the individuals who took the tests between 1973 and 1976, or those who were born between 1956 and 1959. These were the years that showed the largest increases in the cumulative fallout dose recorded up to that time, corresponding to the largest nuclear bomb test series both in Nevada, the Pacific, and Siberia before the temporary test-moratium came into effect at the end of 1958 (Glasstone, 1962).

Following the sharp changes in fallout dose and SAT scores, there occurred the equally dramatic, sudden halt in the decline for the testing years 1976-77 and 1977-78, paralleling exactly the sudden halt in the rise of accumulated fallout dose when nuclear bomb testing came to a temporary halt 17 years earlier in 1959.

Since the U.S.-U.S.S.R. atmospheric bomb tests were resumed in the fall of 1961, it would be expected that the present level trend in the SAT scores will not continue beyond the SAT tests of 1978. One would then expect to see another period of sharp decline as indicated in the dotted curve of Fig. 1, corresponding to the sharp rise in the cumulative fallout dose between 1961 and 1964, followed by another plateau in the SAT scores some time after 1982.

Turning to a more detailed examination of patterns of temporal changes of the SAT scores during the period of heaviest nuclear testing in Nevada closest to the U.S. population centers, one can examine the annual changes grouped by graduating high school class (Table II) rather than the year when the tests were taken (Jackson, 1976). It is then possible to compare the annual changes in verbal SAT scores with the annual additions of radioactive isotopes to the environment as measured by the announced kilotons of equivalent TNT detonated in Nevada 18 years earlier when the test-takers were born (Glasstone, 1962).

Fig. 2 is a graphical representation of the data in Table II, comparing the mean verbal SAT scores by years of high school graduation with the year-by-year kilotonnage of nuclear weapons detonated at the Nevada test-site 18 years earlier. It shows that the greatest declines in scores occurred for the years of largest weapons yields, the decline suddenly ending in 1976, corresponding to the sharp decrease in kilotons detonated in 1958.

A comparison of the annual declines in SAT scores from Table II with the annual weapons yields in kilotons is shown in Fig. 3. Note that the declines in SAT scores are strongest in the years of the greatest weapons test-yield, and least in the years when no weapons were tested at all.

Thus, the detailed comparison of the SAT score declines grouped by graduating class with the known yearly production of fission products in Nevada when the average test-taker was born agree with the long-term correlation between SAT score decline by testing year and the annual changes in the measured fallout radiation dose. It therefore appears that fallout radiation exposure in utero or in early infancy was accompanied by declines in the SAT scores some 17 to 18 years later.

Table III addresses itself to the pattern of geographical distribution in SAT declines. When grouped by regions as presently available by high school classes (Jackson, 1976), the greatest drops during the period of sharpest decline (class of 1974 to 1976) occurred not in the large urban areas of the mid-West, Middle-Atlantic and New England areas, but in the far West, closest to the Nevada, Pacific and Siberian test-sites. While the Mid-West declined 8 points during the birth-year period 1956-58 bracketing the year 1957 of largest Nevada testing, the Western Region from Alaska and Hawaii to Wyoming and Colorado declined 19 points, consistent with the hypothesis that proximity to the test-sites or high rainfall downward from the point of detonation should lead to the largest decline, while locations of low rainfall should show small declines. This hypothesis is further supported by the fact that the second lowest decline of 11 points took place in the dry South-West, to the south of the Nevada test-site and out of the path of the major fallout pattern that was oriented generally towards the North-East (U.N. 1959). New England, with its greater rainfall but greater distance from Nevada and the Pacific was next with a drop of 12 points, followed closely by the South (13 points) and the Middle Atlantic states (14 points) that include the most densely industrialized and therefore most heavily polluted areas such as Pennsylvania, New York and New Jersey.

Thus, none of the heavily urbanized areas in the United States showed a drop as great as the relatively non-urbanized and less heavily industrialized areas of the far West which include Hawaii, Alaska, Washington, Oregon, Montana, Idaho, Wyoming, Colarado, Arizona, California, Utah and Nevada, again supporting the hypothesis that bomb fallout is the previously neglected environmental factor involved in the sharp decline of SAT scores in the United States.

A more detailed test of this hypothesis was possible as a result of the availability of some state-by-state data on radioactivity in the milk beginning with the measurements carried out by the U.S. Public Health Service in 1957 (Campbell, 1959) and corresponding state-by state data for the SAT tests (Jackson, 1976). Beginning in June 1957, the Public Health Service reported monthly measurements of both the short-lived radioisotopes Iodine-131 (Half life 8.1 days), Barium-140 (Half life 12.8 days) and Strontium-89 (Half-life 53 days) as well as the long-lived isotopes Strontium-90 (Half-life 28 years) and Cesium-137 (Half-life 33 years) in the milk for certain metropolitan areas in 5 states. These were Sacramento, California; Salt Lake City, Utah; St. Louis, Missouri; Cincinna i, Ohio and New York City, New York.

The SAT data for four of the five states were available (College Board, 1979), namely California, New York, Ohio and Utah for the high school classes of 1972-73 to 1976-77, which bracket the years of the largest decline, 1973-74 to 1975-76. This set of data may be found in Table IV, along with the changes between the 1974 and 1976 high school classes. The largest drop for this two year period bracketing the birth year 1957 occurred in Utah, where the decline was 26 points, compared with 2 points in Ohio two thousand miles to the east of the test site. The decline in Utah was higher than the 19 point drop for the Western Region as a whole and the 20 point drop in California, consistent with the close proximity of Utah to the test site and the general north-eastw d motion of most of the fallout clouds produced by the Nevada tests.

New York dropped by 17 points, an amount intermediate between that of Utah and Ohio. This is consistent with the higher rainfall and the compounding factors of urban air-pollution, drug use, and other physical and psycho-social problems in New York City compared with more rural Ohio.

Although the available radioactivity data for milk were not gathered on a state-wide basis and therefore are not strictly comparable with the state-wide SAT scores, they support the hypothesis that fallout levels were much greater in Utah than for instance in New York. Thus, Table 2 (Campbell, 1959) gives an average concentration of Iodine-131 for the period June 1957-April 1958 of

249 pCi/liter of milk in Salt Lake City, compared with an average of only 79 pCi/liter in New York City. A comparison with Sacramento, which has a relatively low annual rainfall and is located far to the north of Los Angeles does not provide a good measure of the milk, air and dietary levels in Southern California closest to the test-site, but it does show a lower level of short-lived isotopes than Salt Lake City in accordance with the present hypothesis. Thus, the average concentrations for Iodine-131, Barium-140 and Strontium-89 were 30.0, 19.7 and 21.2 pCi/liter in Sacramento compared with 249, 49.1 and 30.5 pCi/liter respectively in Salt Lake City.

To summarize these findings, both the temporal and geographical patterns of the changes in SAT scores are consistent with the hypothesis that radioactive fallout from nuclear weapons testing in Nevada, the Pacific and Siberia exerted a significant influence on the mental development of infants in utero at the time of heaviest nuclear weapons testing.

The observed sharp decline in SAT scores followed by an equally sudden halt some 17 to 18 years after the largest weapons tests, together with the fact that the greatest changes took place nearest to and downwind from the Nevada test site, where the intense short-lived radioactivity had an opportunity to pass through the food chain before it decayedaway, points to nuclear fallout as the most important environmental factor involved in the observed changes in the SAT scores. Such rapid, localized fluctuations cannot be readily explained by excessive television viewing, long-term changes in school curricula, gradual changes in the type of student taking the tests, diminished seriousness of purpose of the students or teachers, grade inflation, broken homes, student motivation or national political turmoil as suggested by the Wirtz Commission, although any or all of these factors could clearly aggravate the problem in a synergistic manner.

Similarly, the effect of toxic environmental agents other than fallout such as drugs, cigarettes, alcohol, air-pollution, automobile exhaust, pesticides, herbicides, medical x-rays, or changes in obstetrical practices during delivery could not, by themselves, explain the sudden drop in scores followed by an equally sudden end to the decline since they continued to act essentially unchanged when bomb testing was briefly halted between 1959 and 1961. Nor is there any evidence to suggest that these factors should be concentrated in the Western United States, and in particular in Utah, where the Mormon religious customs have in fact resulted in very low per capita consumption of cigarettes (Tobacco Tax Council, 1971).

In support of the hypothesis that fallout was the new, widespread environmental agent that began to affect the children born after 1945 to a steadily growing degree, evidence exists that childhood leukemia (Lyons, 1979) and thyroid abnormalities (Weiss, 1967), rose significantly in Utah for the children in utero during this period. Such effects had not been thought possible as the relatively low radiation doses involved until the discovery of Stewart and Kneale (Stewart, 1970) that the embryo and fetus in some ten to one hundred times more sensitive to the induction of childhood leukemia and other cancers by a few diagnostic x-rays of comparable dose than the middle-aged adult, the sensitivity decreasing with the stage of intra-uterine development.

Not only did childhood leukemia and thyroid abnormalities rise in Utah following the Nevada tests, but so did infant mortality for all causes of death. From a minimum of 20.4 per 1000 live births, the mortality rate rose to a peak of 22.1 in 1958, decreasing again to 19.6 by 1960 when nuclear testing was temporarily halted between 1959 and 1961 (U.S. Vital Statistics). This rise of 8.3% is larger than the rise of 4.2% observed for California, 2.7% in New York and 2% in Ohio, paralleling the relative effect on SAT score declines for these states for the children born during the 1955-59 period of weapons testing.

Furthermore, following the end of the atmospheric tests in 1963, infant mortality rates for Utah and the United States as a whole began to decline once more until in the most recent years, the rate of decline for both white and non-white infants in the United States once again resumed its pre-1950 rate (See Fig. 4). Thus, the temporal pattern of infant mortality changes agrees with the pattern of fallout, kilotonnage detonated, and SAT declines.

More recently, a large-scale epidemiological study at Johns Hopkins University (Diamond, 1973) showed that the risk of death associated with diseases of the central nervous system was significantly increased by relatively small amounts of radiation during intra-uterine development. Likewise, the risk of congenital defects has been shown to be increased by intra-uterine radiation in animal studies as well as in observations of infants accidentally exposed to radiation during intra-uterine development. Since cognitive deficits are far more frequent among individuals with congenital abnormalities, one would expect to find increasing incidence of congenital defects.

Evidence suggesting an increased incidence of congenital defects following the deposition of fallout was first presented by Le Vann for the province of Alberta in Canada (Le Vann, 1963). Although the findings were complicated by the simultaneous introduction of thalidomide into Canada in the early 1960s that acted synergistically to increase the effect of radiation (Sternglass, 1977), LeVann's data showed a greater incidence of congenital defects in areas of higher rainfall, exactly as for the case of SAT score declines discussed above.

The fact that the incidence of congenital defects also rose in Utah following the onset of the Nevada bomb-tests is illustrated by the data for the annual deaths due to congenital defects of children 0 to 4 years old in Utah between 1938 and 1968, together with the number of deaths due to accidents for comparison (Fig. 5), (Sternglass, 1972). The number of deaths associated with congenital defects showed a large peak between 1953 and 1958, followed by a sudden decline in 1959 and 1960 corresponding to the sharp drop in the SAT scores in Utah and a partial recovery after the end of the Nevada tests in 1958. Furthermore, a second peak in 1961-62 corresponds to the resumption of nuclear bomb tests in the fall of 1961, suggesting that a second period of SAT score decline should begin in Utah and to a lesser degree elsewhere in the U.S. in 1979-80. No such clear rises and declines occurred for accidental deaths in Utah for this age group during the same period.

The fact that radiation can produce mental retardation in large human populations exposed to ionizing radiation during intra-uterine development was also emphasized in a report of the United Nations Scientific Committee on the Effects of Radiation published in 1969 (U.N., 1969). Figure 6 represents a plot of the prevalence of severe mental retardation among individuals exposed to the atomic bomb radiation in utero as a function of the radiation dose taken from Table V, p. 86 of the U.N. report. This plot reveals a direct relation between the prevalence of mental retardation as measured by psychological tests at age 20 and the radiation dose received during early development, without any evidence for a safe threshold below which no effect occurs.

It should be noted that the thyroid doses to the fetus and infant in Utah, although relatively small, were within the lower range of doses received by the surviving infants in Hiroshima and Nagasaki namely 1-100 rads (Weiss, 1967).

There is, however, a difference in the duration of the exposure, which was only a matter of seconds at Hiroshima and Nagasaki, while it was protracted over periods of weeks or months in Utah and other areas affected by distant fallout. For this reason, it is of interest that a high prevalence of mental retardation was also discovered in a population exposed to above normal background radiation over long periods of time in Kerala, India (Kochupillai, 1976). Comparing the prevalence of chromosomal abnormalities, Down's syndrome and various forms of mental retardation in two similar fishing villages over 20 miles apart but with large differences in annual background radiation due to natural thorium sands, the results for the prevalence of mental retardation at birth are presented graphically in Fig. 7 for comparison with the data for a brief exposure in Fig. 6.

The dose needed to double the normal incidence in Kerala is about 300 mrads per year, or 12 rads over a period of 40 years. This is not very different in magnitude from the estimate of 15±5 rads arrived at for the doubling dose in Hiroshima and Nagasaki. The total doses over periods of years are therefore of the same general order as the annual doses to the thyroids of children in Utah during the period of Nevada bomb tests.

As to the nature of the biological mechanism leading to subtle forms of cognitive impairment by fallout, the outstanding fact is that the greatest effects occurred in the Western Region of the United States nearest the Nevada test site. This is an area showing the highest concentration of Iodine-131 and other short-lived iodine isotopes which concentrate in both the fetal and infant thyroid to a much greater degree than in the thyroid of the adult. It suggests that the principal biological effect is one of the growth-controlling hormones produced by the thyroid gland, especially during the last few months of fetal development.

This conclusion finds support in the extensive studies carried out on the Marshallese Island children accidentally exposed to fallout following the 1954 Bravo hydrogen bomb test (Conard, 1965, 1966). There was striking degree of growth retardation associated with hypothyroidism, particularly for the youngest children at the time when the fallout arrived, with doses to the thyroid generally estimated to have been in the range of 10 to 1000 rads. As in the case of the Utah population, there was also an increase in thyroid nodules and thyroid cancer many years later, but the earliest effect was apparently one of hormonal disturbance.

The fact that the SAT scores in Utah and elsewhere in the United States did not return to the levels that existed prior to the onset of nuclear bomb testing as soon as the Iodine-131 disappeared from the environment in 1959 and 1960 suggests that the biological action of the fallout was not solely due to the radioactive iodine on the thyroid gland of the developing infant in utero. There are a number of biological mechanisms that can lead to a cumulative effect such that later-born children show a greater effect than those exposed in the first few years of bomb testing.

Cumulative damage to the ova and the sperm-cells of the parents would provide one possible explanation of effects that increase with time, similar to the Kerela situation, where the reproductive cells of the parents are exposed for many years.

Another mechanism that could bring about a cumulative deterioration of cognitive abilities would be the long-term build-up of radioactive isotopes in the body, particularly the skeleton of adolescent females consuming large quantities of milk. In particular, Strontium-90 has been found to build up in the human body over a period of many years, the biological half-life for elimination from the skeleton being of the order of 5 to 10 years depending upon the age. Not only does the Strontium-90 circulate in the blood, thus contributing to the dose received by soft-tissue organs, but it also transforms itself by radioactive beta decay to the radioactive daughter product Yttrium-90 which has a different chemical valence state than Strontium-90, causing it to accumulate preferentially in critical soft tissue organs such as the pituitary gland and the male and female gonads, (Spode, 1958), (Graul, 1958).

As a result, a young woman who has consumed Strontium-90 that goes along with calcium in the milk and diet will have a steadily increasing amount of both Strontium-90 and Yttrium-90 in her body during the period of weapons testing. If she then becomes pregnant, the newly developing baby, drawing on the mother's reservoir of calcium in her bone, will also receive along with it elevated levels of both the toxic Strontium and Yttrium.

Thus, it is possible that the pituitary gland of the developing infant will be damaged by the beta rays emitted from the Yttrium-90, leading to various degrees of secondary hypothyroidism since the pituitary gland in turn controls the function of the thyroid.

As a result, one would expect growth retardation from the cumulative ingestion of long-lived Strontium-90 by the mother prior to pregnancy, as well as due to the short-lived Iodine-131 going directly to the fetal thyroid. The former would lead to a cumulative effect such that later-born children would experience greater growth retardation than those born earlier in the bomb-testing period, thus explaining the overall decline during the period of weapons testing as indicated by Figures 1 and 2.

The short-lived Iodine-131 would dominate in areas close to and downwind from the site of detonation, especially in the case of small tactical weapons in the kiloton range, where the fireball touches the ground and the resulting heavy radioactive debris descends within minutes or hours in the downwind areas before the short-lived isotopes have had a chance to decay. This is in sharp contrast to the case of megaton bombs detonated well above the surface, where the radioactive debris rises high into the stratosphere and takes many months to reach the ground (Glasstone, 1962).

Since a number of studies have revealed a close correlation between fetal and infant mortality and levels of Strontium-90 in the milk [Sternglass, 1969(a) and 1972(b)], (Lave, 1971), (Bertel, 1979), it is reasonable to assume that for every child that dies in the first year of life, there will be many who survive but who will show minimal or sub-clinical developmental retardation, thus explaining the subtle effects on cognitive functions for individuals who are otherwise free of any obvious congenital defects.

Undoubtedly there exist still other, more complex mechanisms whereby radioactive fallout with its large number of different chemical elements can induce both short and long-term effects on cognitive functions, for instance as a result of an increased susceptibility to infectious diseases that are capable of producing brain damage such as measles and encephalitis.

Whatever the detailed biological mechanisms may turn out to be, the existing evidence for surprisingly large effects of low-level environmental radiation on verbal and reasoning ability as reflected in SAT scores would seem to call for a complete reexamination of our existing standards for environmental radiation that are largely based on genetic and somatic effects for the adult rather than on developmental effects for the much more sensitive infant in utero. An extensive program of epidemiological studies is clearly needed to investigate in detail the effect of past radioactive releases on hormonal functions and cognitive ability in order to evaluate the full impact of world-wide fallout from nuclear weapons, natural background radiation and the releases of radioactive wastes from peaceful nuclear operations into the environment.

Table I

Mean Verbal and Mathematical SAT Scores
By Year of Testing, 1956-57 to 1976-77

SAT Testing Years	Birth Years*	Mean Verbal S.A.T. Score	Mean Math. S.A.T. Score
1956-57	1939	473	496
1957-58	1940	472	496
1958-59	1941	475	498
1959-60	1942	477	498
1960-61	1943	474	495
1961-62	1944	473	498
1962-63	1945	478	502
1963-64	1946	475	498
1964-65	1947	473	496
1965-66	1948	471	496
1966-67	1949	467	495
1967-68	1950	466	494
1968-69	1951	462	491
1969-70	1952	460	488
1970-71	1953	454	487
1971-72	1954	450	482
1972-73	1955	443	481
1973-74	1956	444	478
1974-75	1957	437	473
1975-76	1958	429	470
1976-77	1959	429	468

* Birth years are generally 17 years prior to the earliest year of S.A.T. testing, or 18 years prior to the last test.

Table II

Mean Verbal SAT Scores by Year of High School Graduation
Compared with Kilotons of Tactical Nuclear Weapons Detonated
in Nevada 18 Years Earlier

Year of H.S. Graduating Class	Year of Birth and A-Tests	Mean Verbal SAT Score (U.S.)	Annual Change in Score	Kilotons Detonated in Nevada
1967	1949	466	-	0 kt
1968	1950	466	0	0 kt
1969	1951	463	-3	111 kt
1970	1952	460	-3	104 kt
1971	1953	455	-5	252 kt
1972	1954	453	-2	0 kt
1973	1955	445	-8	167 kt
1974	1956	444	-1	0 kt
1975	1957	434	-10	303 kt
1976	1958	431	-3	18 kt
1977	1959	429	-2	0 kt
1978	1960	429	0	0 kt

Table III

Mean Verbal SAT Scores by Year of Birth and
Year of High School Graduation for California,
New York, Ohio and Utah

Birth Year	California		
1955	1972-73	452	
1956	1973-74	450	
1957	1974-75	435	-20
1958	1975-76	430	
1959	1976-77	427	

	New York		
1955	1972-73	454	
1956	1973-74	454	
1957	1974-75	441	-17
1958	1975-76	437	
1959	1976-77	434	

	Ohio		
1955	1972-73	457	
1956	1973-74	459	
1957	1974-75	456	-2
1958	1975-76	457	
1959	1976-77	459	

	Utah		
1955	1972-73	528	
1956	1973-74	532	
1957	1974-75	516	-26
1958	1975-75	506	
1959	1976-77	515	

Table IV

Changes in the Mean Verbal SAT Scores of High School Graduating Classes 1976 Compared with 1974 by Region*
(Birth Years 1956 and 1958)

	H.S. Class		
New England	1974	447	-12
	1976	435	
Middle Atlantic	1974	445	-14
	1976	431	
South	1974	426	-13
	1976	413	
Mid-West	1974	459	-8
	1976	451	
South-West	1974	444	-11
	1976	433	
West	1974	454	-19
	1976	435	

* The college board regions consist of the following states:

New England: Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut
Middle Atlantic: New York, Pennsylvania, New Jersey, Delaware, Maryland, District of Columbia, Puerto Rico
South: Virginia, Kentucky, North Carolina, Tennessee, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Florida
Mid-West: North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Indiana, Michigan, Ohio, West Virginia
South-West: New Mexico, Texas, Oklahoma, Arkansas
West: Alaska, Hawaii, California, Arizona, Oregon, Washington, Idaho, Montana, Wyoming, Colorado

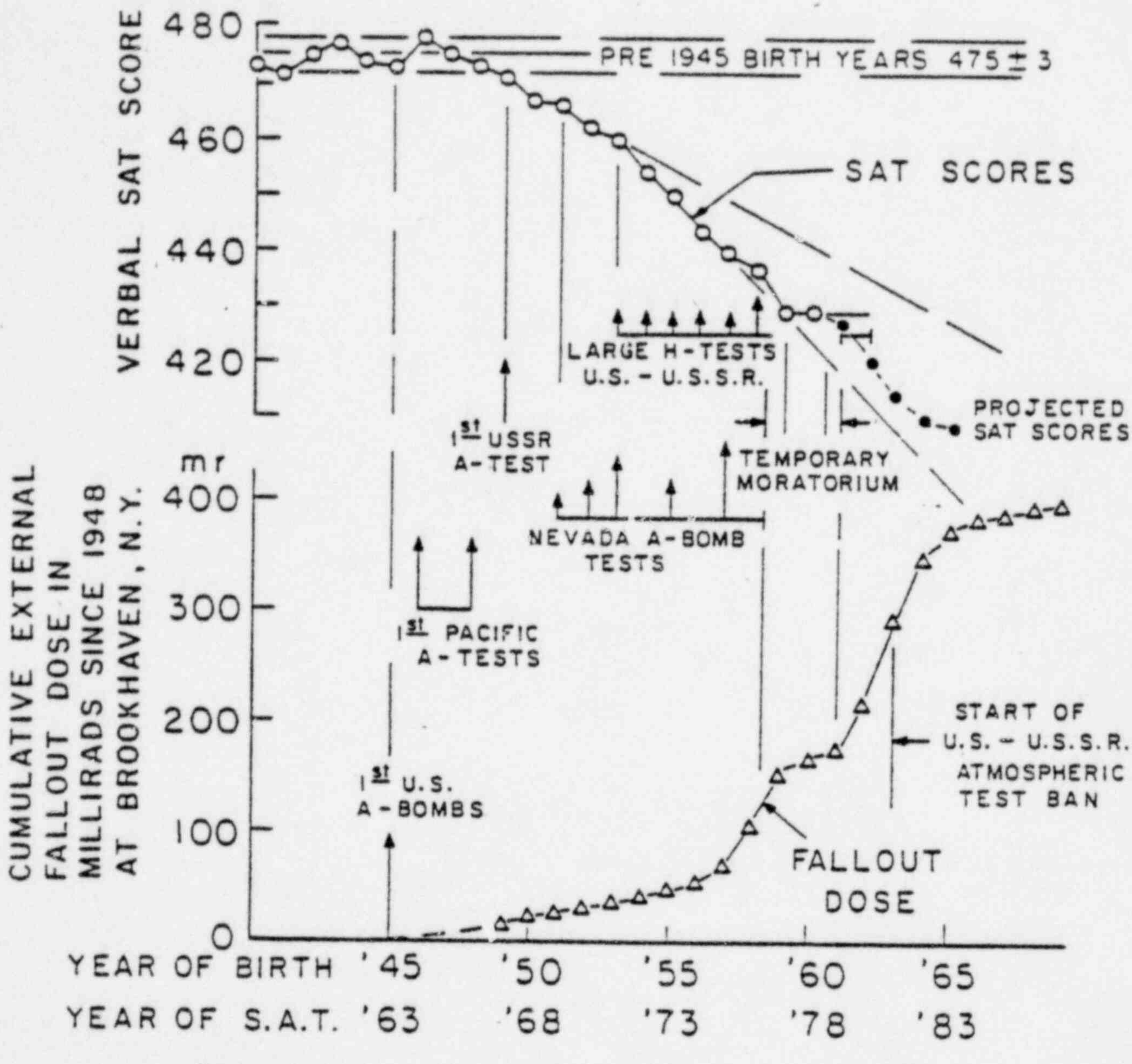

FIGURE 1. TREND OF MEAN VERBAL SAT SCORES IN THE UNITED STATES BY YEAR OF APTITUDE TEST COMPARED WITH THE CUMULATIVE EXTERNAL GAMMA RADIATION DOSE FROM FALLOUT AS MEASURED IN NEW YORK STATE 18 YEARS EARLIER WHEN THE TEST-TAKERS WERE BORN.

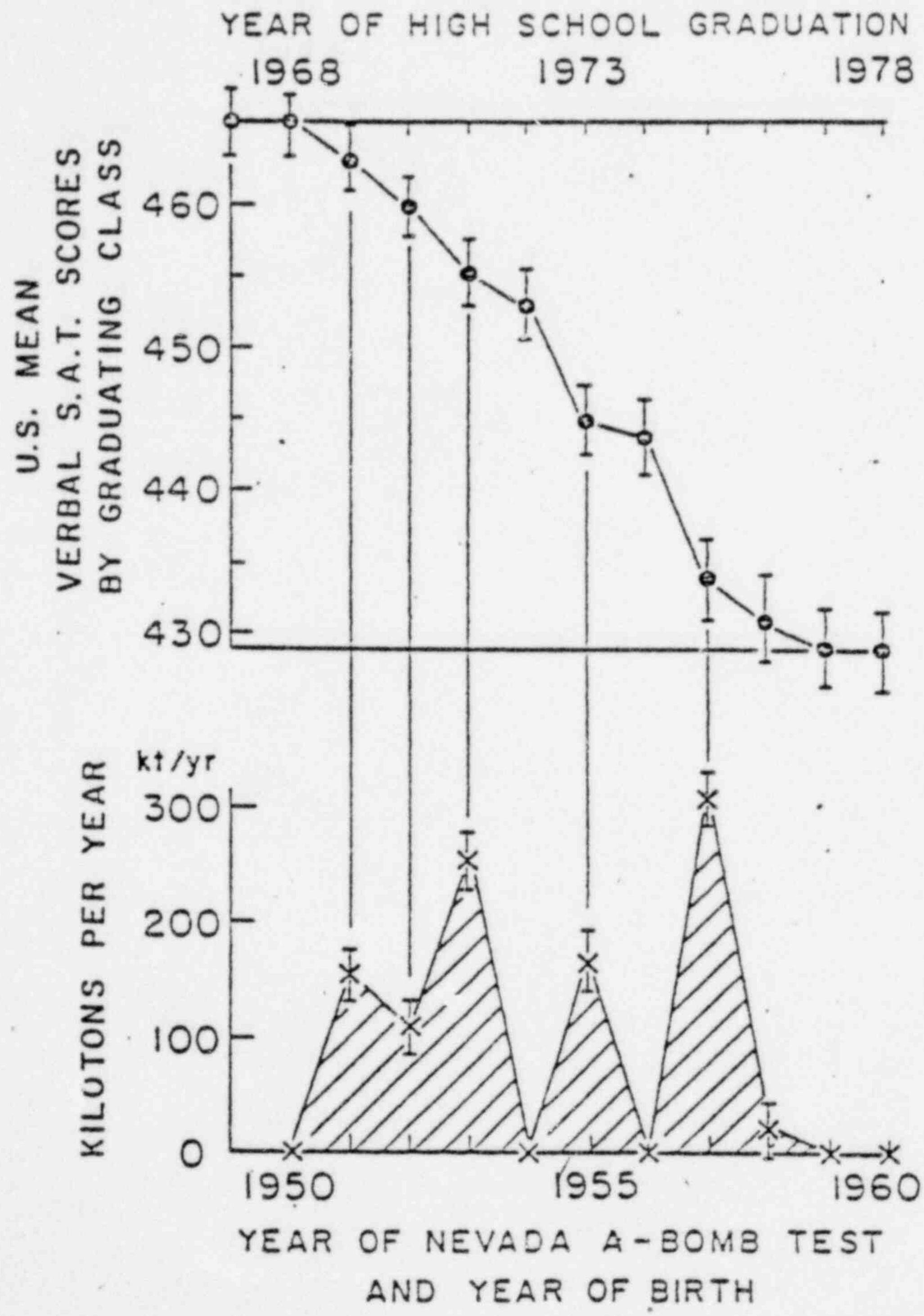

FIGURE 2. TREND IN THE MEAN VERBAL SAT SCORES FOR U.S. HIGH SCHOOL GRADUATES COMPARED WITH THE ANNUAL KILOTONS OF SMALL ATOMIC BOMBS DETONATED IN NEVADA 18 YEARS EARLIER.

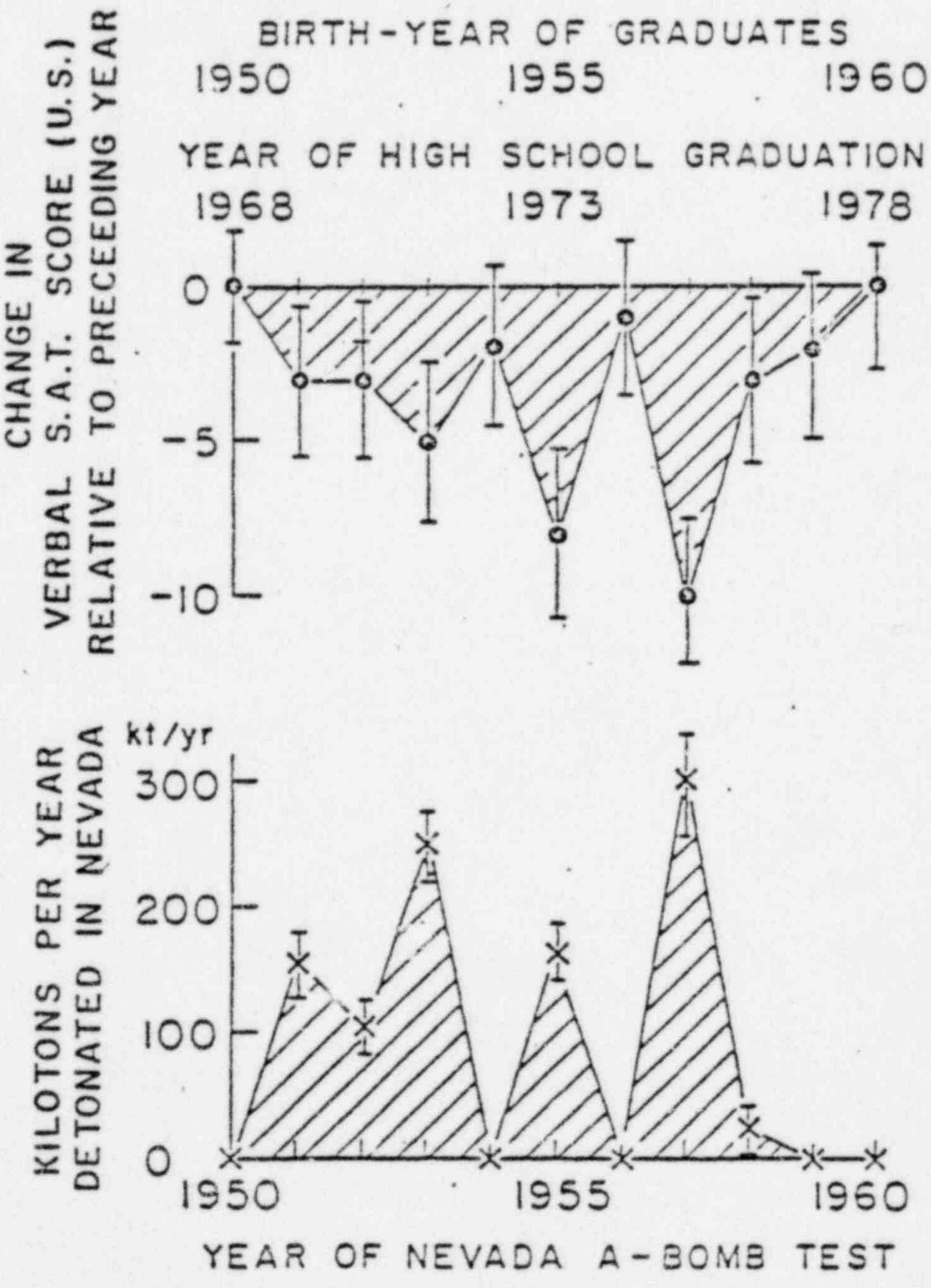

FIGURE 3. ANNUAL DECLINES IN THE MEAN VERBAL SAT SCORES BY YEAR OF HIGH SCHOOL GRADUATION COMPARED WITH THE ANNUAL KILOTONS OF SMALL ATOMIC BOMBS DETONATED IN NEVADA 18 YEARS EARLIER.

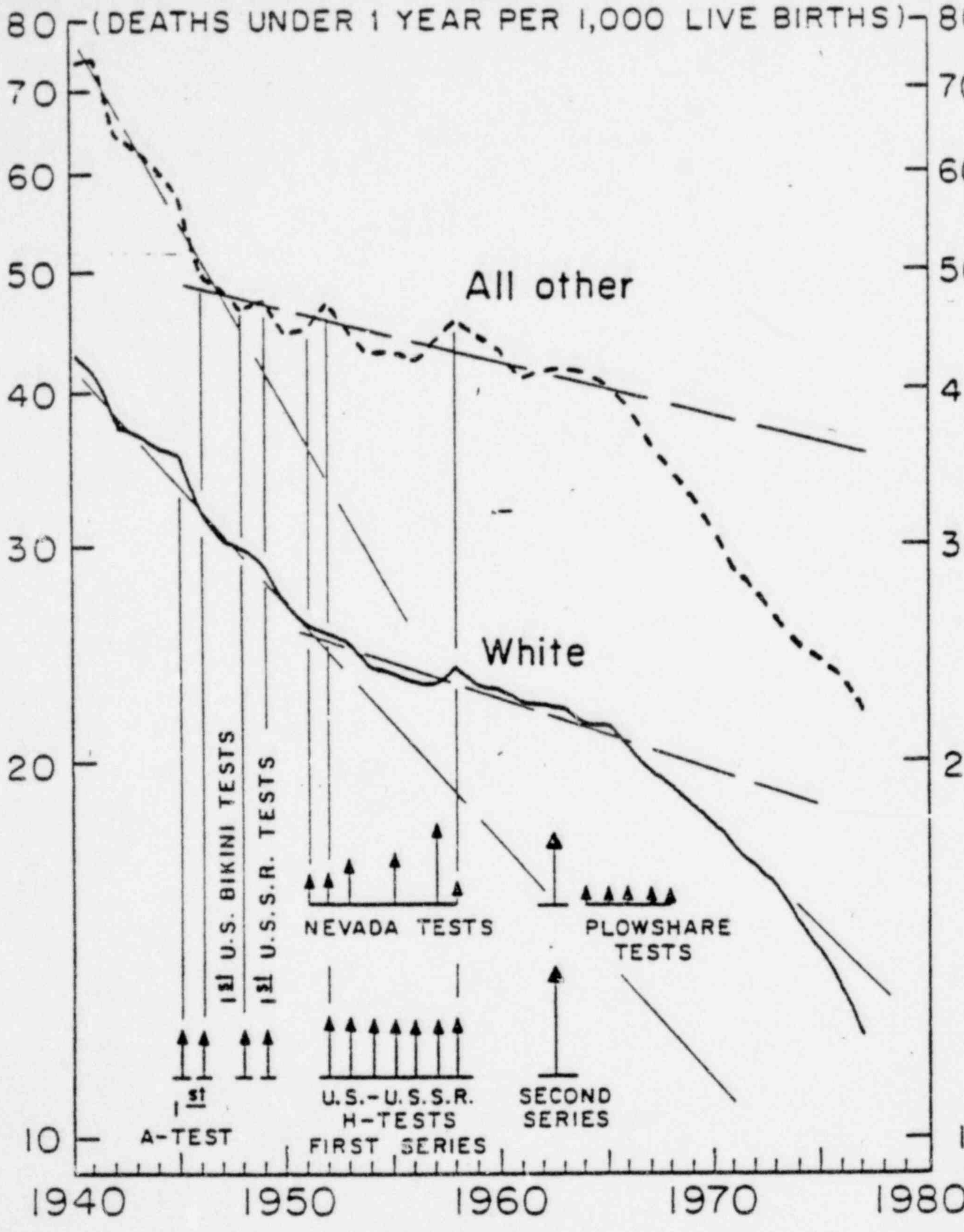

FIGURE 4. CHANGING TRENDS IN INFANT MORTALITY IN THE UNITED STATES FOR WHITE AND NON-WHITE POPULATIONS 1940-77. BEFORE, DURING AND AFTER LARGE-SCALE ATMOSPHERIC NUCLEAR WEAPONS TESTS. DATA FROM U.S. MONTHLY VITAL STATISTICS, VOL. 28, NO. 1, MAY 11, 1979, WITH PERIODS OF MAJOR ATOMIC TESTS ADDED.

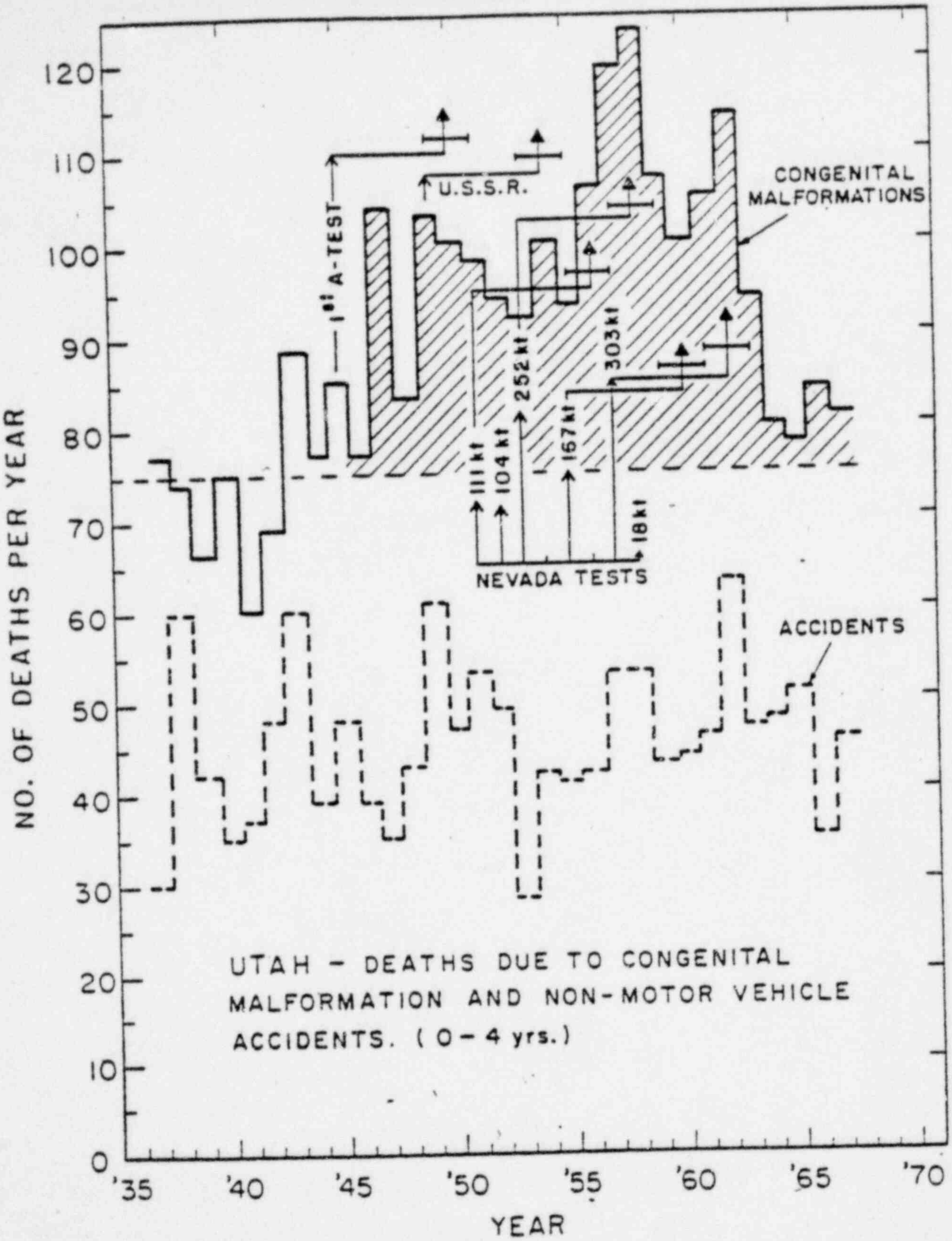

FIGURE 5. ANNUAL NUMBER OF DEATHS PER YEAR DUE TO CONGENITAL DEFECTS FOR 0-4 YEAR OLD CHILDREN IN UTAH, 1938-1967 COMPARED WITH ANNUAL DEATHS DUE TO ACCIDENTS.

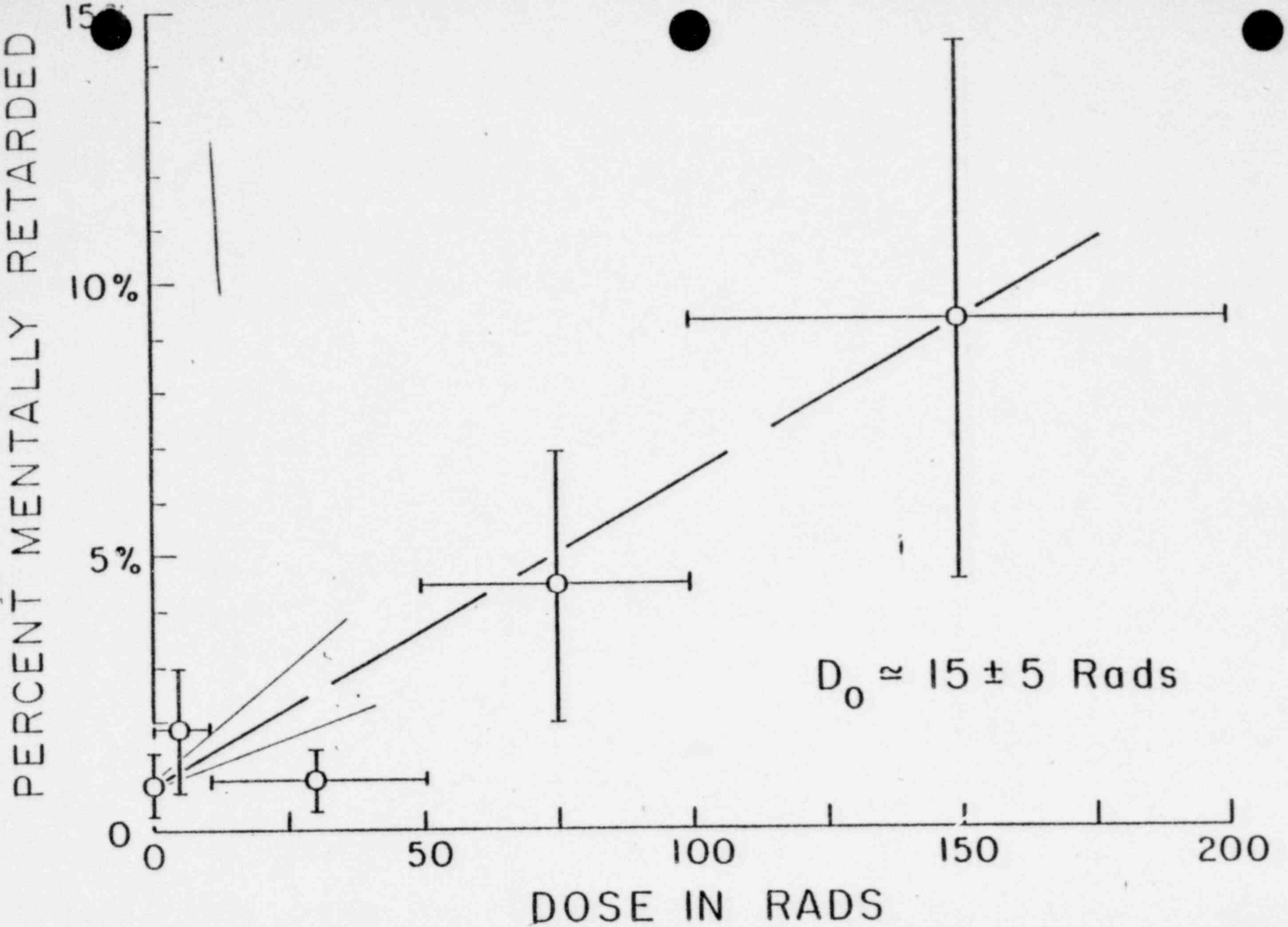

FIGURE 6. INCIDENCE OF MENTAL RETARDATION FOLLOWING RADIATION EXPOSURE IN UTERO IN HIROSHIMA AND NAGASAKI 20 YEARS EARLIER AS A FUNCTION OF DOSE. DATA FROM TABLE V, P. 86, 1969, U.N. SCIENTIFIC REPORT ON THE EFFECTS OF ATOMIC RADIATION.

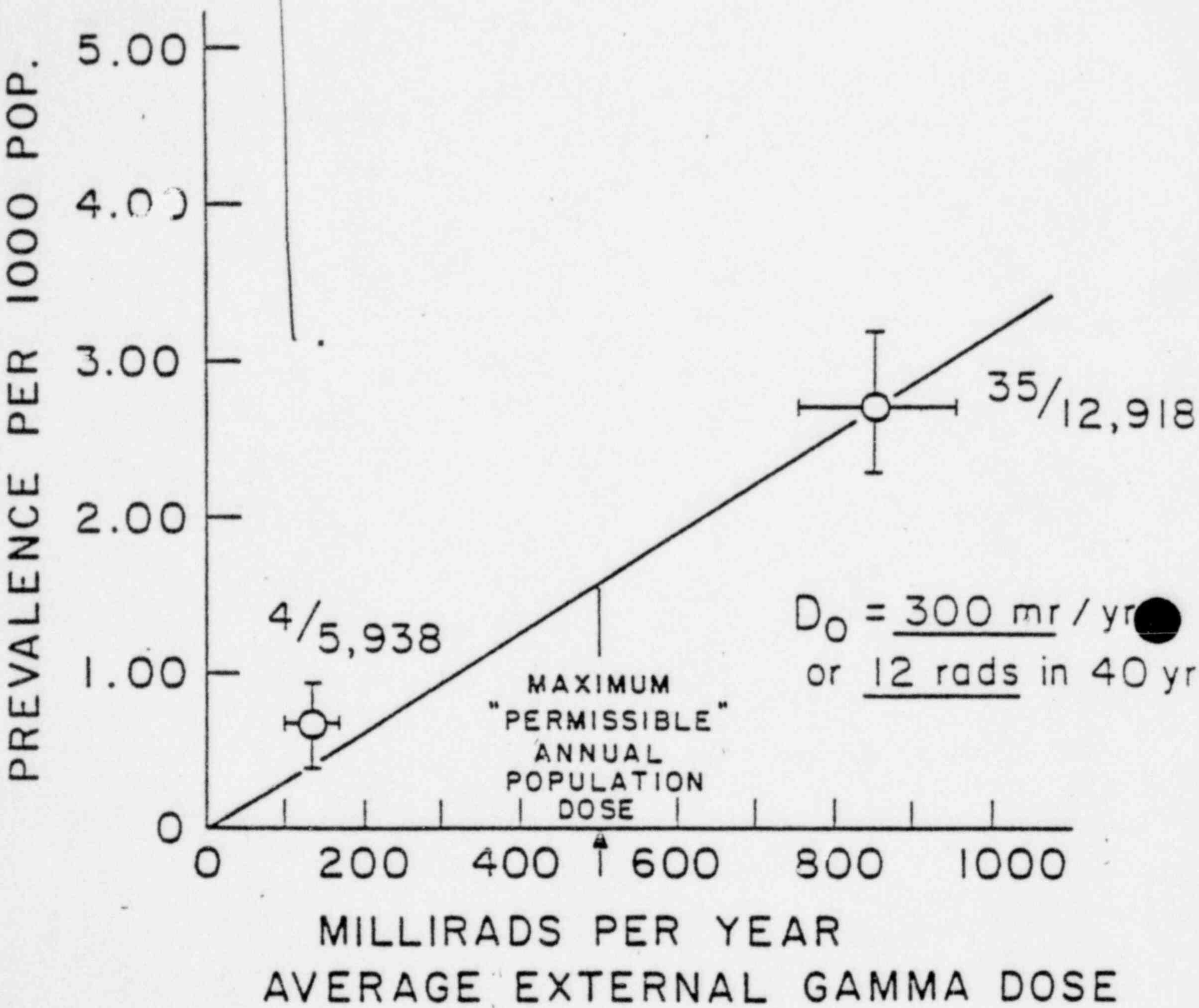

FIGURE 7. NUMBER OF INDIVIDUALS WITH SEVERE MENTAL RETARDATION PER 1000 POPULATION FOR AREAS OF DIFFERENT NATURAL BACKGROUND RADIATION LEVELS IN KERALA, INDIA. THE RADIATION DOSE IS THAT DUE TO EXTERNAL GAMMA RADIATION ONLY AS AVERAGED FOR THE TWO AREAS STUDIED.

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INFANT MORTALITY CHANGES FOLLOWING THE THREE MILE ISLAND ACCIDENT

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Presented at the 5th World
Congress of Engineers and
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Tel-Aviv, Israel
January 25, 1980

Summary

An examination of the monthly changes in infant mortality in Pennsylvania and the nearby areas of Upstate New York as given in the U.S. Monthly Vital Statistics reports indicate that the mortality rate rose significantly shortly after the Three Mile Island accident in the directions where the plume of radioactive gases was known to have moved. The number of reported infant deaths per month rose from a minimum of 141 in March of 1979 just before the accident to a peak of 271 in July, declining again to 119 by August. This is an unprecedented and highly significant rise of 92% in the summer months when infant mortality normally reaches its lowest values. In the four month period following the accident, there were 242 deaths above the normally expected number in Pennsylvania and a total of about 430 in the entire Northeastern area of the United States. The hypothesis that this abnormal rise was associated with the gaseous releases from Three Mile Island is shown to be strongly supported by the following considerations. First, large amounts of radioactive Iodine-131 were released from the plant, estimated by the utility's own radiological consultants to have amounted to 14 curies, together with 10 million curies of other fission gases, most of the activity escaping in the first two days before the order to evacuate pregnant women and young children was issued. Secondly, infant mortality peaked three to four months after the initial releases took place. This corresponds to the period required for infants to be born whose thyroid glands were most active in taking up the radioactive iodine while producing growth hormone when the accident occurred, thus explaining the large rise in the number of immature and underweight infants that died of respiratory distress as indicated by an examination of hospital records. Thirdly, the greatest rises took place in areas closest to the plant, decreasing with distance away from Harrisburg and the state of Pennsylvania, until for states well to the west and south, there was a decline in infant mortality rates. Thus, while Pennsylvania

increased from 10.4 per thousand live births in March to 18.5 in July of 1979, the United States rate as a whole declined from 14.1 to 12.5. The rise moved Pennsylvania from well below the U.S. average to the highest infant mortality rate for any state east of the Mississippi River. Other evidence supporting this conclusion is discussed, including the occurrence of abnormal increases of infant mortality rate in areas that received heavy fallout from nuclear weapons tests during the 1950's and 60's when Iodine-131 levels reached comparable levels, as well as similar effects in areas close to other nuclear reactors known to have released comparable amounts of radioactive gases from damaged fuel elements over a period of years in the course of normal operations. The implications for further health effects due to cancer and other diseases are discussed.

Although the major emphasis in estimates of the health impact produced by the accident at Three Mile Island has been on the increase in cancer risk and the effect of the psychological stress[1], the greatest immediate concern was connected with the possible effects on the developing infant in the mother's womb due to the known tendency of radioactive iodine to concentrate in the fetal and infant thyroid glands[2].

It was the existence of uncontrolled large releases of fission-produced radioactive gases including Iodine-131 that led Governor Thornburg of Pennsylvania to order the evacuation of all pregnant women and children below school age from within a radius of five miles around the plant on the third day of the accident, Friday, March 30, 1979.

Subsequent studies by various government and private organizations have confirmed that large quantities of radioactive Iodine-131 were in fact released in the course of the accident, the estimates ranging from 1.4 curies in an early study prepared by the NRC[3] to as high as 14 curies of Iodine-131 in a later study by a private consulting firm for the utility[4]. To appreciate the significance of these amounts, it is only necessary to point out that the unit which is used to measure concentrations of Iodine-131 in milk is the pico-curie, which is one millionth of one millionth of a curie.

These studies further showed that most of the gaseous releases took place in the first two days after the accident that began in the early morning of March 28. Thus, it was calculated that of the 10 million curies of radioactive gases released in the first five and a half days, 7 million curies has been emitted in the first 36 hours.[4]

Likewise, most of the external gamma ray dose due to the passing clouds of fission gases estimated by all organizations to have been in the range of 70 to 80 millirems to individuals nearest the plant was found to have been received in the first few days of the accident.

These studies further showed that most of the thyroid dose was received through the inhalation of radioactive iodine isotopes rather than through the ingestion of milk or water[4].

For the infant thyroid, the maximum dose was calculated to have been of the order of 10 mrem by inhalation and 1.1 mrem by ingestion of milk[4]. Due to the smaller volume of air inhaled by infants, the maximum dose was found not to have been much larger than for adults despite the ten-fold smaller size of the infant thyroid.

No estimates were published for the fetal thyroid, which is known to begin functioning actively in about the fifth to sixth month of intra-uterine development.[5][6] However, earlier measurements carried out for comparably small exposures during periods of heavy fallout from nuclear weapons testing clearly indicate that fetal thyroid doses can be some 10 to 20 times larger than for infants or 100 times that of adults[7][8]. This arises from the fact that the early thyroid gland has a very small mass of the order of 0.10 to 0.20 grams, or some one to two hundred times smaller than the 20 gram adult human thyroid.

Thus, it is possible to estimate that the thyroid gland of fetuses in the more heavily exposed areas within five to ten miles of the Three Mile Island plant are likely to have received radiation doses of the order of 100 to 1000 mrems from Iodine-131 alone. To this must be added the whole-body gamma dose from noble gases and the contributions from the many short-lived iodine isotopes as well as the whole body doses from the other important isotopes such as Cesium-137, Cesium-134, Tritium, Barium-140, Strontium-89, etc., depending upon the mother's diet in the weeks following the accident.

Thus, typical thyroid doses 200 to 1100 (in excess of 200) mrems are likely to have been received by developing infants in their mother's womb for those in their 5th to 9th months of development. Due to the fact that the radioactive gas plume frequently touched the ground within a few miles of the plant, individuals in these areas could easily have received five to ten times higher doses than the average in the first one or two days of the accident, before the evacuation of pregnant women was ordered.

A dose of the order of 200 to 1100 mrems is comparable with that received by the fetus in the course of diagnostic x-ray examinations since a single abdominal film gives a fetal dose of the order of 200-300 mrem(9) (10).

The fact that diagnostic x-ray exposures during fetal development can lead to serious biological damage is by now widely recognized in the medical community as a result of the large scale epidemiological studies of Stewart(11), MacMahon(12), Diamond(13), Bross(14), Graham(15) and others.

Not only is there an increased risk of leukemia and cancer as first discovered by Stewart(11) but the more recent prospective study of Diamond and his associates at Johns Hopkins University(13) revealed an increased risk of death from all causes for those who received x-rays in utero, primarily within the first year of life. These included deaths from respiratory system problems, infectious diseases and diseases of the central nervous system. Furthermore, both the Johns Hopkins study and the study of Stewart(11) revealed that the earlier the exposure takes place, the greater is the risk of adverse effects.

Thus, Stewart's study showed that whereas the dose needed to double the risk of leukemia and cancer was of the order of 1,200 mrem just before birth when most x-rays were taken,a mere 80 mrem doubled the risk when x-rays were given in the first three months of pregnancy(11).

Thus, doses of 200 to 1100 mrem to the critical thyroid gland controlling the growth and development of the fetus beginning in the 5th to 6th month of pregnancy could be expected to produce a significant effect on the fetus through retardation in growth and maturation, thereby increasing the risk of mortality within the first year of life. The greatest mortality occurs during the critical period of transition from intra-uterine existence when the lung of the newborn must suddenly take over the life-sustaining function of respiration[(16)].

A large number of studies have shown that infants that are born immature, underdeveloped or underweight have a much higher incidence of respiratory distress or hyaline membrane disease[(16)]. Thus, even a small degree of retardation in development due to a reduced output of growth hormone by the thyroid gland during the last three to four months of intra-uterine development would be expected to increase the risk of death due to respiratory insufficiency immediately after birth. Failure of the critical lung surfactant to be produced in adequate amounts can therefore lead to respiratory problems and death as a result of damage either to the thyroid or the pituitary gland which in turn controls the thyroid's output of growth hormone[(17)].

The fact that radioactive iodine from nuclear weapons tests can indeed reduce human fetal and infant growth has been observed as a result of the accidental fallout exposure of the Marshallese Islanders following the large hydrogen bomb test BRAVO in 1954[(18)]. Not only was there an increase in fetal deaths among the women exposed at that time, but there was also a severe reduction in growth of the children exposed to fallout, the effect being greater the young the children were.

The effect of even small doses of radioactive iodine on fetal development is further supported by the fact that the birth-weight of babies born in the United States suddenly began to decline during the 1950's, [(19)] the period when the heaviest fallout from weapons testing occurred in the continental United States. Furthermore, since the end of large-scale atmospheric bomb-tests by the U.S. and the U.S.S.R., there has not only been an end to the trend towards smaller birth-weight but there was also an unexpected resumption in the decline of infant mortality which had also halted during the period of heavy fallout (20) (21).

This is shown graphically in Figure 1 taken from the most recent summary of infant mortality trends published by the U.S. Department of Health, Education and Welfare's National Center of Health Statistics (22). As shown by the arrows added to indicate periods of heavy nuclear testing in the atmosphere, the decline of infant mortality rates in the United States came to a sudden halt between 1945 and 1951, when the testing of nuclear weapons at Alamogordo, New Mexico, in the Marshall Islands, and in Siberia began.

Between the years of heaviest weapons testing in the lower atmosphere namely 1956 to 1958, there was actually a reversal of the previous downward trend of infant mortality, which ended only when nuclear testing was temporarily halted during the years 1959-to 1961, after which there was a brief renewal of bomb testing that did not end until the 1963 test-ban treaty was concluded.

Although France and China continued to test nuclear weapons in the atmosphere, the end of large atmospheric tests by the U.S., U.S.S.R. and U.K. led to a gradual reduction in infant mortality rates, until in the last few years, both white and non-white populations showed a resumption of the pre-testing rate of decline that had so dramatically halted during the 1950's for reasons that were not understood at the time (23).

A connection between fallout and infant mortality changes was first suggested in 1969[20]. However, at that time the evidence that the fetus in the early phases of development may be fifteen times more sensitive to radiation than the full term infant had not yet been published by Stewart and Kneale[11] so that it was difficult to explain the large magnitude of the effect[24]. Also, the study of Diamond and his coworkers had not yet been published showing that all causes of death and not merely leukemia and cancer were increased by small intra-uterine exposures, so that a generalized effect on all forms of mortality was unsubstantiated.

As a result it was argued by some authors that the halt in the decline of infant mortality might be due to the fact that all possible effects of improved medical care, diet and drugs had been exhausted, and that therefore infant mortality had gone down as far as it would ever be able to decline in the United States[24].

However, as Figure 1 clearly shows this did not turn out to be the case: infant mortality started to decline once again after heavy fallout ended and in the most recent years has actually accelerated its rate of decline, rapidly approaching the projected rate that would have existed if there had been no halt during the time of massive nuclear weapons tests[21].

The effect of small amounts of short-lived fission products such as I-131 as distinct from the long-term trend that is correlated with the build-up of Strontium-90 in the bone of young women prior to pregnancy[21] is shown particularly strikingly in Figure 2.

Here, the infant mortality rate for New Hampshire some 2,500 miles to the east of the Nevada test site has been plotted for the years 1946 to 1974, together with the officially announced yields of small tactical nuclear weapons detonated in Nevada between 1951 and 1962[25].

Inspection of this plot shows that simultaneously with the onset of Nevada tests in 1951, there was a sudden halt in the long-term decline of infant mortality followed by brief periods of small reversals in the downward trend which occurred in the same years as the nuclear weapons tests in Nevada. Whenever there was a test in Nevada, there was a sharp rise in infant mortality in New Hampshire, where the fallout came down with the heavy rain and snow falls in the White Mountains.

Not until the Nevada tests ended did these highly abnormal spikes in infant mortality disappear, and only after the end of all large scale nuclear weapons tests did the infant death rate decline once more, finally reaching the low values that would have been reached had the pre-bomb testing rate of decline continued.

The significance of these results for the case of the Three Mile Island accident is that the external gamma ray doses from bomb fallout in the eastern United States in any given year were generally smaller than external gamma doses of 70 to 80 mrem measured in a few days at Three Mile Island.

Thus, the long-term gamma dose measurements carried out at the Brookhaven National Laboratories since the late 1940's[(26)] show that only in 1963 did the annual gamma ray dose reach 76 mrem, the same dose experienced at Three Mile Island in a matter of days.

Yet, both Figure 1 and 2 clearly show significant peaks in infant mortality associated with weapons tests in Nevada, the Pacific and Siberia. This indicates that the actual internal doses to critical organs from inhaled and ingested fission products far outweigh in their biological importance the external gamma dose recorded by badges and survey meters whenever fission products are released into the atmosphere[(27)].

This is supported by a more recent study that found a correlation of changes in infant mortality in different sections of Wisconsin with measured changes in Sr-90 levels in the milk following bomb-tests and the start-up of nuclear power plants[(28)]

Clearly, whatever the still not fully understood biological mechanisms are that cause prematurity and early neonatal death associated with respiratory distress, external gamma doses from fission products containing I-131 of the order of 10 to 50 millirems were associated with yearly infant mortality changes of the order of 5 to 25% in the eastern U.S. during the late 1950's, that is changes of about 0.5%/mr

It follows that the releases of fission products containing I-131 in the Three Mile Island accident should also be followed by detectable peaks in infant mortality associated with immaturity and respiratory distress within a few months after the accident, when the infants whose thyroids had begun to function when the iodine was released were born. Furthermore, since fetuses of less than 5-6 months gestational age do not have fully developed thyroid gland able to concentrate I-131 to the same extent as those that are present in the last 3 months of gestation, [5] there should be a rapid decline in newborn deaths beginning in the third and fourth month after the end of the gaseous releases.

That this is indeed the pattern of infant mortality changes that has taken place following the Three Mile Island accident is apparent from the following considerations.

Turning first to the data on the month-by-month infant mortality in Pennsylvania as reported in the Monthly Vital Statistics reports published by the National Center for Health Statistics [29] plotted in Figure 3, one sees that a large peak in the infant mortality rate occurred in the summer of 1979, some three to four months after the releases took place. Grouped in 3 months periods, the rise was 32% (Table I).

Compared with the normal pattern of infant mortality throughout the year, which generally declines in the summer months when the risk of pneumonia and influenza is small, the 78% rise from a rate of 10.4 per thousand live births in March to a peak of 18.5 in July, followed by a decline to the normally expected low of 8.5 in August, is totally anomalous. However, it is completely consistent with the expected action of radioactive Iodine-131 on the fetal thyroid.

The rise from 141 to 271 infant deaths is statistically highly significant representing an increase by more than 5 standard deviations for which the probability of a purely statistical fluctuation is much less than 1 in 1000 ($P \ll 0.001$).

Such a large rise did not occur for the United States as a whole as shown in the plot of Fig. 4[29]. Furthermore, it is seen that there was no such large rise in mid-summer in previous years as illustrated for 1977 and 1978 in Figure 4.

In fact, the July infant mortality rate of 18.5 per 1000 live births in Pennsylvania was the highest for any state in the entire United States east of the Mississippi, moving Pennsylvania above such rural states as Mississippi and Alabama, where the large non-white population with its poorer socio-economic status, medical care and diet had traditionally been associated with a much larger infant mortality[30]. (Table II).

Whereas prior to the Three Mile Island accident, Pennsylvania had an infant mortality rate well below the U.S. average, by July it had moved well above the U.S. average, returning to its normal position below the U.S. mean in August, 4 to 5 months after the accident. (See Figure 5). This was the time when infants were being born that did not have a fully developed active thyroid gland at the time of exposure.

Since for the first few days when the initial release occurred, the winds were mainly towards the West, North-West and North[3], one would expect significant increase in infant mortality in the summer months in upstate New York and Western Pennsylvania, but not in New York City directly to the East. (See maps of Figure 6 and 7). At the same time, the Harrisburg area should show the greatest increase in the newborn mortality rate.

This expectation is born out by the changes in infant mortality for three month periods before and after the Three Mile Island releases ended, (Fig. 8 and Table III). In this table, the data from the U.S. Monthly Vital Statistics is listed together with data obtained for a major hospital in each of Harrisburg and Pittsburgh,[31] since the county-by-county data in Pennsylvania were not yet available.

As can be seen from Table IV and Figures 8 and 9, there was a 7 fold rise or a 630% increase in the number of newborn deaths associated with immaturity and respiratory diseases in the Harrisburg hospital for the three month period of May-June-July 1979 relative to both the same period in 1978 and the immediately preceding three month period of February-March-April.

A similar pattern is seen to have occurred in the Pittsburgh area as reflected in the data for a major hospital that accounts for nearly half of all deliveries (Table and Fig. 10) though with a smaller percent change. Again, there is an unusual summer peak in 1979 that did not occur in the previous year. In fact, examining the case for the peak month of July in Figure 11, it is seen that both the total number of deaths and the rate per thousand births was declining before 1978, rising again from 8 deaths in July of 1978 to 24 in July of 1979.

This unusual peak of infant deaths in July was also observed in Northern New England but not in Southern New England, as expected from the known northward direction of the winds in the first few days of the accident. (See TableVI).

Although the increases in the number of deaths among newborns in the Harrisburg Hospital are small in absolute numbers, they are nevertheless highly significant statistically. The average number of newborn deaths per month during 1978 was 0.42 per month with a standard deviation of ± 0.2, while the average for the summer months was only 0.33 per month. Thus four such deaths in June of 1979, exactly three months after the accident, represents a 10 to 12 fold increase above normal expectations, whose occurrence by mere chance is much less than 1 in 100.

Combined with the geographical pattern of infant mortality changes from Ohio to New England, and the absence of any similarly large summer peak of infant mortality in the previous years, it seems inescapable to conclude that the accident at Three Mile Island did in fact lead to a significant increase in infant mortality similar to those encountered from earlier comparable episodes involving fission products from nuclear weapons testing and releases from nuclear plants.

For the 3 month period May through July 1979, the total number of excess deaths was 352 compared with that normally expected in the states of Pennsylvania, Ohio and New York, using the rate of decline for the United States as a whole[†].

Comparable percent increases are likely to occur for childhood cancer and leukemia in the next ten to fifteen years[(32) (33)], as well as somewhat lower percent increases in all causes of death in the much larger general population according to the studies of Lave and his associates for the case of 50 metropolitan areas in the United States during the heavy fallout period of the early 1960's[(34)]. It would therefore appear that the Three Mile Island accident will turn out to have produced the largest death-toll ever resulting from an industrial accident, with total deaths from all causes likely to reach many thousands over the next 10 to 20 years.

Since for every infant that dies as a result of retarded growth and development, there are many more individuals (perhaps ten times as many) that are minimally damaged in their physical and mental abilities[(16) (35)], the effect on society will be much large than premature death alone. In the light of these findings, it must be of great concern that the releases of radioactive gases and iodine from routine operations of nuclear reactors such as the Millstone Plant in Connecticut have been comparable in magnitude wi

† If one adds the excess deaths in April, there were 40 in Pennsylvania and 35 in Upstate New York for a total of 427.

the releases from Three Mile Island, namely 3 million curies of mixed fission gases and 10 curies of I-131 in 1975 alone[36].

The full magnitude of the danger to the biological survival of nations that choose to pursue the development of nuclear reactors near their large population centers is therefore only now beginning to become apparent.

This is especially brought out by the fact that the greatest number of deaths actually occur in areas ten to one-hundred miles distant from the reactor site so that even a decision to locate nuclear reactors only in less populated areas would not appreciably change the mortality figures either for the effect of normal releases or major accidents. Nor would an evacuation plan for the population within 5 or 10 miles of the reactor significantly affect the overall number of deaths resulting from a repetition of the Three Mile Accident, since most of the deaths occur in the more distant areas due to the larger total populations they contain[37], though the greatest individual risk exists nearby.

This is illustrated by the observed infant mortality changes in the State of Rhode Island located between 20 and 50 miles downwind to the east of the Millstone Reactor near New London, Connecticut as shown in Figure 12.

In this plot, the infant mortality rate for Rhode Island has been plotted for the years 1965 to 1976, together with the releases of radioactive fission gases as published by the Nuclear Regulatory Commission (NRC)[36] since the start of operations in 1970.

For comparison, the infant mortality rate for the State of New Hampshire more than 150 miles to the northeast is also shown in this plot.

Inspection of Figure 12 shows that in the years prior to the start of the Millstone Plant in 1970 and the Connecticut Yankee plant at Haddam Neck in 1968, both states showed the same infant mortality rate.

However, beginning in 1970, the rate of decline of the Rhode Island infant mortality slowed down, while that of New Hampshire kept declining rapidly, leading to the development of a large gap in the mortality rates between the two states by early 1976. In the first quarter of that year, Rhode Island had a rate of 18.6 practically equal to its 1967 level of 19.3, while New Hampshire declined to an infant mortality only half as great, or 9.3 per 1000 live births.

The fact that the emissions from the Millstone plant are likely to be responsible for this dramatic gap is illustrated by Figure 13which is a plot of the percent excess infant mortality in Rhode Island relative to New Hampshire versus the announced gaseous releases from the Millstone plant. A two-year moving average of the emissions is used in this plot to take account of both the short-lived I-131 and the longer-lived Cs-137 and Sr-90 in the releases that build up in the environment.

It is seen that the data fit a logarithmic or fractional power law of the form a D^x with a = 38% and x = ¼. This is the type of law expected on the basis of a free-radical type of indirect chemical action on cell membranes discovered by Petkau (39), which rises more rapidly at low doses and low dose-rates than at high doses and dose-rates. It is also the type of dose-response relation expected on the basis of a wide difference in sensitivity of different individuals in the population as discussed by Baum (40), Bross (41) and Morgan (42), or a type of dose-response that leads of a large underestimate of health effects at low doses from data taken at high doses (43).

Based on an external gamma dose of 500 mr for the maximum permissible release of some 25 million curies per year (38), the slope of the dose-response curve increases from 2%/mr at 1 million curies per year to about 6%/mr at 0.1 million curies per year.

Based on the external dose from the gas-cloud alone, one would therefore expect an increase in infant mortality for the case of the Three Mile Island accident of 38 x 10½ or 120% in an area some 20-30 miles distant. This is in good agreement with the three month increase in newborn infant mortality in Harrisburg of 600%, which reduces to 150% when averaged over the period of a year.

Thus, both qualitatively and quantitatively, the releases from normal operation from the Millstone Plant and the accompanying increases in infant mortality in Rhode Island some 20 to 30 miles downwind correctly predict the infant mortality changes in the Harrisburg area from the comparable noble gas and iodine discharges at Three Mile Island.

The importance of releases of Cesium-137 and Strontium-90 in addition to Iodine-131 for the more distant large metropolitan areas is illustrated by the plots of the Cs-137 and Sr-90 spatial distribution around the Millstone plant as taken from the utility's own environmental reports to the NRC[44] shown in Figures 14 and 15. The 4 to 5 fold greater concentration of both of these isotopes in the milk near the stack of the plant as compared with the more distant areas strongly argues against the interpretation advanced by the utility[45], the NRC[46] and the EPA[47] that these levels can be explained by fallout from nuclear weapons tests.

The hypothesis that these highly localized levels are indeed due to plant emissions is also strongly supported by the fact that the changes in concentrations of these isotopes in the milk throughout the year are greatest near the plant in the summer months following spring refueling, and least at more distant locations such as Delaware along the Atlantic Coast as seen in Figure 16 for Cs-137. Particularly significant is the fact that both within 10 miles of the plant and in Rhode Island, there was a peak in Cs-137 concentrations in the summer of 1976 before the heavy

Chinese fallout arrived in October. It should be noted that this fallout episode was also followed by a sharp rise in infant mortality along the north-east coast 3-4 months later.

The fact that the increases in cancer mortality around the Millstone Plant after it began operating have the same geographical distribution as the measured CS-137 and Strontium-90 concentrations in the milk, and the fact that the increase in infant mortality in Rhode Island is correlated with the releases from the Millstone Plant indicates that there is likely to be a significant cancer increase from the Three Mile Island accident.

But perhaps the most significant confirmation of the serious biological effect of routine radioactive gas releases from nuclear reactors is the plot of infant mortality rates at different distances from the Millstone Plant for July 1978 shown in Fig. 18, before the releases from Three Mile Island affected the mortality rates in New England.

It is seen that while New Hamsphire, which has no operating nuclear reactor, declined to a low of only 1.9 infant deaths per thousand births from 21 in 1965, Rhode Island, directly downwind and close to both the Connecticut Yankee and Millstone Reactors, showed a ten-fold greater infant death rate of 19.9, completely nullifying 13 years of advances in public health and medical care.

Vermont, whose only nuclear reactor is located in its most southernly tip so that most of the state is not affected by the releases, reached a low of 4.2 per 1000 births. But all the other New England states with more nuclear generation of electricity, showed higher infant mortality rates than either New Hampshire or Vermont.

For these reasons, it appears doubtful whether any efforts to improve the safety of nuclear reactors, changes in their locations, or evacuation plants can significantly alter the public health impact of normal releases and such potentially more ri accidents as occurred at Three Mile Island, where only a small fraction of the total fission products generated actually escaped into the environment. Needless to say, the mortality changes following Three Mile Island would be enormously multiplied in the event of a complete melt-down and rupture of the containment, threatening areas as large as the entire eastern United States with enormous damage in terms of cancer and thyroid damage for all age groups out to distances of hundreds of miles[37].

Since neither coal nor oil nor gas nor solar energy lead to the large-scale production of short-lived radioactive iodine and other fission products that seek out the critical organs of the developing infant, it would seem prudent to apply future technological efforts to the more forgiving sources of energy that do not threaten the most precious of our nation's resources: the physical and mental well-being of our children for generations to come.

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APPENDIX I

POOR ORIGINAL

Table 2. DEATHS AND INFANT DEATHS: EACH REPORTING AREA, JULY 1978 AND 1979, AND CUMULATIVE FIGURES, 1977-79

[By place of occurrence]

Area	Deaths (all ages)					Infant deaths (under 1 year)				
	July		January-July			July		January-July		
	1979	1978	1979	1978	1977	1979	1978	1979	1978	1977
New England	8,646	7,908	65,078	68,251	[4]58,594	110	107	998	880	6
Maine	889	916	6,117	5,998	6,087	12	10	92	68	
New Hampshire	622	420	4,165	4,138	[4]4,215	8	2	73	54	
Vermont	210	346	2,119	2,738	2,543	5	3	37	52	
Massachusetts	3,997	3,372	32,035	32,542	32,415	54	44	479	401	4
Rhode Island	770	747	5,424	5,438	5,403	16	21	116	112	
Connecticut	2,182	2,107	15,016	15,503	14,961	15	27	201	193	2
Middle Atlantic	29,747	29,115	200,050	206,655	206,296	649	633	4,018	4,032	4,1
New York[1]	14,708	14,249	94,410	97,987	97,882	295	316	2,100	2,094	2,2
New Jersey	5,424	5,429	37,274	37,794	37,643	83	114	616	619	7
Pennsylvania	9,615	9,437	68,366	70,874	70,771	271	203	1,302	1,319	1,2
East North Central	[2]20,698	27,704	[2]198,237	213,589	208,546	[2]443	654	[2]4,573	4,580	5,1
Ohio	7,729	7,090	54,255	57,340	57,231	147	151	1,120	1,137	1,2
Indiana	3,762	3,703	27,404	28,123	27,140	101	68	634	515	5
Illinois	---	8,006	[3]50,841	59,124	58,008	---	223	[3]1,379	1,489	1,5
Michigan	6,128	5,738	42,528	44,047	42,514	147	131	1,120	1,042	1,0
Wisconsin	3,079	3,169	23,201	24,956	22,565	48	71	320	339	[illegible]
West North Central	[2]9,525	17,334	[2]88,213	95,573	90,159	[2]200	283	[2]1,818	2,083	2,0
Minnesota	---	2,741	[3]16,040	19,818	18,505	---	70	[3]324	473	4
Iowa	2,074	2,177	15,064	15,978	15,438	37	50	259	[illegible]	2
Missouri	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	66	[illegible]	[illegible]	7
North Dakota	519	463	3,212	3,269	3,214	21	11	97	86	1
South Dakota	520	478	3,661	3,837	3,647	7	9	77	106	1
Nebraska	1,138	1,232	8,167	8,636	8,256	25	34	168	233	1
Kansas	1,738	1,630	12,044	12,713	12,022	35	21	226	261	2
South Atlantic	25,258	[4]25,252	188,308	[4]191,473	184,263	632	[4]525	4,438	[4]4,254	4,4
Delaware	400	447	2,950	2,998	2,768	10	6	70	54	
Maryland	2,609	2,661	18,506	19,058	18,243	68	68	331	322	3
District of Columbia	634	[4]724	5,497	[4]5,277	4,526	22	[4]52	232	[4]278	2
Virginia	3,230	3,207	23,289	24,026	23,168	91	77	583	564	5
West Virginia	1,474	1,425	11,336	12,169	11,317	27	29	251	285	2
North Carolina	3,952	3,810	27,563	28,378	27,598	104	98	725	783	6
South Carolina	1,933	2,075	13,837	13,950	14,108	59	64	472	523	4
Georgia	3,135	3,361	25,442	25,234	25,349	89	96	755	580	5
Florida	7,901	7,587	59,901	59,383	56,199	164	133	1,028	875	9
East South Central	10,440	10,958	77,782	79,781	79,346	250	325	2,116	2,149	2,2
Kentucky	2,453	2,839	19,315	20,198	20,407	50	56	435	402	4
Tennessee	3,463	3,214	24,483	24,682	24,529	81	38	650	696	5
Alabama	2,737	2,962	20,629	20,993	20,705	60	63	523	570	5
Mississippi	1,787	1,963	13,355	13,908	13,704	59	89	508	472	4
West South Central	15,591	[4]15,731	113,123	[4]113,017	108,316	478	469	2,169	3,411	3,4
Arkansas	1,785	1,606	12,717	12,910	12,581	49	25	268	275	2
Louisiana	2,794	2,941	20,649	21,456	20,498	99	109	666	763	7
Oklahoma	2,210	[4]2,270	16,035	[4]16,311	15,245	43	46	273	259	2
Texas	8,802	8,915	63,722	62,340	60,012	285	290	1,983	2,018	1,9
Mountain	6,272	6,356	45,607	45,001	42,941	228	200	1,568	1,459	1,4
Montana	475	534	3,715	3,775	3,613	16	15	85	79	
Idaho	509	547	3,504	3,640	3,622	8	9	94	98	
Wyoming	259	251	1,621	1,805	1,878	6	2	29	24	
Colorado	1,546	1,617	10,887	11,192	10,664	51	43	324	306	3
New Mexico	799	730	5,109	5,059	4,690	29	26	217	190	1
Arizona	1,545	1,521	12,262	11,674	11,087	64	51	387	402	3
Utah	764	781	5,028	4,790	4,567	52	46	321	279	2
Nevada	466	375	3,331	3,068	3,032	14	8	88	72	
Pacific	19,078	16,589	134,189	140,081	135,274	[illegible]	420	[2]2,590	2,561	2,4
Washington	2,548	2,290	[illegible]	[illegible]	17,2[illegible]	24	52	253	417	
Oregon	1,750	1,763	[illegible]	[illegible]	11,9[illegible]	40	40	252	[illegible]	
California	[4]14,175	[4]12,025	100,674	106,154	102,217	---	[4]298	[3]2,064	2,5[illegible]	2,5
Alaska	167	172	952	[illegible]	955	8	19	80	[illegible]	
Hawaii	430	333	3,020	[illegible]	2,736	18	11	97	114	1
New York City	5,302	5,564	41,927	42,911	43,157	150	141	1,045	1,087	1
Puerto Rico	---	1,533	---	10,752	10,757	---	---	---	---	73
Virgin Islands (U.S.)	---	34	---	264	226	---	2	---	36	

[1] Includes figures shown below for New York City.

[2] Excludes July figures for State for which data are shown below as not available.

[3] [illegible]

[4] [illegible]

POOR ORIGINAL

Table 1. LIVE BIRTHS AND MARRIAGES: EACH REPORTING AREA, JULY 1978 AND 1979, AND CUMULATIVE FIGURES, 1977-79

[By place of occurrence]

Area	Live births					Marriages				
	July		January-July			July		January-July		
	1979	1978	1979	1978	1977	1979	1978	1979	1978	1977
New England	14,562	[4]12,842	91,875	[4]85,970	[4]86,284	8,725	[4]9,075	49,907	[4]52,250	51,681
Maine	1,440	1,308	9,351	8,462	8,977	1,278	1,580	6,420	6,258	6,247
New Hampshire	1,089	[4]1,035	7,332	[4]6,989	[4]6,482	998	[4]1,209	3,003	[4]3,300	[4]4,536
Vermont	513	711	3,988	4,232	3,887	625	446	2,881	2,228	2,177
Massachusetts	6,690	5,556	42,733	39,354	42,032	2,810	2,591	18,551	22,389	22,021
Rhode Island	1,149	1,054	7,067	6,718	5,802	679	778	3,946	3,870	3,894
Connecticut	3,681	3,179	21,204	20,215	20,704	2,272	2,394	13,296	12,394	12,291
Middle Atlantic	45,578	42,747	277,387	272,059	280,302	33,149	30,131	155,959	147,330	145,232
New York[1]	22,355	21,435	134,175	133,065	140,166	15,514	14,179	80,154	73,304	71,275
New Jersey	9,041	8,110	52,425	51,332	52,293	4,916	5,594	29,650	28,154	28,983
Pennsylvania	14,680	13,202	91,287	87,062	87,341	12,719	10,358	46,125	48,472	46,974
East North Central	[2]40,574	54,133	[2]350,253	349,347	360,218	41,309	[4]43,451	219,548	[4]213,701	213,526
Ohio	14,071	11,817	92,954	86,950	92,546	10,053	10,749	56,550	58,128	53,325
Indiana	7,885	8,681	48,687	47,340	48,741	6,642	6,492	33,293	32,410	32,277
Illinois	...	15,210	[3]85,164	96,716	99,453	11,101	11,539	58,554	57,618	60,504
Michigan	12,346	12,409	80,717	78,609	78,258	8,974	10,271	44,315	46,384	45,600
Wisconsin	6,272	6,216	42,731	40,232	40,112	4,539	[4]4,350	22,336	[4]22,163	21,220
West North Central	[2]18,315	22,594	[2]151,632	152,432	148,941	18,077	17,113	94,687	96,564	91,260
Minnesota	...	5,492	[3]21,210	35,535	34,432	3,745	3,465	19,132	18,010	16,602
Iowa	4,177	3,988	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Missouri	6,250	5,872	43,881	44,058	40,163	6,069	5,213	30,148	31,683	30,077
North Dakota	1,128	1,072	7,381	7,025	7,101	999	991	3,243	3,158	3,156
South Dakota	1,150	900	7,143	6,732	6,801	971	1,003	5,154	5,873	5,740
Nebraska	2,207	2,213	14,800	14,497	14,730	1,579	1,547	8,150	7,779	7,202
Kansas	3,260	3,157	20,897	19,758	19,582	2,523	2,265	14,143	13,814	13,537
South Atlantic	44,172	[4]42,066	294,032	[4]284,437	289,111	38,240	38,786	228,912	222,115	215,564
Delaware	820	798	5,203	5,213	5,213	396	529	2,418	2,262	2,220
Maryland	4,179	4,128	23,027	28,898	28,364	4,617	4,454	25,317	24,988	24,394
District of Columbia	1,133	[4]1,219	9,907	[4]17,016	12,733	549	411	2,828	2,507	2,707
Virginia	6,535	6,477	41,741	39,971	40,721	5,716	5,289	32,158	32,768	32,741
West Virginia	2,520	2,735	17,580	18,797	17,351	1,870	1,789	9,937	9,492	10,013
North Carolina	7,660	7,420	47,690	48,320	48,091	4,493	4,392	25,967	25,206	24,393
South Carolina	4,253	3,949	25,422	25,903	27,294	5,027	5,764	30,878	30,320	29,214
Georgia	6,700	5,614	46,905	47,270	48,193	6,293	6,490	37,752	38,798	37,312
Florida	10,282	9,496	66,557	61,419	62,546	9,273	8,706	60,217	56,590	52,077
East South Central	21,043	19,570	125,897	120,135	125,024	16,252	17,745	95,973	93,954	92,000
Kentucky	5,618	4,838	24,762	22,946	24,928	3,261	4,047	19,287	19,470	20,177
Tennessee	6,231	5,956	40,785	39,052	40,168	5,867	5,909	33,344	31,754	30,889
Alabama	4,893	4,789	34,317	32,533	34,244	4,509	4,982	28,067	27,578	25,808
Mississippi	4,253	3,987	25,433	25,604	25,684	2,616	2,717	15,205	15,054	15,125
West South Central	32,890	34,052	232,054	216,234	220,757	23,468	23,200	158,159	151,028	146,677
Arkansas	3,029	2,940	19,665	17,751	19,709	2,828	2,457	13,812	12,928	14,067
Louisiana	7,735	7,523	43,241	41,525	42,122	3,983	3,498	24,143	22,141	20,449
Oklahoma	4,318	3,659	27,182	24,915	25,021	4,106	3,817	25,225	24,840	23,101
Texas	18,298	20,230	141,066	132,439	133,906	12,543	13,528	95,079	91,117	89,060
Mountain	19,073	16,896	123,402	113,320	110,821	22,821	[4]25,526	143,285	[4]132,091	[4]129,948
Montana	1,149	1,085	7,949	7,749	7,515	1,030	958	4,574	4,346	4,123
Idaho	1,828	1,247	11,407	11,071	10,513	1,219	942	7,271	7,244	7,279
Wyoming	738	695	4,954	4,345	4,140	732	584	3,305	3,461	3,016
Colorado	4,243	4,152	27,496	25,189	24,988	3,127	3,229	17,700	17,129	16,254
New Mexico[4]	2,817	1,241	15,282	12,503	12,732	1,582	[4]1,556	9,713	[4]9,851	[4]9,412
Arizona[4]	3,686	3,206	24,936	23,398	23,693	2,262	2,206	17,130	16,221	15,457
Utah	4,105	3,815	24,918	22,584	21,238	1,510	1,321	9,717	9,241	8,063
Nevada	904	775	6,218	5,681	5,904	11,079	14,531	73,875	69,203	64,733
Pacific	37,678	37,855	260,787	274,697	284,943	23,992	21,749	125,270	125,891	128,755
Washington	5,075	4,504	31,491	32,935	31,724	5,160	4,196	24,533	23,277	21,547
Oregon	3,870	3,547	24,412	22,331	22,249	2,222	2,239	11,243	10,918	11,277
California	[4]26,580	[4]27,065	193,756	204,571	198,103	14,981	13,767	83,463	82,559	85,252
Alaska	676	788	5,270	5,209	4,750	507	516	2,917	[illegible]	2,970
Hawaii	1,477	1,231	9,925	9,251	9,749	1,109	1,011	5,614	5,928	5,752
New York City[5]	9,300	8,530	61,668	61,022	64,844	5,470	4,600	33,868	31,472	30,347
Puerto Rico	...	5,661	...	40,892	47,228	...	3,048	...	21,929	...
Virgin Islands (U.S.)	...	192	...	1,454	1,329	...	...	...	...	510

[1] Includes figures shown below for New York City.
[2] Excludes [illegible] shown below as not available.
[3] [illegible]

TABLE I

Infant Mortality Changes in Pennsylvania Following the

Three Mile Island Accident on March 28, 1979

1979	No. of Infant Deaths	No. of Live Births	Rate 1000	Average Rate	% Change in Rate
February	147	11,892	12.4		
March	141	13,589	10.4	11.9	
April	166	12,520	13.3		
May	198	13,201	15.0		
June	163	12,293	13.3	15.7	+32%
July	271	14,680	18.5		

Source: U.S. Monthly Vital Statistics

TABLE II

Infant Mortality East of the Mississippi in July of 1979.

1979

	Infant deaths	Live births	Rate per 1000
Pennsylvania	271	14,680	18.5
New York+	295	22,855	12.9
N.J.	83	8,041	10.3
Maine	12	1,440	8.3
N. Hampshire	8	1,089	7.3
Vermont	5	513	9.7
Mass.	54	6,690	8.1
Rhode Island	16	1,149	13.9
Conn.	15	3,681	4.1
Ohio	147	14,071	10.4
Indiana	101	7,885	12.8
Illinois	N.A.	N.A.	N.A.
Michigan	147	12,346	11.9
Wisconsin	48	6,272	7.7
Delaware	10	830	12.0
Md.	66	4,179	15.8
D.C.*	22	1,133	19.6*
Virginia	91	6,535	13.9
W. Va.	27	2,520	10.7
N. Carolina	104	7,660	13.6
S. Carolina	59	4,253	13.9
Georgia	89	6,700	13.3
Florida	164	10,362	15.8
Kentucky	50	5,616	8.9
Tennessee	81	6,281	12.9
Alabama	60	4,893	12.3
Mississippi	59	4,253	13.9
New York City	150	9,300	16.1
U.S.	3,800	306,000	12.4

+ Includes N.Y. City

* Majority of population is non-white and has had much above average infant mortality for decades.

Table III

Comparison of Changes in Infant Mortality Rates Following the Three Mile Island Accident in Harrisburg and Adjoining Areas at Increasing Distance East and West of Harrisburg

	Feb., March, April		May, June July		% Change in Death Rate	Approximate Distance in Miles
	No.	Rate	No.	Rate		
Ohio	482	12.0	480	11.7	-3%	200m West
Pennsylvania	454	11.9	632	15.7	+32%	180m West
Pittsburgh#	31	14.2	52	23.4	+65%	180m West
Harrisburg+	1	1.9	7	13.9	+630%	10-20m North
Upstate New York	404	13.0	477	14.3	+8%	100m Northeast
New York City	429	17.1	438	16.4	-4%	200m East
United States		14.0		12.6	-10%	200m
PA and NY State	1769		2027			
Change in No.			+ 258			

For Magee Hospital with 50% of births in the area

+ For Harrisburg Hospital with 35% of births in the area

TABLE IV

Newborn Mortality Rate Changes in the Harrisburg Hospital in 3 Months Period Before and After the Three Mile Island Accident March 28, 1979*, Compared with the Same Periods in 1978.

1978	No. of Infant Deaths	No. of Live Births	Rate 1000	Average Rate	%Change in Rate
February	0	128	0.0		
March	1	187	5.3	2.2	
April	0	137	0.0		
May	1	175	5.7		
June	0	154	0.0	2.1	-5%
July	0	154	0.0		
1979					
February	1	186	5.4		
March	0	172	0.0	1.9	
April	0	167	0.0		
May	2	166	12.0		
June	4	154	26.0	13.9	+630%
July	1	182	5.5		

* This hospital accounts for about one-third of all deliveries in the Harrisburg area. Newborn infant mortality is defined as a live-born infant that dies within a short time, most die within a few hours. (Data from monthly Pediatric Conference Records).

Table V

Newborn Infant Mortality Rate Changes in the Pittsburgh Area
From Hospital Records for Three Months Before and After the Three Mile
Island Accident March 28, 1979, Compared With the Same Period in 1978

	No. of Infant Deaths	No. of Live Births	Rate 1000	Average Rate	% Change in Rate
1978					
February	7	633	11.0		
March	6	750	8.0	14.4	—
April	16	625	25.6		
May	11	719	15.3		
June	8	684	11.7	12.5	-13%
July	8	763	10.5		
1979					
February	10	682	14.7		
March	11	786	14.0	14.2	—
April	10	721	13.9		
May	21	664	31.6		
June	7	759	9.2	23.4	+65%
July	24	798	30.1		

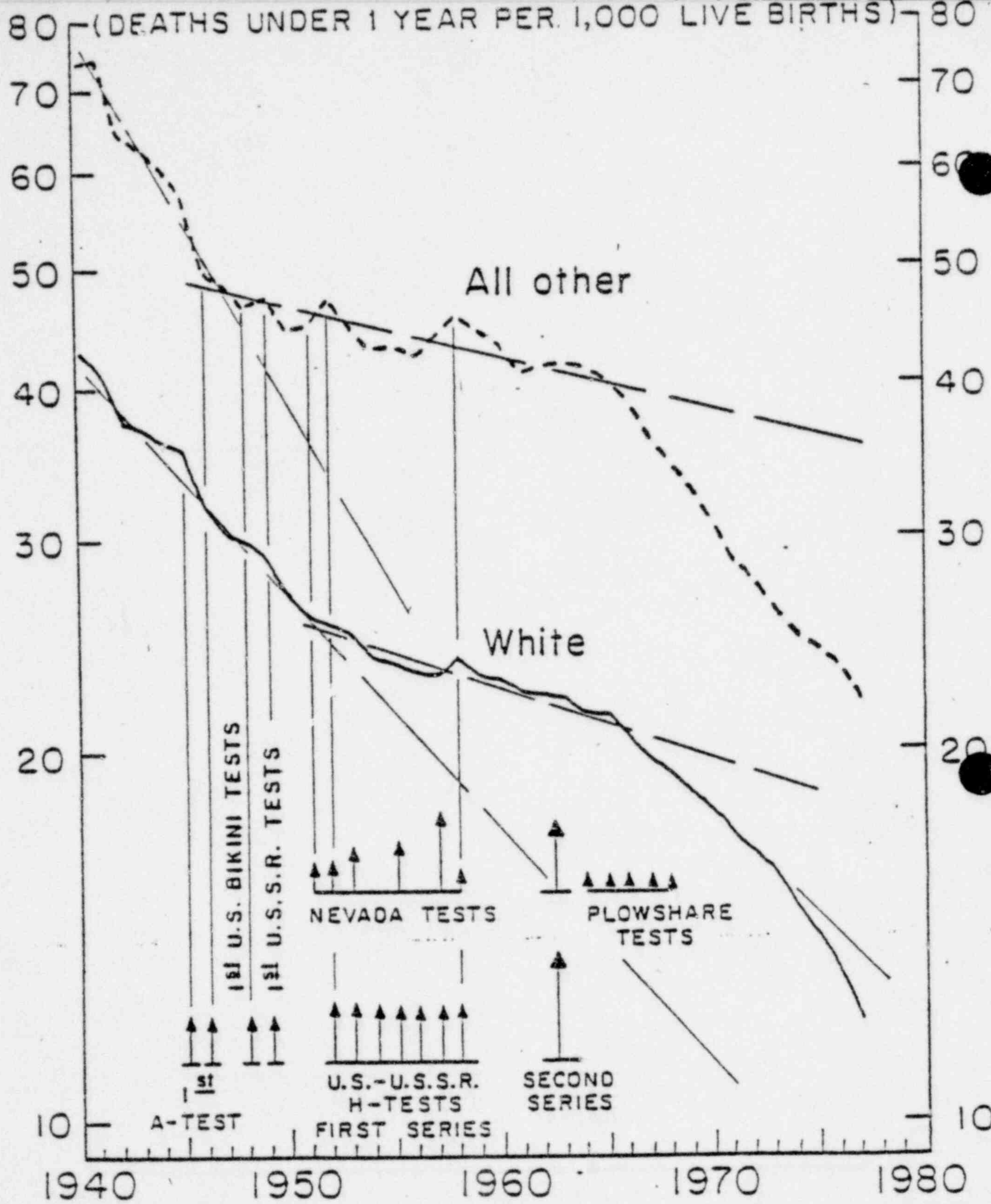
+ Data are from Magee Womens Hospital, which handles approximately one-half of all Pittsburgh area deliveries. Newborn infant death is defined as a live-born infant that dies within one month; most die within hours after birth. (Data supplied by Department of Pathology.)

Table VI

Infant Mortality Changes In Northern and Southern New England in July 1979 After Three Mile Island Accident Compared with July 1978

	JULY 1978			JULY 1979			
Northern New England States	No. of Deaths	No. of Live Births	Rate per 1000	No. of Deaths	No. of Live Births	Rate	% Change in Rate
New Hampshire	2	1036	1.9	8	1089	7.3	+284%
Vermont	3	711	4.2	5	513	9.7	+131%
Maine	10	1306	7.7	12	1440	8.3	+8%
Northern New England	15	3053	4.9	25	3042	8.2	+67%
Southern New England States							
Connecticut	27	3179	8.5	15	3681	4.1	-52%
Rhode Island	21	1054	19.9	16	1149	13.9	-30%
Massachusetts	44	5556	7.9	54	6690	8.1	+3%
Southern New England	92	9789	9.4	85	1152	7.4	-21%

Source: U.S. Monthly Vital Statistics



FROM: U.S. MONTHLY VITAL STATISTICS REPORTS; VOL. 28, NO. 1 MAY 11, 1979

Figure 1. Infant Mortality Rates By Color: United States, 1940-1977

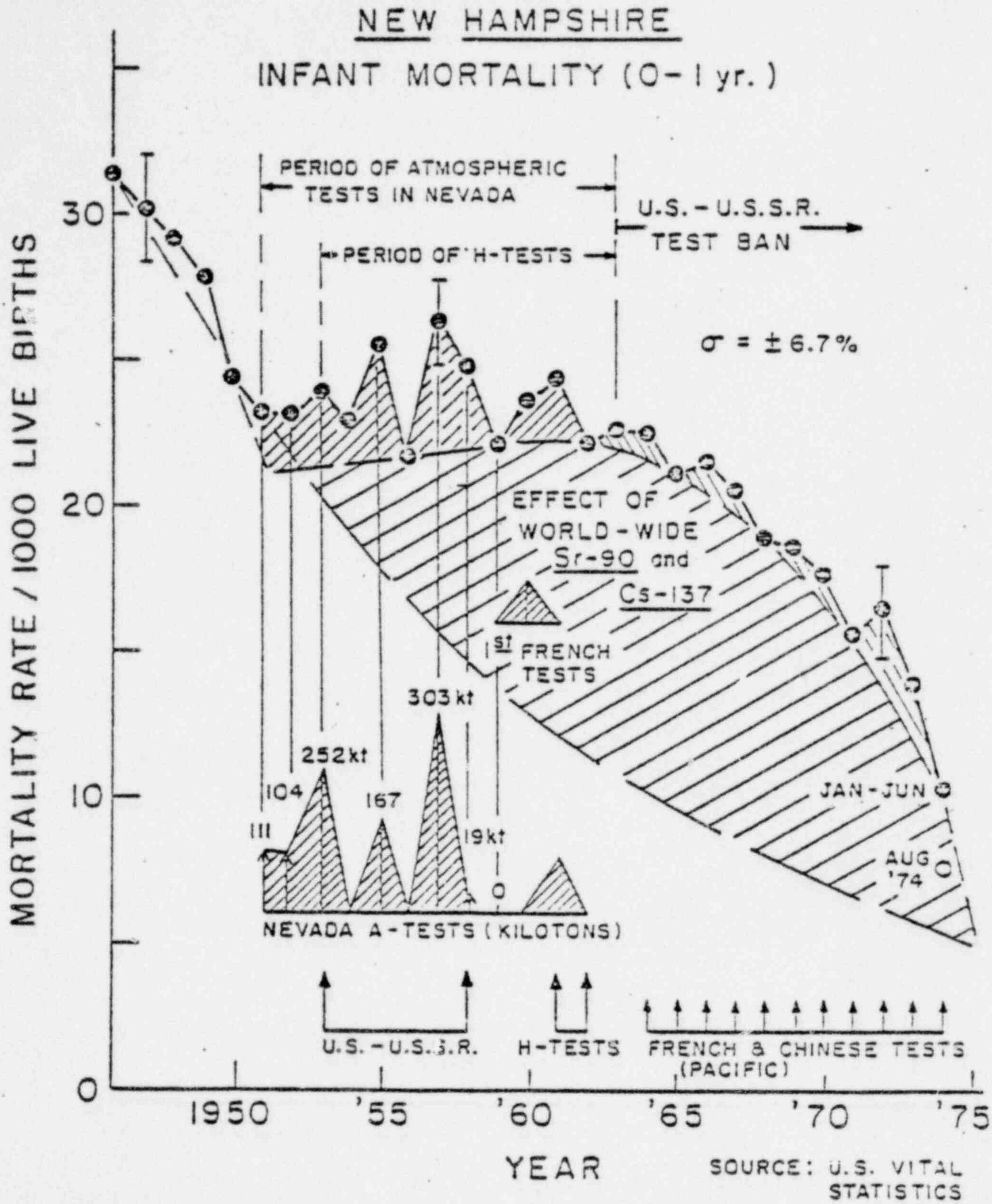


Figure 2. Infant mortality rate in New Hampshire between 1945 and 1974 together with announced yields of atmospheric nuclear weapons tests in Nevada. Note close correspondence between the sharp peaks in mortality rates and the peaks of weapons test yields in Nevada.

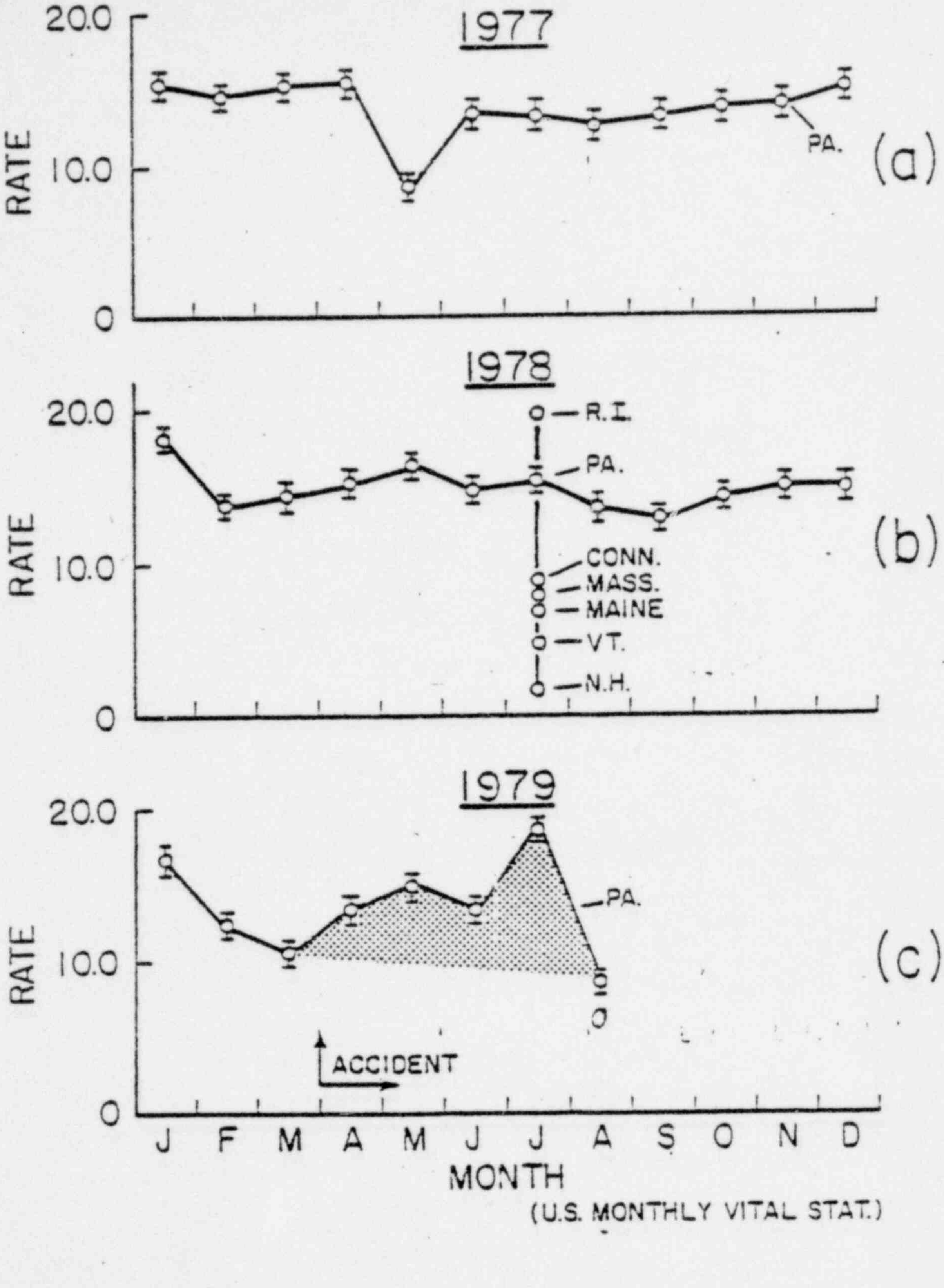


Figure 3. Monthly infant mortality rates in Pennsylvania before and after the Three Mile Island accident of March 28, 1979. (a) 1977, (b) 1978 and (c) 1979. In (b) the July 1978 infant mortality rates have been plotted for the New England states. Note that Rhode Island downwind from the Millstone Reactor had the highest mortality rate, and distant New Hampshire the lowest.

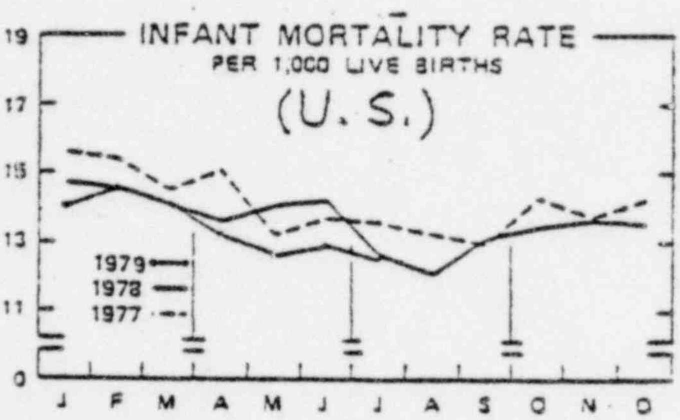


Figure 4. Monthly U.S. infant mortality rate for 1977, 1978 and 1979 (to July). Note normal pattern of low infant mortality rates in the summer months.

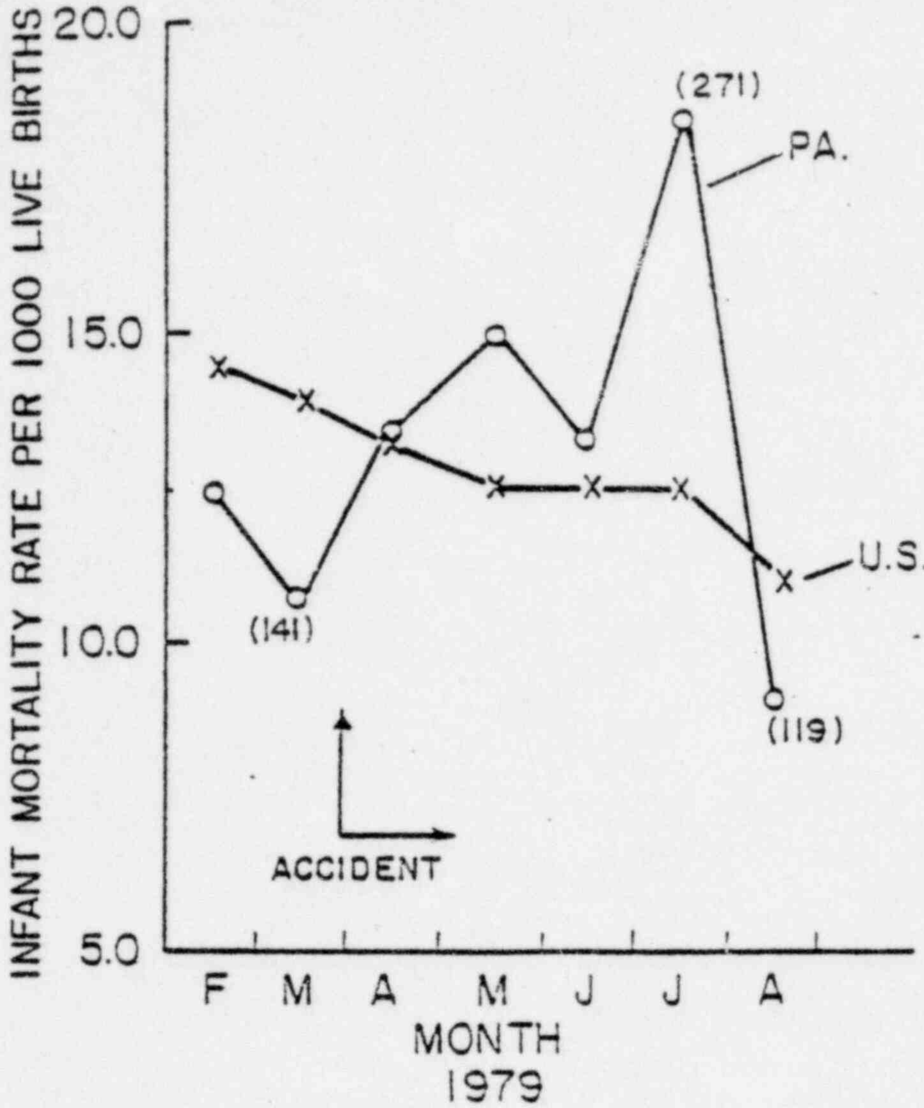


Figure 5. Comparison of the monthly infant mortality rates for Pennsylvania and the United States as a whole for February to August 1979, before and after the Three Mile Island accident on March 28. Figures in brackets indicate number of infant deaths.

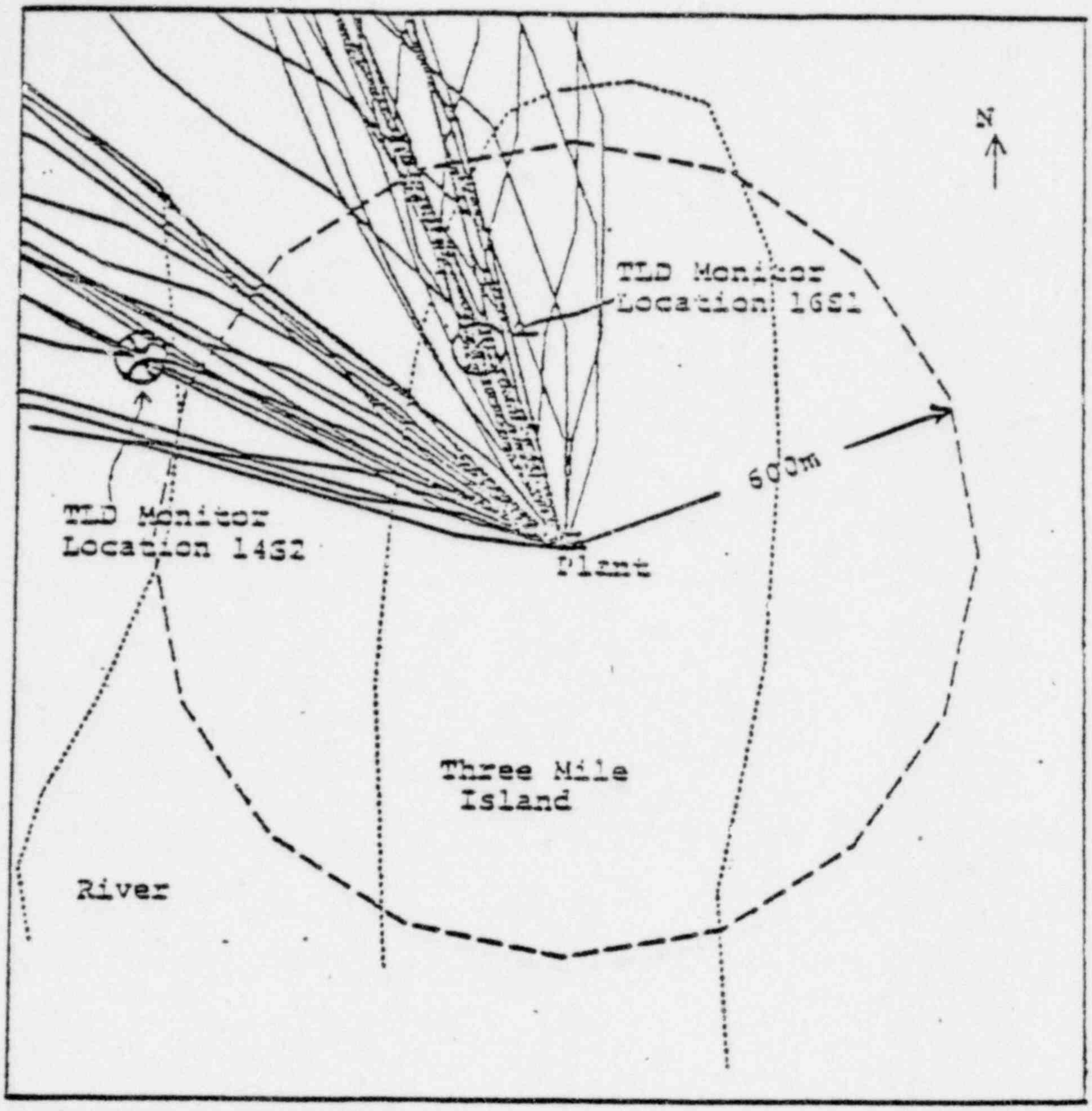


Figure 6. Approximate tracks of plume centerlines for the radioactive gases released during the Three Mile Island accident every 15 minutes starting at 5 p.m. March 29, 1979. (Based on TMI Outsite, Meteorological Tower Data, Reference 4, Figures 4-5).

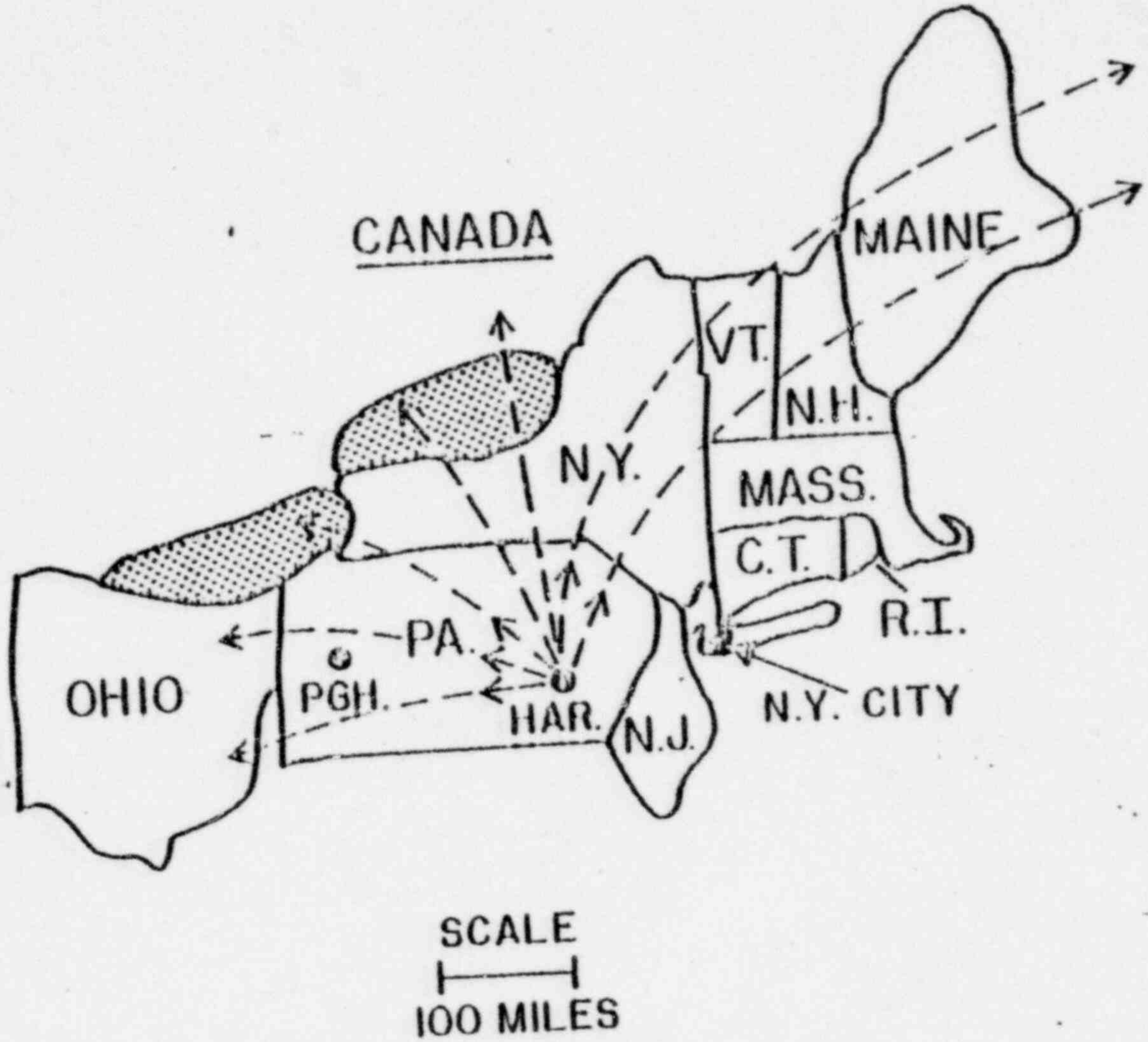


Figure 7. Map of the north-eastern United States showing location of Harrisburg, Pittsburgh and neighboring states together with the principal directions in which the radioactive gases drifted in the first two days of the accident at Three Mile Island.

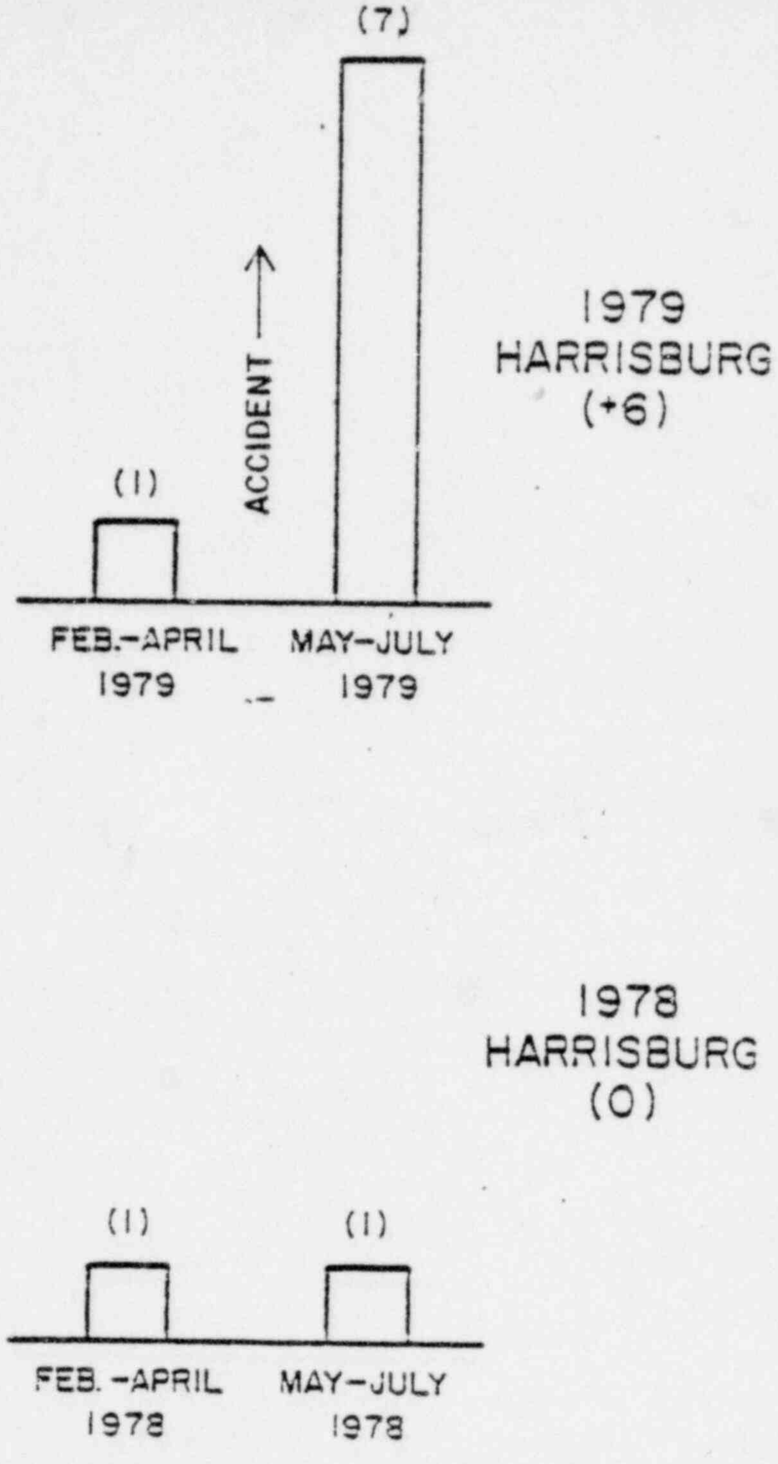


Figure 8. Newborn infant deaths in the Harrisburg Hospital for three month periods before and after the accident at Three Mile Island, March 28, 1979. Figures in brackets represent the change in the number of deaths. Note the absence of any increase in May/June/July of 1978.

IMAGE EVALUATION
TEST TARGET (MT-3)

MICROCOPY RESOLUTION TEST CHART

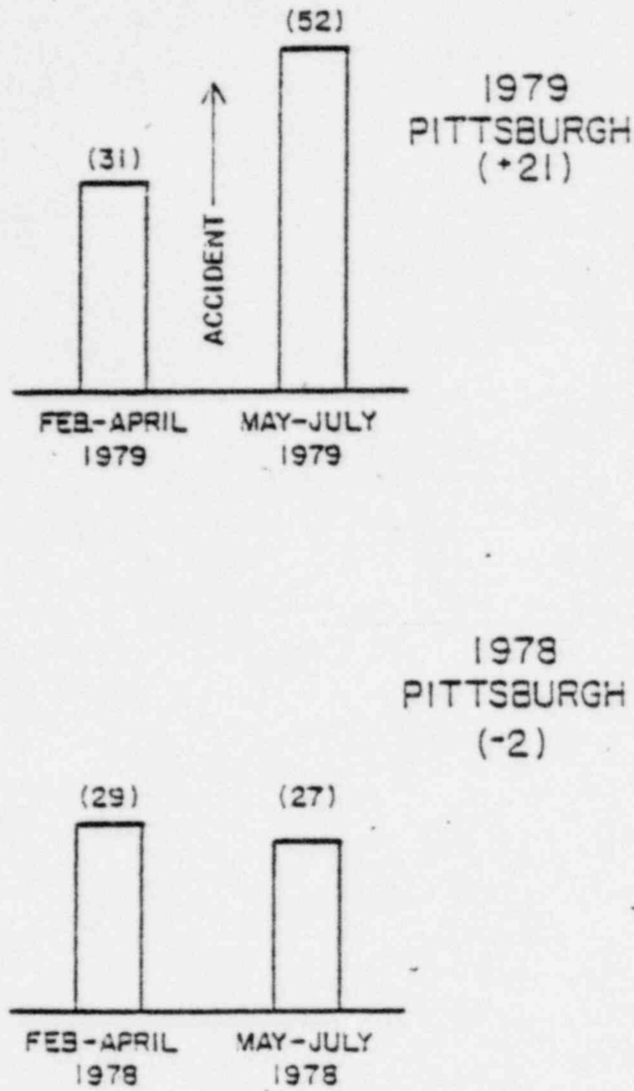


Figure 9. Newborn infant deaths in Pittsburgh (Magee Hospital) for 3 month periods before and after the Three Mile Island Accident of March 28, 1979. Note the absence of any rise in May/June/July of 1978.

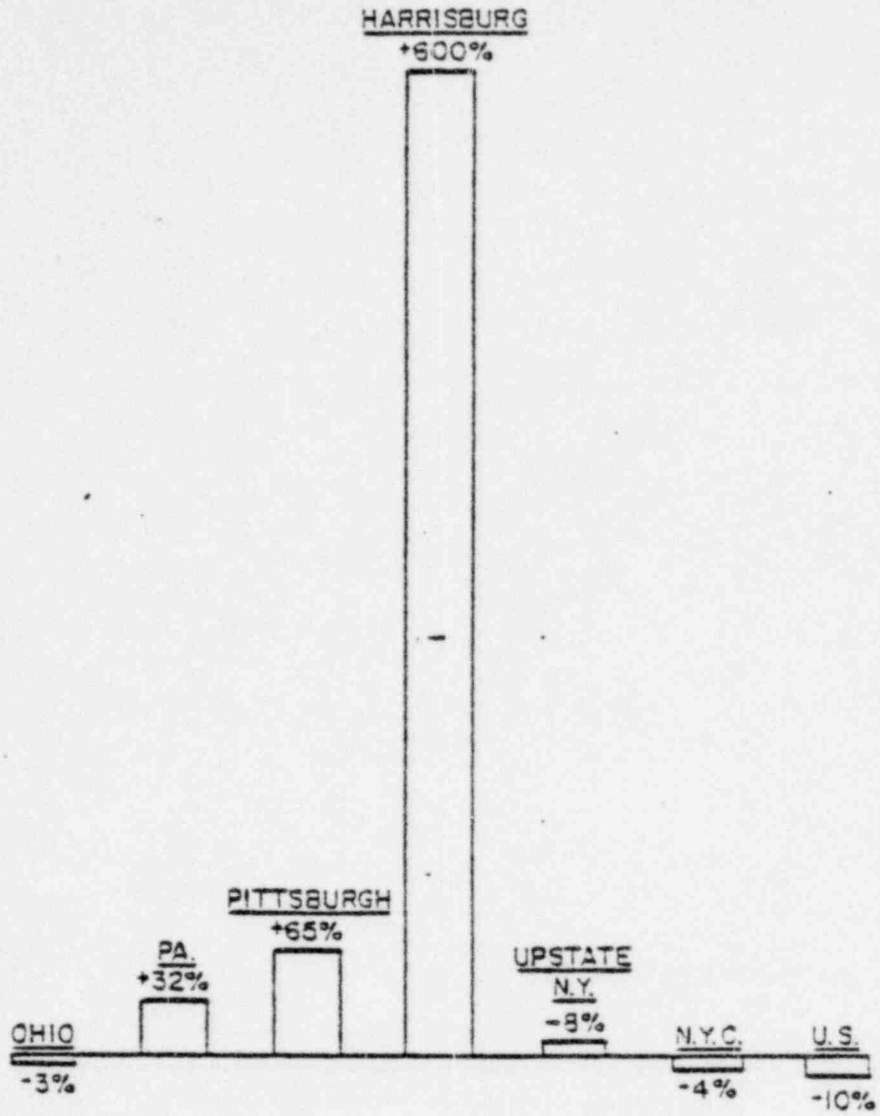


Figure 10. Geographical pattern of newborn infant mortality changes at various distances from the Three Mile Island plant located 10 miles south of Harrisburg. Figures represent percent changes between February/March/April and May/June/July 1979. Note that greatest rises occurred closest to the plant.

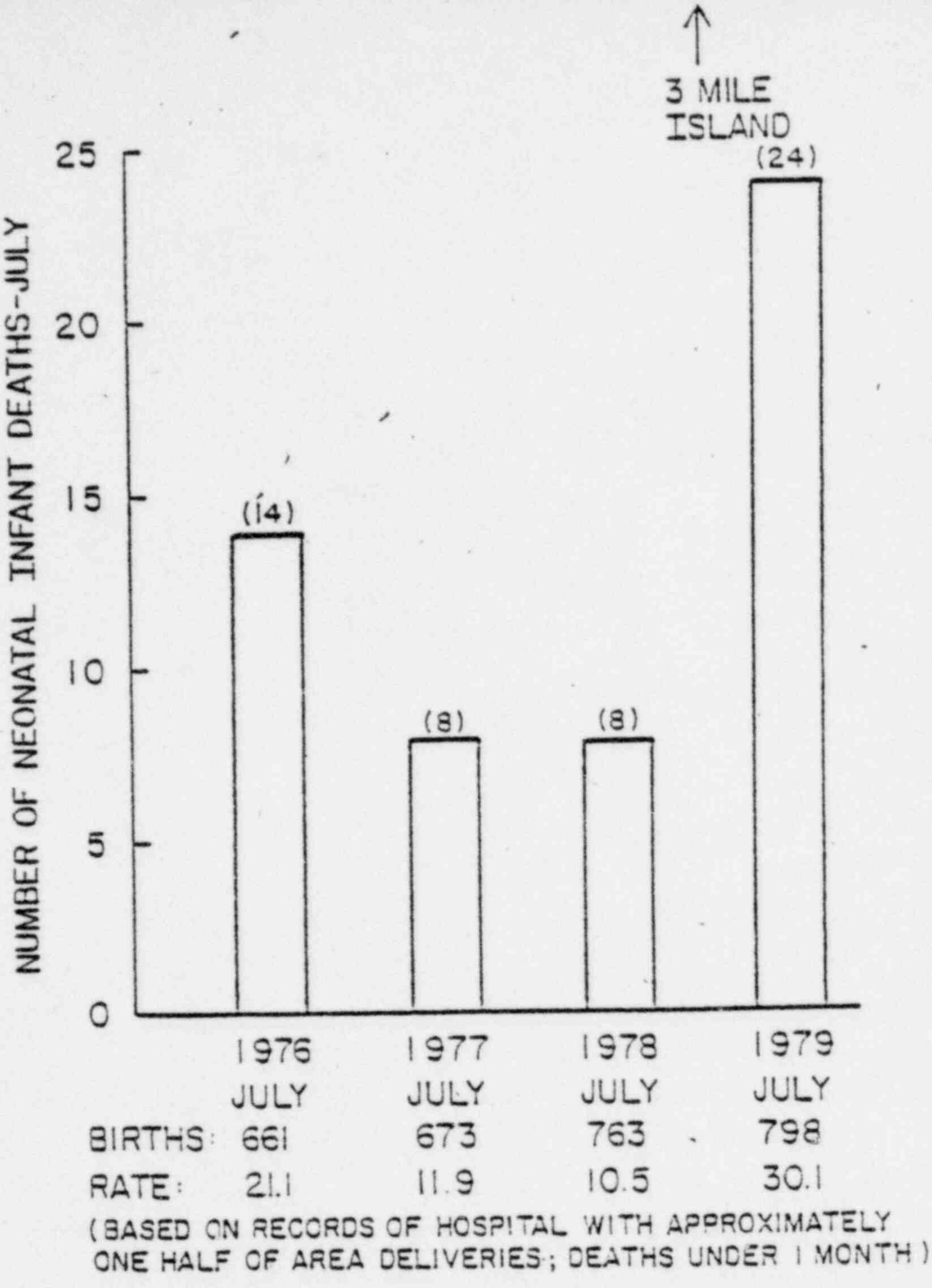


Figure 11. Trend in the July infant mortality rates in the Pittsburgh area before and after the Three Mile Island accident in March 1979. Numbers in brackets refer to the number of newborn infant deaths at Magee Hospital for the month of July 1976, 1977, 1978 and 1979. Note that the death-rate tripled between July 1978 and July 1979.

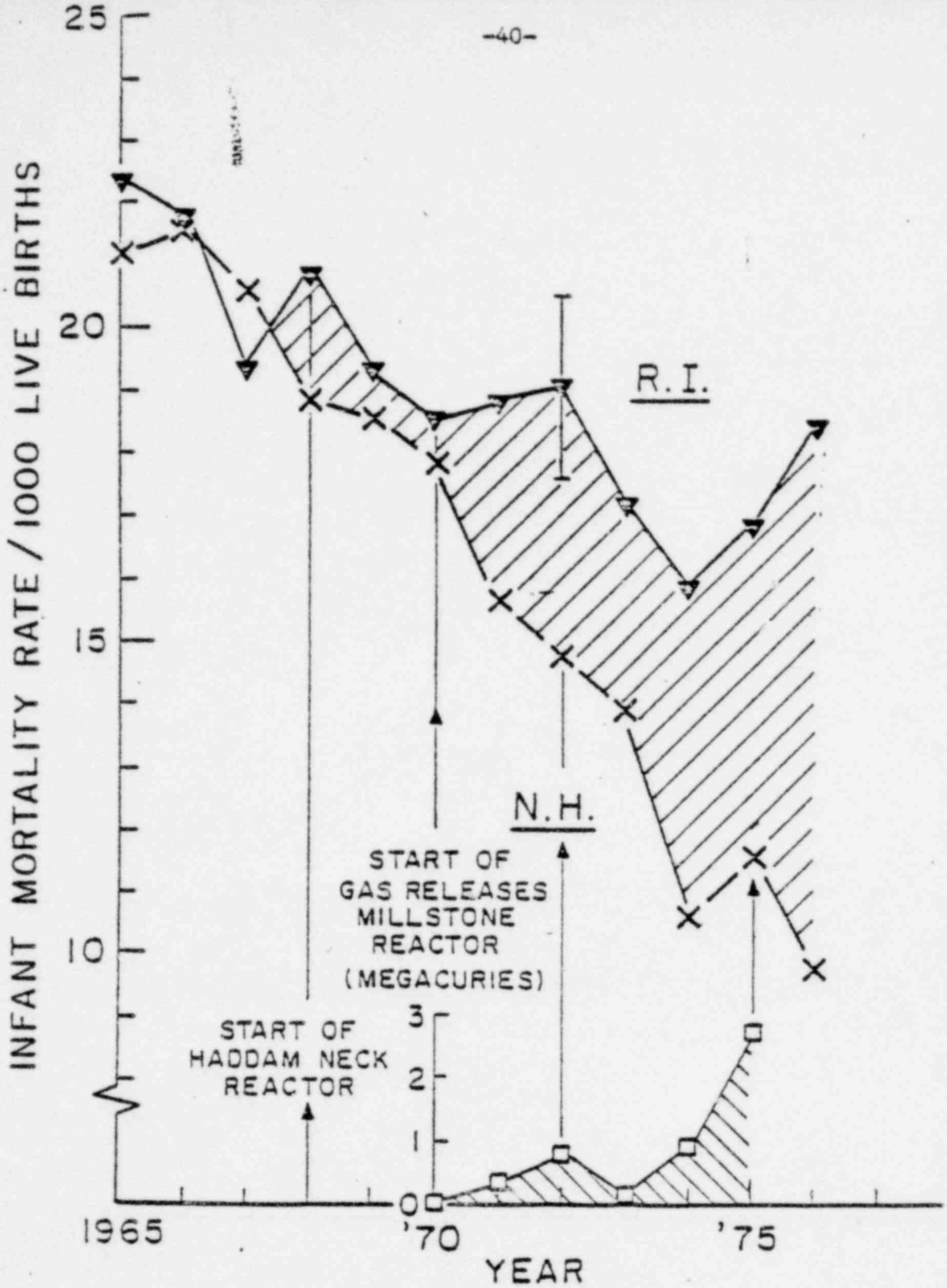


Figure 12. Infant mortality rate trends in Rhode Island 20-40 miles downwind from the Millstone Reactor in Connecticut between 1965 and 1975 compared with the rate for New Hampshire more than 100 miles to the north. Also shown are the annual releases of gaseous radioactivity in millions of curies. Note the widening gap between the two states indicated by the shaded area following the start of nuclear reactor operations.

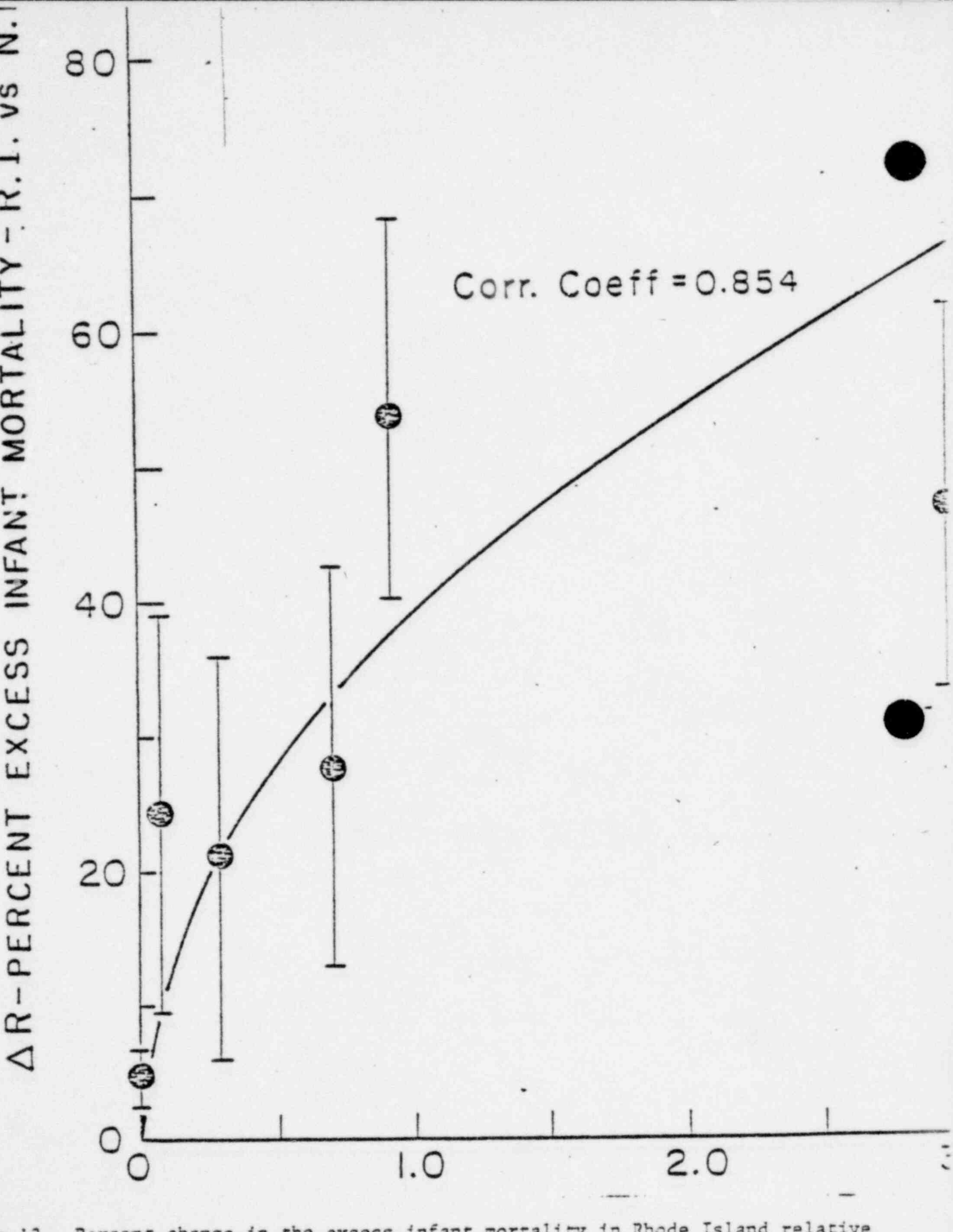


Figure 13. Percent change in the excess infant mortality in Rhode Island relative to the more distant state of New Hampshire as a function of the total gaseous radioactivity releases from the Millstone plant near the Rhode Island border taken from Figure 12. (Two year moving averages). Note that the data points are best fitted by a curve that rises more rapidly at low doses than at high doses.

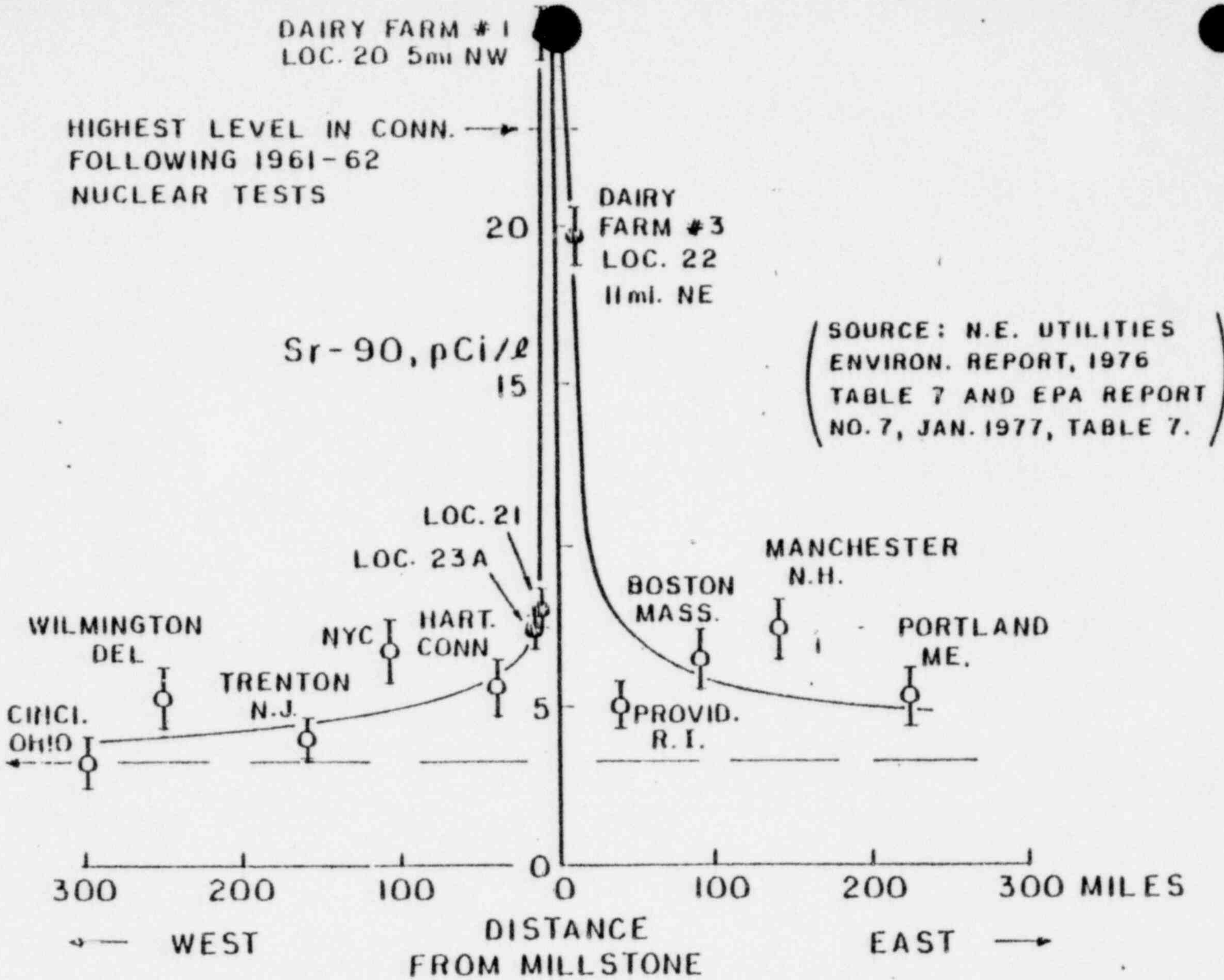


Figure 14. Geographical pattern of Strontium-90 in milk at different distances from the Millstone Nuclear plant near Waterford, Connecticut for July 1976. Solid points represent the samples collected by the utility, open points represent EPA measurements. Note that the concentrations measured nearest the plant are close to those measured during heavy nuclear weapons testing in the early 1960's.

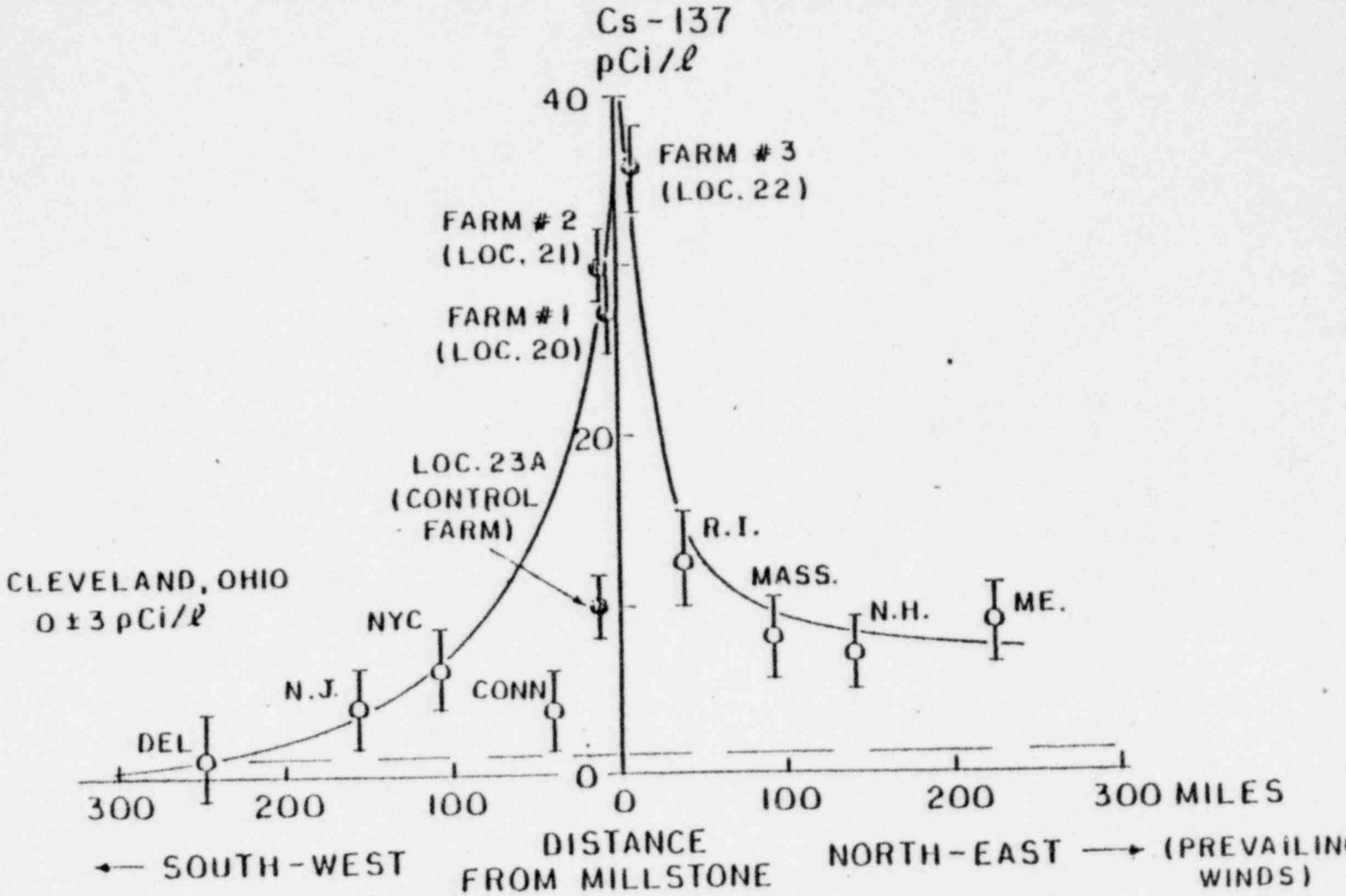


Figure 15. Geographical pattern of Cesium-137 concentrations in the milk at different distances from the Millstone Nuclear plant in August of 1976. Solid points represent data collected by the utility, open points EPA data. Note that highest levels near the plant are three times greater than for the control form (Location 23A), and as much as 10 times greater than for the upwind locations in New Jersey and New York City.

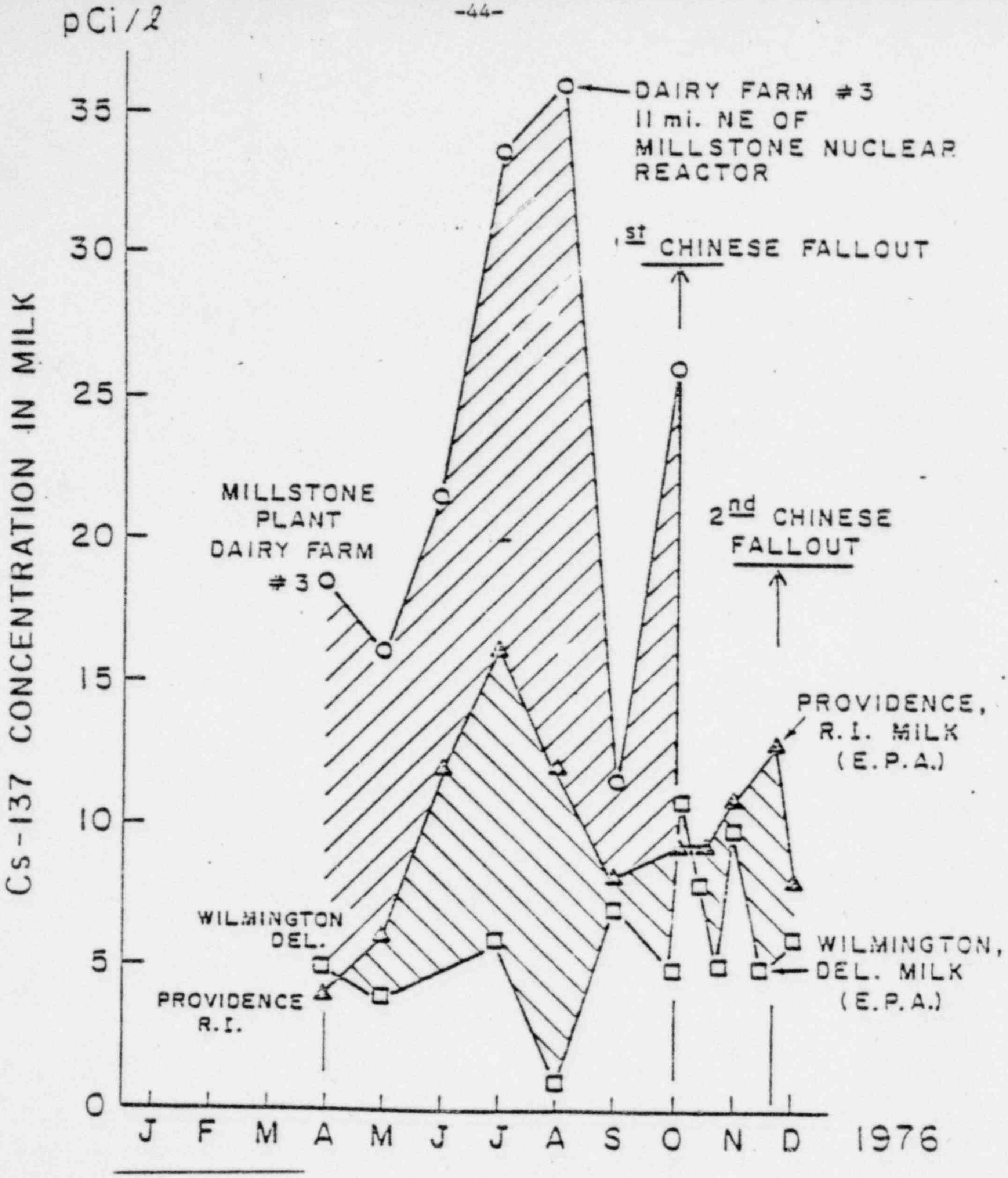
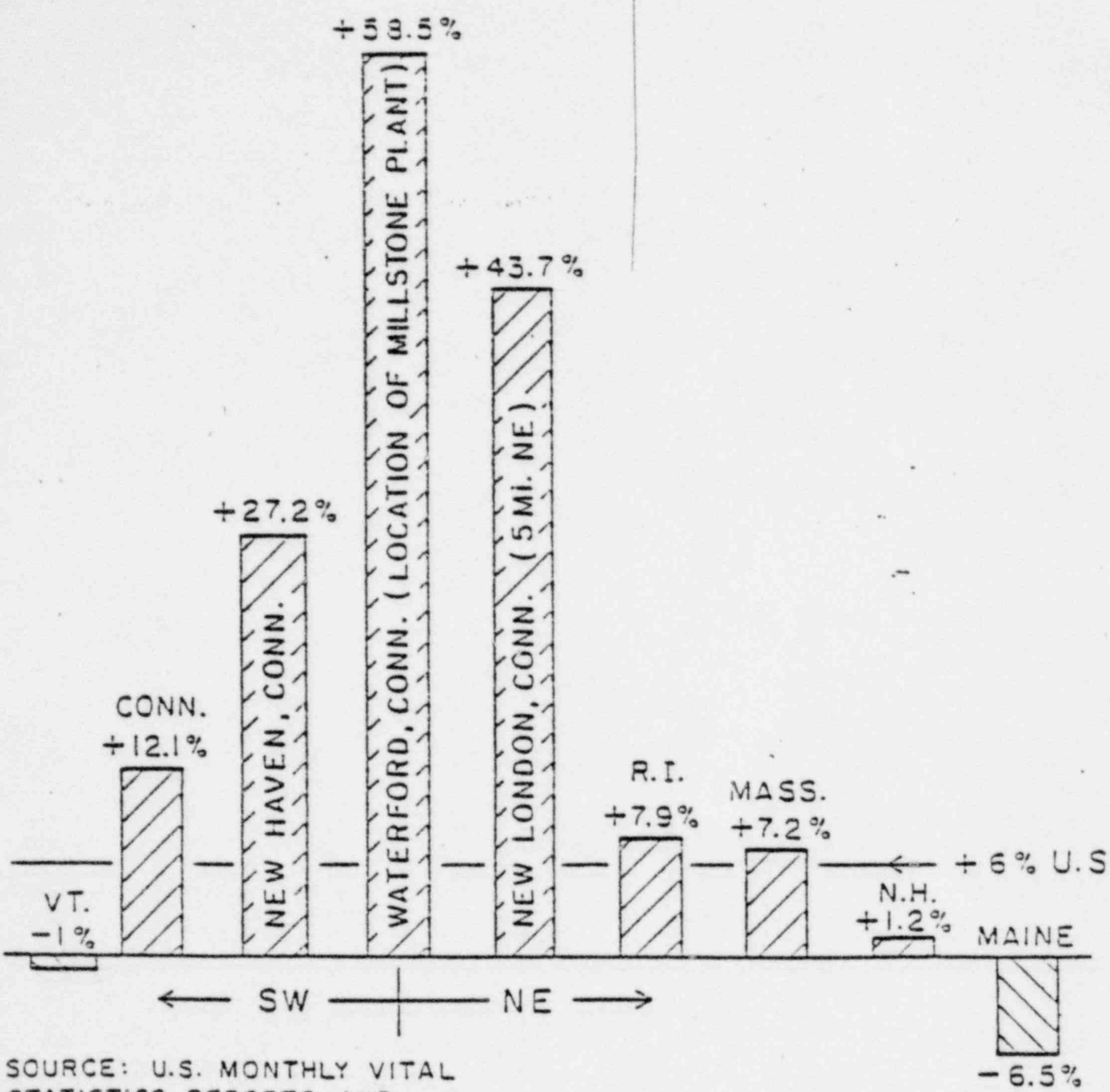


Figure 16. Changes in monthly values of Cesium-137 concentrations in milk in 1976 for three different locations at different distances from the Millstone Nuclear Reactor in Waterford, Connecticut. Note that the largest value occurred closest to the plant in August 1976, the next largest in Providence, Rhode Island, and the lowest in Wilmington, Delaware far to the south. Furthermore, it occurred before the nuclear test by China in September. Also note that the peak associated with the arrival of the heavy fallout from the September 1976 Chinese atmospheric bomb test has a lower magnitude than the July/August maximum measured near the plant, further indicating that the high Cs-137 levels near the plant cannot be attributed to fallout from Chinese bomb tests.



SOURCE: U.S. MONTHLY VITAL STATISTICS REPORTS AND STATE OF CONN. VITAL STATISTICS

Figure 17. Geographical pattern of cancer mortality changes near the Millstone Nuclear Reactor in Waterford, Connecticut between the start of the plant in 1970 and 1975. Note that this pattern is similar to that of the Sr-90 and Cs-137 concentrations in milk of Figure 15 and 16.

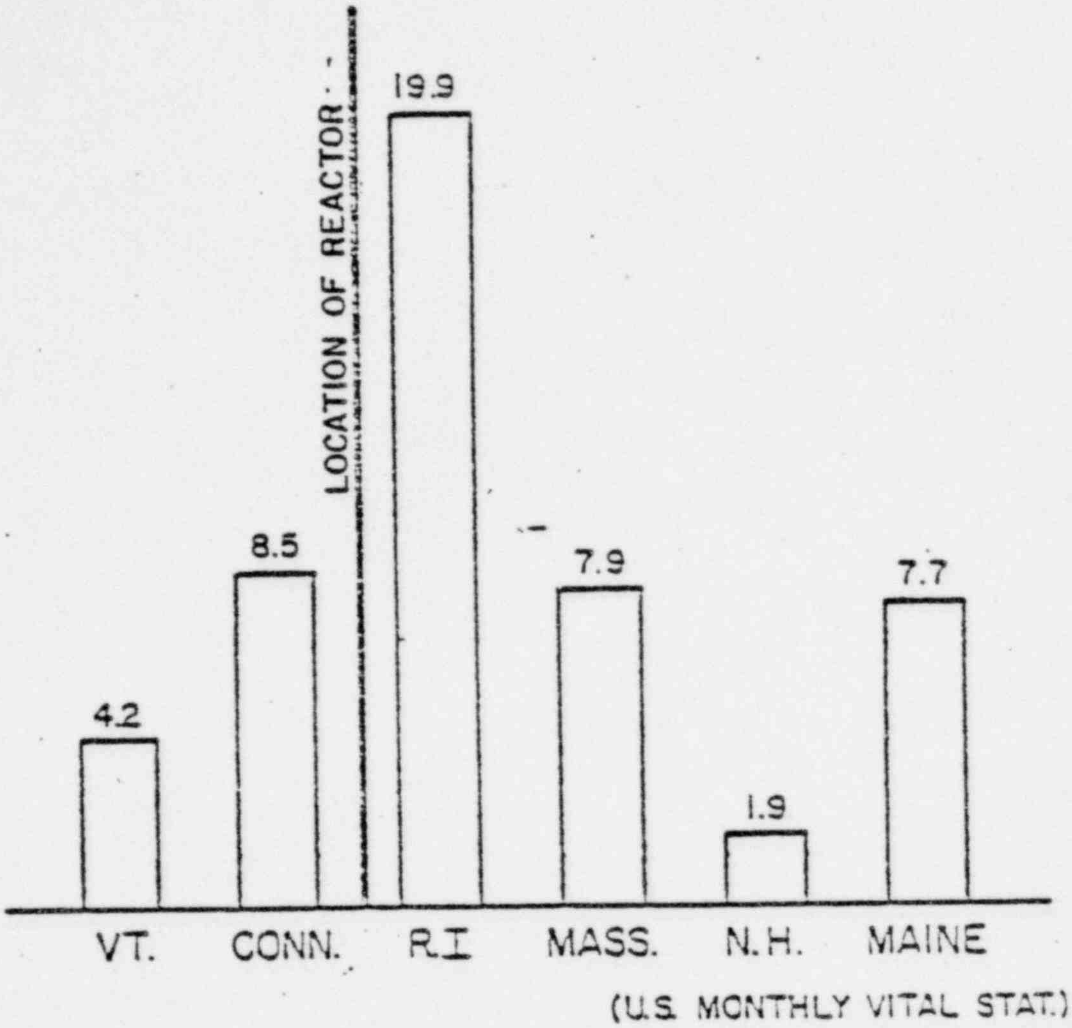


Figure 18. Geographical pattern of infant mortality changes at different distances from the Millstone Nuclear Power Station located near the border between Connecticut and Rhode Island. Note the high rate downwind from the plant in Rhode Island.

RADIATION EXPOSURE TO THE PUBLIC FROM RADIOACTIVE EMISSIONS OF NUCLEAR POWER STATIONS

Critical Analysis of the Official Regulatory Guides

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A b s t r a c t

Current regulations for radiation protection involve determining dose limits for the exposure of the individual to radioactive emissions of nuclear power stations. Supposing that a known quantity of radioactivity is emitted, exact knowledge of the parameters for the abiotic dispersion and the transfer into food-chains including the behaviour of radioactivity in the human body is very important.

Comparison of the official regulatory guides of the USA and the Federal Republic of Germany (F.R.G.) for calculating annual human doses with the results reported in the international literature shows that the recommended factors for essential radionuc-

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lides (Cobalt 60, Strontium 90, Iodine 131, Caesium 137, Plutonium 239 etc.) for the transfer from soil into plants, from fodder into animal products, and from the gastro-intestinal tract into the blood are determined in some cases in a scientifically questionable way and that the factors are often located at the lower end of the range of realistic values. Thus, the potential radiation dose is substantially underestimated. A further reason for current underestimates is that the chemical form of the radionuclides in the foodchains is often neglected (e.g., Cobalt 60 bound in vitamin B 12). For conservative estimates of radiation doses, as required under the radiation protection regulations of the F.R.G. mainly for radiation exposures due to longterm accumulation of radionuclides in the environment, potential exposures must be taken into account which could be more than two orders of magnitude higher than previous estimates. There is therefore no guarantee that even if the emission unit ~~of 1 Ci~~ aerosols/year is coupled with the dose would be within limits. A further problem is the population dose, which should also be taken into consideration because of its importance for the cumulative global health risk from emissions of radioactivity.

1.) Introduction

The radiation protection standards of many countries limit the exposure of the individual to radioactivity emitted from Nuclear Power Stations. These values, which are mainly derived from recommendations of the ICRP, for example, limit the exposure for the "worst case" in the F.R.G. to 30 mrem/year for the whole body, while for different organs special values exist (SSVO, 1976).

Usually, compliance of the dose limits with the discharge limits of nuclear facilities is proved by radioecological reviews, which try to describe the complex behaviour of radionuclides in the abiotic and biotic environment mathematically. A prediction is attempted of the maximum possible radiation dose within a period of several decades. The often stated value of 1 mrem/year radiation dose to the public from radioactive emissions from nuclear power stations is the result of calculations and not of measurements. Even in routine releases nuclear power reactors emit hundreds of radionuclides of which Table 1 gives a selection. There we find noble gases, products of fission, activated corrosion products, and others. Radionuclides which are discharged into the environment, undergo a great number of transport processes, where they are more or less diluted or enriched and can lead by many different ways to radiation exposure of the indivudual (figure 1). One of the most important exposure pathways is by ingestion of contaminated foodstuffs through aerosols, which accumulate in the soil. Points we have to consider include the atmospheric dispersion, the behaviour of radionuclides and the systems soil to plant, plant to animal, and foodstuff to man. Attempts have been made to calculate potential doses, using mathematical models and standard table values for transfer factors (Ng, 1968, Fletcher, 1971, USNRC 1976, SSK 1977). The main problem lies not so much in the calculation model but rather in the enormous variability of the different factors which is found in nature. This paper attempts to illustrate the problems by examples involving the main radioecological parameters.

TABLE 1 Selection of radionuclides emitted by nuclear facilities into the air ($t_{1/2} \geq 8$ d)

nuclide	$t_{1/2}$
P 32	14.3 d
P 33	25.3 d
Cr 51	27.7 d
Mn 54	312.2 d
Fe 55	2.7 a
Fe 59	44.6 d
Co 58	70.8 d
Co 60	5.3 a
Ni 63	100 a
Nb 92	10^8 a
Sn 117m	14 d
W 185	75.1 d
U 237	6.8 a
ACTIVATED CORROSION PRODUCTS	
Kr 85	10.8 a
Xe 129m	8.9 d
Xe 131m	12 d
Xe 133	5.3 a
NOBLE GASES	
I 129	$1.57 \cdot 10^7$ a
I 131	8 d
IODINE-ISOTOPES	

nuclide	$t_{1/2}$
Sr 89	50.5 d
Sr 90	28.5 a
Y 91	58.5 d
Zr 95	64.0 d
Nb 95	35.2 d
Ru 103	39.4 d
Ru 106	368 d
Te 127m	109 d
Te 129m	33.6 d
Cs 134	2.1 a
Cs 136	13 d
Cs 137	30.1 a
Ba 140	12.8 d
Ce 141	32.5 d
Ce 144	284.8 d
Nd 147	11 d
OTHER FISSION PRODUCTS	
Pu 239	24 000 a
Pu 240	6 600 a
Am 241	458 a
Cm 242	164 d
Cm 244	17.8 a
α - AEROSOLS	

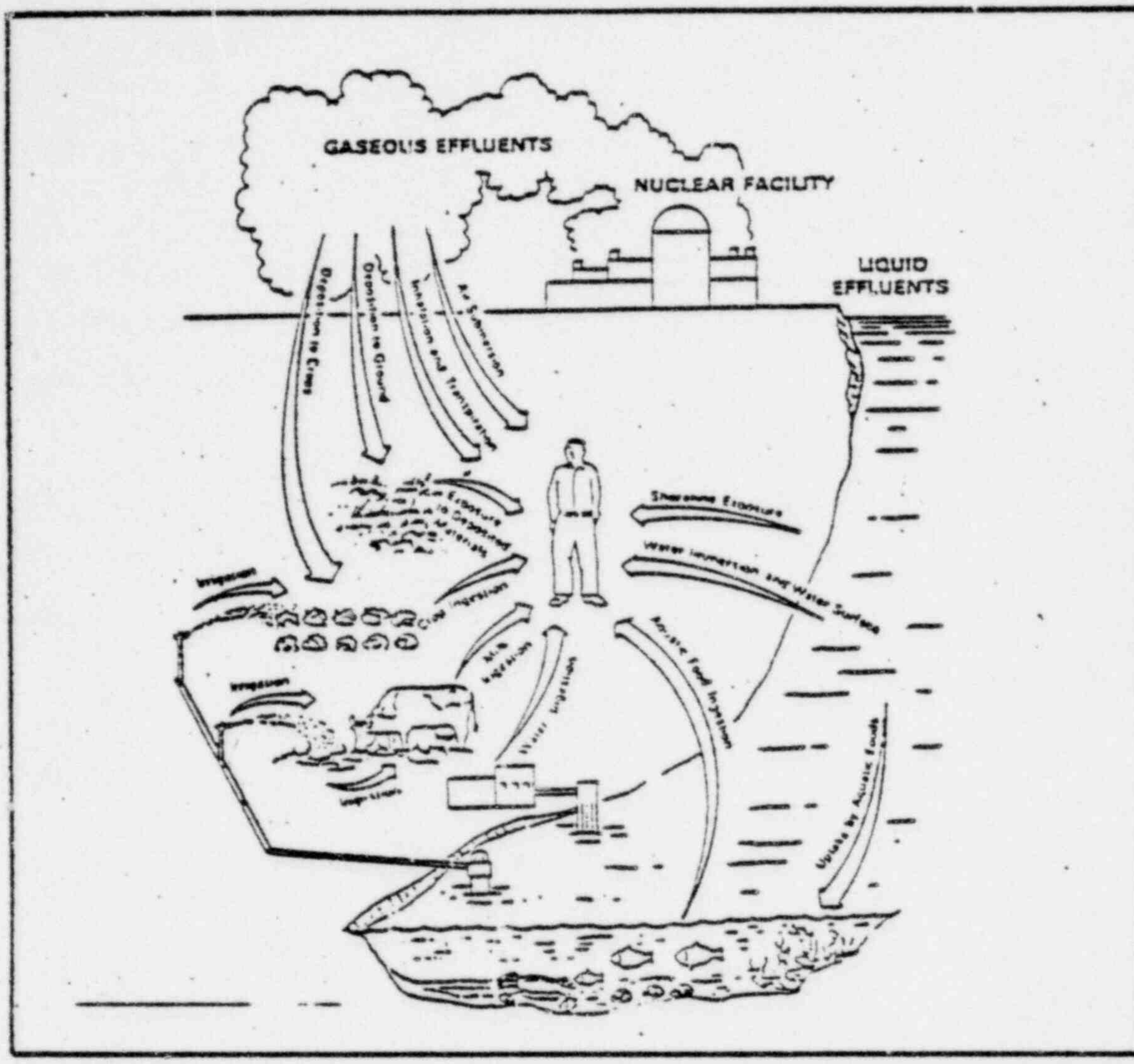

FIGURE 1 : Exposure pathways by effluents of radioactivity of nuclear facilities (from: Soldat, 1976)

2.) Transfer of Radionuclides from Soil into Plant

The transfer factor soil to plant (pCi/kg plant fresh weight: pCi/kg soil, dry) describing how much radioactivity taken up by plants depends on an enormous number of parameters, for example:

- elements
- plant species
- part of the plant
- chemical form of radionuclide
- type of soil
- fertilization
- humidity of soil
- temperature
- concentration of stable isotopes and similar elements in soil
- perhaps concentration of radionuclides in soil
- biological activity of the soil

The reason, why for example the transfer factor for caesium varies by four orders of magnitude can be found in these influences (figure 2). The Caesium isotopes Cs 134 and Cs 137 contribute to the radiation dose from ingestion of contaminated foodstuff in the vacinity of nuclear facilities. In figure 2 values for the transfer factors for Caesium (pCi/kg plant, dry: pCi/kg soil, dry) are correlated with the clay content of soil (in percent). The water content of plant is assumed to be 80 %. In all, 142 values of different experiments and measurements for grass-plants by different authors have been taken into account. For comparison, the officially recommended transfer factors

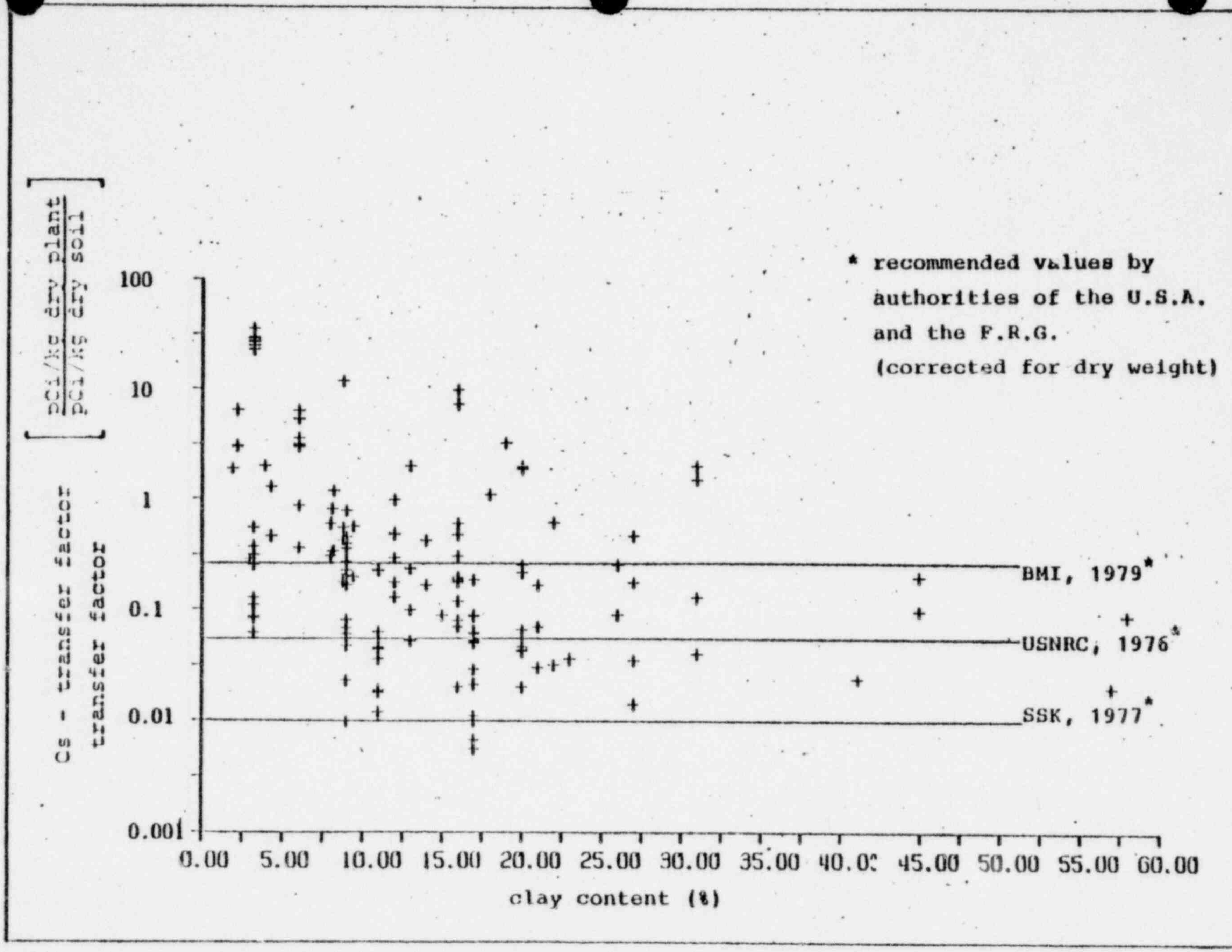

FIGURE 2 : Transfer factor plant/soil (pCi/kg dry plant : pCi/kg dry soil) for cesium against clay content in soil (%) (from: Franke,Ratka,van de Sand, 1978)

TABLE 2 : Variation of transfer factors plant/soil for cesium and strontium (pCi/fresh plant : pCi/kg dry soil) (from Franke, Ratka, van de Sand, 1978)

plant species	transfer factor Cs	transfer factor Sr
leaf vegetables	0.0075 - 0.9	0.08 - 7.8
grass	0.00068 - 14	0.01 - 9.8
potatoes	0.023 - 0.16	0.015 - 0.38
clover	0.004 - 33	0.22 - 7.4
root vegetables	0.0025 - 0.15	0.055 - 21
"vegetation"* or "vegetables"**	0.01	0.2

* as recommended in USNRC, 1977

** as recommended in SSK, 1977

for Caesium from American and German (F.R.G.) are indicated (plotted). Although the factor can vary by more than 4 orders of magnitude in most previous radioecological reviews, in the recommendations only 1 transfer factor for all plant species and soil types has been recommended. It is clear, that with such an instrument an accurate radioecological assessment is not possible. Analysis of the recommended transfer factors soil to plant showed that for most radionuclides the recommended values lie in the lower part of the range of realistic values. In table 2 the variation in transfer factors for Caesium and Strontium, derived from a great number of references, for different plant species is compared with the values recommended in the official handbooks. As may be seen, the recommended values may in special cases underestimate the transfer of radionuclides 10fold, 100fold, or even 1000fold.

How have the values in the official handbooks been derived? An analysis of the history of these values by Teufel et al., 1979, for Caesium is shown in figure 3. The references indicated for the recommended values and the references cited in those references had been analysed. The astonishing result was that the values recommended by the German Radiation Protection Commission are derived from a very poor study of references and that the cited values did not agree with the recommended values. The value of 0.002 (pCi/kg plant fresh: pCi/kg soil, dry) has been derived from a publication of Baker, 1976. Baker derived his values from a handbook by Fletcher, 1971, in which, for example, for leaf vegetables/soil the transfer factor of 0.019, 10fold the value in SSK 1977 is given. Fletcher cites five references and the values in those references are

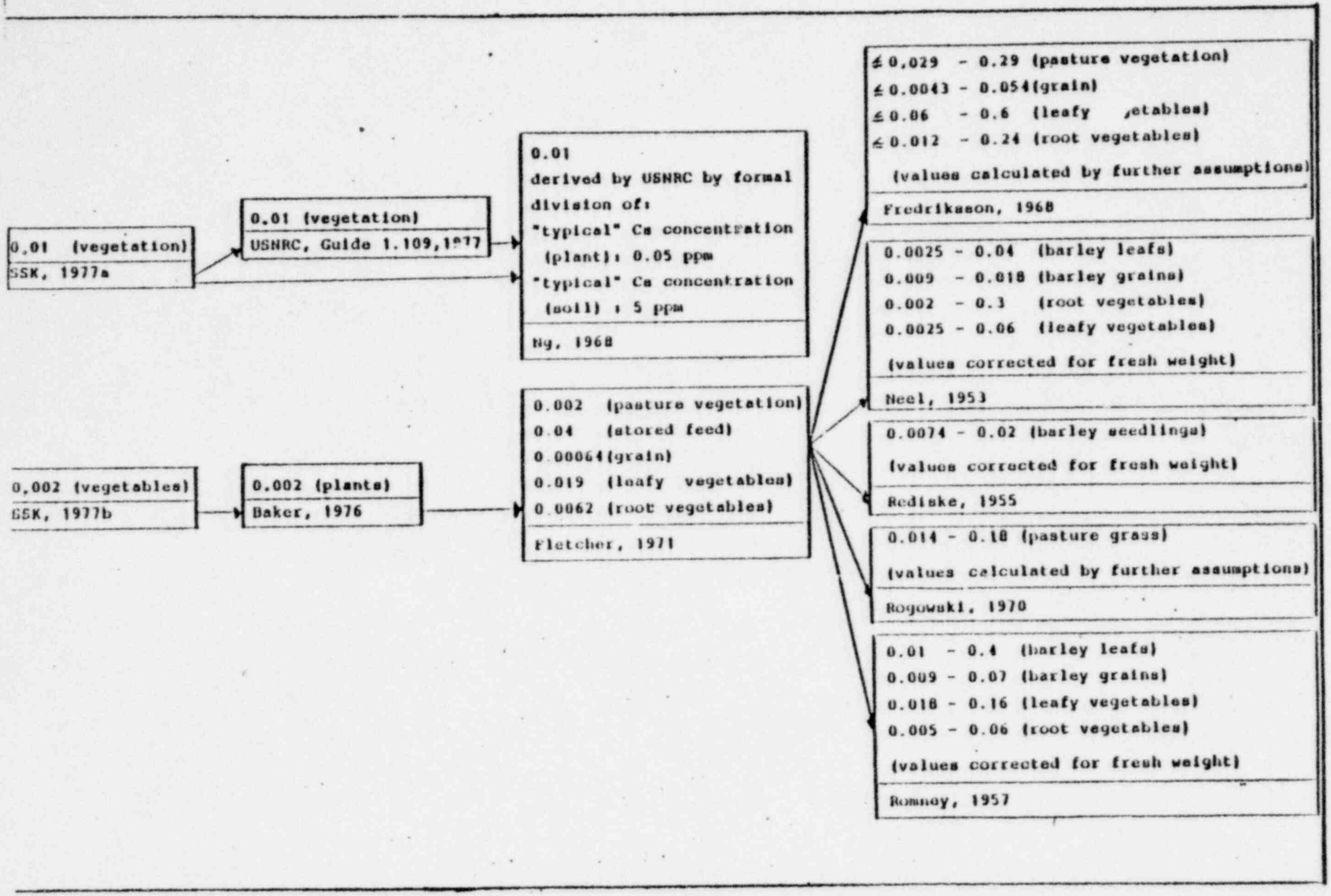

FIGURE 3 : References for Cs transfer factor plant/soil

1 to 2 orders of magnitude higher than the recommended values by SSK, 1977. The value recommended by the USNRC, 1976 has been derived by a formal division of stable element concentrations in plants (reference: english handbook) and soil (reference: russian handbook) in Ng, 1968. This method is more than questionable on scientific grounds.

Nevertheless, previous radioecological reviewers, administrations and members of radiation protection commissions, use these false values, to state that the values used would be conservative, meaning that real values would only be <u>less</u> than the ones used.

It should be clear, that in future instead of fixing on theoretical regulatory values, the transfer factor for soil for radionuclides in the surrounding of planned nuclear facilities should be measured to give a proper base for radiological assessments.

3.) Transfer of radionuclides from fodder into animal foodstuffs (meat)

Another problem is the transfer of radionuclides in meat. The transfer is indicated by a factor which gives the daily amount of the radioactivity ingested by the animal that is found in 1 kg of meat (dimension: pCi/kg meat : pCi/day intake). An analysis of the recommended values led to the result, that for important radionuclides these values are not suitable for a realistic or conservative assessment. Our research showed, that these recommended values also had been derived by a questionable method dividing non-corresponding concentrations of stable elements in meat and fodder (Franke, Höpfner, 1978b). Other American handbooks, for example the collection of data of Baker, 1976, and Fletcher, 1971, indicate transfer factors based on experimental results. Table 3 compares the values recommended by the USNRC, the West-German authorities, with values in literature. A realistic value for the transfer of Caesium into beef must be taken as 0.075 $\pm$ 0.02 and a conservative value of 0.1. On the contrary, the recommended value for all sorts of meat is given as 0.004, lying below all experimental observations. Using such an inaccurate transfer factor, results in a linear underestimation of potential radiation dose. The ratio of conservative to offical values for beef is e.g. for Cs 25 : 1. for Sr 5 : 1, for I 7 : 1, for Pa 350 : 1. If, for example, a radiation dose by beef consumption of Cs 137 contaminated beef is calculated to be 1 mrem/year, a radiation dose of, for example, 25 mrem/year will result.

4.) Behaviour of radionuclides in human body

The 3rd important radioecological area is the system foodstuff to man. The behaviour of radionuclides in human body depends among other influences on

- the chemical form of radionuclides
- the amount of stable isotopes in the foodstuff
- the age of the individual
- state of health
- genetical constitution
- composition and amount of foodstuff

TABLE 3: Transfer factors meat/fo(r (pCi/kg meat : pCi/d intake) for selected radionuclides (from Franke and Höpfner, 1978)

nuclide	animal species	BMI, 1979 USNRC, 1976	Fletcher, 1971	Baker, 1976	Franke and Höpfner, 1978 realistic	conservative
Cs	beef	0.004	0.03	0.03	0.075 ± 0.02	0.1
	calf				0.42 ± ?	1.5
	pork		0.04	0.26	0.26 ± ?	0.26
Sr	beef	0.0006	0.002	0.0003*	0.002 ± 0.001	0.003
	pork		0.008	0.0073	0.008	0.01
I	beef	0.0029	0.02	0.02	0.015 ± 0.005	0.02
	pork		0.09	0.09	?	0.09
Pu	beef	0.000014	–	0.005	?	0.005
	pork		–	0.01	?	0.01

* apparently a printing error in Baker, 1976; correctly: 0.003

Because of the various influences the same amount of radioactivity can lead to very different radiation exposures for individual humans. Instead of reflecting this variation the recommended dose conversion factors vary only between adults and children. None of the other influences stated above are considered. Instead, it is often asserted that the recommended dose conversion factors, actually calculated for a "reference man" would be "conservative", implying that all potential radiation doses are considered. This is not right. As example the behaviour of zinc, plutonium, and cobalt show. Radioactive zinc can be emitted by nuclear power reactors as an activated corrosion product and thus contaminated foodstuffs. As these foodstuffs are consumed, it is very important to ask how much of the radioactive zinc in foodstuff will be resorbed in gastro-intestinal tract of humans. In previous recommendations of the US and F.R.G., using values from ICRP II, 1959, it is assumed that 10 % of the ingested radioactive zinc will be resorbed in the GI-tract. A literature review (Steinhilber-Schwab, Teufel, 1978) shows that the mean resorption rate for zinc actually lies at about 50 % with extreme values higher than 90 % (figure 4).

The differences are even more obvious in the case of the radiotoxic element plutonium. In previous recommendations the assumed resorption rate for plutonium from the GI-tract into blood is 0.0001 to 0.003 %. That means, that only from 1 of million parts up to 3 of 100 000 parts of the ingested plutonium by foodstuff will be resorbed. Our literature analyses showed, that the resorption rate of plutonium depends very much on its chemical form in the environment. The officially recommended resorption rates are only valid for poorly

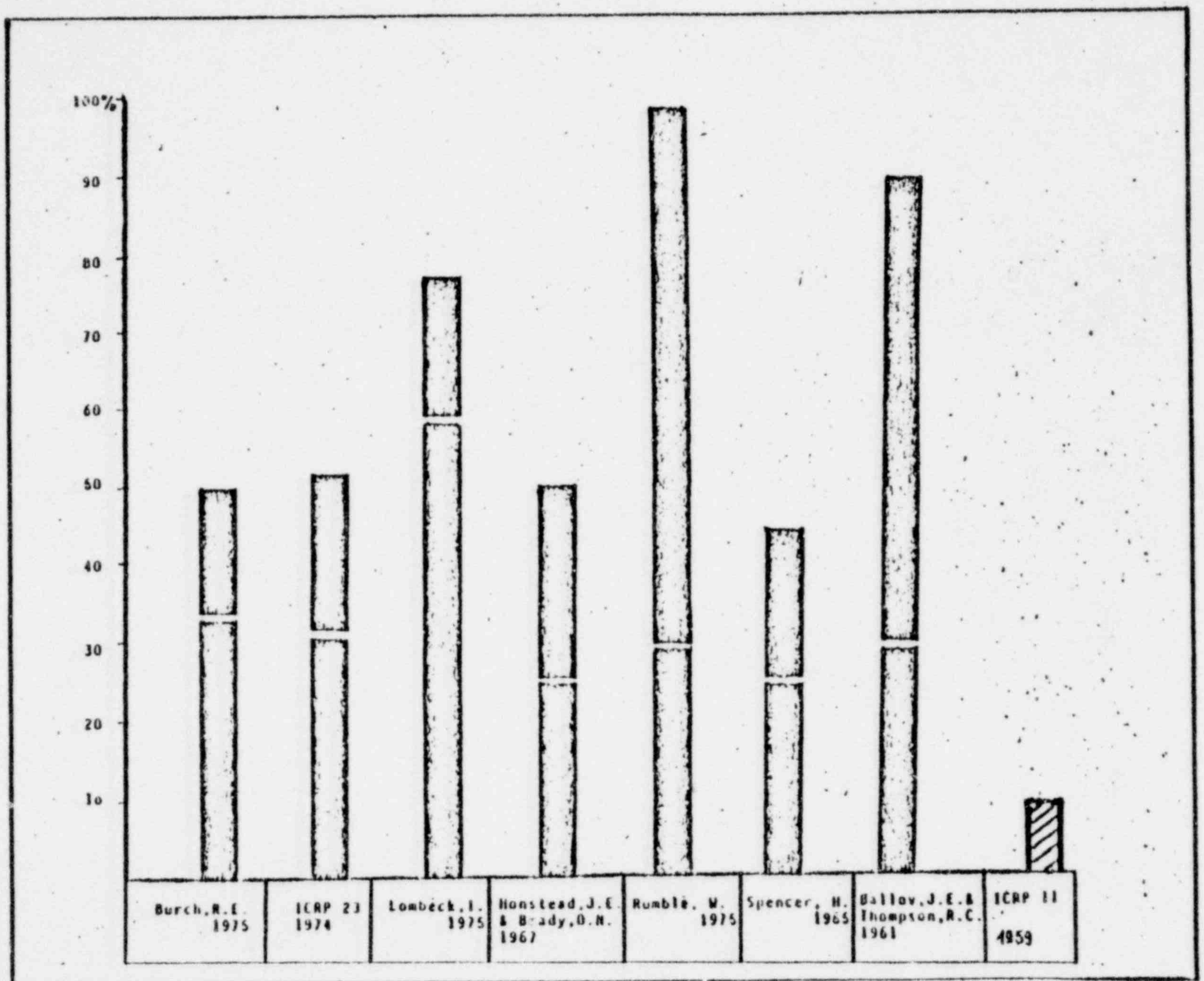

FIGURE 5: resorption of zinc in human GI-tract (% of ingested)
(from: Steinhilber-Schwab, Teufel 1978)

soluble plutonium, however, for example, as Pu-nitrate or Pu-citrate or as Pu VI, plutonium is resorbed at a rate, 3 to 4 orders of magnitude higher than PuO_2 (figure 5). The potential hazard lies in the biological mechanisms that will complex PuO_2 which is emitted by nuclear facilities in the environment. Similar behaviour is known for other heavy metals, e.g., lead. Another problem is the changing oxidation state of plutonium under varying chemical conditions. Larson and Oldham (1978) found that plutonium which in oxidation state IV can be changed into Pu VI by chlorinated drinking water. Pu VI is resorbed in human Gl-tract 1000fold better than Pu IV. Highest amounts of Pu VI were formed when drinking water had been heaten up, for instance, in preparation of food, tea or coffee. The resorption rate for plutonium is related linearly to the radiation dose to man. Therefore, it can happen, that the radiation dose from plutonium in drinking water or from plutonium taken up by plants can be up to 1000fold higher than calculated by official recommendations.

A third example is radioactive cobalt which is emitted by nuclear power stations as an activated corrosion product, similar to zinc. Cobalt is found naturally in soil and in plants in inorganic form. When taken up in this form by man, resorption and transfer rates in different organs as well as the biological halflife in the organism is relatively small (ICRP 1959). Cobalt is, however, an essential constituent of a biologically very important compound: vitamin B 12. In this case the physiological behaviour of cobalt is completely different from the inorganic forms: as vitamin B 12 is essential for the human organism and cannot be synthesized by the human body,

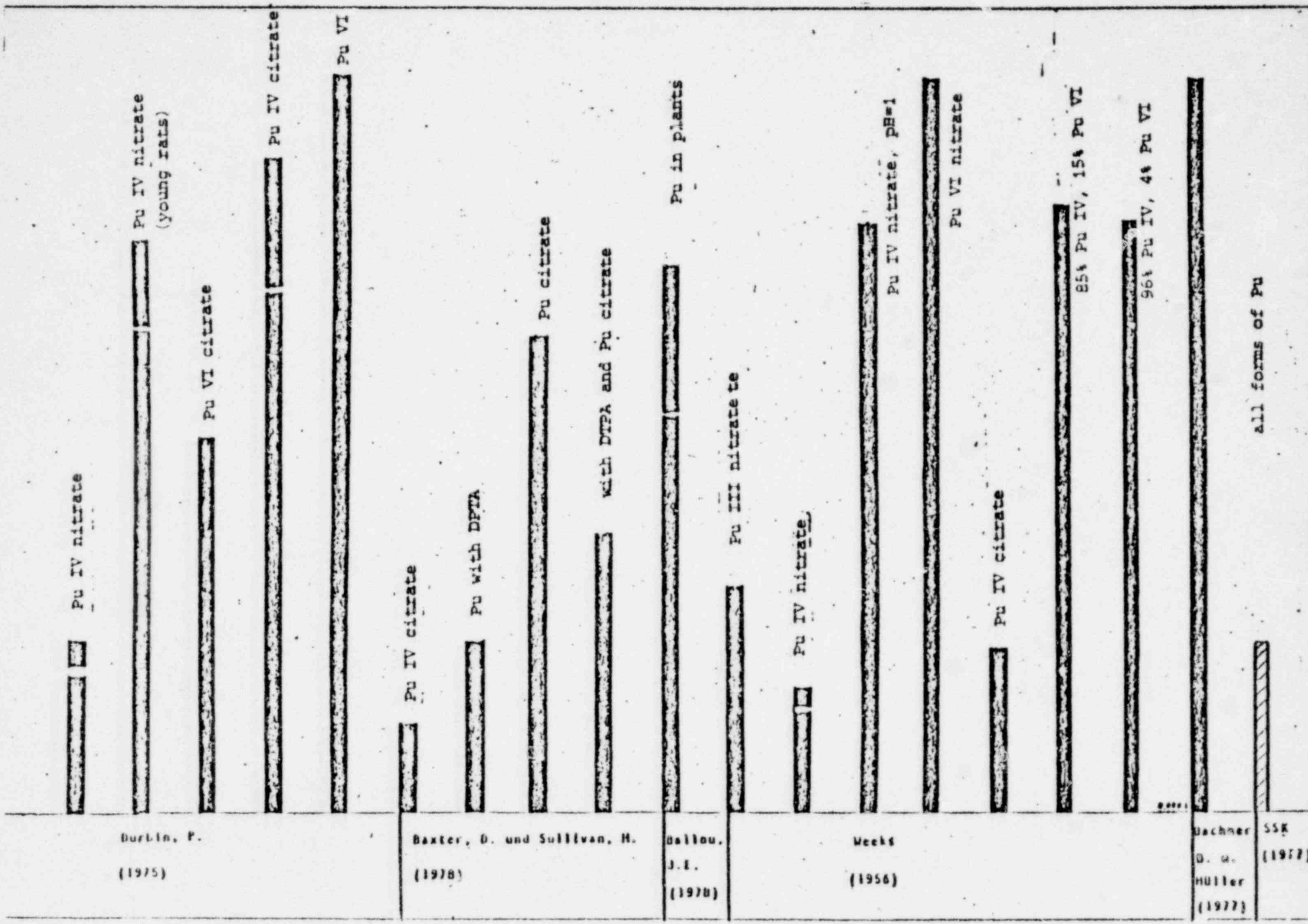

FIGURE 6 : Resorption of plutonium in human GI-tract (% of ingested) (From: Stat...

it is resorbed from food to a very high degree. Vitamin B 12 has a very long biological halflife (up to 750 days) in liver, which compares to the biological halflife of inorganic cobalt, assumed by ICRP II to be 9.5 days. The effective radiation dose from radioactive cobalt in the form of vitamin B 12 is up to 5 700 times higher than the radiation dose from inorganic cobalt. Although in many foodchains a proportion of the cobalt is built into vitamin B 12 (e.g. in beef 5 % and in milk 23 %), this problem has not been considered in previous radioecological assessments (Bruland et al., 1979).

The degree of underestimation of the radiation dose from Co 58 and Co 60 for the exposure pathways involving beef and milk consumption can be seen from table 4, in which the variation of potential values is given. In previous estimates the radiation dose from cobalt 60 contaminated milk is underestimated by a factor of 280 to 2300.

Because of the great uncertainties involved in making calculation models for radiation doses, it seems to be important to verify the model calculation by direct measurements. Hoffman et al. (1978) investigated the variation of the input-parameters for calculating the thyroid dose by I 131 (grass-cow-milk-child-pathway).

Although this pathway is one of the best investigated ones, the calculated dose for a given concentration of I 131 in air (in mrem/a : pCi/cm^2) varies in the range of 1800 to 50 000, a factor of 28.

TABLE 4: COMPARISON OF RADIATION DOSES TO LIVER BY ^{58}Co AND ^{60}Co AFTER CONSUMPTION OF CONTAMINATED ANIMAL FOODSTUFFS WITH AND WITHOUT CONSIDERATION OF THE TRANSFER INTO VITAMIN B_{12}
(RELATIVE UNITS, ROUNDED)
(from: Bruland, Franke and Teufel, 1979)

exposure pathway	inorg. Co [1]	^{58}Co conside-ring vit. B_{12}	^{60}Co conside-ring vit. B_{12}
consumption of beef	1	5.4 - 77	22 - 480
consumption of milk	1	67 - 370	280 - 2300

Assuming the statistical variation of input-values to be logarithmic, the use of parameters, recommended by USNRC will lead in 30 % of the cases to an underestimation of potential radiation doses by I 131.

Parallel measurements by USNRC of I 131 emissions from nuclear power stations and I 131 concentrations in milk led to the result, that in 28 situations at 5 reactor sites milk concentrations have been underestimated 8 times. Four of the 20 overestimates were greater than 2 orders of magnitude (Hoffman et al. 1978). A considerable source of uncertainty can be referred to meteorological models.

5.) Radiation dose to individuals

Since the various parameters for radiation dose calculation for critical individuals are so uncertain, a conservative assessment of the potential radiation dose seems to be necessary. Compared to previous estimates, a radiation dose lying several orders of magnitude higher than previous estimates seems to be possible. A radioecological assessment for the Wyhl nuclear power plant from the "Tutorium Umweltschutz an der Universität Heidelberg" (department for environmental protection at the University of Heidelberg) led to the results in Table 5, assuming for the area of maximum concentration annual discharge limits for airborn effluents of

- 80 000 Ci noble gases
- 1 Ci aerosols (halflife greater 8 days)
- 0.3 Ci iodine 131.

The calculated whole body dose of 720 mrem is e.g. 24 times the whole body dose limit in F.R.G.

TABLE 5 : Radiation doses to individuals at area of maximum concentration by emissions of radioactivity by the Wyhl nuclear power plant into the atmosphere (from: Tutorium, 1978)

exposure pathway	radiation doses in mrem/a to:		
	whole body	bone	thyroid
noble gases	31	31	31
ground contamination	15	15	15
leaf vegetables	11	323	6.5
root vegetables	40	1 700	0.4
beef consumption	350	900	380
milk consumption	160	840	210
wine	110	940	96
sum	720	4 700	740
dose limit (F.R.G.)	30	180	90

TABLE 6 : Ratio of global collective dose (man-rem), integrated over 500 years and ∞ to collective dose caused by first exposure after emission (calculated from values of Hesel et al., 1978)

nuclide	organ	ratio global collective dose/dose at first exposure	
		$\int$ 500 years	$\int \infty$
H 3	whole body	0.05 : 1	0.05 : 1
C 14	whole body	23 : 1	190 : 1
Kr 85	skin	18 : 1	18 : 1
I 129	thyroid	0.013: 1	100 : 1

It can be concluded, that by conservative assessments compliance of discharge limits with the limits for radiation dose is not guaranteed. To minimize the uncertainties in the assessments, site-specific measurements of transfer-factors plant/soil , meat/fodder, milk/fodder etc. have to be undertaken. The radioecological parameters, used in previous estimates, are not suitable for conservative estimates.

Similar results have been obtained in the research by Krüger, 1978;, SAIU, 1978; Handge et al., 1978.

6.) The problem of collective doses

For the assessment of health risk from emissions by nuclear facilities, the collective dose seems to be as (when not more) important as the dose to individuals. The rise of emission height of a facility (e.g. 200 m instead of 100 m) will lead to a dilution of radioactivity in the vicinity of the plant and so to lower values but the collective dose (in man-rem) will be the same, nevertheless. Figure 6 shows how much the relative importance of various nuclides will change with time, for the collective dose from a single emssion of various radionuclides from a reprocessing plant. Integrating the collective dose over a long time period, the relative importance of C 14 and I 129 changes considerably. Considering only the first radiation exposure after emission, even if integrated globally, the collective dose in man-rem caused by this emission can be underestimated considerably, thus underestimating the health risk for the population as a whole. Considering, for example, only the first radiation exposure from Kr 85 emission, the radiation dose

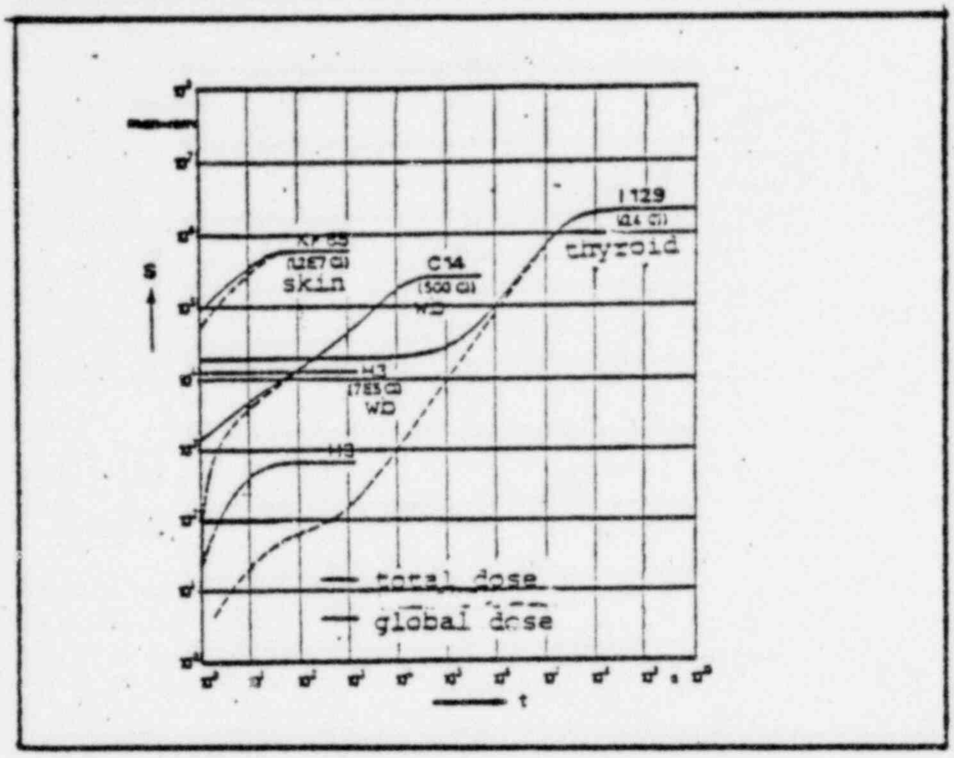

FIGURE 6 : Collective doses by one-year emission of H 3, C 14, Kr 85 and I 129 in dependence of integration time (world population $1 \cdot 10^{10}$) (from: HESEL et al., 1978)
wb=whole body

to the skin will thus be underestimated by a factor of 18. The collective dose which is of primarily importance for the potential health risk (cases of cancer a.s.o.) merits serious attention and should be reviewed worldwide in the interest of future generations.

7.) Conclusions

The following conclusions can be drawn:

1.) Recommendation and use of radioecological factors for calculating the behaviour of radionuclides in the environment should be limited. Fixing of factors, for example, in regulatory guides can lead to the neglect of the complexity existing in nature.

It is incorrect to represent the complexity and variation of nature by choosing such factors as are found in radioecological regulatory guides. An analysis of these guides shows on the contrary, that the assessment of many of the most important radioecological parameters is up to several orders of magnitude too optimistic. Thus, radiation doses calculated from these regulatory guides will be underestimated considerably.

2.) Major attention should be given to site-specific measurements of parameters for the transfer of radionuclides in the different ecological compartments, e.g. transfer factors plant/soil etc.

3.) Similar research is necessary in the field of physiological behaviour of most radionuclides, particularly for risk groups in population (the old and insane, the embryo etc.).

4.) Attention should also be given to nuclides not considered previously, e.g., Tc 99, Fe 55 etc. The longterm behaviour of radionuclides, e.g. Pu 239, which can be more easily taken up by plants owing to complexing in soil, should also be investigated.

5.) To evaluate the potential health risk for the world population by radioactive emissions from nuclear facilities, not only the individual radiation dose, but also the collective radiation dose should be reviewed.

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Errata

p.7 description of the ordinate: cancel "transfer factor"
description of the value SSK, 1977b instead of SSK, 1977

p.8 "leafy vegetables" instead of "leaf vegetables"

p.10 insert in description: (dimension: $\left[\frac{\text{pCi/kg plant, fresh weight}}{\text{pCi/kg soil, dry weight}}\right.$

p.12 16th line: Pu instead of Pa

p.17 description: cancel the word "human"

p.25 insert:

"Aknowledgement
Important parts of this work could be realized by financial support of the ministry of economics and technology of the state of Hessen, F.R.G. Further aknowledgements are given to many people who are not personally named."

p.30 add the following references:

BMI (Bundesminister des Innern), Allgemeine Berechnungsgrundlagen für die Strahlenexposition bei radioaktiven Ableitungen mit der Abluft oder in Oberflächengewässer Gemeinsames Ministerialblatt 30, Nr.21, 15.8.1979

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CANCER MORTALITY CHANGES AROUND NUCLEAR FACILITIES IN CONNECTICUT

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A detailed study of cancer statistics in Connecticut and nearby New England indicates that cancer mortality increased sharply around two large nuclear reactors in south-eastern Connecticut in direct relation to the measured pattern of accumulated levels of strontium-90 in the local milk. Cancer rates increased most strongly closest to the Millstone Nuclear Power Station located in Waterford where the measured strontium-90 levels reached their highest values, with lesser rises being observed for areas with lower values of strontium-90 in the milk located at increasingly greater distances in every direction away from the Millstone Plant, known to have released the largest amount of radioactive gases ever officially reported for any nuclear plant in the United States.(1)

The Haddam Neck plant started to operate in 1968 and the Millstone plant followed in 1970. Between this time and 1975, the most recent year for which detailed data are available, the cancer mortality rate rose 58% in Waterford where the most heavily emitting Millstone plant is located, 44% in New London five miles to the north-east, 27% in New Haven, 30 miles to the west, and 12% for the State of Connecticut as a whole. Rhode Island, whose border is only 20 to 30 miles east of these two plants rose 8%, Massachusetts some 70 miles to the north-east rose 7%, New Hampshire some 120 miles north-east rose only 1%, while for the State of Maine more than 200 miles in the same direction, the cancer death rate actually declined by 6% during the same period.(2)

Likewise, again following the pattern of decreasing strontium-90 in the milk, cancer mortality declined 1% for Vermont more than 200 miles to the north. Even for heavily polluted New York City located some 120 miles to the south-west, cancer mortality did not rise as one might have expected, but actually decreased by 2% between 1970 and 1975, despite the high levels of sulphur, carbon monoxide, automobile exhaust, heavy metals, cigarettes, organic chemicals, food-additives, pesticides and other types of pollutants.

An examination of the radiation doses received by the population drinking the milk in Waterford and nearby New London using the accepted methods recommended by the International Committee on Radiation Protection indicates that the accumulated doses to the bones of children over the period 1970 to 1975 reached values of about 640 millirads from the milk and other food produced in the area, and about 320 millirads to the bone-marrow.(3) This must be compared with a dose of some 2 millirads to the bone-marrow from a typical chest x-ray, so that the very radiation sensitive bone-marrow of children in the New London area received the equivalent of some 160 chest x-rays in the course of 6 years of their most sensitive period of growth and development.

The dose to the bone-marrow produced by strontium-90 from the milk and food of 320 millirems must also be compared with the dose of 1,200 millirems(4) found by Dr. Alice Stewart of Oxford University to have doubled the normal risk of leukemia and cancer for children who had received diagnostic x-ray exposures during their development in their mother's womb, and some 80 millirems for those irradiated in their first three months of intra-uterine development. Comparable doses have also recently been found to double the normal risk of cancer and leukemia among older atomic workers in a study by Drs. Thomas Mancuso, Alice Stewart and George Kneale as reported at recent Congressional Hearings and published in the November 1977 issue of the journal, "Health Physics". (5)

Since bone-marrow type of leukemia is well known from studies of the Hiroshima and Nagasaki A-Bomb survivors to be induced by radiation, and since measurements of the bones of both children and adults have shown a high correlation with levels of strontium-90 in the milk, one is led to conclude the probable existence of a direct causal relation between the abnormally high levels of strontium-90 in the milk near the two Connecticut Nuclear plants and the pattern of cancer changes in Connecticut and nearby New England.

This conclusion is further supported by the fact that the types of cancers that rose most strongly in the Connecticut area are exactly those types that have been found to be most sensitive to radiation in earlier studies as classified by the International Committee on Radiation Protection. Thus, the types of cancers that increased the most in the time available so far were cancers of the respiratory system, which rose 25%, breast cancers, which increased 12%, and cancers of the pancreas, which rose 32%. Since the peak of cancer mortality for respiratory cancers did not occur among the uranium miners until some 7 to 12 years after the onset of irradiation, it is to be expected that further rises in lung cancer will take place in the next five years.(6)(7)

Additional evidence that the pattern of sharply rising cancers in south-eastern Connecticut and nearby New England is likely to be due to the strontium-90 and other fission products that escaped from the Millstone and Haddam Neck Nuclear reactors comes from the fact that cancer deaths show a much greater rise for women than for men, consistent with the findings of Mancuso, Stewart and Kneale for atomic workers exposed to similarly low levels of radiation over a period of years. Thus, whereas cancer mortality rates in Connecticut increased by only 11% for white males between 1970 and 1975, the increase for white females was 17%.

Still another observation supports the conclusion that the sharp local rises in cancer in Connecticut are connected with the localized releases of airborne radioactivity from defects in the nuclear fuel, comes from the evidence that the increases were largest for those who were simultaneously exposed to the highest concentrations of other known cancer promoting pollutants, such as industrial chemicals, dust ,pesticides, sulfates, nitrous oxide and other air-pollutants, both in the area where they live and in the working place.

Such synergistic effects are well-known for the case of uranium miners, where the mortality due to lung cancer is some 5 to 10 times greater for miners who only inhaled the radioactive gases but did not smoke while the rate was 50 to 100 times greater for those who did.(6)

Thus, the combined action of airborne radioactivity and ordinary pollution would be greatest for those who live and work in the most polluted environments, who have the lowest socio-economic status and therefore also the poorest medical care, so that they do not receive the benefit of early diagnosis and treatment. It follows that such synergistic effects involving radioactive and other forms of pollution would be expected to affect most heavily the poorest portion of the population, and this is indeed found to be the case in Connecticut.

Thus, while the total number of cancer deaths increased 15% for the white population of the state as a whole, between 1970 and 1975, this number rose 51% for the non-white or predominantly black population.

Furthermore, in accordance with the greater airborne dust and pollution in chemical factories and other heavy manufacturing, mining and construction activities employing men, the greatest increase in the number of cancer cases during the time the radioactive gases were added to the existing pollutants took place for non-white males, namely by the very large amount of 77%. Thus, the observed pattern of cancer mortality changes in Connecticut and nearby New York and New England since the onset of airborne releases by the two large nuclear plants all fit the expected behavior for radiation - related cancers observed in numerous earlier animal experiments and large-scale epidemiological studies carried out over the last thirty years by many scientists all over the world.

Especially significant is the fact that the cancer increases in Connecticut following the rise of local strontium-90 levels occurred most strongly in those age groups which the recent studies of Milham[10] as well as Mancuso, Stewart and Kneale[5] had shown to have the greatest increases among the carefully monitored workers at Hanford, Washington. These were particularly the oldest workers, for whom the immune system is known not to be as effective in protecting against the proliferation of cancer cells as in the middle aged adult, just as in the case of the developing fetus and the young infant.

As shown in the accompanying table, whereas there was an overall increase in the cancer mortality rate per 100,000 population of 12%, after correcting for the change in age distribution, the cancer mortality rate for the 25 to 49 year old individuals actually declined 15%, presumably due to their much greater resistance to the effects of chronic irradiation on their immune defenses and the general improvement in environmental factors and medical care.[11]

On the other hand, there was an increase in cancer mortality rates for all older age groups, namely +4% for those 50 to 54 years old, +9% for those 55 to 64 years old, and +14% for those over 65 years at death, a pattern that fits the trend of the data for the atomic workers at Hanford found by the Milham and Mancuso studies.[5]

These findings help to explain why earlier observations on workers, x-ray technicians, and radiologists exposed to radiation indicated a much smaller hazard than is now emerging from studies of entire populations under normal peace-time conditions that include the unborn, the young and the very old. NOt only were most workers and radiologists in the least sensitive age group when they were exposed, but they were also receiving relatively brief exposures at considerably higher instantaneous dose-rates than individuals in the general population whose principal dose comes from very low dose, continuous exposure from inhaled or ingested radio-isotopes in their bones and other organs such as strontium-90.

Thus, the range of sensitivity can easily vary by a factor of 100 to 1000, depending on the age and the intensity of the radiation,[12] the effect per unit absorbed dose being most serious for very low-level, protracted environmental exposures to the developing fetus and the individual with reduced immune resistance over 65 years of age,[13] in agreement with the observations of Bross.[14]

This means that the most serious of all radiation exposures are not brief medical x-rays diagnostic isotope tests for the adult, but prolonged environmental exposures to fallout accumulating in the body from nuclear bomb-testing and releases from nuclear facilities acting slowly or the infant in utero, the young child and the oldest individuals in our society.

As a final test of this conclusion, it follows that the greatest effects on cancer rates in the general population during recent years should not be associated with medical x-rays or other environmental factors but with the releases from large nuclear facilities, especially since world-wide strontium-90 concentrations in the diet from bomb-tests have now declined to levels below those measured around these installations. This is supported not only by the findings around the Connecticut Reactors, but also by the pattern of strontium-90 levels and cancer changes around the nuclear fuel reprocessing facility at West-Valley, N. Y. [15]

Thus, one would expect that in general, the most recent unexplained upswing in U.S. cancer mortality rates should have taken place most strongly in the states that have large nuclear reactors and fuel reprocessing facilities within or close to their borders. At the same time, states that do not have such large nuclear facilities operating for more than five to six years should now show either much smaller increases in cancer rates, or manifest declines if strontium-90 and cesium-137 from fission processes play a key synergistic role with other carcinogens in the environment.

As can be seen from an inspection of Table 5 , this is indeed found to be the case. If one examines the rate of change of cancer mortality in the United States for every state during the most recent 3 year period for which, detailed data is available (1972-75), one finds that the greatest upward changes have taken place for the states that have the largest nuclear facilities such as Hanford (Washington), Oak Ridge (Tennessee), Savannah River (South Carolina), or that have nuclear reactors with known large releases in very densely populated areas such as near the Millstone boiling water reactor (Connecticut and Rhode Island) and the Oyster Creek Reactor in New Jersey, which is also of the boiling water (BWR) type.

In fact, according to the figures published annually in the U.S. monthly Vital Statistics Reports, above average rates of cancer increase in the U.S. occurred exactly in these states: Washington, +5.0%; Connecticut, +8.6%; Tennessee, +8.1%; Rhode Island, +8.0%; New Jersey, +5.7%; South Carolina, +5.4% compared with a U.S. average of +3.4% for this period.

On the other hand, cancer mortality rates actually declined during this same period most strongly in the four states having no nuclear facilities at all: Alaska, -10.6%; Montana, -4.4%; New Hampshire, -2.0%; and Hawaii, -1.5%. For Maine, which has only a single pressurized water reactor (PWR) operating since 1972, cancer rates declined 1.3%. Following the same pattern, Virginia with two recently completed PWR's declined somewhat less or by 1.1%.

But perhaps most significant is the fact that New York City, with two pressurized water reactors that emit fewer radioactive gases than the boiling water type located 30 miles north of the city showed a decline of 1.1% in cancer rates despite its enormous air-pollution and socio-economic problems, clearly supporting the conclusion that when large amounts of radioactive gas releases are missing from the mix of pollutants, the resulting effect on cancer and other chronic diseases is much less than when radioactive gases act synergistically with dust, chemicals, cigarettes and other air-pullutants in the environment.

Clearly, it is difficult to understand this striking pattern of cancer changes in any other way. When states that are as environmentally clean of ordinary air-pollutants as the State of Washington and MOntana are changing in opposite directions, one increasing by 5.0% while the other is decreasing by 4.4%, ordinary air and water pollution by itself can hardly be the crucial factor.

And when a heavily urbanized, densely populated and polluted area such a New York City declines in cancer rates compared to such rural, clean areas as the State of WAshington, the State of Tennessee, or the State of South Carolina, one cannot continue to put the principal blame on sulphur emissions from fossil fuel power-plants, automobile exhaust, drugs, food additives, hair-dyes, cosmetics, particulates, and medical x-rays for the present rise in the U.S. cancer rate without considering the role of radioactive releases.

The facts clearly show that the ordinary types of widely distributed, cancer causing agents cannot be the sole factors involved: they could not explain the highly localized cancer rises around Millstone, West-Valley, Hanford, Oak Ridge, and Savannah River, or the sharp declines in areas far from such sources of man-made radioactive wastes.

As difficult as it is for us to face the new facts that have now come to light as to the unexpectedly high sensitivity to prolonged low-level radiation exposure of some segments of our population, we cannot continue to risk the very survival of our nation on the hope that all these new findings will somehow be explained another way. Each year that we persist in closing our eyes to the new data, we will increase the total amount of Sr-90 accumulated in the soil and thus the biological damage to our newborn and the cancer risk for our older population. But if we should be able to accept these disturbing findings, then the evidence for the declining cancer rates in the least polluted areas of our country clearly points the way to the possibility of greatly reducing the risk of cancer and chronic disease in the years to come as we learn how to prevent the subtle damage from what we once believed were harmless levels of man-made and natural background radiation.

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9. See Reference 8.

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15. See Appendix II, Figures 1 and 2 for strontium-90 levels around West-Valley and cancer rate changes in the city of Olean, N. Y. located in Cattaraugus county 25 miles southeast of the N.F.S. facility, showing an increase by 95% in cancer rates peaking 9 years after start of large-scale releases of fission products. Similar patterns of high concentration of strontium-90 in the milk decreasing with distance away from the nuclear facility have also been found for the Trojan Nuclear Plant near Portland, Oregon, a pressurized water reactor completed in 1975 (see figures for June-July 1976 and 1977).

Table of Cancer Mortality Rates in Connecticut and New England Before and After Start-Up of the Mill-stone Nuclear Plant in Waterford, Connecticut

	Approx. Dist. From Millstone	Cancer Death Rate per 100,000 Population 1970	1975	Percent Change
Vermont	200m. NW	176.1	173.9	-1%
Connecticut	35m. NW*	168.1	188.4	+12%
New Haven, Conn.	30m. W	200.9	255.5	+27%
Waterford, Conn.	0	152.6	241.8	+58%
New London, Conn.	5m. E	177.4	255.0	+44%
Rhode Island	50m. NE	200.1	216.0	+8%
Massachusetts	70m. NE	185.0	198.4	+7%
New Hampshire	120m. NE	180.4	182.6	+1%
Maine	200m. NE	197.7	185.0	-6%
U.S.	—	162.0	171.7	+6%
NEW YORK CITY	120m. SW	220.9	216.4	-2%

*Population center of State of Connecticut (Hartford-Waterbury area)

Sources:

Connecticut Health Department, Registration Reports;

U.S. Monthly Vital Statistic Reports.

TABLE 1

TABLE 19—DEATH RATES PER 100,000 POPULATION FROM SELECTED CAUSES, CORRECTED FOR RESIDENCE, FOR TOWNS OF OVER 10,000 POPULATION: CONNECTICUT, 1970

TOWN	Tuberculosis All forms (010–019)	Syphilis (090–097)	Malignant neoplasms (140–209)	Diabetes mellitus (250)	Cardiovascular diseases (390–448)	Diseases of the heart (390–398, 402, 404, 410–429)	Rheumatic fever and rheumatic heart disease (390–398)	Hypertensive heart disease (402, 404)	Ischemic heart disease (410–414)
Column Number	1	2	3	4	5	6	7	8	9
CONNECTICUT	1.7	0.2	188.1	16.4	455.2	324.7	7.3	3.1	313.5
Fairfield County	2.2	0.1	172.9	17.9	446.7	333.0	5.9	2.4	309.7
Bethel	....	....	81.7	9.0	525.6	408.6	....	3.2	408.6
Bridgeport	5.1	....	220.0	25.9	608.9	450.4	10.9	2.0	426.8
Danbury	....	....	195.8	23.5	438.6	326.8	....	....	315.3
Darien	....	....	141.7	4.9	371.5	283.5	4.9	....	[illegible]
Fairfield	1.8	....	174.5	7.0	440.6	297.3	7.0	7.0	274.9
Greenwich	1.7	....	213.7	15.0	454.1	340.5	....	8.2	267.1
Monroe	8.2	....	106.7	8.2	123.1	82.3	....	....	73.3
New Canaan	....	....	165.2	17.1	455.7	279.1	5.7	....	207.1
Newtown	6.7	....	188.6	....	370.4	219.2	28.9	1.2	215.5
Norwalk	2.5	....	153.7	20.0	434.3	331.3	3.3	5.4	309.8
Ridgefield	....	....	59.7	5.4	280.3	[illegible]	....	....	268.1
Shelton	....	....	194.7	3.7	367.4	253.9	7.3	2.7	279.1
Stamford	3.7	....	149.3	18.3	449.6	341.6	9.2	4.0	316.8
Stratford	....	....	172.4	20.0	507.1	372.5	4.0	....	333.5
Trumbull	....	3.2	145.3	18.9	341.0	252.6	9.5	....	240.0
Westport	....	....	148.7	18.1	325.4	253.9	....	....	243.0
Wilton	....	....	91.8	7.3	335.5	269.9	....	....	255.3
Rest of County	....	....	109.7	5.5	223.1	178.2	....	....	167.2
Hartford County	1.5	0.4	166.6	15.9	424.0	307.6	3.1	4.2	287.5
Berlin	....	....	140.6	....	471.1	372.7	7.0	16.3	158.6
Bloomfield	....	....	190.0	32.6	358.3	228.0	....	3.9	206.3
Bristol	....	....	152.5	16.1	438.0	333.7	10.8	1.7	297.5
East Hartford	....	....	172.6	10.4	328.0	255.5	1.7	....	246.9
Enfield	....	....	99.3	2.2	282.4	183.1	2.2	....	174.3
Farmington	6.9	....	156.9	6.9	343.3	255.3	6.9	8.9	224.3
Glastonbury	4.3	....	144.2	9.6	302.8	201.9	....	9.5	201.9
Hartford	2.5	....	202.6	19.0	506.4	403.4	10.8	4.2	376.2
Manchester	....	....	180.0	41.5	415.4	252.4	10.4	....	214.7
New Britain	4.5	1.2	191.7	18.0	523.5	283.0	12.0	....	340.2
Newington	....	....	200.5	11.6	327.5	254.5	3.9	....	243.3
Plainville	5.9	....	184.3	5.9	439.9	344.3	5.9	....	326.9
Rocky Hill	....	....	176.4	58.8	401.8	323.4	....	11.3	313.6
Simsbury	....	....	79.3	17.0	232.2	164.2	....	6.4	141.6
Southington	8.4	....	112.4	12.8	269.7	192.6	6.4	....	176.6
South Windsor	....	....	82.9	....	254.7	171.9	6.4	2.9	105.6
West Hartford	....	1.5	184.8	11.7	573.5	415.1	[illegible]	3.7	388.7
Wethersfield	....	....	205.1	23.8	451.2	346.8	7.5	....	328.2
Windsor	....	....	190.0	25.6	336.6	224.7	8.9	6.6	285.9
Windsor Locks	....	....	98.9	6.6	383.9	203.7	6.6	3.9	250.5
Rest of County	....	2.0	130.1	15.8	321.3	234.0	9.9	....	212.9
Litchfield County	1.4	....	191.4	21.4	506.6	373.0	6.2	6.2	353.0
New Milford	....	....	176.1	6.8	467.5	305.9	6.8	6.8	352.1
Plymouth	....	....	222.1	48.3	444.2	357.3	....	....	328.3
Torrington	....	....	133.8	18.8	531.6	447.0	3.1	15.6	418.0
Watertown	....	....	123.0	25.7	390.3	278.0	....	....	273.0
Winchester	....	....	179.8	27.0	512.5	350.7	....	9.0	322.7
Rest of County	3.5	....	212.0	19.0	502.1	379.2	12.1	3.5	331.5
Middlesex County	0.9	....	158.9	9.7	469.7	305.2	9.7	3.5	340.7
Clinton	....	....	86.4	....	278.3	220.7	....	9.6	201.3
Middletown	....	....	169.2	14.1	502.2	378.0	11.3	2.8	340.8
Rest of County	1.5	....	161.6	8.3	482.1	380.7	10.3	4.4	357.1
New Haven County	1.3	....	179.5	16.7	516.1	387.0	10.5	2.1	364.7
Ansonia	....	....	221.8	23.6	542.6	358.6	14.2	4.7	339.7
Branford	4.9	....	199.6	....	457.6	345.7	4.9	9.7	[illegible]
Cheshire	....	....	196.2	15.9	355.3	270.5	5.3	....	250.0
Derby	....	....	206.2	15.9	570.9	420.3	23.8	....	280.6
East Haven	....	....	162.6	19.8	345.1	273.7	16.5	4.0	249.9
Guilford	....	....	136.6	33.0	428.5	238.4	[illegible]	....	271.9
Hamden	....	....	175.5	3.1	492.2	369.2	17.9	....	351.1
Meriden	....	....	164.3	17.9	582.0	419.6	7.8	....	401.7
Milford	3.9	....	162.5	[illegible]	469.8	318.4	13.0	....	335.7
Naugatuck	....	....	121.1	[illegible]	432.5	315.7	6.6	2.9	298.4
New Haven	2.0	....	200.2	28.4	597.7	469.6	9.2	....	445.8
North Branford	....	....	82.7	9.2	220.6	156.3	....	4.5	147.1
North Haven	4.5	....	187.9	4.5	344.5	288.5	7.3	7.3	216.1
Orange	....	....	153.0	14.7	416.9	307.7	....	7.8	278.4
Seymour	....	....	163.5	7.8	420.3	280.3	....	....	273.5
Wallingford	....	....	139.4	8.4	324.8	287.2	16.7	4.6	254.9
Waterbury	0.9	....	212.7	11.8	678.5	495.1	18.5	....	452.5
West Haven	....	....	189.4	17.0	594.3	462.2	5.7	....	443.1
Wolcott	....	....	113.0	23.8	214.5	158.9	7.9	....	151.0
Rest of County	2.0	....	160.6	12.5	415.1	325.4	8.3	....	312.9
New London County	0.9	....	139.0	15.3	420.5	285.8	2.6	3.1	270.6
East Lyme	....	....	133.9	....	351.3	254.7	8.3	....	237.1
Groton	....	....	85.2	5.2	268.9	191.0	....	....	185.2
Ledyard	....	....	67.6	....	138.3	94.7	....	....	94.7
Montville	....	....	82.0	....	245.9	201.8	....	....	105.5
New London	3.2	....	177.4	12.7	624.1	421.3	3.2	....	408.7
Norwich	2.4	....	210.5	31.5	527.4	348.4	2.4	7.3	324.2
Stonington	....	....	162.6	37.5	560.1	256.3	....	6.3	337.7
Waterford	....	....	152.6	17.6	428.6	238.3	....	11.7	210.7
Rest of County	....	....	130.8	16.4	429.9	301.4	7.0	2.3	278.0
Tolland County	1.0	....	125.5	6.8	301.8	214.2	3.9	1.0	203.5
Mansfield	....	....	91.8	5.4	183.5	140.3	....	....	129.5
Vernon	....	....	94.6	18.2	310.1	225.5	3.6	....	221.9
Rest of County	1.8	....	153.5	1.3	312.2	232.9	5.2	1.8	218.7
Windham County	4.7	....	162.5	13.0	541.7	367.4	13.0	3.5	340.4
Killingly	....	....	198.1	14.7	513.6	350.3	29.3	....	315.5
Plainfield	8.3	....	199.4	16.6	598.3	332.4	8.3	....	324.1
Windham	10.2	....	137.1	....	512.0	306.6	5.1	10.2	330.1
Rest of County	2.5	....	151.7	17.7	548.0	281.7	12.0	2.5	338.9

TOWN	Chronic endocardium and myocardial insufficiency (424, 428)	Cerebrovascular Disease (430–438)	Arteriosclerosis (440)	Pneumonia (480–486)	Emphysema (492)	Cirrhosis of liver (571)	Nephritis and nephrosis (580–584)	All accidents¹ (800–949)	Motor vehicle accidents¹ (810–823)
Column Number	10	11	12	13	14	15	16	17	18
CONNECTICUT	1.8	90.4	13.7	26.4	9.2	18.8	2.9	[illegible]	[illegible]
Fairfield County	2.9	84.3	13.5	23.4	8.2	19.5	9.1	[illegible]	[illegible]
Bethel	....	92.6	9.1	16.2	....	54.4	2.6	[illegible]	5.1
Bridgeport	0.6	113.7	17.3	35.2	10.9	33.6	....	[illegible]	[illegible]
Danbury	3.9	74.4	13.7	17.9	3.9	15.7	....	[illegible]	[illegible]
Darien	....	68.4	14.7	21.4	7.0	14.7	....	[illegible]	[illegible]
Fairfield	1.3	102.2	20.4	28.4	18.4	21.1	3.2	[illegible]	15.0
Greenwich	15.0	90.3	16.7	25.4	[illegible]	21.7	....	[illegible]	[illegible]
Monroe	....	16.4	16.4	[illegible]	[illegible]	....	....	[illegible]	[illegible]
New Canaan	....	119.6	22.5	[illegible]	....	6.7	6.7	107.1	25.9
Newtown	2.5	80.8	....	67.4	7.6	26.4	1.5	[illegible]	[illegible]
Norwalk	....	75.9	7.6	31.5	5.4	21.7	5.4	[illegible]	[illegible]
Ridgefield	....	32.5	....	5.4	....	[illegible]	....	29.4	[illegible]
Shelton	1.8	86.1	7.3	[illegible]	6.4	21.0	7.3	23.8	11.9
Stamford	6.0	81.5	11.9	14.0	12.0	18.0	6.0	33.0	14.0
Stratford	....	108.2	12.0	12.6	....	3.2	....	15.8	12.5
Trumbull	....	50.8	18.9	[illegible]	14.5	18.1	3.0	21.8	[illegible]
Westport	3.9	61.7	3.9	[illegible]	7.3	21.9	....	14.6	[illegible]
Wilton	[illegible]	65.6	....	24.7	11.0	11.0	....	11.0	2.7
Rest of County	2.7	41.1	....	....	....	....	....	[illegible]	[illegible]
Hartford County	0.9	88.9	11.5	26.3	10.4	19.7	2.9	32.5	13.0
Berlin	5.4	34.4	....	[illegible]	7.0	23.1	....	[illegible]	7.0
Bloomfield	1.8	97.7	10.9	16.3	5.3	5.4	3.6	[illegible]	[illegible]
Bristol	....	77.1	7.2	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
East Hartford	....	48.3	12.1	27.6	19.3	[illegible]	[illegible]	37.5	[illegible]
Enfield	....	94.9	4.4	30.9	[illegible]	[illegible]	....	[illegible]	[illegible]
Farmington	....	82.2	6.9	41.4	20.7	27.6	4.8	14.4	[illegible]
Glastonbury	....	51.7	9.6	9.6	4.8	....	[illegible]	41.5	[illegible]
Hartford	0.6	98.2	15.3	40.0	8.9	35.5	[illegible]	41.5	3.3
Manchester	....	124.6	24.9	16.6	10.6	4.2	[illegible]	15.4	10.3
New Britain	1.2	131.5	12.0	26.3	9.6	31.1	....	[illegible]	[illegible]
Newington	....	42.1	....	19.3	11.5	....	....	[illegible]	17.5
Plainville	9.8	65.4	11.9	23.5	11.5	17.8	9.6	[illegible]	58.5
Rocky Hill	....	88.6	....	29.4	9.3	9.8	....	[illegible]	14.0
Simsbury	....	51.0	....	22.7	[illegible]	....	3.2	[illegible]	9.6
Southington	....	48.2	12.8	12.8	12.8	19.2	....	[illegible]	....
South Windsor	....	[illegible]	6.1	19.1	19.1	12.7	1.5	19.1	....
West Hartford	3.7	121.3	10.1	23.7	10.3	10.3	3.7	25.1	[illegible]
Wethersfield	....	74.6	14.9	18.0	3.7	14.0	4.4	48.7	25.6
Windsor	....	88.4	13.3	31.0	31.0	17.7	6.0	46.1	[illegible]
Windsor Locks	2.0	105.5	13.2	....	....	25.1	2.0	31.3	[illegible]
Rest of County	....	69.0	3.9	11.8	7.9	9.9	....	[illegible]	21.7
Litchfield County	2.8	96.1	13.8	33.9	13.8	15.2	2.1	28.3	9.7
New Milford	....	81.3	....	17.4	6.8	13.6	....	27.1	20.3
Plymouth	9.7	67.9	9.7	19.3	9.7	19.3	....	9.7	....
Torrington	3.1	100.0	25.0	50.0	12.5	18.8	3.1	9.4	3.1
Watertown	....	69.5	21.4	10.7	5.3	....	....	10.7	5.3
Winchester	9.0	116.9	9.0	27.0	9.0	45.0	....	36.0	....
Rest of County	1.7	107.3	10.4	32.9	20.8	12.1	3.5	46.7	15.3
Middlesex County	4.4	38.0	6.1	28.5	8.3	21.1	0.9	57.4	27.2
Clinton	....	38.4	9.6	28.8	9.6	9.6	....	48.5	10.1
Middletown	3.5	112.8	2.8	31.0	8.6	35.7	....	53.8	31.0
Rest of County	2.9	79.4	7.3	[illegible]	10.3	14.7	1.5	60.3	25.5
New Haven County	0.9	97.9	13.8	23.6	7.8	18.3	3.1	31.4	15.0
Ansonia	....	146.3	18.9	42.5	14.2	23.6	9.4	4.7	....
Branford	....	73.0	24.3	19.5	4.9	4.9	4.9	34.7	19.5
Cheshire	7.9	53.3	....	[illegible]	....	....	....	[illegible]	[illegible]
Derby	....	118.9	15.9	55.5	....	15.9	....	23.3	7.0
East Haven	....	51.6	4.0	19.8	....	7.9	....	15.9	4.0
Guilford	....	90.6	24.7	33.0	[illegible]	....	....	90.6	90.6
Hamden	....	104.9	10.1	32.3	6.1	12.1	....	16.1	10.1
Meriden	....	133.9	12.5	21.4	5.4	22.1	5.4	30.1	[illegible]
Milford	....	78.3	19.6	23.5	3.9	13.7	3.9	39.1	[illegible]
Naugatuck	....	90.8	8.6	[illegible]	13.0	30.3	....	8.6	....
New Haven	....	97.6	12.4	28.4	6.6	12.6	2.2	30.6	8.0
North Branford	....	55.2	....	[illegible]	15.4	9.2	9.2	73.5	55.2
North Haven	4.5	62.6	....	[illegible]	4.5	8.3	....	[illegible]	[illegible]
Orange	....	102.6	14.7	29.3	7.3	....	7.3	29.3	[illegible]
Seymour	....	109.0	15.6	....	7.8	15.6	....	15.6	....
Wallingford	....	89.2	5.4	44.6	8.4	13.9	5.6	47.4	27.0
Waterbury	3.7	135.1	23.1	33.3	13.0	23.3	2.8	25.9	12.0
West Haven	....	107.9	11.4	15.2	5.7	11.4	1.9	28.4	[illegible]
Wolcott	....	31.3	15.9	31.3	15.9	23.9	7.9	39.7	[illegible]
Rest of County	2.1	50.1	18.8	22.9	12.5	4.2	6.3	54.2	[illegible]
New London County	1.3	101.1	15.7	27.5	9.2	17.0	3.9	48.3	[illegible]
East Lyme	....	70.3	17.6	26.3	....	8.8	....	26.3	8.8
Groton	....	51.8	5.2	[illegible]	7.7	15.3	2.6	[illegible]	31.0
Ledyard	....	20.3	6.8	6.3	....	6.3	....	20.3	13.5
Montville	6.3	37.3	6.3	6.3	18.9	18.9	6.3	[illegible]	12.6
New London	....	148.9	25.2	57.0	3.2	41.2	....	38.0	6.3
Norwich	2.4	145.2	19.4	29.0	14.5	16.9	12.1	50.3	14.3
Stonington	....	125.1	18.5	37.5	25.0	6.3	....	30.0	[illegible]
Waterford	....	115.0	23.5	5.9	5.9	5.9	11.7	[illegible]	47.0
Rest of County	2.3	105.1	16.4	30.4	7.0	14.0	....	[illegible]	42.1
Tolland County	....	63.3	11.7	33.1	8.8	10.7	1.0	40.9	[illegible]
Mansfield	....	32.4	....	18.2	5.4	....	5.4	54.0	[illegible]
Vernon	....	105.5	14.5	47.3	7.3	21.8	....	21.3	10.9
Rest of County	....	52.9	14.1	31.8	10.6	8.8	....	45.9	36.5
Windham County	....	108.3	44.8	18.5	13.0	21.2	3.5	64.3	36.5
Killingly	....	88.0	58.7	22.0	7.3	[illegible]	....	66.0	39.3
Plainfield	....	182.8	49.9	33.2	8.3	....	8.3	26.5	[illegible]
Windham	....	118.3	15.2	15.2	15.2	25.4	3.1	71.1	[illegible]
Rest of County	....	88.5	53.1	15.2	15.2	20.2	2.5	30.7	27.3

¹ Death rates from accidents for counties and towns are based on allocation to place of occurrence of accidents. Rates for Connecticut on this occurrence basis would be: All accidents, 33.9; Motor Vehicle accidents, 15.0.

TABLE I(a)

POOR ORIGINAL

TABLE 19—DEATH RATES PER 100,000 POPULATION FROM SELECTED CAUSES: CORRECTED FOR RESIDENCE FOR
TOWNS OF OVER 10,000 POPULATION: CONNECTICUT, 1973

TOWN	Tuberculosis All forms (010-019)	Syphilis (090-097)	Malignant neoplasms (140-209)	Diabetes mellitus (250)	Cardiovascular diseases (390-448)	Diseases of the heart (390-398, 402, 404, 410-429)	Rheumatic fever and rheumatic heart disease (390-398)	Hypertensive heart disease (402, 404)	Ischemic heart disease (410-414)	Chronic endocarditis and myocardial insufficiency (424, 428)	Cerebrovascular Disease (430-438)	Arteriosclerosis (440)	Pneumonia (480-486)	Emphysema (492)	Cirrhosis of liver (571)	Nephritis and nephrosis (580-584)	All accidents¹ (E800-E949)	Motor vehicle accidents¹
Column Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
CONNECTICUT	0.8	0.2	158.4	14.6	426.2	317.4	6.3	3.2	282.8	0.7	79.5	13.3	22.4	5.8	14.8	2.5	30.3	14.3
Fairfield County	0.7	0.2	190.9	15.1	414.7	304.[illegible]	[illegible]	3.5	276.[illegible]	1.1	81.9	11.0	21.2	[illegible]	14.3	2.3	[illegible]	[illegible]
Bethel	....	....	157.5	....	293.7	207.[illegible]	15.[illegible]	....	214.[illegible]	1.9	110.2	7.9	29.4	15.[illegible]	....	....	31.5	[illegible]
Bridgeport	1.2	....	207.2	21.1	[illegible]	412.8	7.9	2.0	282.9	1.2	101.6	[illegible]	30.3	7.2	17.8	3.9	25.2	[illegible]
Brookfield	....	....	173.[illegible]	....	333.[illegible]	211.[illegible]	17.9	....	187.5	....	71.[illegible]	....	....	....	25.8	....	17.[illegible]	[illegible]
Danbury	....	....	205.8	5.3	280.3	[illegible]	1.8	3.5	159.9	3.5	[illegible]	15.5	14.1	3.5	19.3	3.5	19.3	[illegible]
Darien	4.5	....	74.9	13.3	222.9	206.3	9.0	....	17.9	4.5	71.7	22.4	17.9	4.5	9.0	4.5	9.0	4.5
Fairfield	....	....	213.9	10.2	444.3	331.1	8.5	10.2	295.4	1.7	96.8	6.8	18.7	1.7	11.9	....	20.4	8.5
Greenwich	....	....	124.2	30.0	374.4	295.4	9.5	3.2	[illegible]	....	53.[illegible]	7.9	22.1	1.3	15.8	1.6	23.[illegible]	[illegible]
Monroe	....	....	138.5	7.7	248.2	169.2	....	....	169.2	....	61.5	....	15.4	15.4	15.[illegible]	....	[illegible]	[illegible]
New Canaan	....	....	170.1	10.3	314.4	221.6	5.2	....	201.0	....	[illegible]	5.2	15.5	....	15.5	....	[illegible]	[illegible]
Newtown	....	....	147.9	5.9	207.7	218.9	....	....	207.1	....	47.3	23.5	17.8	....	[illegible]	....	17.3	[illegible]
Norwalk	1.2	2.5	181.3	5.0	448.1	330.4	10.0	3.8	307.9	1.2	91.4	16.3	22.5	13.8	10.3	1.3	26.[illegible]	11.3
Ridgefield	....	....	132.0	10.2	218.3	177.7	10.2	10.2	147.2	....	30.5	10.2	25.4	....	10.[illegible]	....	10.[illegible]	5.1
Shelton	....	....	165.8	20.3	409.[illegible]	324.5	3.4	6.8	304.1	....	81.1	20.[illegible]	16.9	....	16.9	....	16.9	3.4
Stamford	1.8	....	191.1	16.6	434.0	317.6	13.9	2.8	282.5	....	93.3	12.9	20.3	7.4	16.6	1.8	33.[illegible]	14.8
Stratford	....	....	223.1	15.9	523.9	390.4	13.9	....	348.6	....	95.6	12.0	27.9	8.0	6.0	2.0	31.9	23.9
Trumbull	....	....	159.0	20.2	289.0	185.0	8.7	2.9	171.0	....	80.9	5.8	14.5	2.9	11.[illegible]	5.8	33.1	8.7
Westport	....	....	190.3	27.[illegible]	316.2	237.1	....	10.3	213.1	3.4	[illegible]	3.4	24.1	17.2	12.[illegible]	3.4	17.2	3.4
Wilton	....	....	149.7	12.0	281.4	173.7	....	....	161.7	....	101.[illegible]	....	....	....	12.0	6.0	29.9	24.0
Rest of County	....	....	137.1	9.3	229.9	171.3	....	3.1	105.1	....	46.7	18.7	9.3	9.3	3.1	3.1	15.6	9.3
Hartford County	1.0	0.1	186.4	12.4	413.8	299.9	5.1	3.3	277.9	0.5	81.8	13.9	23.0	5.2	15.0	1.8	30.9	15.0
Berlin	....	....	178.8	6.8	463.[illegible]	344.4	....	6.8	291.4	....	92.7	....	19.9	....	6.8	....	[illegible]	[illegible]
Bloomfield	....	....	173.[illegible]	34.7	316.5	252.[illegible]	5.0	....	232.6	....	34.7	5.0	....	....	9.9	....	30.0	19.8
Bristol	....	....	158.8	18.2	432.[illegible]	321.2	9.1	1.8	290.2	....	91.2	3.6	12.8	10.9	10.9	....	31.0	16.4
East Hartford	....	....	170.[illegible]	18.[illegible]	372.[illegible]	274.1	7.4	7.4	244.4	....	37.[illegible]	25.9	22.[illegible]	7.4	[illegible]	3.7	18.5	11.1
Enfield	....	....	124.4	11.1	228.9	206.7	6.7	2.2	186.7	....	55.9	4.4	20.0	....	11.1	4.4	40.0	31.1
Farmington	....	....	178.3	6.4	433.1	331.2	19.1	6.4	223.0	....	82.8	6.4	25.5	6.4	12.7	....	44.[illegible]	38.2
Glastonbury	....	....	103.4	4.3	262.9	185.3	4.3	8.6	163.8	....	51.7	12.9	8.6	....	8.6	4.3	17.2	17.2
Hartford	1.9	0.6	211.0	14.2	444.7	321.9	3.2	2.6	300.3	1.3	88.7	12.3	29.1	5.8	31.4	1.9	31.1	11.7
Manchester	4.2	....	[illegible]	21.2	487.2	347.3	6.4	12.7	309.3	....	91.1	31.8	33.9	10.6	16.9	....	40.3	16.9
New Britain	....	....	216.1	8.7	615.5	381.5	3.7	1.2	340.4	....	119.3	19.9	[illegible]	3.7	15.1	3.7	34.8	11.2
Newington	....	....	170.9	3.6	385.5	280.0	....	....	258.2	....	65.5	18.2	18.2	3.6	....	7.2	21.8	3.6
Plainville	....	....	178.6	6.0	369.0	273.8	....	....	261.9	....	65.5	....	6.0	....	23.8	....	17.0	6.0
Rocky Hill	....	....	252.2	9.0	414.4	189.4	9.0	....	351.4	....	27.0	18.0	18.0	9.0	27.0	9.0	45.0	36.0
Simsbury	....	....	78.[illegible]	....	223.9	144.3	....	5.0	139.3	....	74.6	....	19.9	....	14.9	....	24.9	19.9
Southington	3.0	....	153.8	11.8	340.9	275.1	....	5.9	257.4	....	59.2	3.9	20.7	....	3.0	....	37.[illegible]	5.9
South Windsor	6.3	....	201.3	25.2	213.8	144.7	6.3	....	119.5	....	37.7	12.6	....	....	12.6	....	[illegible]	18.9
West Hartford	....	....	247.1	11.8	567.6	402.9	8.8	1.5	385.3	1.5	117.6	14.7	32.4	5.9	16.2	....	30.9	11.8
Wethersfield	....	....	179.5	11.0	487.2	359.0	7.3	3.7	348.0	....	73.3	25.6	14.7	3.7	7.3	....	29.3	14.7
Windsor	....	....	159.0	4.2	389.1	263.6	4.2	....	255.2	....	83.7	16.7	37.7	8.4	12.6	....	25.1	12.6
Windsor Locks	....	....	193.1	6.9	379.3	255.2	6.9	....	241.4	....	75.9	34.5	6.9	6.9	20.7	....	20.7	20.7
Rest of County	[illegible]	[illegible]	182.[illegible]	7.3	[illegible]	[illegible]	[illegible]	1.9	[illegible]	1.9	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.9	[illegible]	[illegible]
Litchfield County	0.7	....	196.1	10.6	480.2	363.6	7.9	8.6	335.2	....	73.5	14.6	15.9	8.6	14.6	5.3	35.8	[illegible]
New Milford	....	....	117.2	....	393.1	327.2	8.2	....	314.8	....	49.4	....	8.2	....	....	8.2	24.7	[illegible]
Plymouth	....	....	111.1	18.5	388.9	287.0	....	....	259.3	....	74.1	18.5	27.8	18.5	18.5	9.3	9.3	[illegible]
Torrington	....	....	277.6	22.1	[illegible]	410.1	6.3	18.9	375.0	....	82.0	25.2	15.8	15.8	28.4	12.6	31.5	22.1
Watertown	....	....	145.1	10.4	403.2	310.9	20.7	10.4	274.6	....	57.0	15.5	5.2	5.2	....	5.2	46.6	25.9
Winchester	....	....	283.2	17.7	531.0	407.1	....	8.8	380.5	....	70.8	8.8	26.5	....	8.8	....	26.5	8.8
Rest of County	1.6	....	189.7	4.9	486.5	371.3	8.1	6.5	343.7	....	81.1	13.0	17.3	8.1	10.2	1.6	48.6	17.8
Middlesex County	1.7	....	163.2	15.0	461.3	348.9	5.8	3.3	[illegible]	1.7	84.1	17.5	21.6	10.0	19.2	5.0	[illegible]	17.5
Clinton	....	....	203.7	9.3	324.1	240.7	....	....	[illegible]	....	46.3	9.3	13.5	....	13.5	....	37.0	27.8
Middletown	....	....	139.3	10.5	431.3	323.7	5.3	2.3	[illegible]	....	91.9	[illegible]	8.4	10.5	26.2	5.3	23.1	11.1
Rest of County	2.7	....	168.9	13.6	495.9	374.6	6.8	4.1	354.2	2.7	85.6	25.9	23.6	6.3	10.9	5.4	35.4	19.1
New Haven County	0.8	0.1	205.8	16.6	466.8	360.1	7.7	2.2	323.7	0.2	79.3	11.8	24.7	5.6	15.2	2.6	27.6	14.0
Ansonia	....	....	232.3	5.0	400.1	371.3	19.8	5.0	316.5	....	69.3	39.6	24.8	9.9	5.0	....	24.7	19.8
Branford	4.7	....	206.6	....	268.1	174.2	....	....	166.2	....	84.5	....	14.1	....	9.4	....	23.5	9.4
Cheshire	4.7	....	137.4	9.5	312.8	232.2	9.5	....	203.8	....	61.6	9.5	28.4	9.5	9.5	....	47.4	14.2
Derby	....	....	200.5	33.6	445.4	369.7	....	8.4	336.1	....	50.4	....	25.2	8.4	....	....	16.8	8.4
East Haven	....	....	173.4	20.2	391.1	314.5	8.1	....	221.8	....	68.5	....	16.1	8.1	12.1	....	16.1	4.0
Guilford	7.0	....	118.9	7.0	342.7	279.7	7.0	....	216.8	....	42.0	....	21.0	....	....	....	[illegible]	21.0
Hamden	....	2.0	224.0	26.0	472.0	368.0	10.0	....	234.0	2.0	82.0	14.0	28.0	6.0	10.0	10.0	[illegible]	6.0
Madison	....	....	124.0	....	318.8	272.7	8.3	8.3	247.9	....	57.9	....	24.8	....	8.3	....	8.[illegible]	8.3
Meriden	1.8	....	211.4	19.5	522.2	380.1	8.9	3.6	289.5	....	120.8	8.9	21.3	[illegible]	19.5	1.8	25.6	10.7
Milford	....	....	179.7	21.5	396.5	296.9	2.0	....	287.1	2.0	68.4	9.8	23.4	2.0	17.6	3.9	23.4	11.7
Naugatuck	....	....	139.4	31.9	466.1	354.6	4.0	....	342.6	....	87.6	19.9	19.9	8.0	19.9	8.0	31.9	12.0
New Haven	1.5	....	253.5	24.2	531.4	414.2	7.6	3.0	390.2	....	85.4	15.1	37.0	11.3	16.6	2.3	28.0	13.6
North Branford	....	....	156.5	8.7	234.8	200.0	26.1	....	113.0	....	26.1	....	....	....	....	....	....	....
North Haven	....	....	213.0	4.3	326.1	269.6	8.7	....	191.3	....	56.5	3.7	8.7	4.3	13.0	....	4.3	4.3
Orange	....	....	145.7	13.2	337.4	205.3	6.6	....	178.8	....	39.3	13.2	6.6	....	13.2	6.6	19.9	13.2
Seymour	....	....	223.9	22.4	477.6	350.7	7.5	....	328.4	....	111.9	14.9	14.9	....	7.5	....	37.3	22.4
Southbury	....	....	271.8	....	502.2	446.6	48.5	....	388.3	....	77.7	....	19.4	9.7	....	....	77.7	18.5
Wallingford	....	....	165.7	17.1	505.7	391.4	11.4	2.9	320.0	....	102.9	....	42.9	8.6	17.1	2.9	31.4	20.0
Waterbury	....	....	230.0	11.4	535.8	397.7	7.0	6.1	369.6	....	91.3	13.4	18.4	5.3	22.8	1.8	28.3	14.0
West Haven	....	....	205.6	13.0	503.7	416.7	3.7	....	311.1	....	53.7	18.5	20.6	1.9	18.5	3.7	25.9	11.1
Wolcott	....	....	160.3	22.9	282.4	251.9	....	....	228.6	....	30.5	....	30.5	....	38.2	....	61.1	38.2
Rest of County	....	....	156.5	8.7	379.1	255.1	2.9	....	220.3	....	58.0	8.7	20.3	5.8	5.8	2.9	37.7	26.1
New London County	0.8	....	166.9	14.6	403.6	292.2	7.1	3.8	265.0	1.7	80.6	12.5	24.2	5.0	15.0	2.5	33.4	15.4
East Lyme	....	....	139.5	31.0	434.1	294.6	31.0	15.5	201.6	7.8	85.3	15.5	23.3	7.8	23.3	....	23.3	15.5
Groton	....	....	103.4	21.7	257.5	181.6	13.6	2.7	157.2	....	59.6	8.1	16.3	2.7	8.1	2.7	19.0	8.1
Ledyard	....	....	63.7	6.4	114.6	82.8	....	....	70.1	....	25.5	6.4	6.4	....	....	....	41.8	31.8
Montville	....	....	86.4	12.3	216.0	135.8	....	....	111.1	....	55.6	6.2	6.2	6.2	6.2	6.2	18.5	12.3
New London	....	....	255.0	3.3	635.8	486.8	3.3	....	460.3	....	102.6	16.6	33.1	6.6	19.9	3.3	33.1	6.6
Norwich	....	....	188.[illegible]	20.2	501.1	382.0	11.2	6.7	350.6	2.2	78.4	22.5	42.7	2.2	22.7	4.5	38.2	11.2
Stonington	....	....	[illegible]	11.9	446.4	297.6	....	6.0	273.8	6.0	119.0	....	17.9	6.0	11.9	....	35.7	11.9
Waterford	....	....	[illegible]	5.5	494.5	307.7	....	....	231.[illegible]	....	142.9	22.0	16.5	11.0	11.0	....	16.5	16.5
Rest of County	3.3	....	121.1	11.5	299.5	224.2	3.3	1.6	200.5	1.6	58.9	1.6	19.6	4.0	6.5	1.6	36.0	21.3
Tolland County	0.9	....	142.5	13.9	254.4	189.7	1.9	0.9	177.6	0.9	40.7	13.0	17.6	4.6	7.4	1.9	29.6	11.8
Mansfield	....	....	94.4	11.1	133.3	116.7	5.6	....	111.1	....	11.1	....	11.1	5.6	....	....	33.3	[illegible]
Stafford		....	220.0	20.0	160.0	220.0	....	....	220.0	....	70.0	30.0	30.0	20.0	10.0	10.0	30.0	[illegible]
Vernon	....	....	149.3	10.4	298.6	201.4	....	....	191.0	....	69.4	13.9	20.8	3.5	10.4	....	20.8	[illegible]
Rest of County	1.0	....	128.4	15.6	251.5	200.6	1.9	1.0	185.2	1.9	29.2	13.6	11.7	1.9	7.8	1.0	33.1	[illegible]
Windham County	....	1.1	197.0	23.4	489.8	381.8	7.8	1.1	361.8	1.1	79.0	11.1	25.6	4.5	20.0	2.2	49.0	25.6
Killingly	....	6.7	153.3	53.3	573.3	440.0	20.0	....	406.7	....	80.0	26.7	20.0	6.7	13.3	....	60.0	26.7
Plainfield	....	....	213.1	16.4	491.8	385.2	16.4	....	360.7	....	65.6	10.4	16.4	....	8.2	8.2	32.8	32.8
Windham	....	....	220.6	9.8	514.7	411.8	4.9	4.9	387.3	4.9	73.5	9.8	19.6	4.9	34.3	....	73.4	39.2
Rest of County	....	....	190.5	21.3	447.4	345.6	2.4	....	333.3	....	85.2	4.7	33.1	4.7	18.9	2.4	35.5	16.6

¹ Death rates for residence accident total and motor vehicle.

TABLE I(b)

POOR ORIGINAL

STATE DEPARTMENT OF HEALTH

REGISTRATION REPORT

CANCER INCREASE IN CONNECTICUT 1970-75

BY SITE AND KNOWN RADIATION SENSITIVITY

	Increase in %	Increase in No.	Fraction of Incr. No.	ICRP Radiation Sensitivity
All Sites Combined	+12%	793	100%	---
Respiratory System	+25%	292	37%	HIGH
Breast Cancer	+12%	127	16%	Not Class.
Digestive System	+6%	155	20%	HIGH
Pancreas	+32%	84	11%	HIGH
L-Intest.	+11%	71	9%	HIGH

Source: Connecticut Annual Registration Reports

TABLE 2

TABLE XVII—DEATHS AND DEATH RATES PER 100,000 POPULATION FROM MALIGNANT NEOPLASMS, ACCORDING TO SITE: CONNECTICUT, 1966–1975

Site of Disease (International List, Eighth Revision 1967)	1975	1974	1973	1972	1971	1970	1969	1968	1967	1966
Total (140–209)	5909	5691	5474	5388	5185	5116	5102	5017	4818	4677
Digestive organs and peritoneum (150–159)	1777	1736	1600	1687	1562	1622	1516	1573	1556	1535
Respiratory system (160–163)	1284	1185	1173	1102	1024	992	953	920	823	814
Breast (174)	595	552	532	528	534	468	530	481	449	455
Lymphatic and Hematopoietic system (200–209)	541	535	529	504	508	513	530	452	433	395
Female genital organs (180–184)	320	324	319	296	328	353	320	332	353	291
Male genital organs (185–187)	286	254	296	240	266	246	243	223	217	231
Urinary system (188–189)	274	269	263	267	230	231	223	254	240	264
Buccal cavity and pharynx (140–149)	149	150	126	139	150	131	147	158	122	129
Brain, spinal cord, meninges, and eye (190–192)	149	144	120	124	136	127	139	95	98	80
Skin (172–173)	73	75	64	60	60	53	67	71	61	61
Soft tissue (171)	38	36	29	37	23	27	31	46	38	28
Bone, including jawbone (170)	19	32	29	22	26	27	29	23	33	20
Endocrine glands (193–194)	23	26	18	23	24	26	21	15	14	22
Other and unspecified sites (195–199)	381	379	376	359	314	300	351	369	379	348
	Rate per 100,000 population									
Total (140–209)	188.4	182.3	176.1	174.4	169.3	168.1	169.1	169.2	164.5	162.7
Digestive organs and peritoneum (150–159)	56.6	55.4	51.5	54.6	51.0	53.3	50.2	53.2	53.1	53.4
Respiratory system (160–163)	40.9	38.0	37.7	35.7	33.4	32.6	31.6	31.0	28.1	28.3
Breast (174)	19.0	17.7	17.1	17.1	17.4	15.4	17.6	16.2	15.3	15.8
Lymphatic and hematopoietic system (200–209)	17.2	17.1	17.0	16.3	16.5	16.9	17.6	15.2	14.9	13.7
Female genital organs (180–184)	10.2	10.4	10.3	9.6	10.7	11.6	10.6	11.2	12.0	10.1
Male genital organs (185–187)	9.1	8.1	9.5	7.8	8.7	8.1	8.1	7.5	7.4	8.0
Urinary system (188–189)	8.7	8.6	8.5	8.6	7.5	7.6	7.4	8.6	8.2	9.2
Buccal cavity and pharynx (140–149)	4.7	4.8	4.1	4.5	4.9	4.3	4.9	5.3	4.2	4.5
Brain, spinal cord, meninges, and eye (190–192)	4.7	4.6	3.9	4.0	4.4	4.2	4.6	3.2	3.3	2.8
Skin (172–173)	2.3	2.4	2.1	1.9	2.0	1.7	2.2	2.4	2.1	2.1
Soft tissue (171)	1.2	1.2	0.9	1.2	0.8	0.9	1.0	1.6	1.3	1.0
Bone, including jawbone (170)	0.6	1.0	0.9	0.7	0.8	0.9	1.0	0.8	1.1	0.7
Endocrine glands (193–194)	0.7	0.8	0.6	0.7	0.8	0.9	.7	0.5	0.5	0.8
Other and unspecified sites (195–199)	12.1	12.1	12.1	11.6	10.3	9.8	11.6	12.5	12.9	12.1

TABLE 2(a)

INCREASE IN NUMBER OF

CANCER DEATHS IN CONNECTICUT - 1970-75

AFTER START OF MILLSTONE POINT NUCLEAR PLANT IN 1970

	Total No.	No. White	No. Non-Wh.	Population(Million)
1970	5197	5005	192	3.044
1975	6001	5711	290	3.137
PERCENT INCREASE	+16%	+14%	+51%	+3%

Source: Table 10, State of Connecticut, Department of Health Annual Register Reports

TABLE 3

RELATIVE EFFECT OF RADIOACTIVE

RELEASES ON CANCER DEATHS IN

DIFFERENT AGE GROUPS IN CONNECTICUT

1970 - 1975

AGE	20-24 yrs	25-49 yrs	50-54 yrs	55-64 yrs	65 + yrs	All AGES
Number in 1970	20	540	412	1207	2929	5197
Number in 1975	23	486	422	1439	3559	6001
% Change in cancer deaths	+15%	-10%	+2%	+19%	+22%	+15%
Change in Pop.	+15%	+5%	-2%	+10%	+8%	+3%
Net Change in cancer rate	0%	-15%	+4%	+9%	+14%	+12%
% of all Cancer Deaths in 1975	0.4%	8%	7%	24%	59%	----

(Source: Connecticut Annual Registration Reports)

TABLE 4

RECENT CHANGES IN U. S.

CANCER MORTALITY RATES 1972-75

IN STATES WITH AND WITHOUT

LARGE NUCLEAR RELEASES

AREA	% CHANGE	NUCLEAR FACILITY
Connecticut	+8.6%	Millstone and Haddam Neck
Tennessee	+8.1%	Oak Ridge
Rhode Island	+8.0%	Millstone and Haddam Neck
New Jersey	+5.7%	Oyster Creek (BWR)
S. Carolina	+5.7%	Savannah River
Wash. State	+5.0%	Hanford
U. S. Average	+3.4%	----
N. Y. City	-1.1%	2 PWR (1962;73)
Virginia	-1.1%	2 PWR (1972;73)
Maine	-1.3%	1 PWR (1972)
Hawaii	-1.5%	No Nuclear Reactor
New Hampshire	-2.0%	No Nuclear Reactor
Montana	-4.4%	No Nuclear Reactor
Alaska	-10.6%	No Nuclear Reactor

Source: U.S. Monthly Vital Statistics

TABLE 5

Table 5. DEATHS AND DEATH RATES FOR MAJOR CAUSES OF DEATH FOR THE UNITED STATES, EACH REGION, DIVISION AND STATE; BY COLOR AND SEX FOR THE UNITED STATES: 1977

[By place of residence. Refers only to resident deaths occurring within the United States. Excludes fetal deaths. Rates per 100,000 estimated population in each color-sex group and area. Numbers after causes of death are category numbers of the Eighth Revision, International Classification of Diseases, Adapted, 1965]

Color, sex, and area	Diseases of heart (390-398,402,404, 410-429)		Malignant neoplasms, including neoplasms of lymphatic and hematopoietic tissues (140-209)		Cerebrovascular diseases (430-438)		All accidents (E800-E949)		Motor vehicle accidents (E810-E823)	
	Number	Rate	Number	Rate	Number	Rate	Number	Rate	Number	Rate
United States	725,384	343.0	365,513	168.0	212,344	102.5	115,448	55.4	56,278	27.0
Male	424,634	418.5	188,474	185.7	95,300	94.0	79,752	78.6	40,134	39.5
Female	332,133	310.3	157,114	147.2	117,944	110.5	35,696	33.4	16,084	15.1
White	654,762	374.2	309,336	170.0	187,350	103.0	98,225	54.0	48,754	26.8
Male	365,602	434.1	167,579	188.7	83,210	93.6	67,100	75.8	34,506	38.0
Female	290,180	321.0	141,558	152.2	104,140	112.0	31,036	33.4	14,108	15.3
All other	71,462	271.5	36,382	138.2	25,394	99.7	17,222	65.4	7,514	28.5
Male	38,832	308.4	20,736	165.2	12,170	96.6	12,572	99.8	5,628	44.7
Female	32,650	237.6	15,586	113.4	13,814	100.6	4,650	33.8	1,886	13.7
Regions:										
Northeast	208,024	414.3	93,636	190.4	47,510	95.5	20,516	41.3	9,226	18.5
North Central	220,150	383.8	96,342	187.8	61,169	107.4	30,475	53.4	14,160	25.1
South	224,154	344.7	103,210	158.8	72,124	111.0	42,392	65.2	21,458	33.0
West	103,125	292.0	52,370	145.3	31,544	88.6	21,686	60.7	10,436	29.5
NORTHEAST										
New England	45,893	379.1	22,490	183.8	12,138	99.6	5,328	44.0	2,194	18.1
Maine	4,628	443.9	1,924	187.3	1,206	115.8	558	54.1	222	21.5
New Hampshire	2,752	355.8	1,440	158.0	890	115.0	348	45.0	160	20.7
Vermont	1,634	368.1	768	157.0	432	93.9	208	45.2	100	21.7
Massachusetts	22,734	302.6	11,032	190.3	5,754	99.3	2,794	48.0	1,110	19.2
Rhode Island	4,094	422.5	1,938	200.0	878	90.6	360	37.2	134	13.3
Connecticut	9,989	324.5	5,328	174.3	2,905	94.6	1,068	34.7	470	15.1
Middle Atlantic	152,164	425.7	71,208	199.3	35,474	94.2	15,183	40.4	7,028	18.7
New York	77,034	418.6	34,352	190.3	16,442	89.7	6,930	37.7	3,242	17.7
New Jersey	23,811	403.7	13,842	184.8	6,456	87.8	2,720	39.7	1,204	17.5
Pennsylvania	53,236	447.7	22,372	190.4	12,516	105.1	5,328	44.8	2,432	20.9
NORTH CENTRAL										
East North Central	155,129	380.4	67,478	165.4	41,223	101.1	20,310	49.8	9,828	24.1
Ohio	40,446	377.2	18,086	168.4	10,375	102.6	5,234	48.8	2,460	22.9
Indiana	18,802	355.5	8,442	150.1	6,034	114.3	2,333	55.6	1,500	28.4
Illinois	46,034	425.5	19,438	173.3	11,334	100.8	5,222	46.5	2,394	21.2
Michigan	30,525	333.5	14,730	158.2	7,939	85.7	4,590	50.0	2,359	26.2
Wisconsin	17,226	380.8	7,320	163.3	4,366	107.5	2,322	51.0	1,128	24.9
West North Central	65,182	392.1	28,666	173.7	20,434	122.3	10,166	62.4	5,132	30.3
Minnesota	12,133	337.6	6,252	161.1	4,410	115.7	2,258	59.0	1,072	27.7
Iowa	12,128	420.9	5,118	177.5	3,648	126.5	1,740	60.3	928	32.2
Missouri	20,194	425.4	9,024	189.1	6,274	132.2	2,938	61.8	1,468	30.9
North Dakota	2,182	339.4	886	133.7	782	118.9	432	67.6	190	30.0
South Dakota	2,778	397.9	1,112	155.5	700	119.4	758	112.9	304	44.7
Nebraska	6,288	396.3	2,712	177.5	2,018	131.0	942	61.5	484	31.7
Kansas	8,830	380.0	3,982	174.3	2,622	115.6	1,252	55.6	636	30.2
SOUTH										
South Atlantic	111,286	348.9	52,010	163.1	34,284	107.4	20,394	63.9	10,210	32.0
Delaware	2,124	372.0	894	158.1	434	76.4	264	46.0	132	25.1
Maryland	13,188	325.9	6,386	157.8	2,562	63.3	1,762	43.5	810	20.0
District of Columbia	2,582	339.4	1,554	204.0	702	93.4	446	59.0	112	14.3
Virginia	14,773	310.1	7,240	151.9	4,188	91.6	2,742	57.3	1,058	22.6
West Virginia	8,148	453.9	3,302	183.1	2,200	123.1	1,290	71.9	580	31.2
North Carolina	18,984	323.4	7,020	134.0	5,908	111.2	3,996	71.7	2,002	38.3
South Carolina	8,418	312.2	3,456	128.6	2,394	111.1	2,004	74.6	1,042	39.5
Georgia	14,899	310.5	6,386	134.0	5,940	123.5	3,250	77.6	1,604	33.8
Florida	30,596	416.6	15,410	212.2	9,175	128.3	4,628	63.0	2,420	32.9
East South Central	47,234	359.9	20,683	157.1	17,082	129.6	9,324	70.8	4,844	36.8
Kentucky	13,400	408.2	5,678	172.4	4,046	122.4	2,224	67.3	1,112	33.8
Tennessee	14,890	364.7	6,156	150.4	5,254	129.3	2,570	65.6	1,339	34.3
Alabama	11,234	320.5	5,360	153.0	4,700	133.5	2,606	74.0	1,380	39.2
Mississippi	7,700	345.3	3,444	152.8	3,132	135.3	1,826	80.3	954	42.3
West South Central	65,634	327.9	30,452	152.6	20,983	105.0	12,684	63.5	6,404	32.0
Arkansas	8,006	398.7	3,462	172.3	2,944	146.6	1,508	75.1	755	37.6
Louisiana	12,525	333.6	5,702	153.5	3,723	99.7	2,376	63.6	1,102	29.5
Oklahoma	10,128	353.3	4,468	159.7	3,760	123.1	1,700	64.6	805	30.6
Texas	34,886	298.6	16,739	144.0	11,276	95.4	7,398	61.2	3,740	32.2
WEST										
Mountain	22,897	255.5	10,742	121.0	6,510	73.6	6,570	74.0	3,384	38.1
Montana	2,289	319.6	1,170	123.6	682	95.3	642	89.7	330	46.0
Idaho	2,214	291.9	990	127.2	633	90.1	704	33.2	310	41.1
Wyoming	1,148	325.7	432	124.9	392	114.6	314	91.0	174	50.3
Colorado	6,118	268.4	2,768	117.1	1,540	69.4	1,290	58.8	712	30.1
New Mexico	2,186	192.0	1,174	110.1	700	65.1	962	89.4	504	46.8
Arizona	5,082	237.0	2,574	121.1	1,290	65.7	1,444	73.6	779	33.6
Utah	2,403	219.0	1,002	89.9	728	65.3	732	42.1	380	31.1
Nevada	1,225	250.0	732	137.1	418	78.4	408	76.5	208	39.0
Pacific	62,526	303.9	41,928	152.2	25,334	83.1	15,236	56.1	7,250	25.7
Washington	11,274	324.0	5,340	150.7	3,124	102.0	1,958	57.1	830	24.0
Oregon	7,410	330.6	3,518	151.0	2,518	115.1	1,273	63.1	750	34.5
California	61,133	308.4	31,426	155.1	18,908	92.5	12,404	55.3	5,440	23.7
Alaska	310	95.4	220	67.7	78	24.0	275	84.3	78	22.0
Hawaii	1,402	171.4	688	103.5	366	45.1	280	34.3	142	17.4

TABLE 5 (a)

POOR ORIGINAL

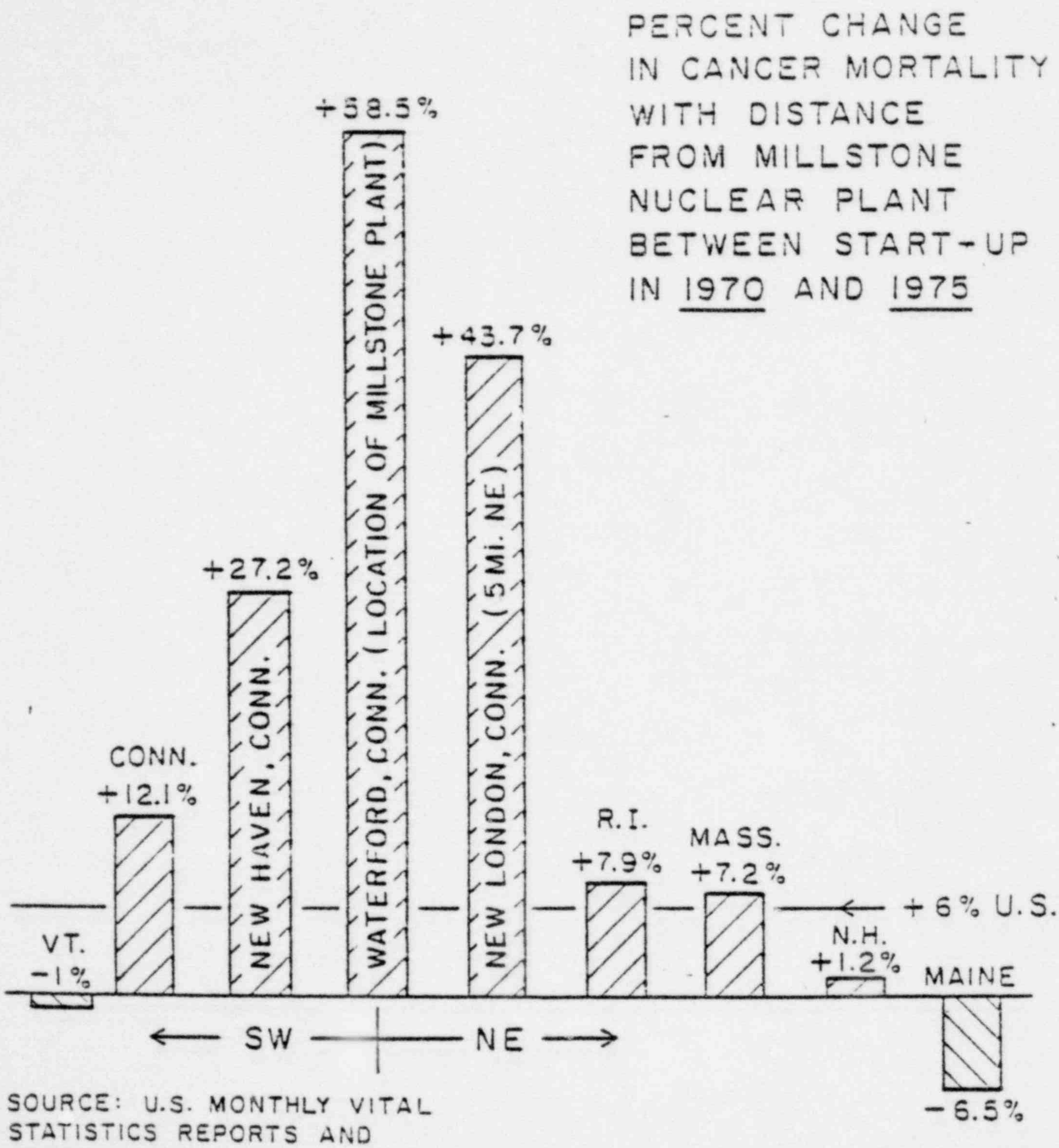
Table 5. DEATHS AND DEATH RATES FOR MAJOR CAUSES OF DEATH FOR THE UNITED STATES, EACH REGION, DIVISION, AND STATE; AND BY COLOR AND SEX FOR THE UNITED STATES: 1975

[By place of residence. Refers only to resident deaths occurring within the United States. Excludes fetal deaths. Rates per 100,000 estimated population in each color-sex group and area. Numbers after causes of death are category numbers of the Eighth Revision, International Classification of Diseases, Adapted, 1965]

Color, sex, and area	Diseases of heart (390-398, 402, 404, 410-429)		Malignant neoplasms, including neoplasms of lymphatic and hematopoietic tissues (140-209)		Cerebrovascular diseases (430-438)		All accidents (E800-E949)		Motor vehicle accidents (E810-E823)	
	Number	Rate	Number	Rate	Number	Rate	Number	Rate	Number	Rate
United States	716,215	336.2	365,693	171.7	194,038	91.1	103,030	48.4	45,853	21.5
Male	399,575	385.2	199,443	192.3	84,296	81.3	72,378	69.8	33,597	32.4
Female	316,711	289.7	166,250	152.1	109,722	100.4	30,624	28.0	12,256	11.2
White	643,737	350.0	325,513	176.8	170,689	92.2	87,760	47.4	39,333	21.5
Male	342,416	401.1	176,128	194.8	73,318	81.1	61,186	67.7	29,392	32.2
Female	285,421	301.3	149,411	157.7	97,371	102.8	26,574	28.0	10,791	11.4
All other	66,173	244.4	40,174	144.0	23,349	83.7	15,270	54.7	5,970	21.4
Male	35,885	277.1	23,335	173.3	10,968	82.4	11,180	84.1	4,505	33.9
Female	31,293	214.7	16,839	115.5	12,381	84.9	4,090	28.0	1,465	10.0
Regions:										
Northeast	189,274	382.7	96,347	196.0	41,633	84.2	18,240	36.9	7,631	15.4
North Central	273,575	352.9	99,790	171.3	54,628	95.1	26,172	45.4	11,533	20.0
South	219,275	321.9	112,001	164.4	66,394	94.2	38,079	55.9	17,612	25.9
West	104,151	275.0	57,635	152.2	30,650	87.9	20,533	54.2	9,774	24.0
NORTHEAST										
New England	43,287	354.0	23,716	194.4	10,579	86.7	4,316	33.5	1,335	15.4
Maine	4,127	389.7	1,853	186.0	1,044	99.3	524	49.5	225	21.2
New Hampshire	2,538	310.3	1,434	182.6	782	95.6	355	43.4	153	19.4
Vermont	1,671	354.3	812	173.9	387	82.2	233	49.9	106	22.5
Massachusetts	21,263	384.5	11,364	198.4	5,103	87.7	2,400	41.2	920	15.9
Rhode Island	3,876	410.5	2,032	215.0	761	82.1	310	33.4	135	14.6
Connecticut	9,972	319.9	5,373	189.0	2,421	80.5	999	32.0	441	14.2
Middle Atlantic	145,987	391.4	73,231	194.5	31,028	83.3	13,421	36.0	5,479	15.1
New York	69,581	392.9	35,220	194.1	13,946	77.0	5,626	32.3	2,270	12.1
New Jersey	27,146	373.4	14,285	195.5	6,392	90.0	2,549	34.6	1,107	15.1
Pennsylvania	49,261	418.0	23,615	198.0	11,283	91.2	5,201	43.8	2,103	15.2
NORTH CENTRAL										
East North Central	142,978	346.7	63,460	159.5	36,360	90.1	17,588	42.6	7,632	18.6
Ohio	37,318	361.5	18,326	175.0	9,560	92.6	4,220	41.3	1,733	16.1
Indiana	17,966	332.6	8,391	181.3	5,438	103.3	2,570	43.4	1,157	21.8
Illinois	43,148	387.2	19,871	179.3	9,334	83.4	4,538	41.5	1,941	17.4
Michigan	28,246	309.6	14,462	159.2	7,286	79.5	3,931	43.5	1,849	20.2
Wisconsin	15,330	345.3	7,400	156.8	4,054	84.5	2,020	43.9	952	20.7
West North Central	60,027	363.1	29,420	177.5	17,910	107.4	8,614	51.5	3,971	23.4
Minnesota	12,412	316.1	6,182	181.9	3,494	99.2	1,865	47.5	799	20.1
Iowa	11,048	384.9	5,259	186.7	3,225	112.4	1,454	50.7	696	24.3
Missouri	18,883	392.4	9,113	191.3	5,325	111.8	2,483	51.0	1,106	23.2
North Dakota	2,120	340.0	822	165.2	579	91.2	420	64.6	176	27.7
South Dakota	2,536	371.0	1,128	163.7	715	104.3	431	63.1	214	31.3
Nebraska	5,510	359.4	2,737	179.3	1,712	110.9	864	55.8	387	25.0
Kansas	8,244	368.1	3,389	175.4	2,464	108.7	1,161	51.2	533	23.5
SOUTH										
South Atlantic	110,215	325.3	55,315	163.3	31,237	92.7	17,768	52.7	8,794	26.0
Delaware	1,955	337.7	933	161.5	348	60.1	239	41.1	128	22.1
Maryland	12,117	302.0	6,302	156.4	2,103	58.4	1,563	39.1	701	17.1
District of Columbia	2,173	303.6	1,563	218.3	554	79.8	312	43.7	94	13.1
Virginia	14,397	293.8	7,463	150.3	3,919	73.3	2,528	50.8	1,027	20.9
West Virginia	7,760	430.4	3,373	183.2	1,331	101.3	1,049	58.2	453	25.1
North Carolina	15,616	304.4	7,364	143.9	5,247	96.3	3,263	59.9	1,579	29.0
South Carolina	8,121	297.7	3,820	135.0	2,726	96.7	1,662	59.0	821	29.1
Georgia	14,401	292.5	6,331	134.7	5,135	104.3	2,905	59.0	1,404	28.5
Florida	31,976	381.3	18,247	213.5	9,771	108.5	4,247	51.3	1,827	22.1
East South Central	45,379	335.2	22,133	165.1	15,717	116.0	8,188	60.3	3,751	27.7
Kentucky	12,751	375.5	5,957	175.7	3,841	113.1	1,984	58.4	899	26.4
Tennessee	14,144	337.7	6,357	153.7	4,825	116.9	2,232	55.7	1,120	27.0
Alabama	10,948	302.9	5,127	161.2	4,190	115.9	2,284	62.6	1,077	29.8
Mississippi	7,556	322.1	3,734	137.3	2,791	119.0	1,588	67.7	646	27.5
West South Central	63,850	306.2	32,721	156.9	19,942	95.6	12,143	58.2	5,767	27.7
Arkansas	7,333	374.9	3,793	179.3	2,723	128.7	1,129	42.6	620	29.4
Louisiana	12,444	323.3	6,151	152.5	3,481	91.3	2,275	60.0	969	25.6
Oklahoma	10,253	379.1	[illegible]	179.4	3,124	111.9	1,637	59.1	781	28.4
Texas	33,233	271.8	[illegible]	146.3	10,724	87.6	6,932	56.6	3,417	27.9
WEST										
Mountain	22,773	236.1	12,121	127.7	6,559	68.0	5,320	61.3	2,031	30.4
Montana	2,177	291.0	1,098	146.8	484	64.8	592	77.8	259	35.8
Idaho	2,234	272.4	1,113	135.7	701	85.5	555	64.0	295	34.9
Wyoming	1,026	274.1	486	129.9	337	92.1	311	83.7	154	42.9
Colorado	5,951	234.1	3,073	121.3	1,074	42.1	1,325	52.3	600	23.7
New Mexico	2,012	175.7	1,315	114.7	660	57.8	883	77.0	477	41.6
Arizona	5,255	240.8	3,215	144.6	1,465	65.5	1,287	57.9	679	30.5
Utah	2,426	203.6	1,148	95.3	712	59.9	608	50.2	274	22.7
Nevada	1,373	232.0	874	147.6	484	31.3	353	60.0	133	30.9
Pacific	81,188	288.3	45,334	160.6	24,091	85.3	14,129	51.8	6,143	21.8
Washington	11,712	321.7	6,129	164.5	3,164	89.4	1,783	50.3	803	22.7
Oregon	7,232	322.6	3,344	168.0	2,337	102.1	1,252	51.8	570	24.9
California	61,061	289.7	34,321	162.0	18,112	85.5	10,922	51.4	4,520	21.3
Alaska	280	75.9	213	60.5	73	20.2	415	118.2	120	34.1
Hawaii	1,471	182.0	927	107.2	336	45.4	253	29.2	122	15.3

TABLE 5 (b)

POOR ORIGINAL



SOURCE: U.S. MONTHLY VITAL STATISTICS REPORTS AND STATE OF CONN. VITAL STATISTICS

FIGURE 1

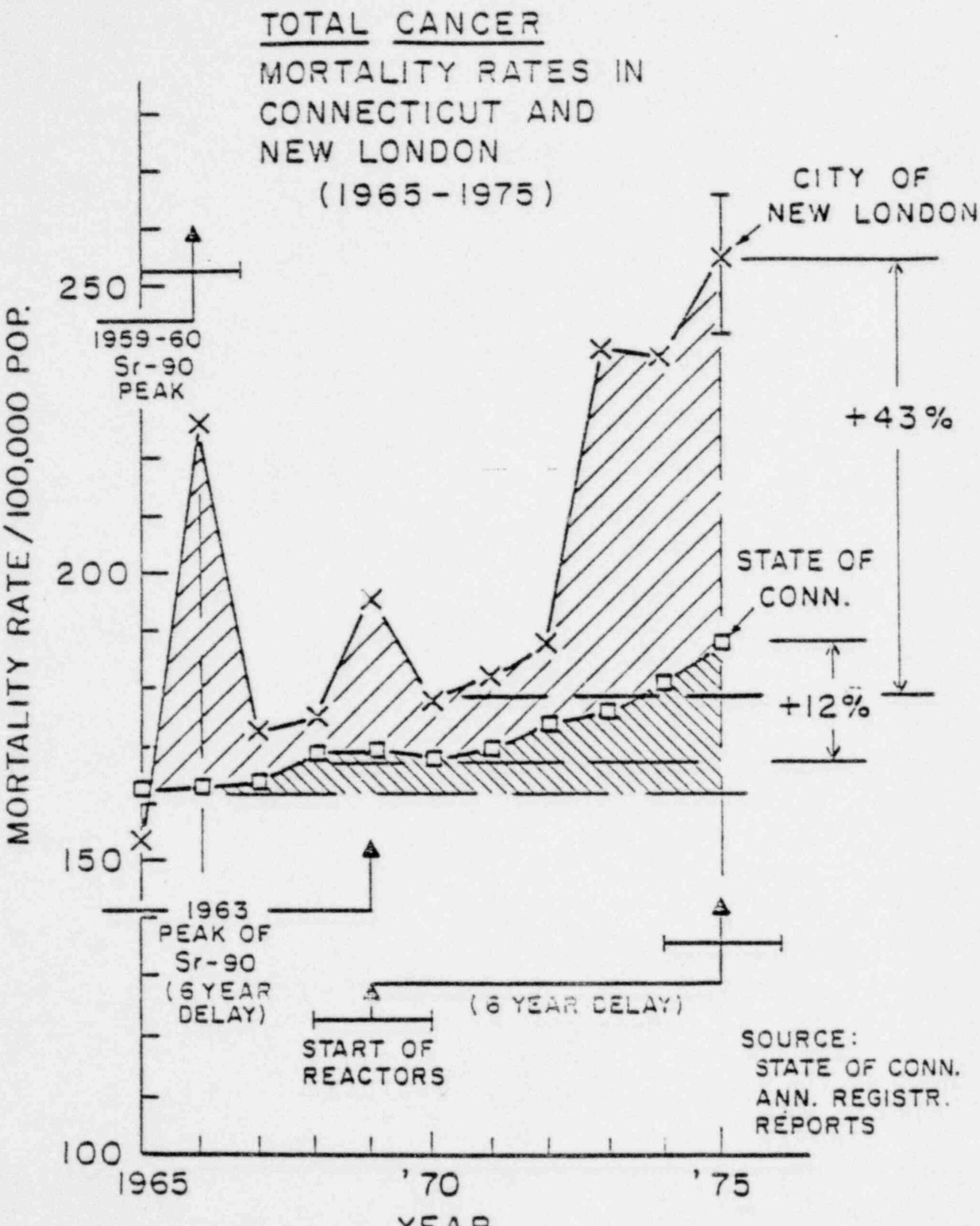

TOTAL CANCER
MORTALITY RATES IN
CONNECTICUT AND
NEW LONDON
(1965-1975)
MORTALITY RATE/100,000 POP.
250
200
150
100
1959-60
Sr-90
PEAK
CITY OF
NEW LONDON
+43%
STATE OF
CONN.
+12%
1963
PEAK OF
Sr-90
(6 YEAR
DELAY)
START OF
REACTORS
(6 YEAR DELAY)
SOURCE:
STATE OF CONN.
ANN. REGISTR.
REPORTS
1965
'70
'75
YEAR

FIGURE 2

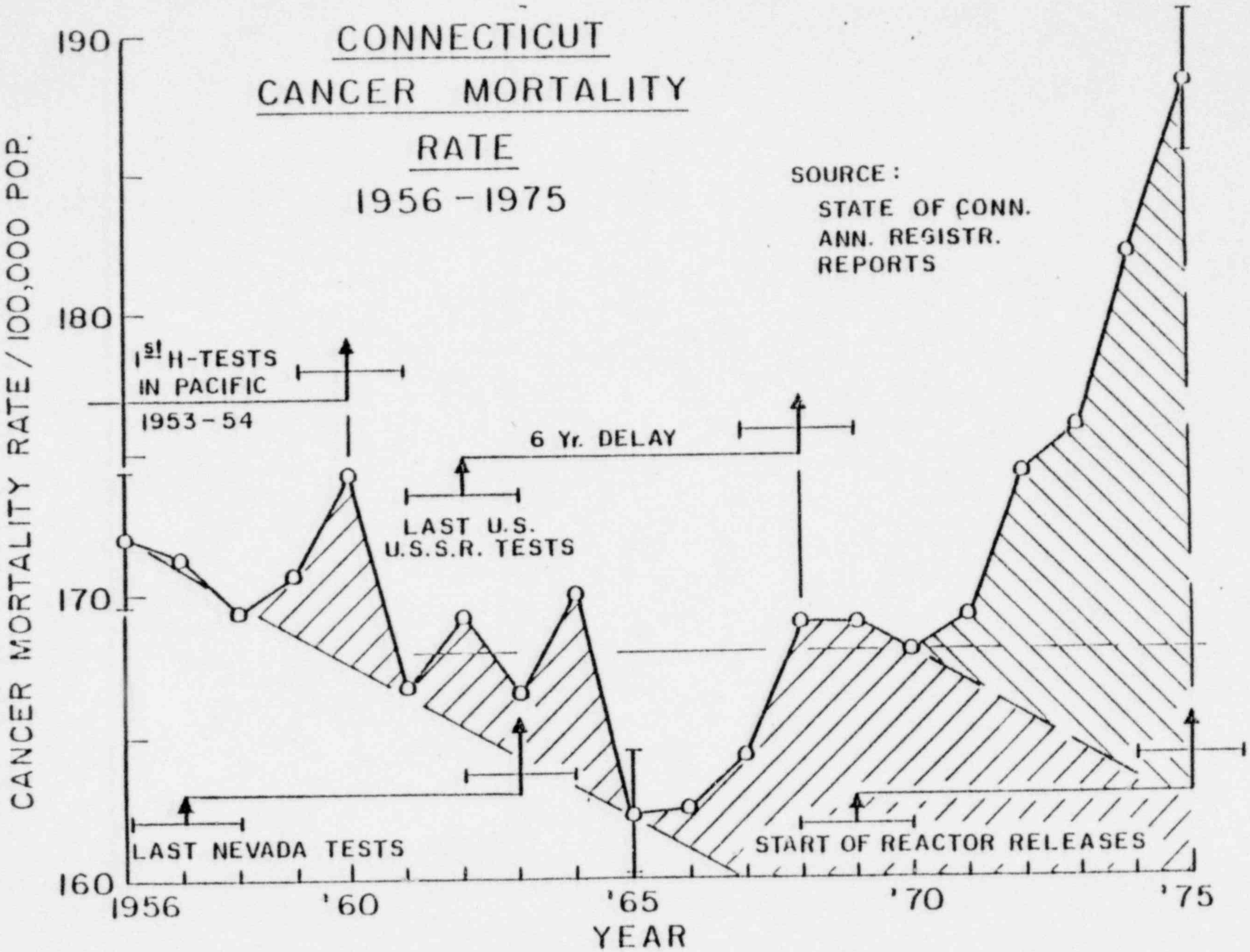
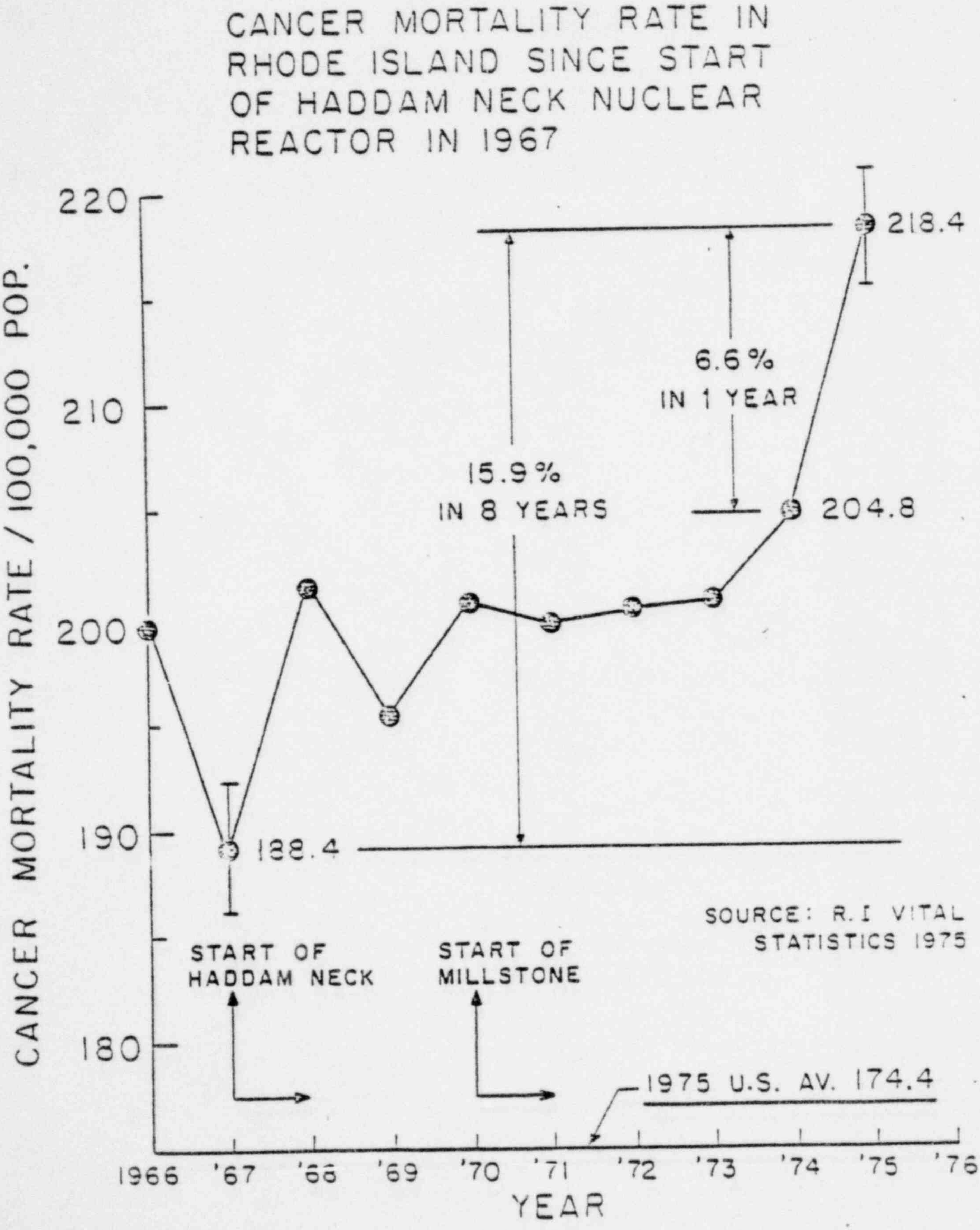

CONNECTICUT
CANCER MORTALITY
RATE
1956 - 1975
SOURCE:
STATE OF CONN.
ANN. REGISTR.
REPORTS
1st H-TESTS
IN PACIFIC
1953 - 54
6 Yr. DELAY
LAST U.S.
U.S.S.R. TESTS
LAST NEVADA TESTS
START OF REACTOR RELEASES
CANCER MORTALITY RATE / 100,000 POP.
190
180
170
160
1956
'60
'65
'70
'75
YEAR

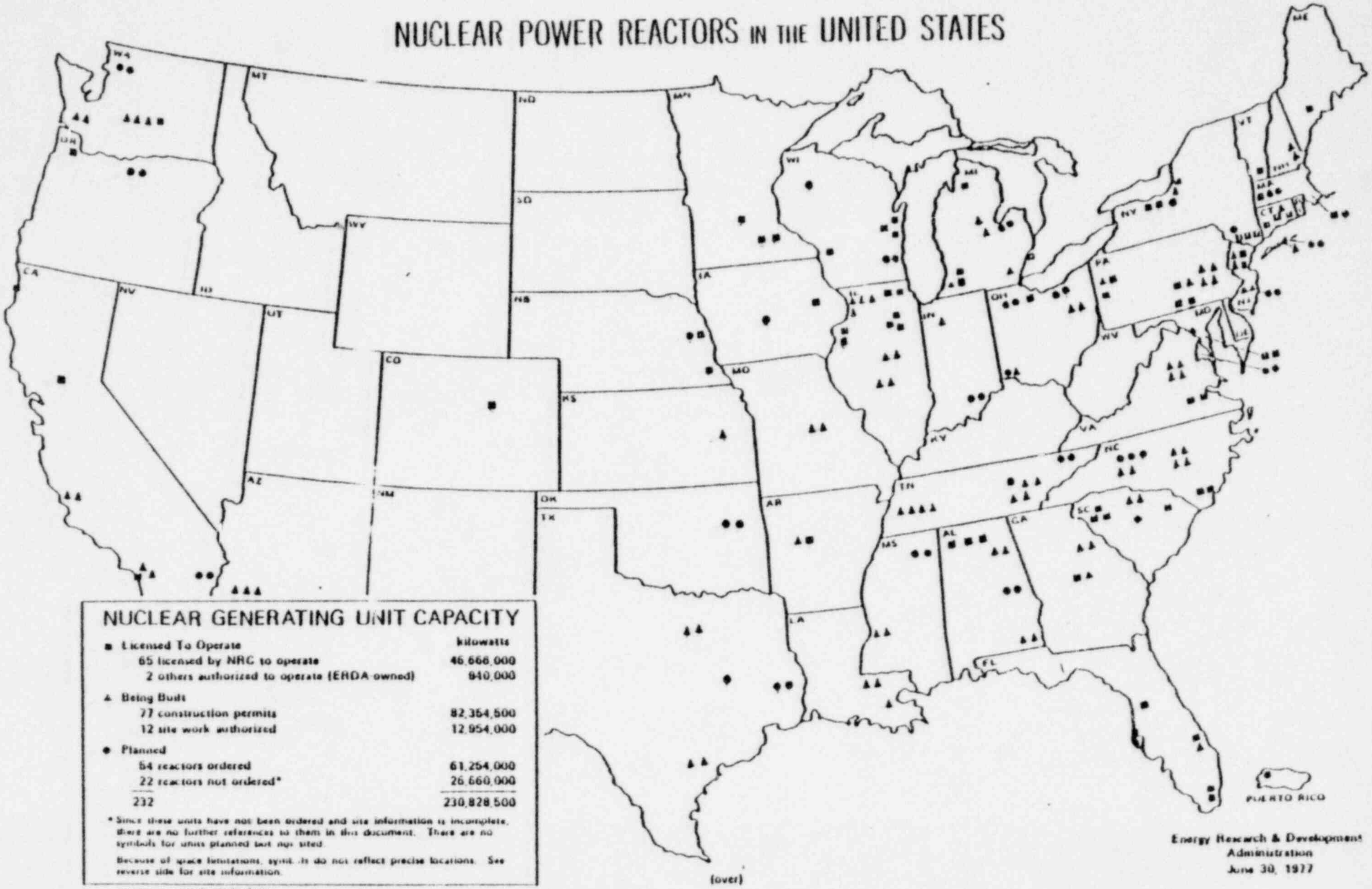
FIGURE 3



CANCER MORTALITY RATE IN RHODE ISLAND SINCE START OF HADDAM NECK NUCLEAR REACTOR IN 1967
CANCER MORTALITY RATE / 100,000 POP.
220
210
200
190
180
218.4
6.6 % IN 1 YEAR
15.9 % IN 8 YEARS
204.8
188.4
SOURCE: R.I VITAL STATISTICS 1975
START OF HADDAM NECK
START OF MILLSTONE
1975 U.S. AV. 174.4
1966
'67
'68
'69
'70
'71
'72
'73
'74
'75
'76
YEAR

FIGURE 4

NUCLEAR POWER REACTORS IN THE UNITED STATES



NUCLEAR GENERATING UNIT CAPACITY

	kilowatts
■ Licensed To Operate	
65 licensed by NRC to operate	46,666,000
2 others authorized to operate (ERDA owned)	940,000
▲ Being Built	
77 construction permits	82,354,500
12 site work authorized	12,954,000
● Planned	
54 reactors ordered	61,254,000
22 reactors not ordered*	26,660,000
232	230,828,500

* Since these units have not been ordered and site information is incomplete, there are no further references to them in this document. There are no symbols for units planned but not sited.

Because of space limitations, symbols do not reflect precise locations. See reverse side for site information.

(over)

Energy Research & Development Administration
June 30, 1977

FIGURE 5

COMMERCIAL NUCLEAR POWER REACTORS IN THE UNITED STATES

SITE	PLANT NAME	CAPACITY NET kWe	UTILITY	COMMERCIAL OPERATION
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

*Site not selected

POOR ORIGINAL

APPENDIX I

TABLE 1

Cows milk measurements near Millstone Plant, reproduced from Environmental Statement for 1976.

TABLE 7
DAIRY MILK
(PCI/L)

LOCATION	COLLECTION DATE	SR-89	(+/-)	SR-90	(+/-)	I-131	(+/-)	CS-137	(+/-)
20	2/23/76	0.0	0.7	14.5	0.5	0.01	0.06	22.7	1.1
20	4/12/76	1.6	1.2	7.7	0.4	0.0	0.08	12.4	0.4
20	5/10/76	0.3	1.1	7.9	0.3	0.30	0.09	13.5	0.9
20	6/ 7/76	0.2	1.5	16.2	0.6	0.0	0.08	26.3	0.8
20	7/19/76	0.0	1.7	27.1	0.8	0.05	0.08	32.0	2.0
20	8/ 2/76	0.0	2.0	13.0	0.6	0.09	0.10	27.0	2.0
20	9/13/76	1.1	0.7	15.2	0.5	0.0	0.08	24.2	1.1
20	10/ 5/76	37.0	2.0	14.2	0.7	310.00	6.00	19.5	1.5
21	2/23/76	0.0	0.7	10.2	0.4	0.05	0.08	22.0	2.0
21	4/12/76	1.5	1.2	6.9	0.4	0.0	0.07	17.3	0.3
21	5/10/76	0.4	1.0	7.4	0.3	0.0	0.08	10.3	0.3
21	6/ 7/76	0.7	0.6	9.3	0.4	0.10	0.08	15.3	1.1
21	7/19/76	0.9	0.7	8.0	0.4	0.0	0.06	15.7	0.5
21	8/ 2/76	0.0	1.1	13.1	0.5	0.13	0.09	30.0	2.0
21	9/13/76	0.3	0.9	12.9	0.9	0.0	0.07	31.3	1.3
21	10/ 5/76	44.0	2.0	11.3	0.5	416.00	3.00	16.8	1.4
22	2/23/76	0.0	0.5	5.6	0.3	0.07	0.08	16.7	1.0
22	4/12/76	0.0	0.6	6.3	0.3	0.0	0.08	15.5	0.5
22	5/10/76	1.6	1.3	7.7	0.4	0.0	0.08	16.0	1.0
22	6/ 7/76	0.3	0.9	11.4	0.5	0.0	0.06	21.3	1.2
22	7/19/76	0.0	1.1	19.7	0.6	0.0	0.05	33.3	1.7
22	8/ 2/76	0.0	2.4	16.3	0.6	0.0	0.07	36.0	3.0
22	9/13/76	1.7	0.9	10.8	0.5	0.20	0.09	11.4	1.8
22	10/ 5/76	37.2	1.5	13.6	0.6	217.00	5.00	26.0	2.0
23A	2/23/76	0.0	0.4	4.5	0.3	0.05	0.08	11.8	1.1
23A	4/12/76	1.1	0.9	4.0	0.3	0.0	0.08	8.3	0.4
23A	5/10/76	0.5	0.9	5.2	0.3	0.0	0.07	13.6	1.0
23A	6/ 7/76	0.0	0.6	4.2	0.3	0.40	0.08	4.8	0.8
23A	7/19/76	0.0	0.8	7.4	0.5	0.02	0.06	5.5	0.4
23A	8/ 2/76	1.0	2.0	6.8	1.1	0.04	0.07	10.0	0.8
23A	9/13/76	0.4	0.6	7.0	0.4	0.0	0.08	13.7	1.3
23A	10/ 5/76	4.3	1.3	7.2	0.8	37.90	1.30	6.2	0.7

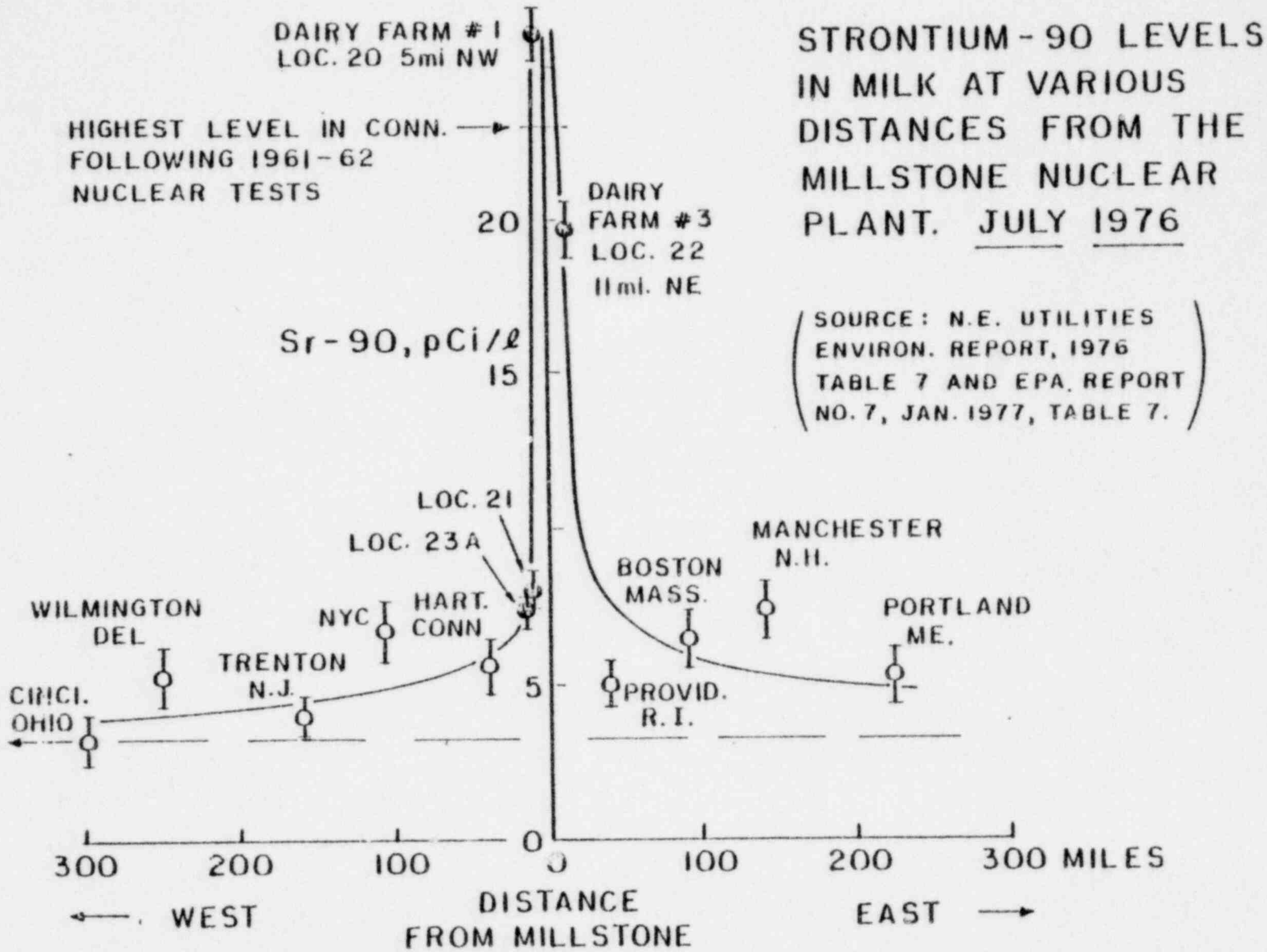


FIGURE 2(a)

APPENDIX I

MEASURED CONCENTRATION
OF Cs-137 IN MILK
FOR VARIOUS DISTANCES
FROM MILLSTONE
NUCLEAR PLANT
AUGUST 1976

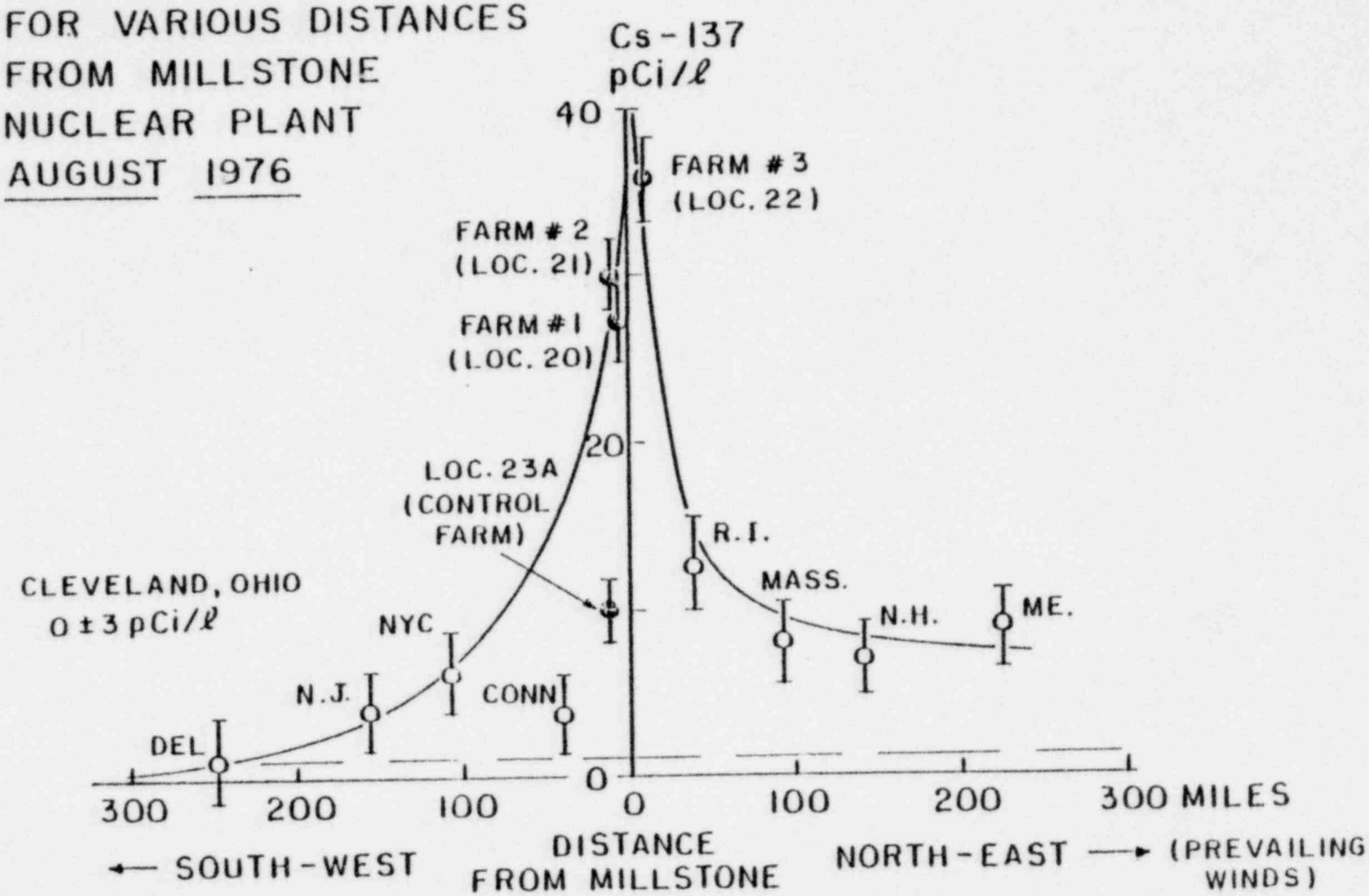


FIGURE 2(b)

VARIATION OF Cs-137 IN MILK WITH TIME FOR VARIOUS DISTANCES FROM THE MILLSTONE REACTOR

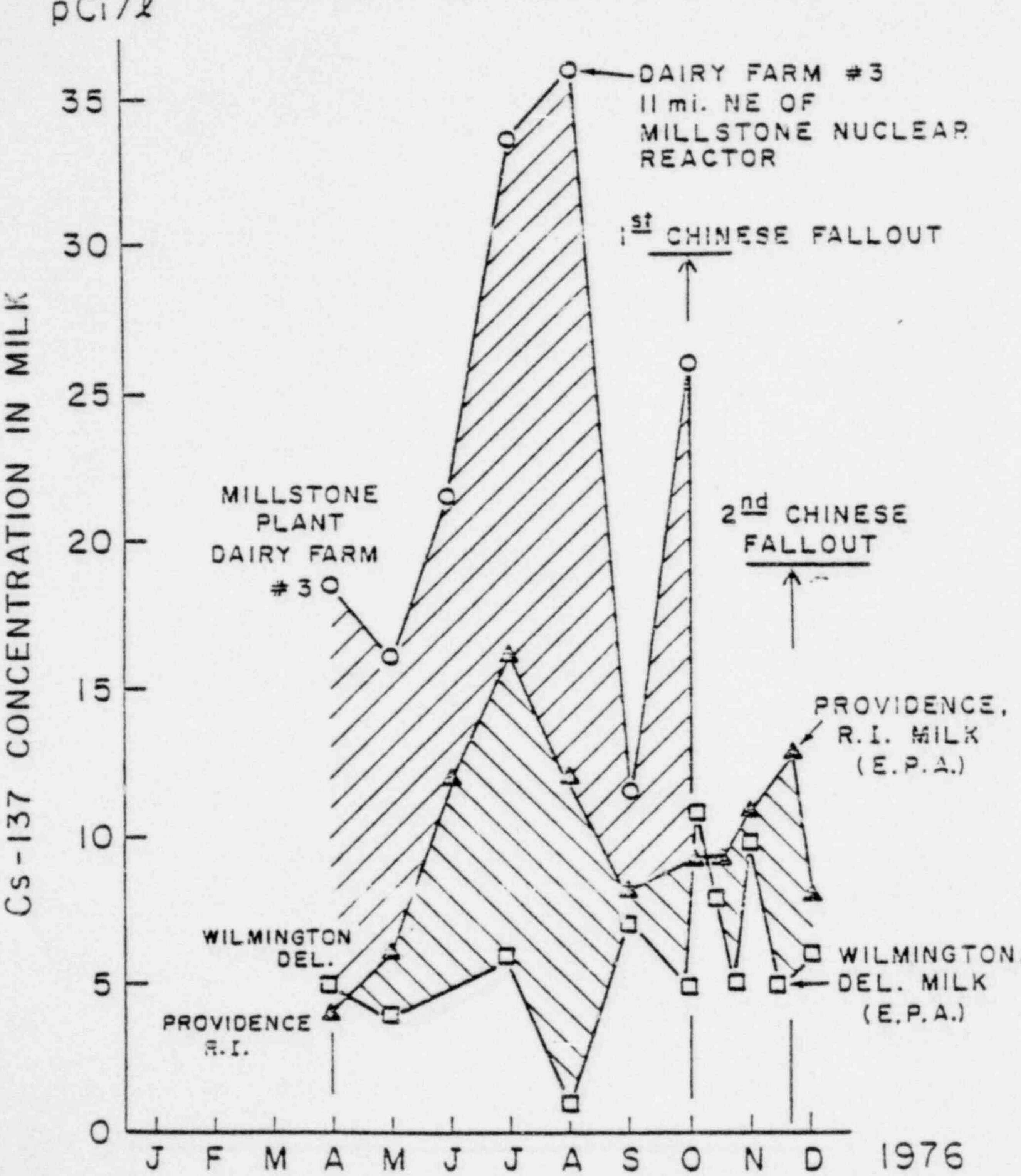


FIGURE 4

TABLE 9

Comparison of Sr-90 Concentrations in Milk Near the Millstone Nuclear Reactor With Concentrations in Hartford and the U.S. as a Whole - 1970 to 1976

Year	(a) Av. Daily Milk Sr-90 Concentr. Near Millstone pCi/l	(b) Av. Daily Milk Sr-90 Concentr. In July (Hartford) pCi/l	(c) Av. Daily Milk Sr-90 Concentr. for Year In U.S. pCi/l	Excess Sr-90 In Milk Near Millstone over U.S. pCi/l	%Exc Sr-9 Near Mill pCi/
1970‡	9.8	8	8	1.8	—
1971	8.8	9	7	1.8	20%
1972	9.6	7	6	3.6	38%
1973	15.0	4	5	10.0	67%
1974	14.8	Not Avail.	4	10.8	[illegible]%
1975	10.7	3.1	3	7.7	72%
1976	13.0	5.7	4	9.0	69%

‡ Millstone Operation began in October 26, 1970
Conn. Yankee (Haddam Neck, 20 miles N.W., Started July 24, 1967.

(a) Three locations within 10-15 miles $1\sigma = \pm 0.2$ pCi/l
From Millstone environmental reports, annual averages

(b) E.P.A. Measurements (Rad. Data and Reports) in July.
$1\sigma = \pm 1$ pCi/l

(c) E.P.A. Network Average (Rad. Data and Reports)
$1\sigma = \pm 0.2$ pCi/l

TABLE 10

Doses to the Bone of Children Due to Sr-90 in the Milk and Total Diet Near the Millstone Nuclear Plant - 1970 to 1976

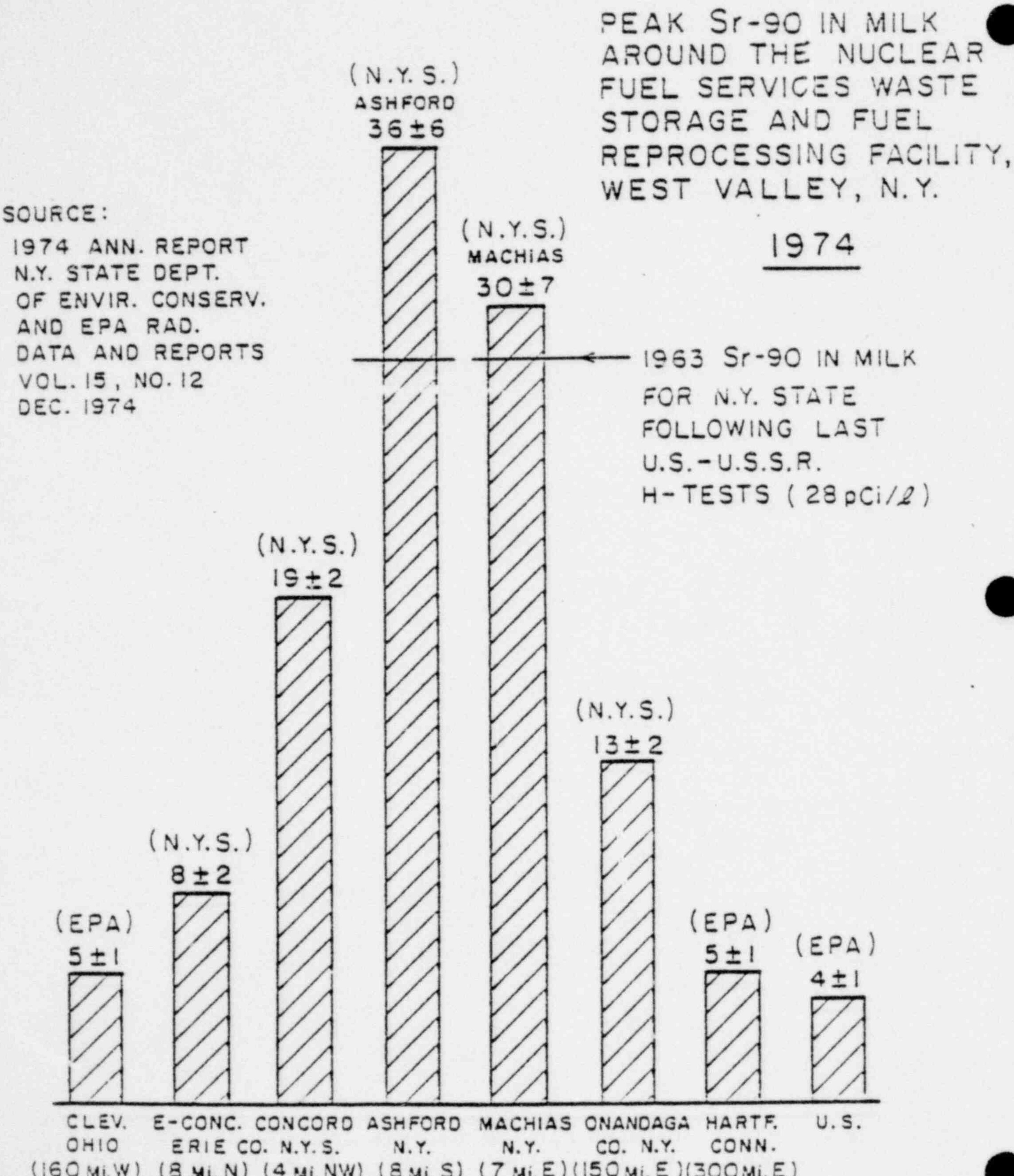
Year	Total Diet Sr-90 Intake - Near Millstone pCi/day	(a) Annual Sr-90 Bone Dose For Child-All Sources mrem/yr	(b) Annual Sr-90 Bone Dose For Child Due to Millstone - mrem/yr.	Cumul. Sr-90 Bone Dose For Child Due To Millstone mrem	(c) Annual Sr-9 Bone Dose F Child Due T Millstone a % of Natura
1970‡	29.4	185	—	—	—
1971	26.4	166	33	33	47%
1972	28.8	181	69	102	99%
1973	45.0	283	190	292	271%
1974	44.4	279	204	495	291%
1975	32.1	202	145	640	207%
1976	39.0	245	169	809	241%

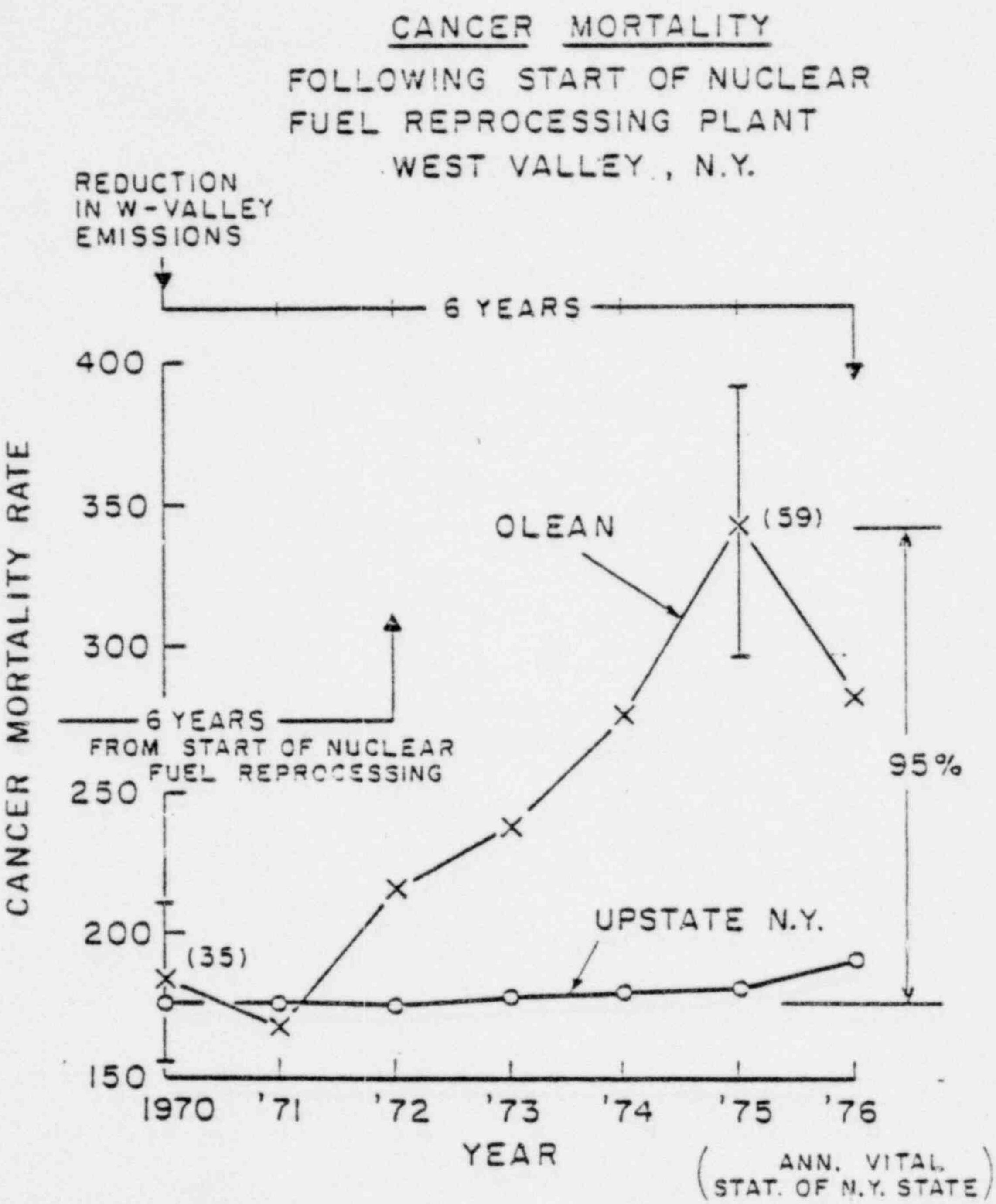
‡ Millstone Operations Began October 26, 1970

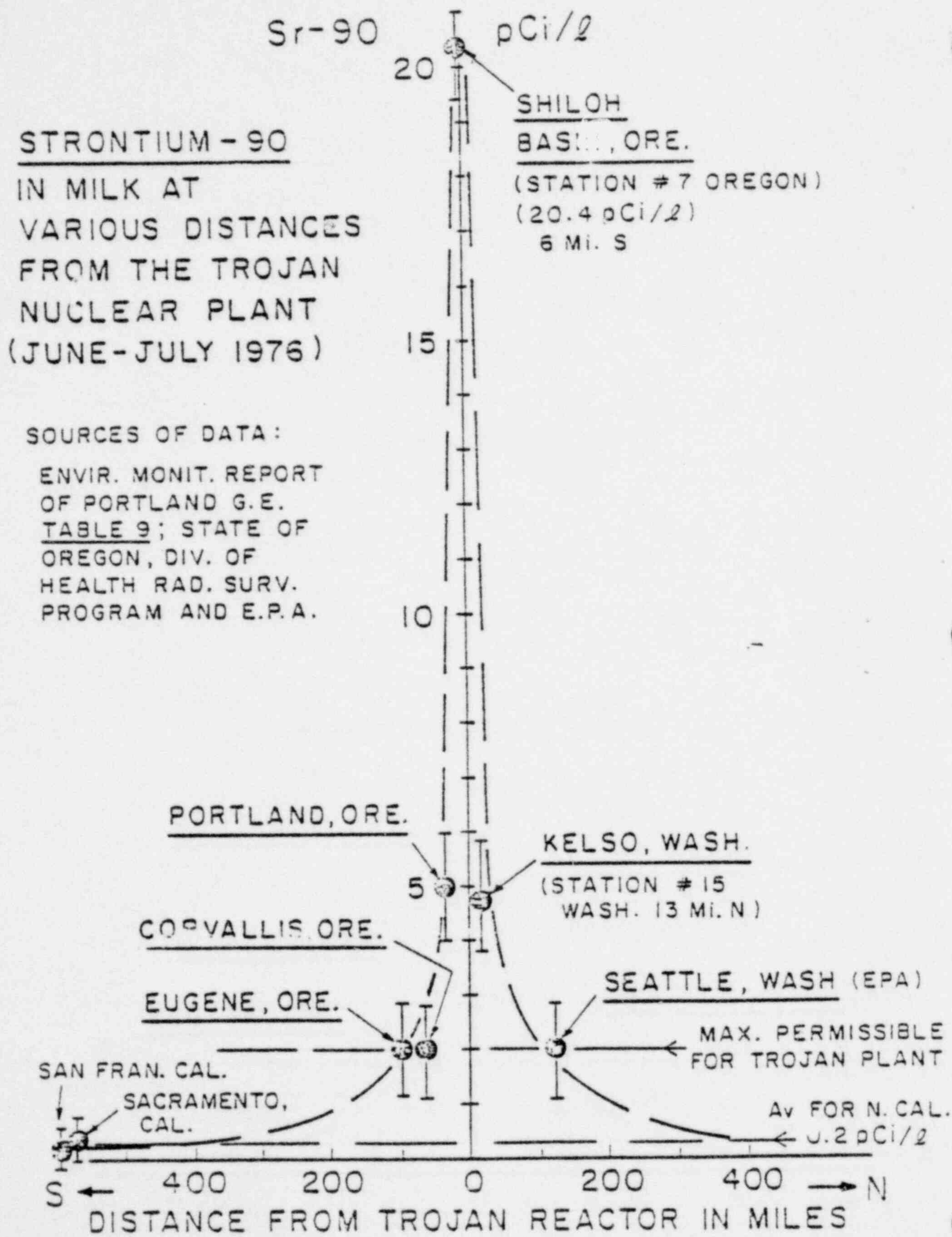
(a) Using dose factor of 0.0172 mrem/pCi annual intake from Table A-5, NUREG 1.109 (N.R.C., March 1976), equivulant to 6.28 mrem/yr. per 1 pCi daily intake in total diet.

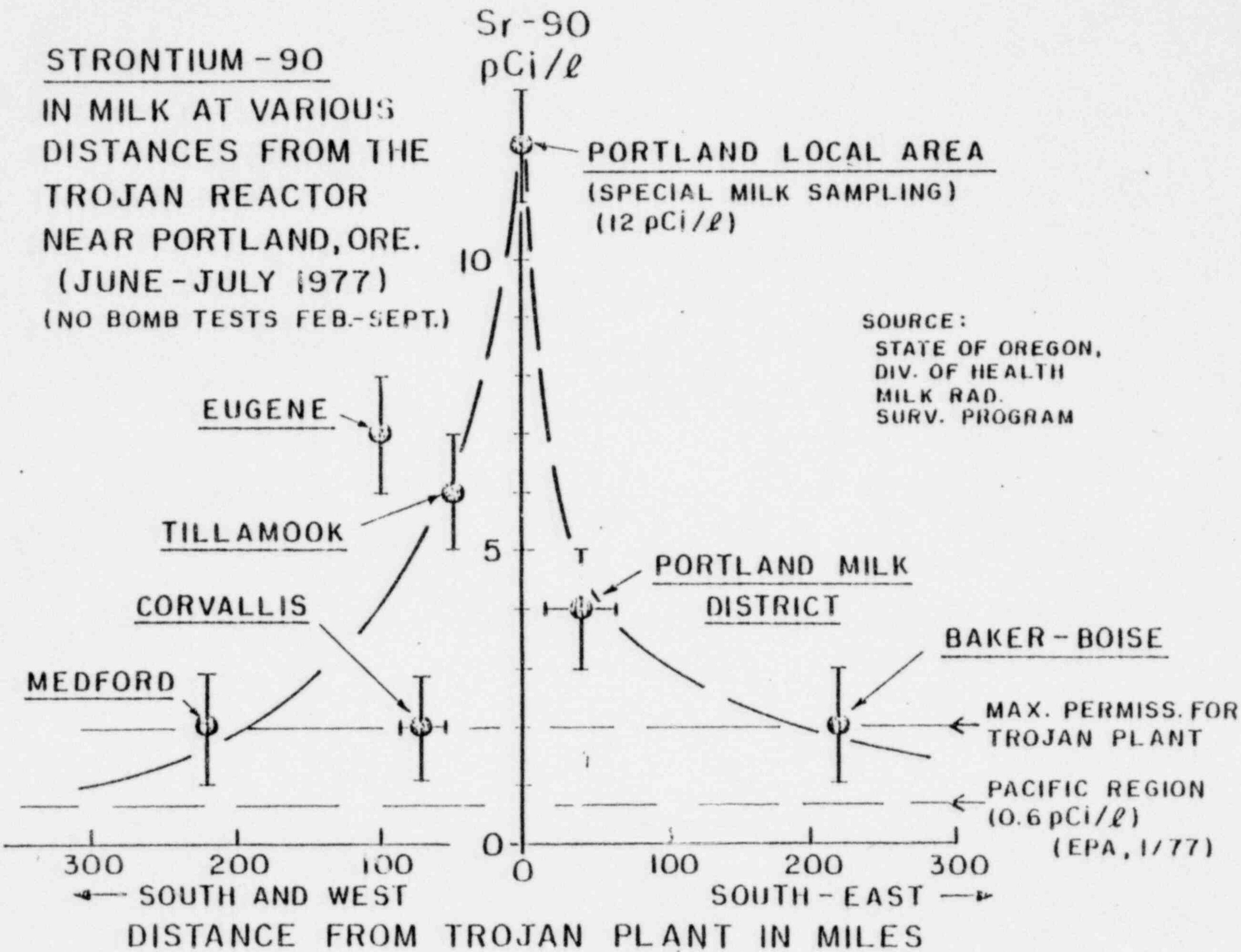
(b) Using percent excess Sr-90 levels due to Millstone from milk measurements (Table 9).

(c) Natural Radiation background 70 mrem/yr. ((E.P.A. measurements; E.P.A. report on Haddam Neck
E.P.A. - 520/3-74-007 ; Sect. 7.7 , page 109


PEAK Sr-90 IN MILK AROUND THE NUCLEAR FUEL SERVICES WASTE STORAGE AND FUEL REPROCESSING FACILITY, WEST VALLEY, N.Y.
1974
SOURCE:
1974 ANN. REPORT N.Y. STATE DEPT. OF ENVIR. CONSERV. AND EPA RAD. DATA AND REPORTS VOL. 15, NO. 12 DEC. 1974
1963 Sr-90 IN MILK FOR N.Y. STATE FOLLOWING LAST U.S.-U.S.S.R. H-TESTS (28 pCi/ℓ)
(EPA) 5±1
(N.Y.S.) 8±2
(N.Y.S.) 19±2
(N.Y.S.) ASHFORD 36±6
(N.Y.S.) MACHIAS 30±7
(N.Y.S.) 13±2
(EPA) 5±1
(EPA) 4±1
CLEV. OHIO (160 Mi.W)
E-CONC. ERIE CO. (8 Mi. N)
CONCORD N.Y.S. (4 Mi. NW)
ASHFORD N.Y. (8 Mi. S)
MACHIAS N.Y. (7 Mi. E)
ONANDAGA CO. N.Y. (150 Mi. E)
HARTF. CONN. (300 Mi. E)
U.S.


CANCER MORTALITY
FOLLOWING START OF NUCLEAR
FUEL REPROCESSING PLANT
WEST VALLEY, N.Y.
REDUCTION
IN W-VALLEY
EMISSIONS
6 YEARS
400
350
300
250
200
150
CANCER MORTALITY RATE
OLEAN
(59)
95%
6 YEARS
FROM START OF NUCLEAR
FUEL REPROCESSING
(35)
UPSTATE N.Y.
1970
'71
'72
'73
'74
'75
'76
YEAR
(ANN. VITAL
STAT. OF N.Y. STATE)


Sr-90 pCi/ℓ
STRONTIUM-90
IN MILK AT
VARIOUS DISTANCES
FROM THE TROJAN
NUCLEAR PLANT
(JUNE-JULY 1976)
SOURCES OF DATA:
ENVIR. MONIT. REPORT
OF PORTLAND G.E.
TABLE 9; STATE OF
OREGON, DIV. OF
HEALTH RAD. SURV.
PROGRAM AND E.P.A.
SHILOH
BAS..., ORE.
(STATION #7 OREGON)
(20.4 pCi/ℓ)
6 Mi. S
20
15
10
5
PORTLAND, ORE.
KELSO, WASH.
(STATION #15
WASH. 13 Mi. N)
CORVALLIS ORE.
EUGENE, ORE.
SEATTLE, WASH (EPA)
MAX. PERMISSIBLE
FOR TROJAN PLANT
SAN FRAN. CAL.
SACRAMENTO,
CAL.
Av FOR N. CAL.
U.2 pCi/ℓ
S ← 400 200 0 200 400 → N
DISTANCE FROM TROJAN REACTOR IN MILES


STRONTIUM - 90
IN MILK AT VARIOUS
DISTANCES FROM THE
TROJAN REACTOR
NEAR PORTLAND, ORE.
(JUNE - JULY 1977)
(NO BOMB TESTS FEB.-SEPT.)
Sr - 90
pCi/ℓ
PORTLAND LOCAL AREA
(SPECIAL MILK SAMPLING)
(12 pCi/ℓ)
SOURCE:
STATE OF OREGON,
DIV. OF HEALTH
MILK RAD.
SURV. PROGRAM
EUGENE
TILLAMOOK
CORVALLIS
MEDFORD
PORTLAND MILK
DISTRICT
BAKER - BOISE
MAX. PERMISS. FOR
TROJAN PLANT
PACIFIC REGION
(0.6 pCi/ℓ)
(EPA, 1/77)
10
5
0
300
200
100
0
100
200
300
SOUTH AND WEST
SOUTH - EAST
DISTANCE FROM TROJAN PLANT IN MILES

STATISTICAL STUDIES OF THE EFFECT OF LOW LEVEL RADIATION FROM NUCLEAR REACTORS ON HUMAN HEALTH

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CARNEGIE-MELLON UNIVERSITY

1. Possible effects of nuclear reactors

Government policy with regard to the construction and operation of nuclear power plants is of great public concern, not only because of the possibility of a serious accident at one of these plants, but also because of the possibility that radioactive discharges from these plants during their routine operation may affect the health of nearby populations. In particular, because of the vulnerability of the human fetus, it is possible that exposure of a population to these discharges may be reflected in the infant mortality rate, the fetal death rate, the prematurity rate, and similar health indices of the population.

Since several nuclear reactors have been in operation in the United States for at least five years, and some for more than ten years, the relevant data for a statistical study of this problem are largely available in published records. A study of this type would necessarily be retrospective in nature and confined to short term effects of low level radiation. If these effects are discernible, then they should be reflected in certain relationships between the health indices mentioned above for a given population and various measures of radioactivity in the environment.

2. Populations to be considered

Annual infant and fetal mortality rates, as well as prematurity rates, are typically available on a county by county basis in the published vital statistics of each state. It is suggested for simplicity, therefore, that counties form the basic units of population to be considered. Thus, for a given reactor, annual health indices for the county containing the reactor and for nearby counties would be investigated over a period both before and after the reactor became critical for possible relations with measures of the total annual radioactive

This research was supported in part by the National Science Foundation under grant GP-23708.

discharges from the reactor. Obviously, the counties that might be affected by a given reactor can lie in more than one state.

Furthermore, the health indices for a given county containing or near a reactor can be compared with the corresponding indices in certain "control" counties which are located far from the reactor but which are similar to the given county with regard to other characteristics.

3. Variables to be considered

The basic purpose of the type of study being discussed here is to relate health indices such as the annual infant mortality, fetal mortality, prematurity, and fertility rates for a given population to measures of the annual amounts and compositions of radioactive gaseous and liquid discharges from a given nuclear reactor. It is clear, however, that many other variables besides the radioactive discharges from the reactor can affect these health indices.

Some of the variables which ideally should be included in the study are the distribution of the population by age, sex, and race; meteorological data pertinent to the times of discharge of gaseous effluents and to the geographic distribution of the population; socioeconomic indices such as income, housing, education, and the quality of medical care; the sources of food and water; natural background radiation levels; radioactive fallout from bomb tests; levels of air pollution, both SO_2 and particulate matter; and personal characteristics, such as smoking and dietary habits. Obviously, the list could be extended almost indefinitely and, equally obviously, it will be very difficult to obtain the relevant data for many of them.

In addition, besides simply looking at the overall infant mortality rates for a given population and its various stratifications, it would be valuable to look at these rates for various specific causes of death. Although certain causes of death can more easily be associated with radiation effects than others, this analysis may not be as straightforward as it might at first appear. For example, it is possible that an infectious disease could cause the death of an infant whose susceptibility has been increased by exposure to low level radiation, but not cause the death of an infant who has not been so exposed. Even accidental deaths must be considered. One great hazard of being rushed to the hospital with an acute respiratory ailment is the high speed and often reckless ambulance or automobile ride that one must undergo.

Clearly, when analyzing data of the type being discussed here, one must always interpret changing rates with caution. Although there has been a general decrease in the infant mortality rate in the United States during the period from 1952 to 1967, there has also been a general increase in the prematurity rate over that period. This increase might reflect the increasingly deleterious effects of radiation, air pollution, or other environmental agents, or of changing practices of prenatal care. On the other hand, it might merely reflect changing practices in the reporting of birth weights, or even the beneficial effects of changing medical practices which convert potential fetal deaths into premature live births and consequently also bring about a decrease in the fetal death rate.

4. Results of preliminary regression analyses

In order to get a feeling for the possible magnitudes of the effects of radioactive wastes from nuclear reactors on infant mortality, and for the relative difficulty or ease with which these effects can be identified, some preliminary multiple regression analyses were carried out for the following four reactors: (1) the Dresden reactor in Grundy County, Illinois; (2) the Shippingport reactor in Beaver County, Pennsylvania; (3) the Indian Point reactor in Westchester County, New York; and (4) an experimental reactor at Brookhaven National Laboratory in Suffolk County, New York. In these regression models, the infant mortality rate in a given county containing or near a nuclear reactor, or the logarithm of this rate, was regressed on the amounts of radioactive gaseous and liquid wastes from the reactor and on either the infant mortality rate in a specified reference population or simply on a general linear trend in time. It must be emphasized that none of the multitude of other environmental agents and relevant variables listed earlier in this paper were specifically included in the models.

The general outcome of these preliminary studies is the only one that could have been anticipated, in view of the smallness of the effects and the simplicity of the model. Namely, the studies are inconclusive. They neither establish nor disprove the existence of an effect. They do, however, lead to the inescapable recommendation that more comprehensive and detailed studies of these questions are urgently needed.

The regressions that were carried out will briefly be summarized here. Time series of annual infant mortality rates for the United States as a whole, Illinois, Pennsylvania, New York, and the counties containing or near the four reactors studied are readily available from the published vital statistics of the federal government and the individual states, and will not be reproduced here. Time series of annual gaseous and liquid discharges from Dresden, Shippingport and Indian Point were obtained from the report "Radioactive Waste Discharges to the Environment from Nuclear Power Facilities" by Joe E. Logsdon and Robert I. Chissler, March, 1970, Bureau of Radiological Health, Environmental Health Service, Public Health Service, U.S. Department of Health, Education, and Welfare, Rockville, Maryland 20852. The time series of annual sand filter bed discharges and background radiation levels for the Brookhaven reactor were obtained from a report entitled "Background Radiation Levels in Brookhaven National Laboratory" by Andrew P. Hull, which was presented in March, 1970, at licensing hearings for the Shoreham nuclear power station on Long Island. None of these data are included in this paper because they are available in the sources cited and because the primary purpose of my reporting on these regression studies here is not to convince the reader of the validity and strength of particular conclusions that are reached. Rather, the purpose is to indicate that it is not possible to derive strong conclusions about either the existence or the nonexistence of an effect from the simple regression models used here, and to urge that a full scale statistical study of these problems be carried out.

5. Dresden

The Dresden reactor is located in Grundy County, Illinois, and began emitting radioactive discharges in 1960. Infant mortality rates in Grundy County were studied from 1950 to 1967, the most recent year for which these rates have been published, in order to include a relatively modern time period of reasonable length in which the reactor was inoperative as well as a time period of reasonable length in which it was active.

A relation of the following form was studied:

$$M_t = \beta_0 + \beta_1 t + \beta_2 X_{2t} + \epsilon_t. \tag{1}$$

In this relation, the index t represents the particular year being studied in the period from 1950 to 1967. For simplicity, only the final two digits of the year were used for identification, so that the year 1958, say, would be represented by the value $t = 58$. The interpretation of the other variables is as follows: M_t is the infant mortality rate in Grundy County in the year t (that is, the number of infant deaths per 1000 live births in that year), and X_{2t} is a two year moving average (for the years t and $t - 1$) of the liquid discharge (less tritium) from Dresden measured in curies. It was originally intended also to include the yearly gaseous discharges from Dresden in equation (1), but the gaseous and liquid discharges were highly correlated over the entire period. Hence, only the liquid discharges were used in this model.

The least squares estimates of β_0, β_1, and β_2 turn out to be $\hat{\beta}_0 = 55.4$, $\hat{\beta}_1 = -0.606$, and $\hat{\beta}_2 = 1.59$. Their estimated standard deviations are 30.6, 0.546, and 0.943, respectively, which yield the following t-statistics: 1.81, -1.11, and 1.68. Each of these t-statistics has 15 degrees of freedom. Thus, one might find in these values mild evidence of a positive relationship between liquid discharges and infant mortality superimposed on a general downward trend. The peak liquid discharge from Dresden was more than ten curies in 1966 (two year moving average), and it is seen by using the least squares estimate $\hat{\beta}_2$, that this value corresponds to an infant mortality rate of 15.9 deaths per 1000 live births above the overall linear trend.

It must be emphasized that none of these estimates are very reliable. Grundy County has a population of only 22,000 and the average number of infant deaths per year during the period being studied was only 11.4. Furthermore, it must be kept in mind that even if a definite relationship between infant mortality and radioactive discharges was established by these techniques, one would still be unable to conclude definitely that by actually reducing the discharges in future years, the infant mortality rate would be reduced. In fact, the discharges may simply be surrogates for some other variables which are the actual causative agents. However, it is fair to state that each scientist would regard such statistical evidence as at least favoring to a certain extent the hypothesis that the discharges are affecting the infant mortality rate.

When a similar analysis is carried out for LaSalle County, which is directly to the west of Grundy and has a population of 110,000, no evidence of a relationship is found. The least squares estimates are $\hat{\beta}_0 = 24.3$, $\hat{\beta}_1 = -0.029$, and $\hat{\beta}_2 = -0.222$. The corresponding t-statistics are 1.95, −0.13, and −0.58, respectively.

The next step was to replace M_t in (1) by $\log M_t$, since it is generally believed to be more appropriate to try to fit a linear trend to $\log M_t$ rather than to M_t itself. The results obtained were little changed from before. The t-statistics corresponding to $\hat{\beta}_2$ for Grundy and LaSalle Counties became 1.42 and −0.63, respectively. These values are not much different from their previous values.

Here, the fitted value of M_t is equal to the product of a factor $\exp\{\hat{\beta}_0 + \hat{\beta}_1 t\}$ representing the general trend in time, and a factor $\exp\{\hat{\beta}_2 X_{2t}\}$.

For Grundy County, we now have $\hat{\beta}_0 = 4.26$ and $\hat{\beta}_1 = 0.022$, and the least squares estimate of the general trend factor for 1966 is therefore 16.6. Also, we now have $\hat{\beta}_2 = 0.061$. Thus, the effect of the factor due to the liquid discharge of 10 curies in 1966 (two year moving average) is to multiply the estimated infant mortality rate for that year by $\exp\{0.61\} = 1.84$. This factor therefore corresponds to an infant mortality rate of 13.9 deaths per 1000 live births above the general trend for that year. This estimated increase is not much different from the estimated increase of 15.9 found from the linear model without logarithms.

One important consideration that makes an analysis of this type somewhat questionable, is that although the radioactive liquid discharge from Dresden was 0 for each year in the 1950's and only began to be positive in the 1960's, the populations of Grundy and LaSalle Counties may have been exposed to relatively large levels of radiation during the 1950's from bomb tests that were not present in the 1960's. Thus, in fact, the exposure of the population to radiation may actually have decreased when the bomb tests of the 1950's ceased and the Dresden reactor became active in the 1960's, rather than having increased, as is implicitly assumed in the models being used here.

In order to overcome this difficulty, the linear trend $\beta_0 + \beta_1 t$ in (1) was replaced by $\beta_0 + \beta_1 X_{1t}$, where X_{1t} is the infant mortality rate in the entire United States for the year t. In other words, it was felt that the ups and downs in the infant mortality rate in the United States through the years would reflect the general exposure of the population to radioactive fallout from bomb tests as well as other pollutants and other transient and sporadic effects. Thus, rather than assuming a linear trend, we assume that the expected infant mortality rate in Grundy County is a linear function of the infant mortality rate in the United States plus a multiple of the discharges from the Dresden reactor.

The model used is therefore

$$M_t = \beta_0 + \beta_1 X_{1t} + \beta_2 X_{2t} + \epsilon_t. \tag{2}$$

Regressions were also carried out in which X_{1t} was (i) the infant mortality rate in Illinois, rather than in the United States as a whole, (ii) the infant mortality rate in Illinois minus Cook County, since Chicago forms most of Cook County and was thought to have its own special characteristics; and (iii) the total infant mortality rate in Boone, DeWitt, Logan, McDonough, and Warren Counties in Illinois, which were chosen because they matched Grundy County to some extent with regard to their rural nature and their size, and were not near the reactor.

When X_{1t} is the United States infant mortality rate, the least squares estimates of β_0, β_1, and β_2 in (2) are $\hat{\beta}_0 = -28.4$, $\hat{\beta}_1 = 1.85$, and $\hat{\beta}_2 = 1.57$. Their estimated standard deviations are 45.8, 1.70, and 0.938, respectively. The t-statistic calculated from $\hat{\beta}_2$ is therefore 1.67. It is curious to note that this value is almost identical to the value found from equation (1).

When X_{1t} is the Illinois infant mortality rate, we find $\hat{\beta}_0 = -87.1$, $\hat{\beta}_1 = 4.36$, and $\hat{\beta}_2 = 0.937$, with estimated standard deviations 71.1, 2.85, and 0.552, respectively. The t-statistic calculated from $\hat{\beta}_2$ is therefore 1.70, again almost identical to the previous values.

When X_{1t} is the infant mortality rate in Illinois minus Cook County, we find $\hat{\beta}_0 = -51.6$, $\hat{\beta}_1 = 3.04$, and $\hat{\beta}_2 = 1.46$, with estimated standard deviations 39.9, 1.65, and 0.651, respectively. The t-statistic for $\hat{\beta}_2$ is therefore now 2.24.

When X_{1t} is the infant mortality rate in the group of matched counties, we find $\hat{\beta}_0 = 20.6$, $\hat{\beta}_1 = 0.0393$, and $\hat{\beta}_2 = 0.758$, with estimated standard deviations 16.5, 0.644, and 0.627, respectively. The t-statistic for $\hat{\beta}_2$ is now 1.21. It is interesting to note that the infant mortality rate in Grundy is almost totally unrelated to the infant mortality rate in the matching counties.

Finally, when M_t in (2) is replaced by the infant mortality rate in LaSalle County, we find that $\hat{\beta}_2$ is again negative in each of these regressions.

In summary, regardless of which regression model was used to study the infant mortality rate in small Grundy County, where the Dresden reactor is located, the coefficient $\hat{\beta}_2$ of the amount of radioactive liquid discharge was always found to be positive although the corresponding t-statistics were of modest magnitude. In neighboring LaSalle County, $\hat{\beta}_2$ was always found to be negative.

6. Shippingport

The Shippingport reactor, which is located in Beaver County, Pennsylvania, started up and began discharging tritium in 1958. It began emitting measurable radioactive gaseous and other liquid discharges the following year. The infant mortality rate in Beaver County, which has a population of 206,000 was also studied for the period from 1950 to 1967. The following regression model was used:

(3) $$M_t = \beta_0 + \beta_1 t + \beta_2 X_{2t} + \beta_3 X_{3t} + \beta_4 X_{4t} + \epsilon_t,$$

where X_{2t} is a two year moving average of the gaseous discharges from Shippingport, X_{3t} is a two year moving average of the liquid discharges (less tritium), and X_{4t} is a two year moving average of the tritium discharges. Both X_{2t} and X_{3t} are measured in millicuries and X_{4t} is measured in curies.

No evidence of a positive relationship between the discharges and the infant mortality rate was found, and some of the estimated coefficients are negative. In particular, the least squares estimates are $\hat{\beta}_0 = 55.0$, $\hat{\beta}_1 = -0.569$, $\hat{\beta}_2 = -0.0093$, $\hat{\beta}_3 = -0.0023$, and $\hat{\beta}_4 = 0.032$. The corresponding t-statistics, each with 13 degrees of freedom, are 5.28, −3.02, −0.57, −0.24, and 1.13, respectively.

When equation (3) is applied to Allegheny County, Pennsylvania, which is directly to the southeast of Beaver and has a population of 1,628,000, including Pittsburgh, the estimates are $\hat{\beta}_0 = 38.1$, $\hat{\beta}_1 = -0.239$, $\hat{\beta}_2 = -0.0060$, $\hat{\beta}_3 = 0.0050$, and $\hat{\beta}_4 = -0.021$. The corresponding t-statistics are 12.6, −4.37, −1.26, 1.79, and −2.60. The stability of the infant mortality rates in Allegheny County, because of its large population, is reflected here in the relatively large magnitudes of the t-statistics. Among the coefficients, $\hat{\beta}_2$, $\hat{\beta}_3$, and $\hat{\beta}_4$ of the discharges, however, the t-statistic with the largest magnitude corresponds to the negative coefficient $\hat{\beta}_4$ of the tritium discharge. Thus, evidence of a positive relationship is again lacking.

Similar results were obtained when the linear term in time in (3) was replaced by the infant mortality rate in either the United States or Pennsylvania.

7. Indian Point

The Indian Point reactor, which is located in Westchester County, New York, started up and began emitting radioactive liquid discharges in 1962. The infant mortality rate in Westchester County, which has a population of 853,000, was studied for the period from 1950 to 1967 and regression analyses were carried out similar to those described for the Dresden reactor. Equation (1) was studied first with M_t denoting the infant mortality rate in Westchester and X_{2t} denoting the two year moving average of liquid discharges (less tritium) from Indian Point measured in curies. The gaseous and liquid discharges were again highly correlated (both were 0 over much of the period and then they rose together), so only liquid discharges are included in the regression equation. The least squares estimates of β_0, β_1, and β_2 are $\hat{\beta}_0 = 31.7$, $\hat{\beta}_1 = -0.178$, and $\hat{\beta}_2 = 0.059$, with estimated standard deviations 3.51, 0.062, and 0.028, respectively. Thus, the value of the t-statistic corresponding to $\hat{\beta}_2$, with 15 degrees of freedom, is 2.11.

The liquid discharges from Indian Point were more than 35 curies in both 1966 and 1967, and it is seen by using the least squares estimate $\hat{\beta}_2$ that this value corresponds to an infant mortality rate of 2.03 deaths per 1000 live births above the overall linear trend.

When a similar analysis is carried out for smaller Rockland County, which is across the Hudson River from Westchester and has a population of 192,000, the results are $\hat{\beta}_0 = 25.9$, $\hat{\beta}_1 = -0.064$, and $\hat{\beta}_2 = -0.037$, and the corresponding t-statistics are 1.75, -0.25, and -0.32, respectively.

When M_t is replaced by $\log M_t$ in (1), the results are little changed. The t-statistics corresponding to $\hat{\beta}_2$ for Westchester and Rockland Counties are 2.14 and -0.25, respectively. These values are not much different from their previous values. For Westchester County we now have $\hat{\beta}_0 = 3.54$, $\hat{\beta}_1 = -0.0081$, and $\hat{\beta}_2 = 0.0028$. For 1966, the factor of the fitted infant mortality corresponding to the general trend is therefore $e^{3.00} = 20.1$. The factor corresponding to the liquid discharge of 35 curies in that year (two year moving average) is $\exp\{0.098\} = 1.10$. Thus, the estimated increase in the infant mortality rate corresponding to the liquid discharge for that year, above the general trend, is 2.01 deaths per 1000 live births. Again, this value is in close agreement with the value found from the linear model without logarithms.

Next, equation (2) was studied for models in which M_t is the infant mortality rate in Westchester County and X_{1t} is the infant mortality rate in the United States. The least squares estimates are $\hat{\beta}_0 = 6.395$, $\hat{\beta}_1 = 0.571$, and $\hat{\beta}_2 = 0.065$, and the values of the corresponding t-statistics, again with 15 degrees of freedom, are 1.12, 2.68, and 2.11, respectively.

When X_{1t} is the infant mortality rate in New York State, the estimates are $\hat{\beta}_0 = 2.231$, $\hat{\beta}_1 = 0.802$, and $\hat{\beta}_2 = 0.045$, and the corresponding t-statistics are 0.13, 1.14, and 1.05, respectively.

When M_t is taken to be the infant mortality rate in Rockland County in these two models based on equation (2), the estimates of β_2 are $\hat{\beta}_2 = -0.046$ and $\hat{\beta}_2 = 0.055$. The corresponding t-statistics are -0.37 and 0.37.

Although these data can perhaps be interpreted as evidence at least mildly favoring the existence of a positive relationship between radioactive liquid discharges from Indian Point and the infant mortality rate in Westchester County, it must be emphasized that these discharges were 0 until 1962 and then increased monotonely from 1962 to 1967. Clearly then, this simple pattern might be present in the corresponding time series of many other environmental agents, one or more of which might actually be affecting infant mortality in the magnitude being attributed here to the Indian Point reactor. The fact however that these effects seem to be slightly more established in Westchester County than in Rockland County does provide some evidence, albeit weak, against this possibility.

3. Brookhaven

The final reactor to be studied was an experimental reactor at Brookhaven National Laboratory in Suffolk County, New York, for the period from 1951, the year that radioactivity was first used at the Laboratory, to 1968. The population of Suffolk County is 666,000. The following model was used:

$$M_t = \beta_0 + \beta_1 t + \beta_2 X_{2t} + \beta_3 X_{3t} + \epsilon_t, \quad (4)$$

where M_t was the infant mortality rate in Suffolk County in year t. X_{2t} is the two year moving average of the concentration of the sand filter bed discharge in picocuries per liter, and X_{3t} is an average of two offsite background radiation measurements made in year t and the two measurements made in year $t - 1$, measured in milliroentgens per week.

The least squares estimates turn out to be $\hat{\beta}_0 = 27.6$, $\hat{\beta}_1 = -0.142$, $\hat{\beta}_2 = 0.015$, and $\hat{\beta}_3 = -0.265$. The corresponding t-statistics, with 14 degrees of freedom, are 7.89, -2.19, 4.17, and -0.30. The striking aspect of this relation is the large t-statistic corresponding to the coefficient $\hat{\beta}_2$ of the concentration of the liquid discharge from the sand filter bed. From this relation it is found that an increase in the gross beta concentrations of the liquid releases of 300 pCi/liter, the observed value for 1961 (two year moving average) corresponds to an increase in the infant mortality rate of 4.5 deaths per 1000 live births.

These figures must again be interpreted with the greatest caution since the total amount of radioactivity in the liquid releases from the Brookhaven reactor is small, the maximum value being 219 millicuries in 1961. One interesting possibility suggested by this observation is that the actual composition of these releases may be as important as their total amount in affecting health.

It should also be noted that the background radiation levels bear essentially no relation to the infant mortality rates in Suffolk County.

When M_t is the infant mortality rate in Nassau County, which is to the west of Suffolk County on Long Island and has a population of 1,300,000, the estimates of the regression coefficients are $\hat{\beta}_0 = 24.9$, $\hat{\beta}_1 = -0.148$, $\hat{\beta}_2 = 0$ (to six decimal places), and $\hat{\beta}_3 = 1.66$. Only the years from 1951 to 1967 were included in this analysis, since the infant mortality rate in Nassau County in 1968 was not immediately available. The values of the t-statistics, with 13 degrees of freedom, for these four coefficients are 9.34, -2.79, -0.13, and 2.46, respectively. Thus, there is no evidence whatsoever of a relation between the filter bed discharge and the infant mortality rate in Nassau County, but there is now a relation in the observed data between off site background radiation levels and the infant mortality rate.

As before, when M_t is replaced by $\log M_t$ and the above analyses are carried out, the results are little changed.

9. Summary

It should be emphasized again that the results of these preliminary regression studies are inconclusive. They do not present strong evidence that there is a relationship between the exposure of a population to low level radiation from nuclear reactor discharges and the infant mortality rate in the population, and they do not present strong evidence that there is no such relation. The four reactors studied have different designs, and the inconclusive nature of these studies perhaps suggests that the actual composition of the discharges might be important, as well as whether and how these discharges enter the food chain. Some of the many other variables mentioned earlier in this paper, but not included in the regression models, are likely to be very influential.

The simple studies carried out here and their inconclusive results do lead, therefore, to a very strong and important recommendation. A large scale statistical study is urgently needed to aid in resolving this vital issue. Of course, statistical analysis can neither strictly prove nor disprove the hypothesis that exposure of a population to low level radiation increases the infant mortality rate. However, these analyses can substantially raise or lower the probability that the hypothesis is correct. Indeed, a large scale statistical study, such as the study of the effect of smoking on human health, could go far toward bringing the scientific community into agreement on this question.

In my classes, I usually define a scientist to be a person who can keep clearly in mind the distinction between the subjective utility that he assigns to any specific hypothesis and the subjective probability that he assigns to that hypothesis. In other words, a scientist must never let his hope or desire that there is no relation between low level radiation and infant mortality affect his professional evaluation of the probability that such a relation might exist. Statistical studies performed by interdisciplinary teams of scientists, in this strict sense, could provide information that will be of great help in reaching decisions regarding nuclear reactors that might critically affect large segments of the world's population.

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I am indebted to Dr. Ernest J. Sternglass, who initially stimulated my interest in this topic, for many helpful conversations. I am also indebted to Dr. Lincoln J. Gerende for his kind permission to use freely material he had prepared for a research proposal submitted jointly by him, Dr. Kenneth D. Rogers, and myself to the office of the Attorney General of Pennsylvania. I am further indebted to Dr. Gerende and Dr. Floyd H. Taylor for several valuable discussions of this project. Finally, I am indebted to William J. Franks, Jr., who did most of the groundwork and all of the computations for this paper, and whose assistance has been of great value.

Discussion

Question: P. Armitage, London School of Hygiene and Tropical Medicine, London

Isn't the analysis very sensitive to the true nature of the time trend? If the trend is really quadratic (as might be expected) with the curvature, may not the X factor be taking the place of the quadratic term?

Reply: M. DeGroot

The possible effects of the curvature of the trend were investigated by fitting a linear model to the logarithm of the infant mortality rate, a model for which there is some theoretical justification, as well as to the infant mortality rate itself. As I describe in this paper, the results for the two models were in close agreement and the magnitude of the effect of the radioactive discharge was almost the same for both models. The effects of trend curvature are also greatly reduced in those models where the rate in a given county is regarded as a linear function of the rate in some control population such as the state.

Question: V. L. Sailor, Brookhaven National Laboratory

It should be pointed out that the data used by Dr. DeGroot in his analysis of the Brookhaven Laboratory situation (liquid waste) does not have a plausible connection with infant mortality. The liquid waste flows into a stream which flows to the east through a completely uninhabited area to Peconic Bay away from the high density of population. The magnitude of the emissions are so small that they can no longer be detected a few miles off site, nor do the biota show activity. The total amount released over a period of twenty years was about 1¾ curies. During the same period Suffolk County had more than 100,000 times as much radioactivity deposited on it from weapons tests fallout. Gaseous radioactive release from Brookhaven was far greater (millions of curies per year), but these releases do not correlate with infant mortality since when the gaseous releases were high, the mortality rate was dropping. When gaseous releases were reduced, the mortality rate increased.

Reply: M. DeGroot

It is true that the total amount of liquid waste from Brookhaven National Laboratory was small compared to other contaminants. It is possible, therefore, that this discharge, which was zero until 1951, built up to its peak in 1961, and then steadily diminished, is simply acting as a surrogate for some other factor which seriously affects infant mortality but which was not explicitly identified in the analysis. On the other hand, it may well be true that the important consequences of radioactive discharges are derived not simply from the total amount, but rather from the actual composition of the effluent and the way in which various elements enter the food chain or otherwise reach the embryo.

Furthermore, the effect of radioactive releases on infant mortality cannot be measured simply by noting whether infant mortality went up or down in a given year, since there are obviously many other factors affecting infant mortality. The relevant measure of the effect of radioactive releases must be given in terms of whether or not infant mortality was higher in the given year than *it would have been* if these releases were not present but all the other factors were. It is this type of measure that the statistical methods described in this paper attempt to evaluate.

Question: J. Neyman, Statistical Laboratory, University of California, Berkeley

I am curious about the possible change in the socioeconomic composition of the population in a given county that might have occurred after a nuclear facility went into operation.

Also, how variable were the year to year numbers of live births in a given county. Did these numbers exhibit some temporal trend, and could there be any danger of some spurious correlations?

Reply: M. DeGroot

Dr. Neyman has raised two very interesting questions about my paper. First, he is quite correct that the construction of a nuclear reactor at a given site might well lead to changes in the socioeconomic composition of the population near that site which in turn lead to changes in the infant mortality rates. It is difficult to check this possibility because the relevant census data are published only every ten years. My own guess is that although there might be such changes in the immediate vicinity of the reactor (say within a few blocks) it is less likely that the composition of the county as a whole will shift because of the reactor. Of course, it may shift for other reasons in accordance with certain population trends or patterns, which is equally damaging to the analysis. However, I should think that the particular counties considered in my paper, rural Grundy as well as relatively populated Beaver, Westchester, and Suffolk, retained their same general character over the entire period studied. This question clearly requires further and more careful investigation.

Second, Dr. Neyman is again completely correct that a regression analysis based on rates is a tricky business when both the numerators and denominators are random variables, especially if the distribution of the number of live births in the denominator may be changing with time. Here, however, the yearly time series of the number of births and deaths in the various counties do not reveal any "substantial" changes over the period studied. Perhaps more reassuring, a glance at the graph of the time series of the infant mortality rate for each county seems to indicate that the variability of the annual rate remains roughly the same over the entire period.

HEALTH DANGERS

OF THE

NUCLEAR FUEL CHAIN

AND

LOW-LEVEL IONIZING RADIATION

A BIBLIOGRAPHY/LITERATURE REVIEW

BRITISH COLUMBIA MEDICAL ASSOCIATION
HEALTH PLANNING COUNCIL
ENVIRONMENTAL HEALTH COMMITTEE

AND

PHYSICIANS FOR SOCIAL RESPONSIBILITY
CALIFORNIA BAY AREA CHAPTER

By: ROBERT F. WOOLLARD, MD, CHAIRMAN BCMA
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MAY 1979

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PREFACE

RESPONSIBILITIES TO SOCIETY

An Ethical Physician " . . . will accept his share of the profession's responsibility to society in matters relating to public health, health education, and legislation affecting the health or well-being of the community . . . " (Code of Ethics, Canadian Medical Association, June 1978.)

The Environmental Health Committee of the British Columbia Medical Association agrees with a statement made by Mr. James E. Gander at the Conference on Nuclear Issues in the Community (CONIC) in Vancouver, March 1979 - that economic issues of the energy debate are "light years below ethics and health issues". There seems to be, however, a general lack of factual knowledge among health professionals, the public, the workers, the native peoples, the government, the nuclear industry and the media about the health issues of the nuclear fuel chain which makes intelligent discussion impossible and ludicrous generalizations and comparisons inevitable. This bibliography/literature review is an effort to give a broader understanding to all concerned, as they, their children, and their children's children, will be affected by decisions made in the near future. In the final analysis, it is the public that must become informed and assume an active role in the debate.

The medical profession has for a long time taken a back seat in environmental health issues, but physicians are becoming aware that although our time is almost fully taken in efforts to cure our patients, we should be more actively participating in the prevention of their diseases. We have to, therefore, expand one of the dimensions of this profession - we must become guardians of health.

Because of our vested interest in the well-being of our patients, we need ensure that they and their offspring are the beneficiaries, and not the victims of technology. Those who have suffered or will suffer disease as a result of mercury poisoning at Minamata, from radioactive fallout from atmospheric nuclear tests in Nevada, Utah and elsewhere, etc., might have expected the health profession to have had an important input into prevention.

What follows is an annotated bibliography of many studies relating to the problems of radiation and the nuclear fuel chain. Some non-medical but pertinent, background data, as well as articles illustrating controversial issues, are also provided. It should be remembered that any consideration of uranium mining in B.C. cannot exclude the cumulative health dangers of all aspects of the nuclear fuel chain, as it is in fact not a cycle, but an active progression of events which are inextricably linked.

Due to deadlines, this work is not exhaustive and it is hoped that suggestions and further summaries of medical articles will be forthcoming to add to an up-to-date review in the future.

NOTES ON THE BIBLIOGRAPHY/REVIEW FORMAT

Some notations that are not within quotation marks should be. We apologize to the authors and hope to rectify this situation in a later edition.

( ) Parenthetic brackets around entire summaries indicate that the summary was taken from another article which referred to it. The Environmental Health Committee has not reviewed or verified them, but they are included to give the reader an idea of their content.

[ ] Square brackets indicate *editorial comment.*

(PSR) indicates that the article summary was done by Physicians for Social Responsibility, Po Box 295, Cambridge, Mass 02238, or by the California Bay Area Chapter, 944 Market Street, San Francisco, California 94102.

PREFACE TO THE PHYSICIANS FOR SOCIAL RESPONSIBILITY EDITION

It has been almost nine months since the partial meltdown of the core of the Three Mile Island Nuclear Power Plant in Middletown, Pennsylvania, and a year since the mass suicide at Jonestown. The official offspring of the TMI disaster have undergone gestation and delivery, and the resultant Kemeny Commission Report excoriates the Nuclear Regulatory Commission's performance in overseeing the safety aspects of nuclear power, recommends a moratorium on new licensing and construction until adequate evacuation procedures for densely populated areas can be devised, and finds no way to guarantee against future catastrophic nuclear power accidents. Sources close to the government report that it will probably be at least two years before any new operating licenses are granted. Meanwhile, the 71 remaining nuclear power plants continue to operate, and 10% of the American population continues to live within 30 miles of one. These are the plants whose design, construction and operation cannot fully benefit from the lessons of TMI. They are therefore at similar risk. Many Californians were surprised to learn that they lived near TMI's twin, Rancho Seco, outside Sacramento. Many were even more surprised to learn that the Pacific Gas and Electric Company had built a facility at Diablo Canyon only two and one half miles from an active earthquake fault capable of generating a force ten times that which the plant was designed to withstand.

As the energy crisis deepens, so increases the sense of desperation and panic on the part of an energy-dependent society. A discussion of the health effects of the nuclear fuel chain is often followed by the statement, "But we need the energy, and coal is dirty, too." It is our contention that we do not need the 5% of the total energy output of the US which nuclear power contributes, and that many times that amount could be saved by generating conservation energy rather than nuclear energy. (See Energy Future: The Report of the Energy Project at the Harvard Business School. Random House, New York, 1979.) It is the purpose of this literature review to elucidate the risks to health of all parts of the nuclear fuel chain so that, in the spirit of informed consent, society may choose its options more knowledgeably. We believe that the true Risk/Benefit ratio of nuclear power eliminates it from consideration at this point in the evolution of human technology. A perusal of some other technological mishaps in recent times will show our fallibility in technical endeavors-- the DC-10, the Love Canal and its many relatives throughout the land, Thalidomide, PBB in 98% of Michigan's population, DBCP in California's drinking water, catastrophic oil spills, the chlorine gas spill that recently forced the largest evacuation in North American history, and many more. Nuclear technology is perhaps the least forgiving activity mankind has ever engaged in. An invisible speck of plutonium, once released into the biosphere, remains carcinogenic, teratogenic and mutagenic essentially forever, due to its 24,400 year half life. A genetic mutation that is sub-lethal, once mixed into the human gene pool, will contribute to the progressive genetic degradation of our species, and other species, that will certainly accompany the man-made addition to the inescapable radiation levels which living things must cope with and have evolved with over the past several million years.

Because of its central role in the nuclear power and weapons programs, we have added a section on plutonium to the original edition of this review from British Columbia. This is to be found on pages 44A-F. It should be universally appreciated that the nuclear power industry intends to make plutonium the future currency of our energy economy. This is necessary since uranium-235, the original light water reactor fuel and the substrate for the Hiroshima bomb, is limited in nature. Plutonium, by contrast, can be created by neutron activation of uranium-238, which is abundant. The breeder reactor would use plutonium as fuel, surrounded by a blanket of U-238, thus generating more plutonium. Likewise, the hybrid fusion reactor can also serve to breed new fissile material from fertile material. The current generation of light water reactors also generate large quantities of plutonium, some 400-500 pounds of it yearly. The reprocessing of the spent fuel elements to recover unused uranium and plutonium is necessary for the survival of the nuclear power industry, but it also creates the enormous hazard of huge inventories of weapons-grade plutonium circulating about. Only 20 pounds of this material are necessary to construct an atomic bomb, the technology for which is relatively simple and generally available. Already a large amount is "missing and unaccounted for" (MUF). In order to prevent the clandestine diversion and reprocessing of spent nuclear fuel by foreign governments to whom we have sold reactors, the United States is retrieving it from abroad, thus vastly augmenting our growing inventories of radioactive waste, for which we are still seeking adequate disposal. Thus far the performance of those handling plutonium, the substrate of the Nagasaki bomb, has been less than adequate. The Rocky Flats facility, which manufactures the plutonium triggers for the two hydrogen bombs made daily in the United States, has polluted the Denver metropolitan area through fires and sloppy waste-handling. Dr. Johnson's study of cancer rates as correlated with plutonium concentration in respirable surface dust, is devastating. It awaits peer review by the scientific community. Elsewhere, at Hanford, Washington and West Valley, New York, major and minor dispersals of high-level waste have introduced plutonium into the environment. It is only a matter of time before it finds its way into the food chain. Hanford sits along the Columbia River, which empties into the Pacific Ocean. The repetitive assertion that "There is no immediate danger to the public" may be true, since cancer latency may be many years and the expression of subtle genetic damage may require many generations. We trust that the articles reviewed in the section on plutonium will speak for themselves as to whether or not there is a hazard.

It should also be clearly appreciated that the nuclear fuel chain was originally developed for the sole purpose of manufacturing atomic weapons, and that it still serves that purpose. The original "piles" at Hanford were built to generate plutonium for the Manhattan Project. Later on, the waste heat was coupled to steam generators to boil water for electric turbines. The major portion of radioactive waste comes from weapons construction, although the dream of the nuclear power industry of 1000 reactors by the turn of the century would generate as much waste every three months as we have accumulated in 35 years. (Personal communication, Dr. John Gofman) Despite the fact that both the United States and the Soviet Union now have enough destructive capacity to annihilate every living creature on the planet many times over, the arms race has taken a new, most ominous turn recently. Whereas the traditional nuclear weapons policy of the US has been to insure our security by possessing such retaliatory force as to guarantee Mutually Assured Destruction (MAD), the latest generation of strategic missiles have such long-range accuracy that their purpose is to destroy enemy missiles in the ground, i.e., to initiate World War III by striking first. The development of the first- strike capacity threatens to trigger the last and greatest conflagration. The side believing itself ahead may feel compelled to use such weapons, knowing that the side believing itself behind may feel compelled to strike before it can be disarmed and devastated. Missile systems such as the Trident, being built by Lockheed in Sunnyvale and Santa Cruz, California, serve this purpose.

On Friday, November 2, 1979, a computer error put the strategic forces of the United States on nuclear attack status for six minutes. Fighter planes took off. Missile bases were alerted. The mistake was corrected. Had it not been, a potential arsenel of some 50,000 miniature suns could have ignited on the face of the earth, thus terminating life and civilization as we have known it. How have we arrived at this strange point in history, poised on the brink of annihilation? Clearly, the public has abrogated responsibility for crucial decisions to the experts in nuclear power and weapons policy. Nuclear weaponry has been shrouded in secrecy since its inception, impeding awareness and public debate. The thought of nuclear warfare is so psychologically disruptive that the spectre of total annihilation is difficult for most people to rationally, willingly consider and comprehend. Making new weapons so horrible "that they will never be used" constitutes a flimsy defense against Armageddon. One need only recall that prior to the systematic genocide practiced during the last world war many intelligent people were certain that "it could never happen here." The passive acquiescence on the part of society to leaders who believe that a nuclear war can be fought and won will lead eventually to the same kind of mass suicide which shocked the world a year ago.

The accident at Three Mile Island raised the awareness of all people about nuclear power and may very well have cast the dye for that industry. It would be a mistake for those of us concerned about the reactors in our backyards, however, to ignore the far more complex and less visible threat of the nuclear arms race. In order to justify our concern for the legacy of radioactive waste bequeathed to the next ten thousand generations, or the callous trading of genetically defective offspring and lives shortened by cancer in return for electricity, we must first concern ourselves with insuring that there is a futu at all, and at this point in time it looks grim indeed. We hope hat this short review of the biohazards inherent in nuclear weapor nd power will serve the growing movement to preserve that which is ost precious--our health, our genetic material, our life-support system, and the inviolate beauty of the small planet on which we live.

Peter G. Joseph, M.D.

IONIZING RADIATION

Ionizing radiation is a form of radiant energy which has the ability to shear electrons from matter through which it passes. When that matter is alive, chemical bonds which determine biological processes are altered. If sufficient damage is done to vital cellular structures cell death results. Thus, radiation is useful in cancer therapy to kill tumor cells. Lower doses, however, may result in chromosome damage sufficient to permit continued cell division in an imperfect fashion, thus setting the stage for malignant transformation.

Ionizing radiation occurs in two principle forms, electromagnetic and particulate. The former type consists of X-rays, which are generated by machines, and gamma rays, which are emitted from the decaying nuclei of radioactive substances and also strike the earth from outer space. Cosmic radiation accounts for a sizeable fraction of our yearly background dose, and since they are filtered by the ozone layer of the atmosphere (slowly vanishing) are stronger at higher altitudes. Particulate forms of radiation consist of beta and alpha particles. Beta particles are the equivalent of electrons, with either a positive or negative charge. Alphas are charged helium nuclei, and are relatively much heavier and more destructive than other forms of ionizing agents. A single cellular hit with a particle of beta or alpha radiation will break between 250,000 and 2,500,000 chemical bonds. Some capacity for cellular repair is present but is naturally limited.

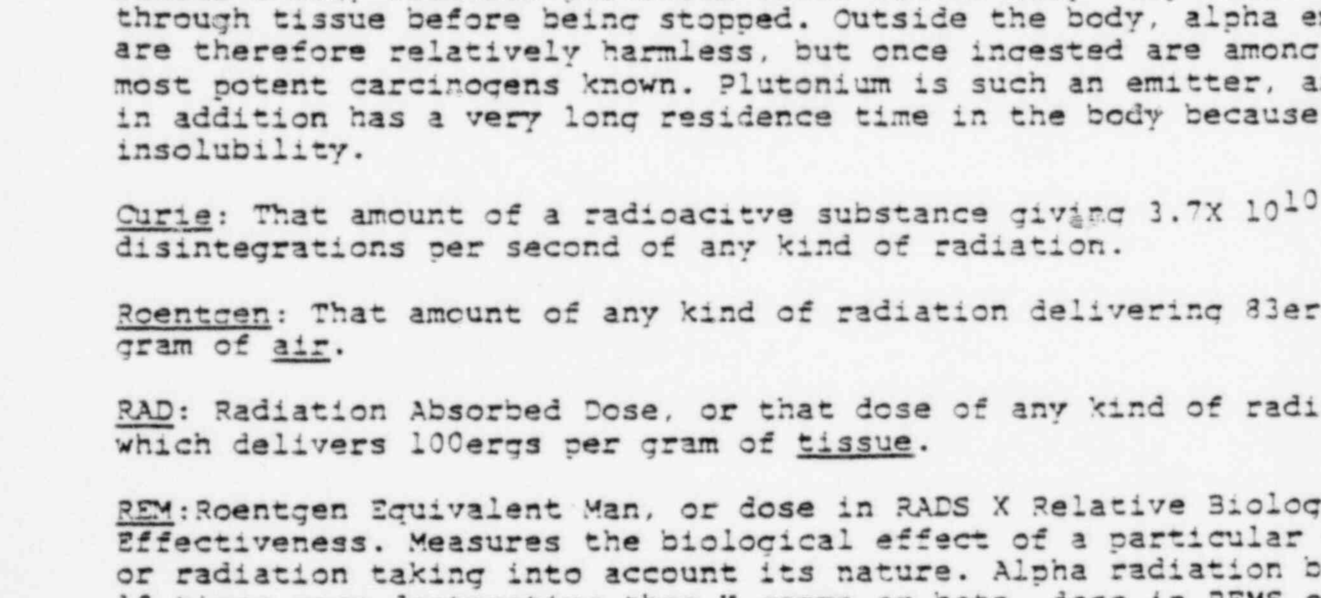
Relative Biological Effectiveness: X, gamma and beta radiation passes relatively easily through tissue, imparting a relatively small fraction of their energy. Their Linear Energy Transfer, L.E.T., is thus termed low. Alpha particles, on the other hand, are relatively massive, High Linear Energy Transfer particles which travel only very short distances through tissue before being stopped. Outside the body, alpha emitters are therefore relatively harmless, but once ingested are among the most potent carcinogens known. Plutonium is such an emitter, and in addition has a very long residence time in the body because of its insolubility.

Curie: That amount of a radioacitve substance giving $3.7X\ 10^{10}$ disintegrations per second of any kind of radiation.

Roentgen: That amount of any kind of radiation delivering 83ergs per gram of air.

RAD: Radiation Absorbed Dose, or that dose of any kind of radiation which delivers 100ergs per gram of tissue.

REM: Roentgen Equivalent Man, or dose in RADS X Relative Biological Effectiveness. Measures the biological effect of a particular dose or radiation taking into account its nature. Alpha radiation being 10 times more destructive than X, gamma or beta, dose in REMS of alpha is 10Xthat measured in RADS. For the other forms, whose biological effect is defined as 1, dose in RADS roughly equals dose in REMS.



Autoradiograph of ce. amic microspheres of ZrO_2 loaded with $^{238}PuO_2$.

I - URANIUM MINING

1) Altshuler, B., Nelson, N., and Kuschner, M., "Estimation of lung tissue dose from the inhalation of radon and daughters", Health Physics, 10: 1137-1161, 1964.

-The cancer-related dose (largest dose to shallow basal cells) associated with 1 Working Level of radon daughters is estimated to be 20 rads/year for nose breathing at 15 l/minute.

-Comparison with animal studies shows working level may not be safe and that 30 pCi/l of daughters (0.1 WL) may not be too conservative for MPC (maximum permissible concentration).

-In 1960, 1 WL = 3 x 10^{-10} Ci/l = 300 pCi/l of radon daughters (which is the daughter activity in equilibrium with 100 pCi/l of radon), was adopted by the American Standards Association as a MPC.

-"there is sufficient probability that the effective dose has been underestimated to justify the introduction of a safety factor"

-Good table of radon daughters, which include radioactive Polonium, Lead and Bismuth, half lives and alpha energy.

-The Findeisen and Landahl model of the respiratory system used is considered inadequate. Its low suggested dose should therefore be lower.

-42 references.

2) Archer, V.E., "Lung cancer among populations having lung irradiation", letter to editor, Lancet, 11(7736): 1261-1262, 4 December 1971.

-has table of excess lung cancer/year/WLM(rad)and(rem)/million persons for Sweden, Joachimsthal, Newfoundland, etc. miners and A-Bomb survivors.

-U.S. uranium miners had 1.8 excess cancer/year/WLM/million persons.

-1 WLM approx. = 2 rads approx. = 6 rem.

-Radiation not only emerges as the only common carcinogenic agent but is associated quantitatively with excess lung cancer.

-Ventilation reduced the radon daughter concentration in U.S. mines by a factor of 5-10.

-Radiation dose/response curve is approximately linear from fairly high levels down to the 0-dose/0-response point.

3) Archer, V.E., Carroll, B.E., Brinton, H.P., and Saccomanno, G., "Epidemiological studies of some non-fatal effects of uranium mining", Radiological Health and Safety in Mining and Milling of Nuclear Materials, Vienna: International Atomic Energy Agency, Volume 1: 21-36, 1964.

- In Colorado Plateau miners 1950-1960 "increased rates of emphysema, shortness of breath, persistent cough, pulmonary fibrosis and cell changes in the sputum suggestive of radiation effects, are associated with increasing radiation exposures in uranium miners", (in smokers as well as non-smokers compared with similar controls).
- There is free silica in the dust in uranium mines, but in less than permissible amounts.
- Good statistical analysis.

4) Archer, V.E., Gillan, D.J., James, L.A., "Respiratory disease mortality among uranium miners as related to height, radiation, smoking and latent period", Proceedings of the Third International Symposium on the Detection and Prevention of Cancer, Nieburgs, H.E. (editor), New York, 1976.

(-more increased cancer in uranium miners who smoke cigarettes than non-smoking miners.

-radiation possibly enhances the fibrotic effect of silicosis.)

5) Archer, V.E., Gillan, J.D., and Wagoner, J.K., "Respiratory disease mortality among uranium miners", Annals of New York Academy of Sciences, 271: 280-293, 1976.

- "Uranium, as found in nature, is normally at or near equilibrium with its decay products, which include the inert gas radon. Because radon diffuses from the rock into open areas of mines, most underground miners are exposed to radon concentrations in excess of those found above ground."
- "When pure radon is breathed, it diffuses throughout the body and gives what is essentially whole-body radiation. Its retention, however, is limited, since most inhaled radon is also exhaled within its half-life of 3.8 days. For the immediate daughters of radon, however, the story is different. These radionuclides (218-Po, 214-Bi, 214-Pb, 214-Po) collectively have an average half-life of about 30 minutes. When formed in the air of a mine, they quickly become attached to solid surfaces, most notably dust particles. When these dust particles with attached radionuclides are inhaled, the radiation from them (largely alpha particles) is delivered to those sites in the nose, pharynx, and tracheo-bronchial tree where the dust particles are deposited. The radiation dose delivered to the lungs of uranium miners by these elements is about 20 times greater than that from inhaled radon."

-"A mortality analysis of a group of white and Indian uranium miners was done by a life-table method. A significant excess of respiratory cancer among both whites and Indians was found. Nonmalignant respiratory disease deaths among the whites are approaching cancer in importance as a cause of death, probably as a result of diffuse parenchymal radiation damage. Exposure-response curves for nonsmokers are linear for both respiratory cancer and other respiratory disease. Cigaret smoking elevates and distorts that curve. Light cigaret smokers appear to be most vulnerable to lung parenchymal damage. The predominant histologic cancer among nonsmokers is small-cell undifferentiated, just as it is among cigaret smokers".

6) Archer, V.E., Lundin, F.E., "Radiogenic lung cancer in man: exposure - effect relationship", Environmental Research, 1: 370-383, 1967.

-"Comparisons are made of lung cancer data from five groups of miners exposed to a wide range of levels of air-borne radioactive particles. Partly because of variable quality of the data for the different groups, alternative estimates of lung cancer risk are used: incidence or mortality rates, ratio of observed to expected rates and proportion of lung cancer to all deaths. These three criteria agree that lung cancer in mining groups tends to be directly proportional to mean radiation exposure. After assuming linearity of this relationship and absence of a dose-rate effect, it is estimated that one rad to the bronchial walls of one million persons produces about one lung cancer per year, and that the average integral dose required to produce one lung cancer is 1.3×10^5 gm. rad. An exposure of 120 WLM (estimated to equal 360 rad) appears to double the lung cancer incidence characteristic of the general population."

-"The estimates of risk are consistent with those for radiation induce thyroid cancer and leukemia in man when expressed as risk/rad/ million/year."

-"There is no evidence for a threshold."

-". . . there is evidence that radiations having high - LET do not exhibit a reduced biological efficiency at chronic low dose-rates . . . "

-"Currently used Maximum Permissible Concentrations (MPC) for radionuclides have a paucity of human data to support them. They are based on theoretical considerations, animal experiments, and on dosage calculations from human radium experience as of 1941."

7) Archer, V.E., Magnuson, H.J., Holaday, D.A., Lawrence, P.A., "Hazards to health in uranium mining and milling", Journal of Occupational Medicine, 4: 55-60, 1962.

-"1. Uranium miners in the Colorado Plateau have been under epidemiologic surveillance since 1950; during this time the working population has increased from approximately 350 to nearly 6,000.
2. Deaths in a study group of 3,317 miners, followed 2-9 years between 1950 and 1959, with 13,270 person-years of observation, have been analyzed by the life-table technic.
3. Preliminary calculations applied to a cohort of 907 whites with 3 years or more of uranium mining experience show 5 lung cancer deaths to have occurred where 1.1 was expected; 8 deaths from heart disease other than arteriosclerotic where 0.4 was expected; and 10 deaths from non-motor-vehicle accidents where 2.5 were expected. All of these differences are interpreted as significant at the 95 per cent confidence level.
4. Concurrent environmental surveys of uranium mines have shown a high proportion of operating mines with concentrations of radon daughter products above the recommended working level of 1.3×10^5 MeV of potential alpha energy per liter of air."

-"Implication of elevated lung cancer risk is supported by suggestive trends in the prevalence of abnormal sputum samples collected in 1960. Furthermore, since the close of the latest life-table analysis there have been 4 more confirmed lung cancer deaths and one additional case diagnosed."

8) Archer, V.E., and Simpson, C.L., "Semi-quantative Relationship of Radiation and Neoplasia in Man", Health Physics, 9: 45-56, 1963.

(-Increased lung cancer in uranium miners is likely a specific result of radiation injury).

9) Archer, V.E., Wagoner, J.K., and Lundin, F.E., "Cancer mortality among uranium mill workers", Journal of Occupational Medicine, 15: 11, 1973.

-No increase respiratory cancer in uranium mill workers but there was a significant excess of malignant disease of the lymphatic and hematopoietic tissue.

10) Archer, V.E., Wagoner, J.K., and Lundin, F.E., "Lung cancer among uranium miners in the U.S.", Health Physics, 25: 351-371, 1973.

-3,366 white underground uranium miners and 780 non-white studied

-found excess respiratory cancer if exposure was equal to or more than 120 WLM.

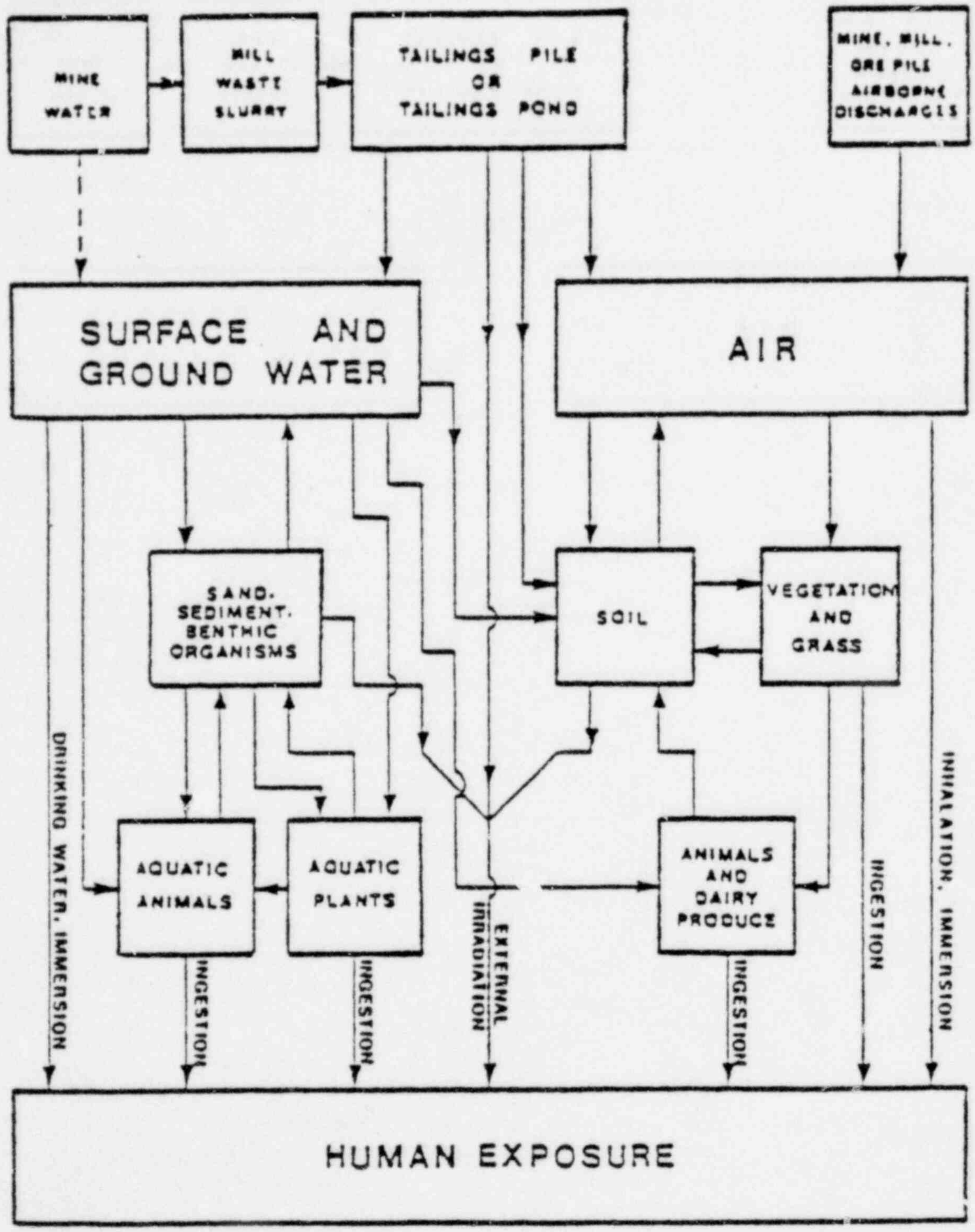


Figure 2: Environmental Pathways
(Taken from Environment Canada's report EPS 3-EC-78-10)

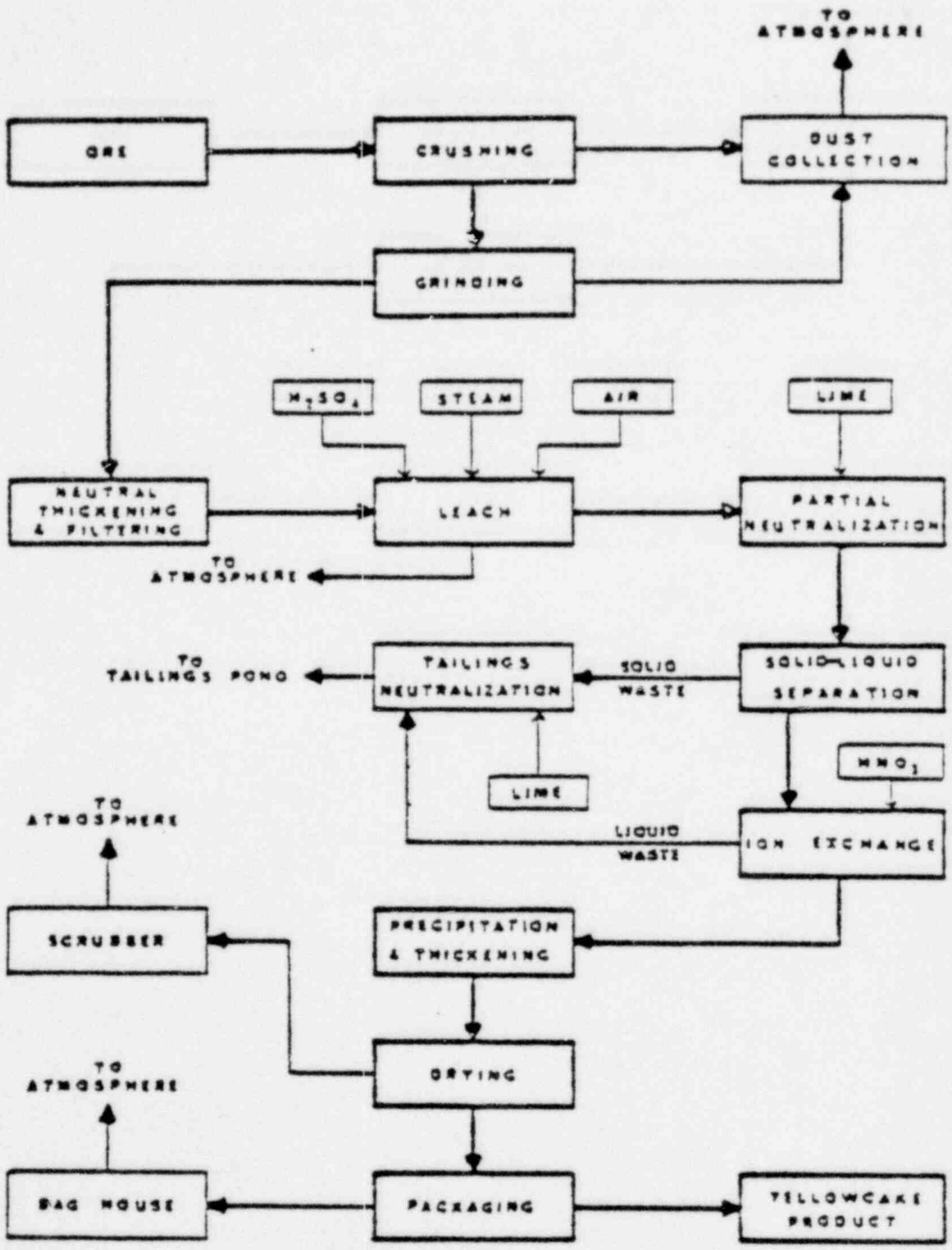


Figure 1: Flow Chart of Ore Processing Operation
(Taken from Environment Canada's report EPS 3-EC-78-10 October 1978)

-no association with non-uranium hard rock mining and respiratory cancer.

-58 deaths from respiratory cancer in underground smoking uranium miners which adjusted for smoking habits the expected was 15.5.

-among non-smokers, expected 0.5 versus observed 2.

-proves the hypothesis that underground uranium workers are constitutionally pre-disposed to develop respiratory cancer is untenable.

-miners may be misclassified into higher WLM's, therefore lower level risk may be underestimated.

-when adjustments were made for latent period and total radiation exposure, no difference in respiratory cancer was found between miners with high exposure rates to those with lower rates. Suggested that radon daughter exposure may be more effective per unit dose in inducing cancer at lower total doses than at high ones.

-cessation of smoking does little to decrease the respiratory cancer risk among uranium miners, whereas after several years the risk drops to near normal levels if a non-uranium miner stops smoking.

-the epidemic among uranium miners is not subsiding.

-a detailed examination of data.

11) Archer, V.E., Wagoner, J.K., and Lundin, F.E., "Uranium Mining and Cigarette Smoking Effects on Man", Journal of Occupational Medicine, 15 (3), March 1973.

-A good article which showed the cumulative effect of radiation and cigarette smoking, and belies the oft-heard claim that the increased incidence of cancer in this industry is related to smoking alone. We are also in possession of a personal communication from Dr. Archer from January of 1977 in which he states, "anyone who argues that Radon is not carcinogenic unless it is combined with smoking is basing his statements on some of our early studies where the followup time was short. Our later studies on animal experiments definitely refute that viewpoint." "The use of the linear hypothesis definitely underestimates the risk of cancer from Radon daughters at low dosage."

12) Bale, W.F., and Shapiro, J.V., "Radiation dosage to lungs from radon and its daughter products", Peaceful uses of atomic energy: Proceedings of the International Conference in Geneva, New York, United Nations, page 233-236, 1956.

(-principal hazard in uranium mine atmosphere is radon daughters--isotopes of lead, bismuth, polonium, and thallium.

-3 X 10^{-9} Ci of radon/l gives tracheal epithelium dose of 0.2 rad/day.

13) Basson, J.K. et al, "Lung cancer and exposure to radon daughters in South African gold/uranium mines", 4th International Conference on the Peaceful Uses of Atomic Energy, Geneva, 1971.

(-hazard of ionizing radiation in uranium and non-uranium mines.

-no increase of cancer at 4 WLM/annum)

[*As noted, this paper has not been reviewed by the committee. A vast majority of medical evidence does not support their conclusion. The committee has not yet had time to study the thoroughness of follow up of underground miners.*]

14) Bertell, R., Personal communication, March 1979.

-only 8% of uranium used in the U.S. is for nuclear power and the rest is for nuclear weapons. There are already enough nuclear weapons to destroy North America, Europe and the U.S.S.R. many times over. Increasing proliferation increases the chance of use.

15) Blair, H.A., "Dose-time relations for induction of lung cancer in uranium miners", Symposium on Radiation-Induced Cancer, International Atomic Energy Agency, Athens, April 28-May 2, 1969.

16) Breslin, A.J., George, A.C., and Weinstein, M.S., Investigation of the Radiological Characteristics of Uranium Mine Atmospheres, New York: Health and Safety Laboratory, U.S. Atomic Energy Commission, HASL-200, December 1969, 24.

(-describes the level of yearly radiation in U.S. mines).

17) Cluff Lake Board of Inquiry - Final Report, The Cluff Lake Board of Inquiry, 802 McCallum Hill Building, Scarth and 12th Avenue, Regina, Saskatchewan, S4P 2G6 - attention Mr. Ian MacPherson, Executive Secretary.

18) Doll, R., "Occupational Lung Cancer: A Review", British Journal of Industrial Medicine, 16: 181-190, 1959.

-a review.

-miners in Schneeberg and Jachymov may have received local doses of 10,000 rads of alpha rays.

-in animals, cancer has been induced more easily by radiation when non-specific inflamation was also present.

-silicosis was prevalent among the miners but not particularly severe in those in which lung cancer developed.

-latency period 15-30 years.

-it is not known if removal of hazard has any significant effect on the size of risk once there has been a prolonged exposure.

19) Duggan, M.J., et al, "The exposure of United Kingdom miners to radon", British Journal of Industrial Medicine, 27(2): 106-109, April 1970.

- epidemiologic studies from 1920's and 1930's in Schneeberg and Jachymov mines had concentrations of 1,000 pCi of Rn-222 and produced a 30 X increase in cancer.
- radon daughters formed in the atmosphere were the major part of radiation to the lungs.
- 1955 International Commission on Radiologic Protection (ICRP) determine maximum permissible concentration in air (MPCa) should be approximately 300 pCi/l air for 40 hour week.
- 1959 MPCa equalled 30 pCi or radon/l of air/40 hour week.
- 1962 International Atomic Energy Agency found it impractical to apply 1959 value, therefore decided MPCa should equal 300 pCi/l/40 hour week.
- 1 working level (WL) equals concentration of Rn-222 daughters/one l air which produces 1.3 X 10^5 MeV of potential alpha energy. 1 WL = 100 pCi/l of Rn-222 in air = 300 pCi/l of radon daughters.
- 1957 Federal Radiation Council recommended exposure to Rn-222 daughters so miners received less or equal to 6 WLM in any consecutive 3 month period and less or equal to 12 WLM in any consecutive 12 months.
- 1968 U.S. Department of Labour required less or equal to 2 WLM in any consecutive 3 months, and less or equal to 4 WLM in any consecutive 12 months producing an approximate average concentration Rn-222, equal to 0.3 WL throughout the year corresponding to 30 pCi/l.
- 1 WLM exposure results from inhalation for 1 working month (170 hrs) of air containing concentration of Rn-222 daughter equal to 1 WL.
- Haque and Collinson 1967 suggested MPCa = 10 pCi/l of air if quality factor (QF) of 10 is considered for the biological effect of alpha rays on producing lung cancer and if annual dose limit is set at 15 rem for any tissue in the lung where the dose is considered.

20) Environment Canada's Reply to Rexspar's First-Stage Report, produced by the Department of Fisheries and the Environment of the Government of Canada, September 1977.

- this is a detailed discussion and response by the Environment Department as regards the original proposal for the mine at Birch Island. The critique is devastating in showing the problems we might expect with the mine as currently designed. This should be read together with the Rexspar proposal to demonstrate the problems one might expect from an unregulated industry.

21) Evans, R.D., and Goodman, C., "Determination of the thoron content of air and its bearing on lung cancer hazards in industry", Journal of Industrial Hygiene and Toxicology, 22: 89-99, 1940.

-"lung tissue appears to be about 25 times more susceptible to alpha radiation than is bone tissue."
"we know that 4.6 and 0.17 erg units over extended exposures will produce cancer in bone and lung tissue respectively but we do not know how much lower either of these quantities can be and still lead to significant radiation damage."

-" . . . rats and mice are about 40 times as resistive as humans to lesions caused by alpha rays, when all dosages are expressed in erg units. The extrapolation of the results of animal experiments to men must recognize this great difference in susceptibility."

22) Federal Radiation Council, Guidance for the Control of Radiation Hazards in Uranium Mining, Report #8, revised, September 1967.

(-12 month exposure to 1 WL = 35 rad dose.

-extensive statistical analysis of increased lung cancer in uranium miners.)

23) Greene, M.W., "Public Health and Uranium Mining", B.C. Ministry of Health, Radiation Protection Service, RPS 0479-2, Vancouver, B.C.

-"The history of uranium mine tailings management has not been encouraging. In many places wind erosion has spread radioactive materials over a wide region."

-"In other places leached materials from tailings ponds have entered the water table."

-"And finally, tailings just seemed to disappear because they have other uses such as land fill and construction related projects."

-for "x-rays or gamma rays we can make the simple assumption: 1 rad = 1 rem = 1 Roentgen."

See Graph #1, Ore Processing Operation

See Graph #2, Environmental Pathways of Radiation

4) Ham, James (Commissioner), Report of the Royal Commission on the Health and Safety of Workers in Mines, Ministry of the Attorney General, Province of Ontario, Toronto, Canada, 1976.

- "Frederic LePlay, a distinguished French sociologist and inspector general of the mines of France in the late nineteenth century, said that the most important thing to come out of mines is the miner. I share his conviction today."
- Ham report shows that of 956 deaths on the Ontario Uranium Nominal Roll of 15,094 people (who worked longer than 1 month) there were 81 deaths of miners or former miners from lung cancer during the period 1955-1974 (versus 45 expected-using vital statistics for the male population of Ontario as a whole).
- typical exposures in Ontario mines were under the 100WLM range. The average numbers of WLM's was 74.5 for the lung cancer cases and 32.8 for the survivors.
- "Though the exposures reported in the present study are small compared with those reported from Colorado, they are just as likely to overstate the quantity of radiation actually needed to produce cancer . . . ". The lapse in time between the initiation of lung cancer and its result in death "provides an opportunity for subjects who have already been affected by prior exposure to accumulate further exposures, which contribute nothing to the outcome already determined and yet add to the apparent dose."
- " . . . to be at all plausible in relation to the Ontario experience, a postulated threshold would have to be lower than 10 WLM (total exposure)."
- " . . . there is no general agreement on the number of Rems of biologically effective irradiation corresponding to the energy of alpha irradiation in Rads."
- "Thus a representative of the Atomic Energy Control Board stated before the Commission that exposures of 4 WLM per annum and 12 WLM per annum could both be consistent with the maximum permissible biological dose of 15 Rems per annum to the lungs as allowed by the regulations under the Atomic Energy Control Act for atomic radiation workers."
- Reviewing the study by Lundin et al, "Radon Daughter Exposure and Respiratory Cancer, Quantitative and Temporal Aspects", Joint Monograph No. 1, National Institute for Occupational Safety and Health, National Institute of Environmental Health, Washington D.C., June 1971, the Ham Commission states: "The most recent major study indicates that there is an excess risk of lung cancer at exposures down to and including the range 120-359 WLM. This report concludes in part that 'these evaluations have failed to find any plausible alternative to the hypothesis that radon daughter exposure is causally related to the excess lung cancer risk in the 120-359 WLM category' and that 'other epidemiological studies of situations

where human lungs were irradiated were not only consistent with the observations of lung cancer in uranium miners, but indicate that excess lung cancer occurs at lower radiation levels than could be adequately studied among [U.S.] uranium miners.' The statistical data derived by the Commission on the basis of analysis of samples are consistent with the foregoing conclusions."

-regarding the obligations to workers and their families: "The Commission sees no excuse for not telling working people the truth, however difficult and imperfect that may be. Nor is it tolerable that there should be no forum in which representatives of workers can engage other parties in the responsibility system in frank deliberation over the risks to health involved in work."

-the Commission makes numerous recommendations based on its analyses.

-hundreds of references.

25) Haque, A.K., and Collinson, A.J., "Radiation dose to the respiratory system due to radon and its daughter products, Health Physics, 13: 431-443, 1967.

- radiation is highest in segmental bronchi.

-at levels of 10.1 X 10^{-12} Ci/l (about 1/3 the MPC for a 40 hour wee' as recommended by the ICRP - 1956), the dose at a depth of 30 microns (a basal cell) is 13.8 rads, and with a quality factor of 5, the rem dose is 69 rem, much higher than the maximum of 15 recommended by the ICRP for limited exposure of internal organs.

-at existing MPC value (3 X 10^{-11} Ci/l) the dose is 41 rad and even taking excellent ventilation into account cannot be lower than 25 rad (125 rem), which is much higher than the maximum recommended 15 rem for an individual organ.

-good mathematical and statistical study with 60 references.

26) Hearings before the Subcommittee on Research, Development and Radiation, of the Joint Committee on Atomic Energy, "Radiation Standards for Uranium Mining", March 17, 18, 1969, and "Radiation Exposure of Uranium Miners", May 9, 10, 23, June 6-9, July 26 and 27, August 8 and 10, 1967. U.S. Government Printing Office, Washington, D.C.

(-increased radiation exposure produces increased lung cancer).

27) Hewitt, D., "Radiogenic lung cancer in Ontario uranium mines, 1955-1974", Commission Project Document, May 1976. (in Report of the Royal Commission on the Health and Safety of Workers in Mines).

-population 15,094 workers - shows 81 lung cancer deaths versus 45.08 expected, violent accidents 400 versus 212.38 expected, arteriosclerotic heart disease 195 versus 287.69 expected, the latter possibly due to medical fitness selection of miners.

-U.S. level in mines approximately 10 times greater radiation than Ontario mines.

-highest exposure in Ontario 375 WLM before death.

28) Holoday, D.A., Evaluation and Control of Radon Daughter Hazards in Uranium Mines, Washington, D.C., U.S. Department of Health, Education and Welfare, No. [NIOSH] 75-117, November 1974.

(-U-238 produces radon and daughters which account for most radioactivity in uranium mines, especially radon (Rn-222 producing alpha rays, half-life = 3.8 days), Radium A (Po-218 producing alpha rays, half-life = 3 minutes), Radium C' (Po-214 producing alpha rays, half-life less than 1 second).)

29) Holoday, D.A., Doyle, H.N., "Environmental Studies in the Uranium Mines", Radiological Health and Safety in Mining and Milling of Nuclear Materials, Vienna; International Atomic Energy Agency, Volume 1, 9-20, 1964.

- U.S. Public Health Service study from 1950-1963 of various uranium mine radon levels and miner exposures.

-1952: greater than 44% of early mines had WL of greater than 10 WL radon concentration, less than 16% had radon concentration less than 0.49, 23.3% had radon concentration from 2.5 to 10 WL.

-1962 approximately 4% of mines had WL of greater than 10 WL radon concentration, approximately 33% had radon concentration less than 1.0, 29% had WL between 3 - 10 WL radon concentration.

-"In many mines the atmospheric concentrations of radon daughters still exceeded the recommended levels."

-"The use of dilution ventilation as the sole method of control has reached the point of diminishing returns."

30) Jacobi, W., "The dose to the human respiratory tract by inhalation of short lived Rn-222 and Rn-220 decay products", Health Physics, 10: 1163-1175, 1964.

-the Findeisen and Landahl model is considered inadequate.

31) Lorenz, E., "Radioactivity and lung cancer; a critical review of lung cancer in the mines of Schneeberg and Joachimsthal, "Journal of National Cancer Institute, 5 (1): 1-16, August 1944.

-primary cancer of the lung (1875-1939) = 43%, (1921-1939) = 52% of deaths in miners.

-a review of many early studies done on those miners with various factors being blamed for the carcingenesis.

-daily radon concentrations estimated at 3,000 pCi/l of radon.

32) Lundin, F.E., Archer, V.E., Smith, E.M., and Wagoner, J.K., "Lung cancer among U.S. uranium miners: current assessment of risk", presented to the American Public Health Association, Miami, Florida, 1967.

(-risk estimates have increase over time.)

33) Lundin, F.E., Lloyd, J.W., Smith, E.M., Archer, V.E., and Holoday, D.A., "Mortality of Uranium miners in relation to radiation exposure, hard rock mining and cigarette smoking - 1950 through September 1967", Health Physics, 16: 571-578, 1969.

-studied 3,414 white underground uranium miners and 761 non-white.

-398 deaths versus 251 expected; violent 120 versus 50.5 expected respiratory tract malignant neoplasms 62 versus 10 expected.

-prior hard rock mining had little overall effect on lung cancer incidence.

-smoking alone would not explain the marked excess.

-higher cumulative exposure levels related directly to increased incidence of cancer.

-60 respiratory cancer deaths were observed among smoking white uranium miners versus 15.5 expected in a smoking non-uranium mining sample, therefore a 4 fold increase.

-non smoking uranium miners have 1.7 excess respiratory cancer deaths per 10,000 person-years versus cigarette smoking uranium miner excess of 17 per 10,000 person-years.

-smoking differences among them could not account for the progressively increasing cancer risks as radiation exposure increased.

-excess lung cancer was noted down to less than 120 WLM (p less than 0.01).

-an excellent, comprehensive analysis.

34) Lundin, R.E., Wagoner, J.K., Archer, V.E., "Radon Daughter Exposure and Respiratory Cancer: Quantitative and Temporal Aspect", NIOSH-NIEH, Joint Monograph #1, Springfield Virginia, National Technical Information Service, June 1971.

-(increased lung cancer in uranium miners due to radon and daughters,
-increased lung cancer down to 120 - 359 WLM category, and other studies indicate excess cancer at even lower levels.
-dose rate does not influence cancer risk at 120 - 359 WLM.
-extensive statistical analysis.)

35) Milham, S., "Workers dying from cancer and other causes", Occupational Mortality in Washington State 1950-1971, HEW publications #(NIOSH 76-17, volumes A, B, and C), 1976.

36) Miller, H.T., "Radiation Exposures associated with surface mining for uranium", Health Physics, 32 (6): 523-527, June 1977.

- -hazards from beta and gamma radiation; uranium dust and surface contamination in open pit mining are about the same as for underground mining.
- -main difference is the very low radon and radon daughter exposure.
- -gamma radiation dose equivalent is approximately 60 - 170 mrem/hr.
- -alpha: radon concentrations in the pit are less than 10 pCi/l.
- -radon daughter concentration is less than 0.3 WL and average rate on daughter concentration is less than 0.06 WL.
- -maximum uranium airborne concentration = 1.7 mg/m^3.
- -a 6 month study.

37) Muller, J., Wheeler, W.C., "Causes of death in Ontario uranium mines (second report)", May 1974.

- -development of the Nominal Roll.
- -41 lung cancer cases in 8,000 miners (1955-1972) gave an excess of 28 over the 13 lung cancer expected deaths.
- -persons on the uranium Nominal Roll have increased risk of lung cancer in Ontario. Risk increased with cumulative exposure and linear hypothesis is consistent.
- -Bancroft: risk of miners = 2.2 X the normal chance of lung cancer.
- -"there is now no longer any real question of recommending a level of exposure to ionizing radiation that in the light of present knowledge can be considered absolutely safe."
- -"direct epidemiological evidence in the circumstances of exposure of the particular working population is considered to provide the best basis upon which to review the standard for exposure to radiation."
- -disagrees with the conclusions of Stewart and Simpson.
- -previous work history shows exposure to less than 1 WLM/annum in Ontario non-uranium mines.
- -the Nominal Roll provides no evidence supporting the hypothesis of a threshold of exposure below which there is not significant excess risk.
- -must have "regard to the human risks that are acceptable in return for the benefits of nuclear power" (based on - accidents and lung cancer risk).
- -"in the absence of evidence of a threshold below which it may be presumed that there is no risk, it is prudent to assume that the risk of excess lung cancer increases with ionizing radiation from zero exposure."
- -sputum cytology is not suited to massive application in occupational medicine.

38) National Academy of Sciences, The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: Report of the Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR report), November 1972.

- "The doubling dose [for genetic defects] for chronic radiation is estimated to fall in the range of 20 - 200 rem."
- "It is calculated that the effect of 170 mrem per year (or 5 rem per 30-year reproduction generation) would cause in the first generation between 100 and 1,800 cases of serious, dominant or X-linked diseases and defects per year (assuming 3.6 million births annually in the U.S.)", and about 5 fold larger incidence at equilibrium.
- "Added to these would be a smaller number caused by chromosomal defects and recessive diseases."
- "In addition to those . . . caused by single-gene defects and chromosome aberrations are congenital abnormalities and constitutional diseases which are partly genetic. It is estimated that the total incidence from all these including those above, would be between 1,100 and 27,000 per year at equilibrium(again, based on 3.6 million births.)"
- "The Risk in Terms of Overall Ill-Health. The most tangible measure of total genetic damage is probably 'ill-health' which includes but is not limited to the above categories. It is thought that between 5% and 50% of ill-health is proportional to the mutation rate. Using a value of 20% and a doubling dose of 20 rem, we can calculate that 5 rem per generation would eventually lead to an increase of 5% in the ill-health of the population. Using estimates of the financial costs of ill-health, such effects can be measured in dollars if this is needed for cost-benefit analysis."
- Such calculations based on these data from irradiated humans lead to the prediction that additional exposure of the U.S. population of 5 rem per 30 years could cause from roughly 3,000 to 15,000 cancer deaths annually, depending on the assumptions used in the calculations."
- Some recommendations were: "The public must be protected from radiation but not to the extent that the degree of protection provided results in the substitution of a worse hazard for the radiation avoided."
  "There should be an upper limit of manmade non-medical exposure for individuals in the general population such that the risk of serious injury from somatic effects in such individuals is very small relative to risks that are normally accepted. Exceptions to this limit in specific cases should be allowable only if it can be demonstrated that meeting it would cause individuals to be exposed to other risks greater than those from the radiation avoided."

"Medical radiation exposure can and should be reduced considerably by limiting its use to clinically indicated procedures utilizing efficient exposure techniques and optimal operation of radiation equipment."
"In addition to normal operating conditions in the nuclear power industry, careful consideration should be given to the probabilities and estimated effects of uncontrolled releases."

-In General: "Concern about the nuclear power industry arises because of its potential magnitude and widespread distribution. Based on experience to date and present engineering judgment, the contribution to radiation exposure averaged over the U.S. population from the developing nuclear power industry can remain less than about 1 mrem per year."

[Not only does this figure either spread out the higher worker exposure over the general population or not include them at all but this figure must be based on the premise that "if everything goes perfectly well then everything will go perfectly well". Its calculation must be providing that:
-there are no transportation accidents or hijacking,
-that there are no accidental serious reactor releases, accidents or sabotage,
-that no-one builds a reactor or uranium mills or reprocessing plants in major earthquake areas,
-that no country which buys a reactor and develops nuclear weapons ever uses them,
-that waste disposal methods are developed for tailings as well as reactor waste,
-that there is no environmental contamination from storage of such waste,
-that "no reactor fuel processing plant or repository anywhere in the world is situated in a region of riots or guerrilla activity, and no revolutions or war - even a 'conventional' one - takes place in these regions. The enormous quantities of dangerous material must not get into the hands of ignorant people or desperados. No acts of God may be permitted." (Hannes Alfven (Nobel Laureate in Physics, 1970), Bulletin of the Atomic Scientists, May 1972.)]

-"Whether we regard a risk as acceptable or not depends on how avoidable it is, and, to the extend not avoidable, how it compares with the risks of alternative options and those normally accepted by society."

-Lung Cancer:
-suggested that 1 WLM results in 5 rems to the lung tissue .
-"... there is little or no dose-rate dependence observed following exposure with high-LET [linear energy transfer] radiation and a definite dose-rate dependence following exposure to low-LET radiation."
-On the basis of present evidence, 1 rad/WLM is probably close to the upper limit for a reasonably uniform dose to the basal cell layer of the epithelium of the larger bronchi..."
-"... the absolute risk [of lung cancer] in these groups (uranium miners and Japanese survivors) will approach $2/10^6$/year/rem.."

-Testes:
-"In men who have received testicular irradiation in criticality

accidents of radiotherapy, the time required for the sperm count to return to normal has varied from about one year after a dose of 100 rem to more than three years after near-lethal exposure."

-hundreds of references.

39) Nader, R. and Abbotts, J., The Menace of Atomic Energy, W.W. Norton & Co. Inc., New York. 1977.

-"It appears that the Public Health Service 1969 estimate by C.C. Johnson that excess lung cancers would affect one-tenth or more of the miners is still accurate. Dr. Archer further indicated that 30 years of exposure at the present 4WLM per year standards would increase by 45 percent the chances that a person would contract cancer. Archer commented: 'The epidemic of respiratory cancers among United States uranium miners is continuing, even though radon daughter levels have been low in recent years. A new epidemic of death from respiratory insufficiency has begun among them'. "

-"... another problem at mines and mills has surfaced - the drinking water for the workers & even their families may be radioactive..."

-In New Mexico in the Grant's Mineral Belt where water "had to be pumped out of the uranium mines to prevent flooding", the "EPA surveyed 6 drinking water supplies & found all 6 excessively contaminated with alpha radiation and radioactive uranium. Alpha radiation levels were 200 times those allowed by drinking water standards proposed by EPA; radium levels were 8 times the allowed levels."

-hundreds of references.

40) Palmer, H.E., Perkins, R.W., Stuart, B.O., "The distribution and deposition of radon daughters attached to dust particles in the respiratory system of humans exposed to uranium mine atmospheres", Health Physics, 10: 1129-1135, 1964.

-Comparison of air samples with whole body counting data obtained for 0.5 - 2.5 hours exposure in mines show nearly 100% deposition of radon daughters (20% in the head, 10% in neck, 70% in chest).

-Radon daughters attach themselves to dust nuclei in the air & release decay energy to local tissues following inhalation.

-Particles carrying the bulk of activity are probably smaller than 0.1 micron.

-No filtering substance is known that will adsorb an appreciable quantity of radon. Approximately 1% is now adsorbed.

41) Porter, A., Interim Report on Nuclear Power in Ontario, Royal Commission on Electric Power Planning, Queen's Printer for Ontario, 1978.

-"Since 1954, when uranium mining began in the Elliot Lake region, there has been serious environmental contamination in the immediate vicinity of the mines resulting from the leaching of radioactive substances, especially radium-226, and from highly acidic tailings."

measured for high emission rates, e.g., those which occurred in 1973 in Gundremmingen or in 1975 in Lingen (model study). We must therefore rely on a theoretical calculation.

Noble gases are formed in the reactor core during the fission process. Since the processes involved in the production of noble gases during fission are not known exactly enough, an exact quantitative calculation of their production in the reactor core cannot be made. Consequently, it is necessary for us to rely on the liberation rates given in the KWS Safety Report (1973), which are based on measurements performed on the Gundremmingen boiling-water reactor (Holm, 1978; Schrüfer, 1974). According to these measurements, noble gases are produced in highly variable quantities. For example, Kr-85 is produced at a rate of 750 Ci/yr, while Kr-89 is produced at a rate of 2500 Ci/hr (in each case it is assumed that the reactor is operated at full load). Since noble gases decay after a certain amount of time, which depends on the half-life, the environmental hazard depends to a critical extent on how long the noble gases remain in the reactor plants.

If the noble gases are conveyed to the chimney through extraction systems (paths 2 - 5), the dwell times in the reactor plants depend on the particular space volume and on the exhaust rate. It was assumed that the noble gases become uniformly distributed in the space immediately after entrance. Of course, if the point of leakage is near the exhaust system, the dwell time is considerably reduced. Since the exact construction plans were not available to us, this case, which might result in elevation of the radiation load, could not be considered. It must be expected, therefore, that a large proportion of the gases escapes by leakage rather than by the prescribed path, namely, via the degassing system. It can be assumed that with increasing operating time the leakage or the activity emissions on the liberation paths become greater.

In accordance with Holm (GRS-8, 1978), the Department of Environmental Protection considered the following liberation paths in particular in its calculations:

1. Primary water purification plant -- exhaust system -- chimney

2. Steam generator heating pipe leakage -- condenser -- chimney

3. Leakage from the primary circulation -- plant buildings -- exhaust air -- chimney

4. Leakage from the primary water purification plants -- annular space air -- chimney

5. Leakage from the primary water purification plants -- auxiliary plant buildings -- chimney

Kausz and Spang (1973) show that about 50% of the noble gas emissions reach the outside through leakages while avoiding the exhaust gas system. Measurements of the National Bureau of Health (National Bureau of Health, STH-2/76) have found rates of even 45% to 98.5%.

In the calculation of the nuclide spectra performed here, the experts worked on the basis of the proposed activity emission of 80,000 Ci/yr, an annual power availability of the nuclear power plant of 80%, time delays of 40 days for xenon and 40 hours for krypton in the exhaust gas system, and estimated, free volumes and exhaust gas rates of the system parts of the Biblis type pressurized water reactor (from D. Holm, GRS-8, 1978). In regard to the percent variation of the proportions of noble gas that are released to the environment via the leakage, it is mainly the proportions that do not pass through the exhaust gas system that determine the radiation load because of the short time delays. Four leakage combinations calculated by us are given in Table 4.3-1, whereby, in accordance with experience (STH-2/76), the amount of noble gas released through the delay system was varied between 1.5% and 50% of the total amount of noble gas activity emitted. The nuclide spectra resulting from this distribution are given in Table 4.3-2. It is seen that there are practically no differences among spectra A to D despite the large variation in the percentage released through the exhaust gas system. There is no great change in the spectrum until all of the noble gas is released through the exhaust gas system (case E). However, a physically unrealistically high source strength would be necessary for this if 80,000 Ci/yr were to be released through the chimney.

The four noble gas nuclide spectra given in Table 4.3-2 are based on 0.8% (A), 2.7% (B), 0.9% (C) and 0.45% (D) of the noble gas activity produced in the fuel rods (source strengths). On the other hand, these values could also be regarded as leakage rates of the fuel element cladding, which, with complete (100%) continuous degassing of the reactor coolant in the degassing system and with the amounts of leakage in the other systems (leakage combinations A to D), result in a release rate of 80,000 Ci/yr. When it is considered that the empirical value for fuel element failure is 1% and is conservatively estimated at 10%, and that the primary coolant is actually degassed to as much as 99% (Kausz; Spang, 1973), then a release rate of 80,000 Ci/yr is perfectly realistic and probable and may even be exceeded in very unfavorable cases, especially with increasing fatigue of the material.

The hazard to man by noble gases is usually given by the mean dose factor, which depends essentially on the nuclide spectrum that is used. The bottom row of Table 4.3-2 shows the mean dose factor for gamma submersion for the calculated spectra. In cases A to D it is always about 13 x 10^{-5}.

The last spectrum (labeled SSK) was recommended by the Radiation Protection Commission (SSK, 1977) for ecological calculations.

It most closely resembles spectrum E, in which it was assumed that all noble gases escape via the exhaust gas system. A quick conversion shows that for a yearly release of 80,000 Ci both spectra are not merely optimistic or unrealistic, but rather patently absurd. Kr-89, which represents a serious radioecological danger and which has a high liberation rate, is not even represented in the SSK spectrum, while Kr-85, which is relatively undangerous due to its low dose factor, is present in a quantity of 2% or 1600 Ci/yr. But this is impossible, for a total of only about 750 Ci/yr Kr-85 is produced in the plant. The SSK is able to arrive at the indicated low mean dose factor of 2.6 x 10^{-5} only by making absurd assumptions such as this. The origin of the even lower value of 1.6 x 10^{-5} that is used in the study by the GRS could not be determined because no nuclide spectrum was given. In our further calculations we used the calculated mean dose factor of 13 x 10^{-5} rem x m^2/Ci x sec.

Table 4.3-1. Percent distribution of the leakage (various assumptions)

		A	B	C	D	E
1	Exhaust gas systen	27.000000	78.000000	50.000000	1.500000	100.000000
2	Steam generator leakage	73.000000	21.000000	12.500000	24.600006	0.0
3	Primary circulation	0.0	0.100000	12.500000	24.600006	0.0
4	Annular space air	0.0	0.600000	12.500000	24.600006	0.0
5	Auxiliary plant buildings	0.0	0.300000	12.500000	24.600006	0.0

Table 4.3-2. Composition of the Noble Gases (in %) under various assumptions.

	A	B	C	D	E	SSK
KRYPTON 83 M	1.700000	1.600000	1.100000	1.100000	0.0	0.0
KRYPTON 85 M	3.500000	1.500000	2.100000	2.100000	0.0	2.000000
KRYPTON 85	0.0	0.0	0.0	0.0	17.600006	2.000000
KRYPTON 87	9.220000	9.300000	6.200000	0.620000	0.0	1.000000
KRYPTON 88	11.200000	11.920100	7.100000	7.100000	0.0	2.500000
KRYPTON 89	8.190000	9.000000	12.400000	12.300000	0.0	0.0
KRYPTON 90	1.600000	3.800000	6.500000	6.500000	0.0	0.0
KRYPTON 91	0.900000	0.850000	1.400000	1.500000	0.0	0.0
XENON 131 M	0.0	0.0	0.0	0.0	2.000000	2.000000
XENON 133 M	0.200000	0.100000	0.100000	0.100000	0.0	0.0
XENON 133	1.466603	1.900100	2.700100	0.270000	80.399994	80.000000
XENON 135	12.900000	12.500000	4.600000	0.600000	0.0	10.000000
XENON 135 M	6.100000	6.600000	5.500000	5.500000	0.0	0.0
XENON 137	12.500000	12.000000	16.000001	16.000001	0.0	0.0
XENON 138	20.000000	20.000000	18.500000	18.500000	0.0	0.050000
XENON 139	4.460000	4.600000	7.900000	7.900000	0.0	0.0
XENON 140	1.400000	1.500000	2.700000	2.700000	0.0	0.0
XENON 141	0.0	0.0	0.0	0.0	0.0	0.0
gamma dose factor	0.000129	0.000129	0.000127	0.000127	0.000011	0.000023

5. Abiotic Dispersion

5.1. Meteorological Dispersion and Settling via the Exhaust Air

5.1.1. Validity of Calculations on Meteorological Dispersion

The purpose of an assessment of this type is not to debate controversial scientific questions, but rather to give guarantees. In regard to atmospheric processes, the number of necessary parameters is large, and their reliability is indifferent in some cases. We therefore consider ourselves obliged, not only to give the values for the meteorological attenuation that are obtained from our computations, but also to estimate the corresponding ranges of error. This is always good practice in science and technology.

We are interested in calculating the radiation load that may be expected from the nuclear power plant during normal operation. In regard to the atmospheric dispersion of noxious substances, this means that we are interested only in long-term data, i.e., the planned nuclear power plant is regarded as a continuous emitter. However, since the output of emissions is subject to great fluctuation (from year to year and in the course of each year) (National Bureau of Health and other sources, e.g., Wiechen states that in the weeks following a reactor shutdown the release of I-131 into the atmosphere increases sharply), the weather data must be known for short intervals of time in order to allow accurate attenuation calculations, i.e., it is not sufficient to have mean values for long periods of time. However, this is impossible with the data presently available. It must be noted, therefore, that the elevation of the doses which is obtained by calculating with correctly superimposed values, compared to dispersion calculations with long-term averages, cannot be even approximately estimated.

Our experts give a realistic account of the meteorological attenuation rather than a cautious one. The conservatism that is necessary in judgments of this sort is guaranteed by furnishing all results with an error estimate.

5.1.2. Dispersion Class Statistics

The required four-dimensional dispersion class statistics (wind speed, wind direction, dispersion category, precipitation) for the planned site of the nuclear power plant (Wyhl) have not been prepared. In the opinion of the German Weather Service, statistics of this sort cannot be prepared. Our experts therefore have no choice but to rely on less suitable data. The applicability of this data to the proposed site of Wyhl is checked in each individual case.

-"At present ... there are approximately 75 million tonnes of tailings in the Elliot Lake vicinity."

-"The safe disposal of these tailings constitutes a major problem. Several lakes and streams have been badly contaminated - notably the Serpent River."

-"As the uranium mining industry expands, it is foreseeable that several hundred million tonnes of mill tailings will be left behind in tailings ponds by the year 2000. This will constitute, as it does at present, an increasing health and environmental problem..."

-"Another important dimension of the mill tailings problem relates to the question of what happens to the tailings ponds when the mining companies cease operations...? ...there are no obvious technological solutions in sight."

-"Some health physicists regard the 5 rem per year dose limit for nuclear workers to be much too high. Professor E. Radford of the Graduate School of Public Health, at the University of Pittsburg has advocated a reduction ... to 0.5 rem."

-over a hundred references.

42) Rockstroh, H., "Zur Atiologie des Bronchialkrebses: in Arsen verarbeitenden Nickelhutten. Beitrag zur Syncarcinogenese des Berufkrebses", Arch. Geschwulstforsch, 14: 151-162, 1959.

(Excess lung cancer in plants that process uranium ores.)

43) Saccomonno, G., Archer, V.E., Auerbach, D., Saunders, R.P., "Susceptibility and Resistance to Environmental Carcinogens in the Development of Carcinoma of the Lung", Human Pathology, 4 (4): 487-495, Dec. 1973.

-8 patients with exposure to radon and radon daughters, with or without smoking, show different responses, i.e. types of Ca developed. One patient developed no Ca.

-Patients with small cell Ca survive a shorter time.

-Carcinogenesis is dose related.

-Cigarette smoking and radon daughters act synergistically.

-8000 cases studied since 1957 - with approximately 200 cases of lung cancer having developed.

44) Saccomanno, G., Archer, V.E., Saunders, R.P., Auerbach, O. and Klein, M.G., "Early Indices of Cancer Risk among Uranium Miners with reference to modifying factors" Occupational Carcinogenesis, Annals of the New York Academy of Science, 271: 377-383, 1976.

-Population of 2,500 - 3,500 uranium miners

-In situ carcinoma shows large number of cells which can be identified as malignant in sputum.

-Average time to develop invasive carcinoma equals 14 years.

-Describes progression from normal to malignant cells.

45) Saccomanno, G., et al., "Lung Cancer of Uranium Miners on the Colorado Plateau", Health Physics, 10: 1195- 1201, 1964.

46) Sikl, H., "The Present Status of Knowledge about the Jachymov Disease (Cancer of Lung in Radium Mines)", Acta Un. Int. Cancr, 6: 1366-1375, 1950.

-In Jachymov (Czechoslovakia), "The mortality by lung cancers among miners is very high (44.6%) almost 50% of the natural deaths."

[Later this was found due to very high levels of radioactivity.]

47) Status Report: Water Pollution in the Serpent River Basin, Ministry of the Environment for the Province of Ontario, 1976.

-A very upsetting document indication the ongoing problems related to contamination of the Serpent River Basin by mines in the Elliott Lake region. Should be read by anyone who feels that we are on the threshold of solving our technological problems in this area.

-Through a combination of radioactive and non-radioactive pollutants, 55 miles downstream from the operation has been rendered unusable by fish of men and there are significant ongoing problems.

48) Stewart, C.G. and Simpson, " On an $(MPC)_a$ for the Short-lived Daughters of Rn-222," Pneumoconiosis, Proceedings of the International Conference, Johannesburg, 1969.

(definite exposure shows increased cancer risk will not occur unless greater than 600 WLM's have been accumulated)

[As noted, this paper has not been reviewed by the committee. A vast majority of medical evidence does not support their conclusion. The committee has not yet had time to study the thoroughness of follow-up of underground miners.]

49) Stewart, C.G., Simpson, S.D., " The Hazards of Inhaling Radon-222 and its Short-lived Daughters: Consideration of Proposed Maximum Permissible Concentrations in Air", Radiological Health & Safety in Mining & Milling of Nuclear Materials, Vienna, International Atomic Energy Agency, Vol. 1: 333-357.

-Historical review of $(MPC)_a$ of Rn-222 & daughters.

50) Tamplin, A.R. and Gofman, J.W., "The Colorado Plateau: Joachimsthal Revisited? An analysis of the lung cancer problem in uranium and hardrock miners," Testimony presented at Hearings of The Joint Committee on Atomic Energy, 91st Congress of the U.S., Jan.2, 1970.

51) United States Public Health Service, Control of Radon and Radon Daughters in Uranium Mines and Calculations of Biological Effects, Wash. D.C.: U.S. Dept. of H.E.W., Public Health Service Publication NO. 494, 1957.

(U-238 produces radon and its daughters which cause most of the radioactivity in uranium mine air.
-radon, radium A, & radium C' give most internal lung radiation.)

52) Wagoner, J.K., Archer, V.E., Carroll, B.E., Holaday, D.A. and Lawrence, P.A., " Cancer Mortality Patterns among U.S. Uranium Miners and Millers, 1950 through 1962", Journal of the National Cancer Institute, 32 (4) : 787-801, 1964.

- -Inhaled radiation produced pulmonary cancer.
- -Examined 90% of miners in the area visited.
- -Colorado Plateau miners - 218 deaths among white uranium miners vs 148.7 expected ($p < 0.01$).
- -Increased pulmonary cancer among miners with 5 or more years underground experience - 15 observed vs 4.2 expected.
- -Increased total cancers - 30 observed vs 18.7 exp.
- -No increase among uranium millers.
- -Open-pit vs underground miners: no statistically significant increase in Ca for open-pit miners - 6 obs. vs 5.3 exp. total Ca, and 3 vs 1.4 respiratory Ca., but a small sample of only 63 deaths was used.
- -Possible:excess of non-malignant resp. disease was due to airborne radiation.
- -Well documented with 38 ref.

53) Wagoner, J.K. et al., " Mortality Patterns among U.S. Uranium Miners & Millers, 1950 through 1962: preliminary report", Radiological Health & Safety in Mining & Milling of Nuclear Materials, Vienna, International Atomic Energy Agency, Vol. 1: 37-48, 1964.

- -5370 miners studied from 1950-1962.
- -A 10 times excess of respiratory cancer was observed in uranium miners with long-term underground experience and was not attributed to smoking, age, silica dust and other ore constituents. Airborne radiation implicated in lung cancer genesis.
- -Open-pit miners had no increase of lung cancer but had higher incidence of accidents.
- -No reason to suspect a genetic basis of excess lung Ca in white miners.
- -In contrast to European mines, constituents of the ore suspected of carcinogenic activity in man (arsenic, chromium, iron & nickel) are present only in minimal amounts in the U.S. uranium mines. Epidemiologic studies have not shown increased lung Ca due to silica dust.
- -Good graphs & statistics.

54) Wagoner, J.K., Archer, V.E., Lundin, F.E., Holaday, D.A. and Lloyd, J.W., "Radiation as the cause of Lung Cancer among Uranium Miners", New England Journal of Medicine, 273: 181-188, 1965,

- -Shows conclusively "through stringent epidemiologic methods, that airborne radiation is a cause of lung cancer in man".
- -Shows dose-response relation and specific increase of certain histological types vs controls.

-Studied 3415 underground miners on the Colorado Plateau (1950-1963)

	Actual	Expected	p value
Deaths	249	153.2	< 0.01
Total cancer	41	21.3	< 0.01
Lung cancer	22	5.7	< 0.01
Violent death (esp. MVA's & mining accidents)	95	33.9	< 0.01

-Cigarette consumption could not explain the dose-response relation with cumulative radiation.

-Very well organized with 51 ref.

II - HISTOLOGICAL TYPES OF LUNG CANCER IN URANIUM MINERS

1) Archer, V.E., Saccomanno, G. and Jones, J.H., "Frequency of different histologic types of Bronchogenic carcinoma as related to radiation exposure", Cancer, 34(6): 2056-2060, Dec. 1974.

- 107 uranium miners who died from lung cancer (1950-1970) vs 107 matched lung cancer controls (for smoking & age).
- Has tables of expected vs observed incidence for 5 types of Ca in 6-WLM groups, showing : a) increase small cell undifferentiated carcinoma (approximately 33 times); b) increase epidermoid carcinoma (approx. 4 times); c) increase adenocarcinoma (approx. 4 times); d) no increase large cell undifferentiated or combined adeno-epidermoid carcinoma.
- Total expected 14.07 vs observed 107, i.e. approx. 7 times the incidence.
- Relative frequency distribution of histologic types of bronchogenic carcinoma in uranium miners is independent of magnitude , although absolute frequency depends on the magnitude of radiation.

2) Auerbach, O., et al., "Histologic findings in the tracheobronchial tree of uranium miners and non-miners with lung cancer", Cancer, 42(2): 483-489, Aug. 1978.

- Combination of cigarette smoking and heavy exposure to an occupational carcinogen produces a significant increased risk of lung Ca vs smokers without exposure to occupational carcinogen.
- Non-smoking uranium miners are at less risk than smoking uranium miners.
- 210 men who died of lung cancer vs 105 matched pairs were analysed: remaining bronchial tree showed numerous changes (96% of miners have Ca in situ other than the primary site; 92% of non-miners have Ca in situ at other than the primary site). Twice as much early atypia found in miners.
- Small cell carcinoma was most common in uranium miners - 41% vs 11% of non-miners.

3) Saccomanno, G. et al., "Histologic types of lung cancer among uranium miners", Cancer, 27(3): 515-523, March 1971.

- 121 cases of U miner lung carcinoma vs 138 non-miners.
- Increase incidence with increased radiation exposure, age and cigarettes with a plateau at 1500 WLM.
- Average was 15.9 years between beginning U mining and development of carcinoma of the lung.
- Radiation increased small cell undifferentiated carcinoma.

III - IONIZING RADIATION IN NON-URANIUM MINERS

1) Boyd, J.T. et al., "Cancer of the lung in iron ore (haematite) miners", British Journal of Industrial Medicine, 27(2): 97-105 1970.

- -Underground miners have 70% higher chance than normal population of developing cancer of lung.
- -5811 death certificates surveyed with 36 lung cancer deaths of underground iron ore miners vs 21 expected deaths.

Radiation levels were 30-300 pCi/litre of radon.

- -46 references.

2) Goran St. Clair Renard, K., "Respiratory cancer mortality in an iron mine in Northern Sweden", Ambio, 3: 67-69, 1974.

(Hazard of ionizing radiation in non-uranium mines)

3) Jorgensen, H.S., "A study of mortality from lung cancer among miners in Kiruna, 1950-70", Work Environmental Health, 10: 126-133, 1973.

(-Hazard of ionizing radiation in non-uranium mines.

-Increase cancer at levels of 120 WLM with annual exposure of 4 WLM.)

4) Jorgensen, H.S., "Lung cancer mortality among miners in Kiruna 1950-70", Lakartidningen, 70: 3365-3368, 1973.

(-Hazard of ionizing radiation in non-uranium mines.

-Linear relationship with high-LET radiations, i.e. alpha rays.)

5) Newfoundland Royal Commission Respecting Radiation, Compensation and Safety in the Fluorspar Mines, St. Lawrence, Nfld., Report, Newfoundland, Queen's Printer, 1969.

(Hazard of ionizing radiation in non-uranium mines)

6) Parsons, W.D., deVilliers, A.J., Bartlett, L.S. and Becklake, M.P., "Lung cancer in a fluorspar mining community, II Prevalence of respiratory symptoms and disability", British Jour. of Industrial Medicine, 21(2): 110-116, 1964.

- -The incidence of pneumoconiosis was low among fluorspar miners (1.93 %).
- -Incidence of chronic bronchitis was comparable to miners elsewhere.
- -High incidence of smoking cannot be sole factor responsible for high incidence of lung cancer, since miners had 29 times the incidence of lung cancer as the average population of Nfld.
- -Smoking and radiation probably have synergistic (potentiating) effects.
- -28 ref.

7) Snihs, J.O., "The approach to radon problems in non-uranium mines in Sweden", Proceedings of the Third Conference of the International Radiation Protection Association, Washington, D.C., Sept. 1973.

(-Hazard of ionizing radiation in non-uranium mines.

-Increased cancer of the lungs at 120 WLM total and at 4 WLM per annum.)

8) Strong, J.C., Laidlaw, A.J. and O'Riordan, M.C., "Radon and its daughters in various British mines", National Radiological Protection Board, Report 39, London, HMSO, 1975.

(Hazard of ionizing radiation in non-uranium mines.)

9) deVilliers, A.J. and Windish, J.P., "Lung cancer in a fluorspar mining community: I Radiation, dust and mortality experience ", British Jour. of Industrial Medicine, 21(2): 94-109, April 1964.

-10 year period 1952-1961, St. Lawrence, Newfoundland.

-23 of 51 deaths were from primary cancer of lung.

-This was 29 times the expected death rate for age group and population.

-Mine water contaminated with 4,240-12,850 pico curies of radon per litre, which produced Radon-222 and daughter products in air and had an average potential energy between 2.5 & 10 times the working level of 1.3 X 10^5 MeV /litre of air. (100 pCi/l.)

-21 of 23 were smokers.

-Age of death was dependent on age at entry into risk.

-Distinct hilar distribution of tumors.

-Incidence of lung Ca as % of miner deaths - 45% (1952-61).

Duration of underground exposure	Av. 12.5 yrs.	Range 5.5-21.3
Age at death	Av. 46.8	Range 33 - 56

-Mortality rates (Canadian Vital Statistics) from lung cancer among males 1956-61:

Newfoundland	0.11 per 1000
Canada	0.24 per 1000
St. Lawrence	2.33 per 1000

[*Does not compare miners with a control sample of smokers.*]

10) Wagoner, J.K. et al., " Unusual cancer mortality among a group of underground metal miners", New England Jour. of Medicine, 269: 284-289, 1963.

(Hazard of ionizing radiation in non-uranium mines. Levels were 6-24 WLM per year.)

11) Waxweiler, R., Archer, V.E. and Wagoner, J.K., "Mortality of potash workers", Jour. of Occupational Med., 15: 486-489, 1973.

-No predisposition of underground potash miners to lung Ca.

-No radon gas was present in air.

IV - WORKER'S COMPENSATION

1) Archer, V.E. and Thompson, H.C., " Workman's compensation for lung cancer in uranium miners", Diagnosis and Treatment of Deposited Radionuclides, Excerpta Medica Foundation, N.V.D. Reidel, Dordrecht, Holland, Drukkerg, p 638-644, 1968.

- -U.S. statutes of limitations, state laws, residency requirements, proving causation, cigarette smoking, all make compensation for lung cancer secondary to radiation from uranium mining difficult to get.
- -The burden of proof has generally rested on the claimant.
- -Personnel had not been wearing monitoring devices capable of measuring airborne alpha-emitting particles, and as yet these devices have not received wide acceptance.
- -WCB pays for disability of dependency but "the period of disability (from time of diagnosis of lung cancer to death) is only a few months in most of these cases, so that disability payments are rarely made before death".
- -To 1968, Workmen"s Compensation "awards have been made in 15 out of 32 claims from a total of about 100 cases of lung cancer among United States uranium miners". Awards averaged about $15,000.

2) Eason, C.F., "AEC compensation standards", Jour. of Occupational Medicine, 12(10): 410-415, Oct. 1970.

- -600,000 estimated radiation workers in U.S.A. in 1970.
- -WCB laws at that time were becoming outmoded as far as causation of radiation induced disease is concerned.
- -20% of workforce was outside the WCB system.
- -Several states had limited low medical benefits.

3) Ham, J., Report of the Royal Commission on the Health and Safety of Workers in Mines, Ministry of the Attorney General, Province of Ontario, Toronto, Canada, 1976.

- -Persons on the Nominal Roll have increased risk of lung cancer in Ontario. The risk is increased with cumulative exposure.
- -"The cases of lung cancer among uranium miners allowed compensation to the end of 1975 total 20. The compensation almost invariably has been as a pension to the widow and family."
- -"In the matter of compensation, the Commission's view, which is not based on scientific premises, is that uranium miners should be compensated without regard to their smoking habits, because they experience a greater risk than the smoking non-miner."
- -"The costs of nuclear power for public use are so vast that the costs of being publicly responsible to uranium miners and their families are by comparison negligible."

- OCCUPATIONAL CANCER AND LOW-LEVEL IONIZING RADIATION

A - GENERAL

1) Archer, V.E., "Occupational exposure to radiation as a cancer hazard", Cancer, 39: 1802-1806, 1977.

-A review.

-"Whether or not neoplasms result from as exposure is apparently determined largely by probabilistic considerations, although there are differences in susceptibility of individuals."

-Radium dial workers are well atudied in the U.S. and Europe: 3 different groups in the U.S. showed 51 ostersarcomas and 20 carcinomas of the head and paranasal sinuses from 26,296 person years of follow-up. Expected less than 1 osteosarcoma and 0 paranasal sinus carcinoma.

-Caused by alpha radiation from Radium or decay products deposited in bone.

-Latent period 20-60 years.

-Radiologists : increased malignancies among them esp. leukemias in the past; multiple myelomas still elevated.

-Linear Hypothesis

-Some exposure-response curves are linear while others are non-linear for radiation cancer.
-"This is a conservative approach for X-rays and other low-LET (linear energy transfer) radiation, but is probably not conservative when dealing with alpha particles or other radiations having high-LET."
-"It appears to be impossible to establish a threshold level for ionizing radiation in the production of neoplasms in experimental animals."
-"...accidents involving radiation occur regularly, and can be expected to increase in frequency as our dependence on nuclear power increases."

-"The cumulative risk of cancer for all sites has been estimated at approximately 5 deaths/year/rem/million persons over 10 years of age at the time of whole body radiation."

-"Any increase incidence of malignant tumors (in the general population) at current radiation standards will undoubtedly be very small."

-47 ref.

2) Browning, E., Toxicity of Industrial Metals, Butterworth, London, p 34-52, 217-227, 1961.

(Arsenic, chromium, iron and nickel are possibly carcinogenic.)

3) Eckardt, R.E., "Recent developments in industrial carcinogens", Jour. of Occupational Medicine, 15(11): 904-907, Nov. 1973.

-General review of cancer causing industrial agents.

-49 ref.

4) Rotblat, J., "The risks for radiation workers", The Bulletin of the Atomic Scientists, 41-46, Sept. 1978.

(PSR) Discussion of low-level ionizing radiation and the production of cancer. Concludes that the allowable dose to radiation workers should be lowered by a factor of 5.

5) Zenz, C., Occupational Medicine - Principles and Practical Applications, Year Book Medical Publishers, Inc., Chicago, Ill. 1975.

-Chapter 22, "Radiologic Health in Occupational Medicine" is a good introduction into that aspect of health.

B - PHYSICIANS

6) Hempelmann, L., Lisco, H. and Hoffman, J.G., "The acute radiation syndrome: A study of nine cases and a review of the problem", Annals of Internal Medicine, 36: 279, 1952.

(Increase skin cancer - basal cell and squamous cell Ca - with X-rays in early experimenters, medical and dental practitioners at high dose rates.)

7) Matanoski, G.M., Seltser, R., Sartwell, P.E., Diamond, E.L. and Elliott, E.A., "The current mortality rates of radiologists and other physician specialists: deaths from all causes and from cancer", American Jour. of Epidemiology, 101(3): 188-198, 1975.

-"The cohort mortality experience of radiologists and other specialists and other specialists over a 50-year period was examined on the assumption that these groups would differ relative to a presumed decrease in radiation exposure. Radiologists had an excess in all-cause mortality rates compared to the other specialists for all cohorts who entered the Radiological Society of North America before 1940; the excess remained even when the cancer deaths were removed from the rates. These data are consistent with the concept of accelerated aging due to radiation. The cancer mortality rates for radiologists were higher than those of other specialists for an additional decade through 1949. The 1950-1959 cohort had not aged sufficiently to demonstrate the expected peak cancer mortality on the 60-64 year age group. Several hypotheses are presented to suggest reasons for differences in the trends of age-specific cancer mortality by cohorts of entry."

8) Matanoski, G.M. et al., "The current mortality rates of radiologists and other physician specialists: specific causes of death", American Jour. of Epidemiology, 101(3): 199-210, 1975.

-"The cohort mortality experience of radiologists over a 50-year period has been compared to that of other specialists with low levels of radiation exposure. The 1920-1929 cohort of radiologists who joined the Radiological Society of North America had the highest mortality for several chronic diseases. After this early period, radiologists ranked highest only for cancer mortality. The excess risk of leukemia which was observed in the 1920-1929 and 1930-1939 cohorts has subsequently decreased. During the same period, lymphoma mortality, especially multiple myeloma, has been increasing with a significant excess of deaths appearing in radiologists who entered the specialty society between 1930-1939 and 1940-1949."

9) Seltser, R. and Sartwell, P.E., "The influence of occupational exposure to radiation in the mortality of American radiologists and other medical specialists", American Jour. of Epidemiology, 81: 2, 1965.

(-American radiologists had higher age-specific death rate vs non-radiological medical specialists who do not receive occupational radiation exposure.

-Mean age at death = 5 years less among radiologists.

-The difference has been lessening in recent years with better machinery and more caution.)

10) United Nations Report of the Scientific Committee on the Effects of Atomic Radiation, General Assembly Official Records: 24th Session supp. No.13, (A/7613), New York, 1969.

(-Increased leukemias with X-ray exposure in radiologists -high dose rates.

-Increase lung cancer with Radon daughter exposure.

-Increase thyroid carcinomas in radiotherapy patients.

-Increase liver hemangioendotheliomas with Thoratrast in diagnostic procedures - with high dose rates.)

C - RADIUM PAINTERS

11) Mays, C.W., Jee, W.S.S. and Lloyd, R.D. (ed.), Delayed Effects of Bone Seeking Radionuclides, University of Utah Press, Salt Lake City, 1969.

(Increase in Ca in radium dial painters -from ingestion)

12) Morgan, K.Z. and Turner, J.E. (ed.), Principles of Radiation Protection, New York, John Wiley & Sons, Inc., 1967.

(Increase bone tumors in radium dial painters and after therapeutic radium administrations - high dose rates.)

13) Sharpe, W.D., "Chronic radium intoxication, clinical and autopsy findings in long-term New Jersey survivors", Environmental Research, 8(3): 243-383, Dec. 1974.

-91 references re radium and watch dial painting and irradiation in general.

D - MUSTARD GAS

14) Yamada, A., "On late injuries following occupational inhalation of mustard gas, with special reference to carcinoma of respiratory tract", Acta Path. Jap., 13: 131-155, 1963.

(-Mustard gas, a radiomimetic agent, has similar increase in lung cancer with similar histology and anatomic position to uranium miners.)

E - NUCLEAR SHIPYARDS

15) Najarian, T. and Colton, T., "Mortality from leukemia and cancer in shipyard nuclear workers", Lancet, p. 1018-1020, May 13, 1978.

-The next of kin of 592 Portsmouth nuclear shipyard workers were contacted and 146 of these were found to have been exposed to radiation at work of about 0.2 rem annually.

-"The increased numbers of cancer and leukemia deaths among Naval nuclear shipyard workers seem out of proportion to predictions based on prior knowledge of the effects of ionizing radiation in man. Previous data suggest that 50-100 rem doubles leukemia mortality and 300-400 rem doubles the number of total cancer deaths. Radiation records from the shipyard were not available to us, but radiation doses seem to have been well within national occupational safety standards. Information provided by 50 past and present P.N.S. nuclear workers suggested total radiation doses of less than 10 rem lifetime. Within the Naval Nuclear Propulsion Program the mean radiation exposure for the industrial workers at risk (which includes the shipyard workers) was 0.211 rem annually. The nuclear workers at the P.N.S. had six times the proportional mortality of leukemia and twice the proportional mortality for all cancers expected for U.S. White males of the same age-groups. These increased figures were found with radiation doses that probably averaged less than 10 rem total lifetime exposure as measured by worker's film badges."

-18 observed deaths vs 8 expected (total).

-6 observed leukemia deaths vs 1 expected.

F - ATOMIC PLANTS

16) Gilbert, E.S., paper presented at Conference on low-level radiation , Environmental Study Conference of House & Senate, Feb.10, 1978.

(-Analysis of Mancuso data.

-Supports Mancuso study for increased cancer in 2 types of malignancies that have high risk at low radiation levels, but reveals no increase overall in cancer deaths among Hanford employees attributable to occupational radiation at those levels.)

17) Mancuso, T.F., Stewart, A. and Kneale, G., "Radiation exposure of Hanford workers dying from cancer and other causes", Health Physics, 33(5): 369-385, 1977.

-An excellent study which outlines some of the difficulties associated with measuring significant health effects in small populations with low doses of radiation.

-1944-1973: Hanford atomic plant , Richland, Washington. Manufacturer of radioactive substances.

-Observed vs expected cancer deaths: 670 vs 670.

-Much higher incidence of myelomas, carcinoma of pancreas, kidney neoplasms, myeloid leukemia, pulmonary carcinoma and liver and gall bladder Ca.

-Much lower incidence of stomach, prostate and rectal Ca.

-Studied 24,934 workers with 9,410 early discharges. Deaths: non-cancer 2850, cancer 670 & unknown etiology 213.

-"The highest radiation dose groups (over 500 centirads)"had the "highest proportion of cancer deaths".

-Older and younger men have a higher risk of radiation-induced malignancies than middle-aged men.

-Suggests the cancer rate is increasing.

18) Milham, S., Occupational Mortality in Washington State, 1950-1971, 3 vol., NIOSH 76-175 (Wash. D.C., Dept. of Health, Education and Welfare).

(Cancer risk in radiation workers in plutonium production at Hanford.)

19) Sanders, B.S., "Low-dose radiation", letter to ed., Lancet, 11(8094): 840, 14 Oct. 1978.

-Refers to Mancuso study.

-Agrees that some types of Ca were higher but points out that others were lower.

-Uses Anderson's and Gilbert's analysis of data and comparisons with siblings.

20) Stewart, A., "Low-dose radiation: The Hanford evidence", letter to ed, Lancet, 1(8072): 1048-1049, 13 May 1978.

-Cancer risk from present maximum permissible dose of 5 rem per year for each year's exposure could be 1 in 150 not 1 in 2000, as in A-bomb survivors.

-3520 Hanford workers died between 1944-1972.

-Average dose < 2 rads / year.

-Higher mortality in them than men in other industries,

-Excess bone and pancreas carcinomas.

-Average exposure observed to be greater with Ca deaths:

work period	mean dose exposures - centirad	
	Ca deaths	non-Ca deaths
< 2 years	42 crad	34 crad
> 2 "	266 "	213 "

21) Stewart, A., "Low-dose radiation", letter to ed., Lancet, 11(8094): 840, 14 Oct. 1978.

-rebuttal to Sanders # 19, p 29.

(22) Kochupillai, N., et al, Down's Syndrome and related abnormalities in an area of high background radiation in coastal Kerala. Nature, 262:60, 1976

-In coastal Kerala, South India, the yearly background radiation is 1500 to 3000 mRem due to the presence of Thorium-containing mineral in the soil.

-Prevalence of mental retardation of the genetic type (mostly Down's Syndrome) is four times higher than a control population receiving 100 mRem yearly background, and chromosomal abnormalities are nine times more frequent.

VI - LOW-LEVEL IONIZING RADIATION

A - CARCINOGENESIS IN GENERAL

1) Archer, V., "Geomagnetic force associations with cancer distribution and weather conditions", Proceedings 10th Midyear Topical Symposium of the Health Physics Society, Saratoga Springs, Oct. 11-13, 1976.

(Confirms increase in radiation related cancers in Denver area where there is increased background exposure.)

2) Bertell, R., "Measurable health effects of diagnostic X-ray exposure", Testimony before the Sub-committee on Health and the Environment, U.S. House of Representatives, July 11, 1978.

-"Concern for prevention (of non-lymphatic leukemia) should be just as important as concern for cure."

-"The medical profession cannot afford to take the guidance of the nuclear industry in a public health issue where they should be assuming the leadership."

3) Bross, I.D.J., Proceedings of a Congressional Seminar on low-level ionizing Radiation; a report submitted by the Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs, U.S. House of Rep./ 94th Congress, 2nd Session, 79-767-0, Nov. 1976.

(-examines all recent information on the effects on people of low-dose ionizing radiation.

-concludes that present health effects are underestimated.)

4) Bross, I.D.J., "Major strategic mistakes in the management of the Conquest of Cancer Program by the NCI", Testimony to the 95th Congress of the United States, House of Representatives, Intergovernmental Relations and Human Resources Subcommittee of the Committee on Government Operations, June 14, 1977.

5) Bross, I.D.J., "An action program to protect the public against the mindless use of diagnostic radiation and other technology", Testimony to the United States Senate Commerce Committee, Oversight Committee for Radiation Health and Safety, June 17, 1977.

6) Brues, A.N., "Radiation as carcinogenic agent", Radiation Research, 3: 272-286, 1955.

(Discusses latency period)

7) Burrows, H. and Clarkson, J.R., "The role of inflammation in the induction of cancer by X-rays", British Jour. of Radiology, 16: 381. 1943.

(Cancer induced more easily by radiation when non-specific inflammation was present.)

8) Furth, J. and Tullis, J.L., "Carcinogenesis by radioactive substances", Cancer Research, 16: 5-21, 1956.

9) Furth, J. and Lorenz, E., "Carcinogenesis by ionizing radiation", Radiation Biology, Hollaender, A. ed., New York, McGraw Hill, vol. 1, part 11, p 1145-1201, 1954.

(Radiation produces tumors in animals and humans.)

10) Gibson, R., "Leukemia in children exposed to multiple risk factors", New England Jour. of Medicine, 279: 906-909, 1968.

11) Gibson, R., Grahan, S. et al., "Irradiation in the epidemiology of leukemia among adults", Jour. of National Cancer Institute, 48(2), 1972.

12) Gofman, J.W. and Tamplin, A.R., A series of 19 reports presented as Testimony before the Joint Committee on Atomic Energy, 91st Congress, 1-28-1970.

(Increased lung Ca with radiation.)

13) Gofman, J.W. and Tamplin A.R., "Epidemiologic studies of carcinogenesis by ionizing radiation", Proceedings of the Sixth Berkeley Symposium on Mathematical Statistics and Probability, Statistical Laboratory, University of Calif., U.C. Press, Berkeley, July 20, 1971.

(Shows why chronic exposure to the permissible dose of 170 mrem per year could provoke between 9,700 & 104,000 extra cancer deaths per year in the U.S.A., with average loss of life expectancy of 13.5 yrs/case.)

14) Graham, S., Levin, M.L., et al., "Methodological problems and designs of the Tri-State Leukemia Survey", Annals of New York Academy of Science, 107: 557-569, 1963.

15) Hempelmann, L.H., "Epidemiologic studies of leukemia in persons exposed to ionizing radiation", Cancer Research, 20: 18, 1960.

16) Klement, A.W., Miller, C.R., Minx, R.P. and Shleier, B., "Estimates of ionizing radiation doses in the United States, 1960-2000", U.S. Environmental Protection Agency, ORP/CSD 72-1, Rockville, Maryland, Aug. 1972.

Average whole body radiation doses in U.S.A. in 1970:

Environmental	millirems/yr.
natural	130 - 45 cosmic - 60 direct terrestrial - 25 natural body radiatn
global fallout	4
all other	< 0.01

Medical	
diagnostic....................	72
dental radiography	0.3
radiopharmaceuticals	1.0
Occupational	< 1.0
Misc. - T.V., air transport	< 3.0
Total -approximately	211

-211 mrem/year is about 6.3 rems/30yrs./person.

17) Medical radiation information for litigation. Proceedings of a Conference. DMRE - 69-3 (CONF-681131) Baylor, University College of Medicine, Houston, Texas, November 21-22, 1968.

18) Morgan, K.Z., "Cancer and low level ionizing radiation", Bulletin of the Atomic Scientists, 30-41, September 1978.

-Morgan: Director of Health Physics Division of Oak Ridge National Laboratory (1943-1972). A health physicist with extensive experience in the nuclear industry since 1943 provides easy to read, broad review of current data which quantify the risks of low level radiation.

-"There is no safe level of exposure and there is no dose of radiation so low that the risk of a malignancy is zero."

19) Morgan, K.Z., "Reducing medical exposure to ionizing radiation", American Industrial Hygiene Association Journal, page 358-368, May 1975.

20) Morgan, K.Z., "Suggested reduction of permissible exposure to plutonium and other transuranium elements", American Industrial Hygiene Association Journal, August 1975. (This summary taken from Nader et al, Menace of Atomic Energy.)

-"Dr. Morgan has suggested that existing radiation standards could underestimate the effects of exposure for many different reasons:

1) Extrapolations are made on data with observation periods of no longer than twenty years. Many conclusions are based on studies of animals with life spans of less than ten years. Because many health effects may not be apparent until twenty to thirty years after the initial exposures, or even longer, and because human beings live more than seventy years, on the average, known health effect rates can only increase as more human data are gathered.
2) The linear model assumes an average exposure. The elderly and the very young may be more susceptible to radiation effects than the middle-aged.

3) Adequate data on the effects of very low exposures have not been developed. Instead, the standards are based on extrapolations from high or intermediate doses down to zero. But at a higher dose a larger fraction of the exposed cells may be directly killed from radiation, instead of showing signs of genetic damage or cancer. At lower doses fewer cells may be killed and more could be likely to suffer latent radiation damage, such as cancer, as a consequence."

-The present maximum permissible body doses for plutonium and similar substances should be reduced at least 200 times.

21) Nelson, N., "Carcinogenic implication of inhaled pollutants", Archives of Environmental Health, 8: 100-104, 1964.

22) Peterson, J.E., Industrial Health, Prentice-Hall Inc., Englewood Cliffs, New Jersey, 1977.

-Excellent chapter on ionizing radiation pages 259-286.

-Makes a good case for conservatism.

23) Pochin, E.E., "Carcinogenic effects of radiation in man: The importance of estimates for protection purposes", Proceedings of a Symposium on Radiation Induced Cancer, Athens, Greece, April 28-May 2, 1969, Vienna, International Atomic Energy Agency, 1969.

(-much data showing that ionizing radiation is a very potent carginogenic agent).

24) Proceedings of the Congressional Seminar on Low-Level Ionizing Radiation, should be available from the United States Congress or the Environmental Policy Institute, 317 Pennsylvania Avenue S.E., Washington, D.C. 20003, U.S.A.

-This is well worth reading in its entirety, for it brings forth a great deal of information important in establishing the health hazards of low-level radiation.

25) Sagan, L.A., "Human radiation effect: An overview", Health Physics, 21: 827-833, 1971.

26) Scholte, Van der Wielen and Ruya, "Negligible and non-negligible risks in radio-diagnostic examination of patients", Radiologic Clinics, 45; 314-325, 1976.

-An interesting resume of how to establish the level of a health risk, and what need be done about it. Contains good bibliographical reference.

27) Symposium on Biological and Environmental Effects of Low-Level Radiation, Volume I, Vienna, International Atomic Energy Agency, 1976.

-This is an esoteric and extremely complex detail of the current state of the art which raises some very disturbing questions on animal studies, particularly those related to pigs, and also demonstrates the paucity of human data in this very important area.

28) Upton, A.C., Allen, R.C., et al., "Quantitative experimental study of low-level radiation carcinogenesis", Radiation Induced Cancer, International Atomic Energy Agency, Vienna, page 425-438, 1969.

-"Interim results reveal a dose-dependent increase in the incidence of neoplasms (chiefly leukemia) and a decrease in the life span (in mice) down to the lowest dose tested (of Cesium gamma rays); namely, 10 rads."

29) Viadana, E., Bross, I.D.J., "Use of medical history to predict the future occurrence of leukemia in adults", Preventive Medicine, 3: 165-170, 1974.

30) White and Frey, "An estimation of somatic hazards to the United States population from dental radiography", Journal of Oral Surgery, January 1977.

-An interesting resume of concerns with an excellent precis of the BEIR Report.

B - IN UTERO

31) Bithell and Stewart, "Prenatal irradiation and childhood malignancy: A review of British data from the Oxford Survey", British Journal of Cancer, pages 31-71, 1975.

-This is the seminal work on the biologic hazards of diagnostic radiation, and has led to significant changes in radiation exposure allowed within the medical profession, and certainly must raise very real questions regarding the possibility of health effects of even very low doses of radiation exposure.

32) Bross, I.D.J, and Natarajan, N., "Leukemia from low-level radiation", New England Journal of Medicine, 287: 107-110, 1972.

-Children with hives or asthma are 8 times more susceptible to leukemia from the same radiation exposure than other children.

-(PSR) Current procedures for setting 'safe' levels for exposure to low-level radiation are based on the assumption that the population exposed to the risk of leukemia is homogeneous.

33) Bross, I.D.J, and Natarajan, N., "Risk of leukemia in susceptible children exposed to preconception, in utero, and postnatal radiation", Preventive Medicine, 3: 361-369, 1974.

(-much higher incidence of leukemia in asthmatics especially if irradiated in utero).

34) Court-Brown, W.M. and Doll, R., "Leukemia in childhood and young adult life", British Medical Journal, 1: 981, 1961.

(-increased cancer with in utero low dose x-rays).

35) Ford, D.D., Patterson, J.C.S., and Treuting, W.L., "Fetal exposure to diagnostic x-rays and leukemia and other malignant diseases in childhood", Journal of the National Cancer Institute, 22: 1093-1104, 1959.

(-a retrospective study of 152 cancer cases and 306 controls dead from other causes. Found a relative risk of 1.7 after intra-uterine x-ray exposure.)

36) Graham, S., "Preconception, intrauterine, and postnatal irradiation as related to leukemia", National Cancer Institute Monograph, 19: 347-371, 1966.

37) Holford, R.M., "The relation between juvenile cancer and obstetric radiography", Health Physics, 28: 153, February 1975.

(-in utero diagnostic x-rays produce increased cancer.)

38) Keith, Brown and Ames, "Possible obstetric factors effecting leukemia in twins", Comparative Leukemia Research, (1975), Bibl. Haemat. No. 43, pages 221-223.

-an interesting paper outlining the difficulty of coming to grips with low-level effects.

39) Landau, E., "Health effects of low-dose radiation: Problems of assesement", International Journal of Environmental Studies, 6: 51, 1974.

(-in utero diagnostic x-rays produce increased cancer.)

40) McMahon, B., "Prenatal x-ray exposure and childhood cancer", Journal of National Cancer Institute, 28: 1173, 1962.

(-increased leukemia at low-dose radiation.

-increase of other cancers as well.)

41) McMahon, B. and Hutchinson, G.B., "Prenatal x-ray and childhood cancer: A review", Acta Unio Int. Contra Cancrum, 20: 1172, 1964.

-"A study of the association between prenatal x-ray and childhood cancer is described. Review of all published studies of this question reveals both positive and negative results. However, many studies are based on small numbers and the results have large sampling errors. All published studies, taken either individually or as a group, are compatible with the cancer risk in children x-rayed in utero being 40 per cent higher than in children not x-rayed in utero. Several individual studies and all studies taken as a group are, on the other hand, incompatible with the hypothesis of no difference in cancer risk between the two groups."

42) MacMahon, B., and Newill, V.A., "Birth characteristics of children dying of malignant neoplasms", Journal of the National Cancer Institute, 28: 231-244, 1962.

(-a retrospective cohort study in which 556 cancer deaths were referred to a cohort of 734,243 with number exposed based on a 1% sample (intra uterine x-ray: 770 exposed, 6,472 unexposed) and a relative risk of 1.44 was found.)

43) Mole, R.H., "Ante-natal irradiation and childhood cancer: Causation or coincidence?", British Journal of Cancer, 30: 199, 1974.

44) Natarajan, N. and Bross, I.D.J., "Preconception radiation and leukemia", Journal of Medicine, 4: 276-281, 1973.

45) Pochin, E.E., "Malignancies following low radiation exposures in man" British Journal of Radiology, 49: 577, July 1976.

(-low level radiation in utero produces increased cancer.)

46) Stewart, A., "Low dose radiation cancers in man", Advances in Cancer Research, 14: 359, 1971.

(-increase of other cancers than leukemia in irradiated in utero children.)

47) Stewart, A., and Kneale, G.W., "Radiation dose effects in relation to obstetric x-rays and childhood cancers", Lancet, June 6: 1185-1187, 1970.

(PSR) - Epidemiological data from the Oxford Survey of Childhood Cancers was analyzed in respect to in utero exposure to x-rays during obstetrical investigations. The risk of cancer was greatest when exposure occurred during the first trimester and excess cancer was directly related to fetal dose.

48) Stewart, A., Webb, J., and Hewitt, D., "A survey of childhood malignancies", British Medical Journal, 1: 1495-1508, 1958.

(-matched 1,638 cancer cases with 1,638 live controls and found a relative risk of 1.92 after intra uterine x-ray exposure.

-a retrospective study.)

C - RADIATION TREATMENTS

49) Albert, R.E., Shore, R.E., "Follow up study of irradiated Tinea Captis cases", a paper presented at 100th Annual Meeting of the American Public Health Association, 1972.

(-radiation induced thyroid carcinoma presents a higher risk in children than in adult population and the risk increases linearly as the dose increases.)

50) Braverman, L., "Consequences of thyroid radiation in children", New England Journal of Medicine, 292: 204-205, 1975.

(PSR)-editorial review of thyroid neoplasia from childhood irradiation and a plea for caution in the treatment of thyrotoxic children and adolescents with I-131 therapy.

51) Court-Brown, W.M., and Doll, R., "Leukemia and aplastic anemia in patients irradiated for ankylosing spondylitis", Medical Research Council Special Report Series, #295, H.M. Stationery Office, London, England, 1957.

52) Court-Brown, W.M. and Doll, R., "Mortality from cancer and other causes after radiotherapy for ankylosing spondylitis", British Medical Journal, 1327-1332, 1965.

-"Exposure to moderate amounts of radiation in childhood has produced cancer of the thyroid, and it seems probable that exposure to small amounts of the order of 1-10 rads in utero produces all the principal types of childhood cancer. Mortality rates from all cancers other than leukemia were raised in American radiologists compared with those in specialist physicians and ophthalmologists and otorhinolaryngologists (Selster and Sartwell, 1965) . . . ".

-"The most important finding, apart from the previously reported excess of deaths from leukemia and aplastic anemia, relates to other cancers originating in heavily irradiated tissues. Deaths attributed to these cancers were increased approximately twofold six or more years after first treatment, and 15 years after first treatment the excess showed no sign of diminishing. The excess was not limited to one or two types of cancer, but many different types contributed to it, approximately in proportion to their normal incidence."

-"It is estimated that in an average follow-up period of 13 years after first treatment the excess deaths from leukemia and from other cancers arising in heavily irradiated tissues, which can be attributed to the effects of ionizing radiations, were 4 per 1,000 patients and 6 per 1,000 patients respectively."

53) Hempelmann, L.H., "Neoplasms in youthful populations following x-ray treatment in infancy", Environmental Research, 1: 338, 1967.

(-radiation induced thyroid carcinoma presents a higher risk in children than in adult populations and risk increases linearly as the dose increases.)

54) International Atomic Energy Agency, Assessment of Radioactivity in Man Vienna, IAEA, 2 volumes, 1964.

(-increased leukemias with high dose x-rays in radiotherapy patients.

55) International Atomic Energy Agency, Handling of Radiation Accidents, Proceedings of IAEA/WHO Symposium, Vienna, May 19-23, 1969.

(-increased leukemias with high dose x-rays in radiotherapy patients.

56) Lewis, E.B., "Leukemia, radiation and hyperthyroidism", Science, 174: 454, October 29, 1971.

(-increased leukemia among persons 50-79 years old who received I-131 treatments.)

57) MacMahon, B., "X-ray exposure and malignancy", Journal of the American Medical Association, 183: 721, 1963.

(-children have higher risk of dying of radiation induced leukemia than do middle-aged persons.)

58) Modan, B., et al, "Radiation induced head and neck tumors", Lancet, 277-279, February 23, 1974.

(PSR)-Radiation for ringworm of the scalp resulted in an increasing risk of brain, parotid and thyroid tumor. The dose causing thyroid carcinoma 6.5 rads, is the lowest reported.

59) Refetoff, S., Harrison, J., et al, "Continuing occurrence of thyroid carcinoma after irradiation to the neck in infancy and childhood", New England Journal of Medicine, 292: 171-175, 1975.

(PSR)-A study from the University of Chicago of 100 persons who received childhood irradiation showing a 7% increase of carcinoma. As 71,000 persons in the Chicago area received childhood irradiation the public health implications are overwhelming.

60) Silvernman, C., and Hoffman, D.A., "Thyroid tumor risk from radiation during childhood", Preventive Medicine, 4: 100, 1975.

(PSR)-Review of 7 epidemiological studies and of radiation doses from diagnostic x-rays, scans and uptakes. The low dose, 6 rads, associated with thyroid cancer in 2 studies, raises questions about the long-term effect of diagnostic procedures in childhood.

61) Simpson, C., and Hempelmann, L., "The association of tumors and roentgen ray treatment of the thorax in infancy", Cancer, 10 42, 1957.

(-great increase in thyroid carcinomas secondary to external radiation, also increased leukemia and bone tumors.)

D - ANIMAL EXPERIMENTS AND CARCINOGENESIS

62) Alper, T., Cell Survival After Low Doses of Radiation, London Institute of Physics, 1974.

63) Cember, H., paper 15/P/900, Proceedings of the Second International Conference on the Peaceful Uses of Atomic Energy, Geneva.

(-squamous tumors induced by implants of radioactive Strontium, single intrathecal injection of radioactive Cesium, and multiple injections of radioactive sulphur.)

64) Cohn, S.H., Skow, R.K., and Gong, J.K., "Radon inhalation studies in rats", Archives of Industrial Hygiene, 1: 508-515, 1953.

(-suggests that radon daughters, not radon, causes cancer.)

65) Gross, P., Pfitzer, E.A., et al, "Experimental carcinogenesis (bronchial intramural adenocarcinomas in rats from x-ray irradiation of the chest", Cancer, 23: 1046-1060, 1969.

(-normal bronchial epithelium is fairly resistant to carcinogenic effect of ionizing radiation.

-effects of radiation and pre-existant pulmonary inflammation and fibrosis are synergistic.)

66) Lisco, H., "Autoradiographic and histopathologic studies in radiation carcinogenesis of the lung", Laboratory Investigations, 8: 162-170, 1959.

(-radiation produces carcinogenesis in animals.)

67) Lisco, H., Discussion at the Scientific Session of the Annual Meeting of the American Cancer Society, 1953.

(-demonstrated pulmonary carcinogenesis in animals exposed to radioactive materials.)

68) de Villiers, A.J., Gross, P., "Morphologic changes induced in the lungs of hamsters and rats by external radiation (x-rays)", Cancer, 19: 1399-1410, 1966.

(-normal bronchial and bronchiolar expithelium of hamsters are quite resistant to oncogenic effect of ionizing radiation.)

E - LUNG FIBROSIS

69) Chameaud, J., et al, "Risques et nuisances des mines d'uranium prevention medicale", Colloque International de Radioprotection dans l'Extraction et le Traitment de l'Uranium et du Thorium, Bordeaux, France, 9-11 Septembre, 1974.

(-possible increase fibrotic effect of silicosis with irradiation in uranium miners).

70) Engelbracht, F.M., Thiart, B.F., and Classens, A., "Fibrosis and Collagen in rats produced by radioactive mine dust", Annals of Occupational Hygiene, 2: 257-266, 1960.

(-radiation exhances the fibrogenic activity of silica in lungs.)

71) Gross, P., and de Treville, R.T.P., "The pneumoconioses", The Industrial Hygiene Foundation of America, Bulletin #12, 1967.

(-radiation possibly enhances the fibrotic effect of silicosis.)

72) Kushneva, V.S., "Remote sequela of combined effect on animals of silicon dioxide and radon", Remote Complications of Exposure Resulting from Action of Ionizing Radiations, Professor D.E. Zakutinsky (ed), published State Publishers of Medical Literature, Moscow, 1959, AEC-tr-4473, translation.

(-radiation enhances the fibrogenic activity of silica in the lungs.

73) Stone, D.J, Schwartz, M.J., and Green, R.A., "Fatal pulmonary insufficiency due to radiation effect upon the lung", American Journal of Medicine, 21: 211-226, 1966.

(-radiation has long been known to be capable of producing both temporary (edema and exudate) and permanent (fibrosis) effects on the lungs of man.)

74) Trapp, E., et al, "Cardiopulmonary function in uranium miners", American Review of Respiratory Disease, 101: 27-43, 1970.

(-possible increase fibrotic effect of silicosis with irradiation in uranium miners.)

F - IRRADIATION AND AGING

75) Bertell, R., "X-ray exposure and pre-mature aging", Journal of Surgical Oncology, 9: 379-391, 1977.

-This article is an excellent resume of the famous Tri-State Leukemia Survey. It produces some rather startling statistics as to measurable health effects of the very low doses of diagnostic radiation, and raises great questions as to the safety of current radiation standards in the nuclear energy field.

-"The question of excessive use of diagnostic x-ray and the combination of medical exposure with excessive environmental pollution must be faced as important public health problems requiring immediate national attention."

-"Patient records should show a cumulative account of all diagnostic x-ray received, including dental."

(PSR)-The risk of developing chronic myelogenous leukemia (CML) increases both with age and with exposure to ionizing radiation. Using the Tri-State Leukemia Study (1963), the author demonstrates that trunk exposure to 1 rad skin dose from diagnostic x-rays amounts to the equivalent of 1 year of natural aging in CML risk. She argues that this relationship may hold for other aspects of aging.

76) Lindop, P.J., and Jacher, G.A., (eds), Radiation and Aging, London, Taylor and Francis, 1966.

(Premature aging with whole body irradiation to many animal species. Displacement of the mortality curve. Radiation hastens the aging process.)

77) Lushbaugh, C.C., Comas, F. and Hofstra, R., "Clinical studies of radiation effects on man", Radiation Research, Supp. 7: 398, 1967.

(-Premature aging produced with whole body irradiation to many animal species. Displacement of the mortality curve showing radiation hastens aging process.

-Connective tissue is not affected by radiation regarding aging.)

78) Matanoski, G.M., Seltser, R., Sartwell, P.E., Diamond, E.L. and Elliott, E.A., "The current mortality rates of radiologists and other physician specialists: deaths from all causes and from cancer", American Jour. of Epidemiology, 101(3): 188-198, 1975.

[*See pg. 26 Section B - PHYSICIANS , # 7 & 8.*]

79) National Council of Radiation Protection and Measurements; Basic Radiation Protection Criteria, NCRP Report # 39, NCRP Publications, Washington, D.C., 1971.

("...life shortening of persons whose exposure is maintained within presently recommended occupational limits would be too small to detect in the presence of so many other variables. While it is probable that some small degree of life shortening from radiation in man may occur following high-dose exposure, its quantative expression is not possible at this time.")

G - PLUTONIUM & CARCINOGENESIS

80) Bair, W.J. and Thompson, R.C., "Plutonium: Biomedical Research", Science, 183: 715-722, Feb. 22, 1974.

(Inhalation of as little as 3 millionths of a gram of Pu-239 can cause lung cancer in dogs.)

81) Bennett, B.G., "Fallout Pu-239 dose to man", Fallout Program Quarterly Summary Report, Health and Safety Lab., U.S. Atomic Energy Commission Report HASL-278, Jan. 1 1974.

(Cumulative intake of plutonium-239 to 1972 equalled 42 pCi per person, most inhaled between 1962-64.)

82) British Medical Research Council Committee on Protection against Ionizing Radiations, "The Toxicity of Plutonium", British Med. Res. Council, H.M.S.O., London, Eng., 1975.

(Estimates toxicity of Pu on lung cancer deaths.)

83) Ellett, W.H., Nelson, N.S. and Mills, W.A., Allowed Health Risk for Plutonium and Americium Standards as Compared to Standards for Penetrating Radiation, Office of Radiation Programs, E.P.A., Wash., D.C., IAEA-SM-L99, 11.

(Plutonium is 30 times as deadly as radium since the former collects in one place on the surface of bone while radium spreads throughout the bone.)

84) Geesman, D.P., Congressional Record, 15 March, 1973.

(-From the Atomic Energy Commission nuclear laboratory, Livermore, California.

-"Dispersed as fine particles into the biosphere, one pound of plutonium-239 represents the potential for some nine billion human lung cancer-doses. It presents a major carcinogenic hazard for more than the next thousand generations.")

85) Gofman, J.W., Cancer Hazard from Inhaled Plutonium, C.N.R. Report 1975-1R.

[*Available from Canadian Coalition for Nuclear Responsibility, # 104 - 2127 W. 40th Ave., Vancouver, B.C., V6M 1W4*]

86) Gofman, J.W., "Estimated production of human lung cancers by plutonium from worldwide fallout", Congressional Records, 121: S 14616, July 31, 1975.

[*Taken from Nader & Abbotts, The Menace of Atomic Energy*]

"Using the projections of the Atomic Energy Commission, Gofman calculated the amounts of plutonium that the atomic industry would handle through the year 2020. He found that even if the industry could contain plutonium with 99.99 percent

efficiency (that is, 0.01 percent of the plutonium in the fuel cycle would reach the biosphere), the industry would still cause 500,000 additional lung cancer deaths per year for about fifty years following the year 2020. Since the current death rate from *all* causes in the United States is about two million per year, Gofman's calculations are quite alarming. He also noted that, considering 'the fallibility of men and equipment plus circumstances of accidents,' it would be a 'miracle' if the atomic industry could actually contain 99.99 percent of the plutonium it handled."

87) Gofman, J.W., "Estimated production of human lung cancers by plutonium from worldwide fallout", Report of the Committee for Nuclear Responsibility, 1975-2, P.O. Box 2329, Dublin, Calif. 94566.

(-Extra 116,000 lung cancer deaths in the U.S. as a result of weapon-test plutonium fallout.)

88) Martell, E.A., letter to Public Interest Research Group (Washington, D.C.) May 22, 1975.

[*Taken from Nader & Abbotts, Menace of Atomic Energy*]

-Recommends that exposure standards for plutonium and similar alpha-emitters be made 1,000 to 10,000 times stricter.

89) Morgan, K.Z., "Suggested reduction of permissible exposure to plutonium and other transuranium elements", Industrial Hygiene Association Journal, 36(8), Aug 1975.

[*See pg.33, Section A - CARCINOGENESIS IN GENERAL, # 20*]

90) Nader, R. and Abbotts, J., The Menace of Atomic Energy, W.W. Norton & Co, Ltd., New York, 1977.

-"Dean Abrahamson, a medical doctor and professor at the University of Minnesota, has called plutonium 20,000 times more toxic than cobra venom or potassium cyanide, the gas used in gas chambers."

-"At Kerr-McGee (nuclear processing facility), however, eighty-seven individuals were exposed to excessive levels of plutonium in 24 different accidents between July 1970 and December 1974."

-"A facility in Erwin, Tennessee, ...has experienced at least 15 separate incidents since 1969 in which more than 50 workers have been exposed to radiation above permissible limits."

-"At NFS, West Valley, at least 15 separate incidents between 1966 and early 1973 exposed 38 persons, who either inhaled or ingested the materials, to excessive concentrations of radioactive materials."

-Arthur Tamplin has "recommended that the government make its standards for plutonium more stringent by factors of 2,000 to 15,000", because "existing standards fail to consider the effects of hot particles". (high-LET particles)

SUMMARY

An Epidemiologic Evaluation of Health Effects in a General Population Residing in an Area Contaminated with Plutonium: A Preliminary Report*

Carl J. Johnson, M.D., M.P.H.**

A large area of land near a plutonium processing plant in Jefferson County, Colorado was contaminated by windblown plutonium and other radionuclides. The contamination of much of the Denver area with plutonium is well-documented, with plant emissions of plutonium recorded as early as 1953, and a major release associated with a fire in 1957. Because of community concern for possible health effects for populations living in this area, and for the safety of further residential development near the plant, an investigation was conducted. A preliminary study of leukemia deaths in eight census tracts (population 78,178) around the plant and in the nearby city of Golden (85,645 person-years) compared with a control area of 19 census tracts with a similar population (97,301) in the relatively uncontaminated part of the county disclosed a significant increase in the age-corrected leukemia death rates in the contaminated areas ($p = 0.01$ and $p = 0.02$, respectively). An evaluation of lung cancer deaths for the contaminated area revealed an age-corrected and age-specific (45-64 years) death rate from lung cancer significantly greater than that for the control area ($p < 0.05$). A preliminary study of congenital malformations found a rate of 14.5 per 1000 births for a large suburban city near the plant compared with a rate of 10.4 per 1000 births for the remainder of the county, and 10.1 for the State of Colorado, a difference of interest.

The Third National Cancer Incidence Survey by the National Cancer Institute for a three year period (1969-1971) provided a strong data base for the investigation of increased rates of cancer near point sources of pollution. The Denver Standard Metropolitan Statistical Area was one of seven such metropolitan areas included in this survey. This data is now available by census tract, essential for investigation of possible associations between measured levels of carcinogenic pollutants and increased rates of cancer. This report describes the first epidemiological evaluation of cancer incidence in areas of census tracts with measured concentrations of plutonium in soil from a point source of emission (the Rocky Flats plant) compared to areas that have contamination only from world-wide fallout from weapons testing.

The population studied (the Denver S.M.S.A.) comprises over one million people studied over a period of three years. Cancer incidence in men in Area I (population 154,170) nearest the Rocky Flats plant (to 21 kilometers downwind) contaminated with plutonium ranging from 50 to 0.8 millicuries per square kilometer (mCi/km^2) was 24% higher than for men in the unexposed population (423,866) outside the area of known contamination but within the Denver SMSA. The cancer incidence for the unexposed population was statistically the same as that for the state, 269 and 270 per 100,000 for men, respectively, and for women, 226 and 227 per 100,000. Cancer incidence in women in the area nearest the plant was 10% higher. In Area II with the next lower range of concentrations (0.8 to 0.2 mCi/km^2), extending from 21 to 29 kilometers downwind from the plant (194,190 people) the cancer incidence was 15% higher for men compared to men in the unexposed population, and for women, 5% higher. In Area III (population 246,905) with lowest levels of contamination (0.2 to 0.1 mCi/km^2 extending from 29 to 33 kilometers downwind) the cancer incidence for men was 8% higher, compared to the unexposed population (Area IV) and for women, 4% higher. The soil levels of plutonium on which the isopleths in figure 1 are drawn are from agricultural soil samples, and serve to indicate the principle direction of plumes from the exhaust stacks as well as the windblown contamination from plutonium lathe oil waste stored onsite.

There was a total of 501 excess cases of cancer, due mostly to an increased incidence of cancer of the lung and bronchus (as high as 41% in men), leukemia (40% in men), lymphoma and myeloma (40% in men, 10% in women), carcinoma of the colon and rectum (43% in men and 30% in women), pharynx, esophagus and stomach (mostly in men), cancer of the testis (about twice as many cases as expected), and ovary (about 24 % higher). A higher incidence than expected was observed also for liver, pancreas, thyroid, and brain. In general, there was a higher incidence of cancer with increasing concentrations of plutonium soil contamination.

These results indicate the importance of continuing complete surveillance of cancer incidence and death rates in this area. Some types of tumors, such as those of bone, have long latent periods before development. A long period of surveillance is necessary to monitor late effects in this population and the investigation should be extended. It is important that a thorough investigation be conducted to determine the adequacy of the filtration system presently in use at the plant, to determine if sub-micron particles of plutonium and other nuclides listed in the Rocky Flats Environmental Impact Statement are not being released in much larger quantities than is being measured. This is of special concern in view of plans to increase the scope of operations at the plant. Definitive actions should be taken by responsible agencies to minimize health effects from exposure to low levels of plutonium, including the establishment by the EPA of much more conservative guidelines to limit human exposure to plutonium, other transuranium radionuclides and their fission products. Nuclear installations should not be located near or upwind of major population centers. Similar comprehensive epidemiological evaluations of cancer incidence rates should be conducted where nuclear installations are located near major population centers.

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*Presented to the Sixth International Congress of Radiation Research, in Tokyo, Japan May 13-19, 1979.

** Dr. Johnson is Director of the Jefferson County Health Department, 260 South Kipling Street, Lakewood, Colorado, 80225

CHILDHOOD LEUKEMIAS ASSOCIATED WITH FALLOUT FROM NUCLEAR TESTING

Joseph L. Lyon, M.D., M.P.H., Melville R. Klauber, Ph.D., John W. Gardner, M.D.,
and King S. Udall, M.D.

Abstract Continuing concern over the possible carcinogenic effects of low-level radiation prompted us to study the population of Utah because of its exposure to fallout from 26 nuclear tests between 1951 and 1958. Certain rural counties (high-fallout counties) received most of the fallout during that period. We reviewed all deaths from childhood (under 15 years of age) cancers occurring in the entire state between 1944 and 1975 and assigned them to a cohort of either high or low exposure, depending on whether they were under 15 between 1951 and 1958. For reasons unknown, leukemia mortality among the low-exposure cohort in the high-fallout counties was about half that of the United States and the remainder of the state. Mortality increased by 2.44 times (95 per cent confidence, 1.18 to 5.02) to just slightly above that of the United States in the high-exposure cohort residing in the high-fallout counties, and was greatest in 10- to 14-year-old children. For other childhood cancers, no consistent pattern was found in relation to fallout exposure. The increase in leukemia deaths could be due to fallout or to some other unexplained factor. (N Engl J Med 300:397-402, 1979)

Larsen, R.P., Plutonium in Drinking Water: Effects of Chlorination on its Maximum Permissible Concentration. Science, 201:1008-1009, 1978 (15 Sept)

-Permissible concentrations of plutonium in drinking water are based on animal absorption studies with Pu(3) and Pu(6) valence states. Most Pu is in the (4) state. Absorption of Pu(6) is three orders of magnitude greater than that of Pu(4).

-Chlorination of drinking water results in the oxidation of Pu(4) to Pu(6), thus increasing its potential absorption by a factor of 1500.

-"The consequences of this observation is that the present values for the maximal permissible concentration of plutonium in drinking water appear to be too high by several orders of magnitude."

Fowler, S.W., High absorption efficiency for ingested plutonium in crabs. Nature, 266:828-829, 1977 (28 April)

-Con_trary to absorption efficiencies of tenths to hundredths of a percent derived from studies with vertebrates, results show that relatively large fractions of plutonium are readily absorbed from ingested food and incorporated into tissues.

-High plutonium absorption efficiency is also common to other marine invertebrates. Thus it is possible that data indicating extremely low gastrointestinal absorption of plutonium by vertebrates are not applicable to species comprising the bulk of the marine biomass.

Green, D., et al, Localisation of Plutonium in mouse testes. Nature 255:77 (May 1) 1975

"The plutonium isotope Pu-239 is a known carcinogen but its ability to produce genetic damage has not been so well investigated... Retention in the gonads of Pu-239 is prolonged, and the genetic effects there have been estimated on the basis of average dose in the gonads. Inhomogeneity of distribution of Pu within gonads has been noted, giving rise to the possibility that some cells may receive a greater radiation dose than others... Here we report that a non-uniform distribution of Pu-239 in the testis results in increased radiation of the spermatogonial stem-cells."

-Because the isotope tends to concentrate selectively near areas of spermatogenesis, the radiation dose to developing sperm is 2.5 times greater than the dose-rate to the organ as a whole.

Beechey, D., Green, D., et al, Cytogenetic effects of Plutonium-239 in male mice. Nature, 256:578 (August 14) 1975

"Increasing amounts of plutonium-239 are processed in the nuclear power industry. The likely magnitude of the associated genetic risk is still uncertain but thought to be less than the risk of cancer induction... (H)owever, plutonium reaching the testis...concentrates in the interstitial tissue, outside the seminiferous tubules... The calculated average dose-rate to spermatogonial stem cells, in which genetic damage can accumulate, was about 2-2.5 times that to the whole testis... The average tissue dose is normally used for protection purposes." (Emphasis added.)

-Male mice injected intravenously with soluble Pu-239 showed a 58% decline in testis weight after 18 weeks and a 51% decrease in sperm count, both attributed to germ cell death.

-Irradiated spermatocytes showed a 2.6 times greater frequency of chromosome fragments (not statistically significant) and a clearly significant increase in quadrivalent configurations (rings and chains of four arising from translocations in spermatogonia.)

-Alpha particle radiation is calculated to be 63 times more potent than gamma radiation in inducing chromosome abnormalities.

-Deposited plutonium in gonad remains for a very long time, and genetic effect is cumulative.

Sanders, C.L., Deposition patterns and the toxicity of transuranium elements in lung. Health Physics 22:607, 1972

"Plutonium is peculiar compared to most inhaled material in that it exhibits such a tenacious retention in the lung." In the case of PuO_2, its biological half life in lung is estimated by animal studies to be 4 years, after which time approximately 50% has translocated to lymph nodes. Due to the inhomogeneous localization within lung, a fraction (2%) of tissue may receive over 40 times the maximal permissible total lung dose (15 rem).

Taylor, D.M., Interaction between transuranium elements and the components of cells and tissues. Health Physics 22:575, 1972

In blood, plutonium binds with transferrin, the iron-transporting protein. In cells, it localizes to lysozomes, creating intracellular "hot spots" and possibly causing damage to lysozomes sufficient to cause release of enzymes which may damage subcellular components, including chromosomes.

Miller, C.L., et al, Transfer of plutonium from milk to cheese. Health Physics 22:563, 1972

-Soluble plutonium appearing in milk is transferred readily (97%) into cheese.

Noshkin, V.E., Ecological aspects of plutonium dissemination in aquatic environments. Health Physics 22:537, 1972

-"There is evidence that plutonium concentrations are increased in organisms of higher trophic levels" (ie, higher on the food chain.) "Bone and liver are major repositories for plutonium in marine vertebrates." "In marine sediments, as in soils, plutonium is more mobile than originally expected.What little is known of the behavior of plutonium in the marine environment should be used conservatively to assess...new plutonium additions derived from sources other than fallout..."

Ballou, J.E., Distribution and retention of plutonium-239 and Neptunium-237 in the rat adrenal. Radiation Research 22:81, 1964

"The deposition of plutonium and neptunium in the adrenal cortex is characterized by discrete zonal concentrations of the radionuclides in areas of the zona glomerulosa and zona reticularis. Estimated local radiation doses to the portion containing the majority of Pu and Np are about five times as high as the average adrenal dose.

-Also points out that the adrenal is relatively radioresistant.

Langham, W.H., The biological implications of the transuranium elements for man. Health Physics 22:943 1972

"It appears quite certain that the transuranium elements in general and plutonium specifically are or will be the most thoroughly studied of the valuable but potentially harmful substances to be introduced into man's ever-expanding industrialized society."

(Seaborg) "visualizes that the annual production rate of Pu-239 will increase from about 20,000 kg in the 1970-80 period to 60,000 kg in the 1980-90 decade and to 80,000 kg in the period 1990-2000...This trend reflects the increasing national power needs over the next three decades before commercial thermonuclear energy production may become a technical and economic reality.(Emphasis added) The first reactors to supply commercial power utilized only the U-235 constituting 0.7% of natural uranium. Their inefficient utilization of the nation's natural resources of uranium eliminates them as a candidate for meeting the nation's expanding power needs... The next generation of reactors is the Liquid Metal Fast Breeder Reactor and will derive about 80% of its energy from Pu fission and the other 20% from...U-238 while producing enough additional Pu to provide fuel for new reactors."

"One can visualize a number of ways whereby Pu may be discharged advertently or inadvertently into the environment...Nuclear power plants can disperse Pu into the environment through improper discharge of gaseous or liquid effluents and through accidents that disrupt the integrity of containment. Pu processing and fabrication plants can contaminate the environment...through accidents such as fires and storage and transportation mishaps...Space power generators could be involved in launch pad explosions and orbital decay with reentry and atmospheric burnup... Contaminated waste management is of paramount importance in controlling environmental contamination."

-Continues by reviewing the history of Pu standards and concludes that with vigilance and dedicated research plutonium will indeed become the future substrate of nuclear power, with acceptible containment.

Ovcharenko, E.P., An experimental evaluation of the effects of transuranic elements on reproductive ability. Health Physics 22:641, 1972

-5000 rats were injected with soluble plutonium and other transuranics (Americium and Neptunium). Doses not cited.

"All of the transuranics studed were characterized by a high retention in the placenta, and an increased transplacental transfer during the later stages of pregnancy... 7% injected Pu concentrated in the placenta, 4% in the first month's breast milk and 1% in the fetus." Increased intrauterine death was seen with all transuranics when administered to both males and females. Live offspring showed "decreased viability, delayed physical development, variations in weight, disturbance in blood formation, change in radiosensitivity and depression in sex function."

Jee, W., Distribution and toxicity of Plutonium-239 in bone. Health Physics 22:583 1972

"Plutonium-239, an alpha-emitting, bone-seeking radionuclide, has proven to be one of the most effective radioelements for osteogenic sarcoma induction. Its pattern of distribution upon bone surfaces allows a large proportion of the alpha particle energy to be absorbed by sensitive bone lining cells. Very little radiation is wasted..."

"In growing bones, there is more bone surface available...and better vascularization...which may offer better conditions for the binding of plutonium."

-The minimum effective dose of Pu-239 for induction of osteosarcoma ranges from 0.0073 to 0.7 microCurie/kg, which for an average 70kg human comes to 0.1 to 9.8 microgram.

Sikov, M.R., Plutonium in the developing animal. Health Physics 22: 707 1972

-Reviews the literature on the differences between young and adult animals with regard to gastrointestinal absorption, radiosensitivity and carcinogenicity.

-There is enhanced absorption from the gut in neonatal dogs and rats of radionuclides ordinarily thought to be poorly absorbed. About a 100-fold increase has been found.

-"The absorption of plutonium bound to protein, as in milk, may be as much as 20-fold greater than in the uncombined form. This might increase the hazard in the juvenile, whose diet is primarily milk."

"It appears that the hazard (of irradiation) to the g.i. tract from ingestion of insoluble radioactive materials may be greater in the infant than in the adult."

-Early in gestation, doses of plutonium "well below the acute lethal range for the adult rat produce extensive prenatal death...through alterations of the fetal membranes." Later on, Pu concentration in the fetal bones exceeded that of the mother and that of the liver approximated that of the mother, indicating free passage through the placenta.

-"Metabolic differences and radiation sensitivity differences related to the juvenile state are almost certainly present in the human as well...They may be of even greater significance since the age-curve of man is distinguished from those of other species by a very long juvenile period. Thus these potential differences will be present for a proportionally greater fraction of the lifespan in the human."

-Data indicate heightened neonatal sensitivity to radiation by factors of 11 for solid tumors, 45 for leukemia and 4 for thyroid cancer.

****PAGES 44A through F WERE PREPARED BY CALIFORNIA PSR****

(44G)

20 June 1979

TO: Alameda County Board of Supervisors
1221 Oak Street, Oakland, California

FROM: Dr. Edward A. Martell
National Center for Atmospheric Research*
P.O. Box 3000
Boulder, Colorado 80307

SUBJECT: Statement for the Public Hearings of 26 June, 1979 on the proposed resolution to close the plutonium facility at Livermore Laboratories and to remove the plutonium from the Livermore site.

This statement is made to advise you of the possible consequences of an accidental release of plutonium and other actinides from the Livermore Laboratories to the surrounding public areas. In particular I must point out that relatively small releases of plutonium can give rise to very substantially increased risks of cancer and early coronaries in exposed population groups in the present and thousands of future generations. The full magnitude of the risks are highly uncertain and controversial because the responsible federal agencies have failed to evaluate the chronic health effects attributable to very small burdens of insoluble alpha emitting dust particles in the lung and other soft tissue organs. It is pointed out below, and in attachments 1-3, why only one or two picocuries of insoluble alpha emitting particles in the lung may give rise to an unacceptably high risk of lung cancer. In this connection, please note that the presently accepted maximum permissible lung burden for occupational exposure to plutonium is 16,000 picocuries—a ten thousand times greater burden! This remarkable discrepancy remains unresolved and serves to illustrate the present hopelessly inadequate basis for plutonium cancer risk assessment.

The substantial lung cancer risk which I attribute to very small burdens of alpha emitting particles in the lung stem from the following general considerations. Both the age distribution of lung cancer and the chromosome aberrations in the tumor cells clearly indicate that a multi-stage process is involved. For a multiple mutation process of cancer induction by alpha emitters it is self-evident that particles of relatively low alpha activity (which I call "warm particles") will carry a much higher risk than particles of higher activity. "Warm particles" give rise to less than one critical alpha hit per day to the cells

*Affiliation given for address purposes only.

1. E. A. Martell comments on "Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the Environment," Report of the U.S. Environmental Protection Agency, EPA 520/4/-77-016, September, 1977.

nearest the particle. At such interaction rates, transformed cells have time to pass through the mitotic cycle and divide before they suffer a second hit. This allows for a succession of interactions which progressively transform some normal cells to the premalignant state and finally to the fully malignant state. By contrast "hot particles" will kill transformed cells before they can proliferate, effectively shutting off the multiple mutation process.

On the basis of such a mechanism as that proposed here, the linear hypothesis would not be applicable for estimating cancer risks for insoluble alpha emitting particles which persist in tissue. In fact, on this basis the linear hypothesis is highly unconservative and its application very seriously underestimates the cancer risks attributable to "warm particles."

I submit that, on the basis of such a mechanism, the small burden of insoluble alpha emitting particles at the bronchial tumor cites in cigarette smokers (Attachment #2) is the likely agent of lung cancer in smokers. Similarly, plutonium at fallout levels can be contributing substantially to the rising general incidence of human cancer. If, as I seriously propose, fallout levels of plutonium contributes substantially to the general incidence of human cancer, can we accept the EPA's "Proposed Guidance on Dose Limits for Persons Exposed to Transuranium Elements in the General Environment," EPA 520/4-77-016, September, 1977? The latter report tries to suggest, without adequate basis, that 200 times fallout levels is an acceptable level of public exposure to plutonium in areas east of the Rocky Flats plant and elsewhere.

In my opinion, it is a national scandal that the federal health agencies have failed to assess the microdistribution of insoluble alpha emitting particles in human soft tissue organs and the cancer risks attributable to such distributions. In particular, until the warm particle hypothesis and other possible mechanisms of cancer induction by alpha emitters are adequately evaluated, the magnitude of cancer risks attributable to plutonium and other alpha emitters in soils, in air, and in human organs will remain very highly uncertain.

Until these problems are resolved the magnitude of the risks associated with plutonium contamination in the environs of Rocky Flats, or Livermore Laboratories and elsewhere will remain in doubt. If the disturbing possibilities which I have proposed are confirmed, fallout levels of plutonium are serious and areas with ten times fallout levels would involve unacceptable risks.

On the basis of the above considerations, I suggest that the continued operation of a plutonium facility at Livermore Laboratories provides a threat that should be a source of major concern to nearby communities. Whether by seismic event, by fire, by explosion, or by other means, the release of only a *few* ounces of plutonium to offsite areas can render tens of square miles of contaminated land area unsuitable for human habitation.

2. Article in American Scientist, "Tobacco Radioactivity and Cancer in Smokers" pp. 404-412, July, 1975.

3. Statement submitted to the National Academy of Sciences BEIR Committee, "Bronchial Cancer in Cigarette Smokers from Alpha Emitting "Warm Particles," July, 1977.

91) Newell, R., "The global circulation of atmospheric pollutants", Scientific American, 224(1): 32-42, Jan. 1971.

-Radioactive fallout is distributed globally by 12 days following an atmospheric nuclear explosion.

92) Stover, B.J. and Jee, W.S.S. (eds.), Radiobiology of Plutonium, Salt Lake City, The J.W. Press, Dept. of Anatomy, University of Utah, 1972.

93) Tamplin, A.R. and Cochran, J.B., "Radiation standards for hot particles: a report on the inadequacy of existing radiation protection standards related to internal exposure of man to insoluble particles of plutonium and other alpha-emitting hot particles", National Resources Defense Council, 1710 N. St. N.W., Wash. D.C., 20036, Feb. 14, 1974.

(By 2020, U.S. nuclear plants would have 440 million pounds of plutonium through the nuclear fuel cycle. Estimates lung Ca deaths from plutonium.)

94) United Nations Report of the Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Sources and Effects of Atomic Radiation, U.N. Publication E-77, IX.1.

-The radiation dose commitment per person due to nuclear explosions by the end of 1975 (the whole world):

	Gonad	Marrow	Bone-lining cell	Lung
mrad	94	170	190	160

95) U.S. Senate Committee, 1979.

[A Senate Committee is currently investigating the reportedly high incidence of cancer in areas of Utah and Nevada subjected to fallout from atmospheric nuclear tests. Copies will probably be available from Senator Edward Kennedy, a committee member, when the investigation is completed.]

H - LINEAR HYPOTHESIS

96) Archer, V.E., "Lung Cancer among populations having lung irradiation", Letter to Editor, Lancet, 11 (7736): 1261-1262, 4 December 1977.

-excess lung cancer among uranium miners = 1.8/yr/WLM/million persons.

-radiation dose/response curve is approximately linear from fairly high levels down to the 0-dose/0-response point.

97) Archer, V.E., "Occupational exposure to radiation as a cancer hazard", Cancer, 39: 1802-1806, 1977.

-the linear hypothesis " . . . is a conservative approach for x-rays and other low-LET (Linear Energy Transfer) radiations but is probably not conservative when dealing with alpha particles or other radiations having high-LET."

-"It appears to be impossible to establish a threshold level for ionizing radiation in the production of neoplasms in experimental animals."

98) Bair, W.J., and Thompson, R.C., "Plutonium: Biomedical Research", Science, 183: 715-722, 1974.

(-100% of dogs with small amounts of Plutonium-239 put in the lung died of lung cancer.)

99) Baum, J.W., "Population heterogeneity Hypothesis on radiation induced cancer", Health Physics, 25: 97, August 1973.

(-at lower doses of radiation the linear hypothesis underestimates the risk of cancer.)

100) Brown, J.M., "Linearity vs non-linearity for dose response for radiation carcinogenesis", Health Physics, 31: 231, September 1976.

(-at lower doses of radiation the linear hypothesis underestimates the risk of cancer.)

101) Bross, I.D.J., Natarajan, N., "Leukemia from low-level radiation", New England Journal of Medicine, 287: 107-110, 1972.

-children with hives or asthma are 8 times more susceptible to leukemia from the same radiation exposure than other children.

(PSR)-current procedures for setting 'safe' levels for exposure to low-level radiation are based on the assumption that the population exposed to the risk of leukemia is homogeneous.

102) Brown, M., "The linear hypothesis", Letter to editor, Bulletin of the Atomic Scientists, September 1977.

-" . . . the linear hypothesis is a very good estimator of effects (cancer induction and genetic mutation) at low to moderate doses (of radiation)."

103) Craig, A.G., "Alternatives to the linear risk hypothesis", Health Physics, 31: 81, July 1976.

(-at lower doses of radiation the linear hypothesis underestimates the risk of cancer.)

104) Hempelmann, L.H., "Neoplasms in youthful populations following x-ray treatment in infancy", Environmental Research, 1: 338, 1967.

(-radiation induced thyroid carcinoma presents a higher risk in children than in adult populations and risk increases linearly as the dose increases.)

105) Lewis, E.B., "Leukemia and ionizing radiation", Science, 125: 965, 1957.

(-linear relationship between dose and risk, infers 1-2 cases/ million person-years at risk per rem.)

6) Modan, B. et al, "Radiation induced head and neck tumors", Lancet, 277-279, February 23, 1974.

(PSR)-radiation for ringworm of the scalp resulted in an increasing risk of brain, parotid and thyroid tumor. The dose causing thyroid carcinoma 6.5 rads, is the lowest reported.

107) Morgan, K.Z., "The linear hypothesis of radiation damage appears to be non-conservative in many cases", Proceedings of 4th International Congress of International Radiation Protection Association, Paris, France, paper #431, August 1976.

(-at lower doses of radiation the linear hypothesis underestimates the risk of cancer.)

108) Muller, J., and Wheeler, W.C., "Causes of death in Ontario uranium mines (second report)", May 1974.

[*Taken from the Ham Report*]

-Cancer risk increased with cumulative exposure.

-Linear hypothesis is consistent.

-"There is now no longer any real question of recommending a level of exposure to ionizing radiation that in the light of present knowledge can be considered absolutely safe."

-The Nominal Roll provides no evidence supporting the hypothesis of a threshold of exposure below which there is not significant excess risk.

-"In the absence of evidence of a threshold below which it may be presumed that there is no risk, it is prudent to assume that the risk of excess lung cancer increases with ionizing radiation from zero exposure."

109) Silverman, C., and Hoffman, D.A., "Thyroid tumor risk from radiation during childhood", Preventive Medicine, 4: 100, 1975.

(PSR)-A review.

-The low dose, 6 rads, associated with thyroid cancer in 2 studies, raises questions about the long-term effect of diagnostic procedures in childhood.

110) Wick, G.L., "Is there a safe radiation limit", New Scientist, page 276-278, August 6, 1970.

-"If the claims of some radiologists, that no 'safe' limit exists, are true, the setting of radiation standards should be a public issue."

-"Damage caused by it (radiation) has been studied much more extensively than that of any form of pollution."

-"Drs. John Gofman and Arthur Tamplin, Lawerence Radiation Laboratory, Livermore, California . . . have claimed that the risk of cancer due to radioactivity are higher than commonly believed, and that maximum permissible limit for radioactive pollution . . . should be immediately lowered by a factor of ten."

-"According to their calculations, an additional 16,000 cases of cancer will be induced in the U.S. unless the upper limit for radioactive pollution is lowered."

-"Other experts disagree with . . . their conclusions."

-The International Committee on Radiological Protection (ICRP) originally based their recommendations on the threshold concept but now base them on the theory "that the risk of damage is proportional to dose even at the lowest levels. Thus the maximum permissible dose is not necessarily a completely safe dose. It depends on 'a risk that is not unacceptable to the individual and to the population at large'."

-"It is important that the public be included since the decision cannot be made on purely scientific criteria."

111) Zenz, C., Occupational Medicine — Principles and Practical Applications, Year Book Medical Publishers, Inc., Chicago, Ill., 1975.

-It is "prudent for purposes of occupational and environemntal exposure guidelines to assume that no threshold does exist for radiation mutagenesis."

-"There is no doubt that a causal relationship exists between radiation and cancer in man."

I - GENETICS

112) de Bellefeuille, P., "Genetic hazards of radiation to man", Acta Radiologica, 56, Part I: 65-80, Part II: 145-159.

113) Bloom, A.D., et al, "Cytogenetic investigation of survivors of the atomic bombings of Hiroshima and Nagasaki", Lancet, 2: 672-674, 1966.

-acute exposure, dose greater or equal to 200 rads.

-94 survivors peripheral leukocytes examined. 34% had exchange-type chromosomal abnormalities (fragments, rings, translocations or dicentric) (p less than 0.001). No direct dose - abnormality relationship found.

114) Bross, I.D.J., "The mindless use of radiation technology: The public health problem of genetic degradation", Testimony before the National Energy Forum, University of Akron, July 27-28, 1976.

115) Bross, I.D.J., Natarajan, N., "Genetic damage from diagnostic radiation", Journal of the American Medical Association, 237 (22): 2399-2401, May-June 1977.

-excellent study of Tri-State Leukemia Survey, which demonstrates methods of measuring health effects of low doses of radiation. Outlines a mathematical model for obtaining meaningful results in this area. This and other papers related to the Tri-State Leukemia Survey are discussed by Dr. Rosalie Bertell, and information may be obtained by contacting her at the Ministry of Concern for Public Health, 151 East St., Buffalo, NY, 14207.

116) Gentry, J.T., "An epidemiological study of congenital malformations in New York state", American Journal of Public Health, 49 (4), April 1959.

117) Ibsen, H.W., "The nuclear power game: Genetic roulette", The Progressive, page 15-18, January 1976.

(-discusses the social consequences.

-discusses the outcast status of survivors of Hiroshima/Nagasaki radiation with respect to desirability as marriage partners and queries nuclear workers being future lepers of society.)

118) Ichikawa, and Nagata, "Nuclear power plants suspected to increase mutations", from the Laboratory of Genetics, Faculty of Agriculture, Kyoto University, Kyoto, Japan 606.

-an interesting article based on the use of bioassay with susceptible plants (the spider-wort) to determine possible health effects of very low-level radiation around a nuclear power plant.

119) International Commission on Radiological Protection: The RBE for High-LET Radiation with Respect to Mutagenesis, Oxford, Pergamon Press, 1972.

(-linear relationship with high-LET radiation, eg alpha rays.)

120) Lisco, H., and Conrad, R.A., "Chromosome studies on Marshall Islanders exposed to fallout radiation", Science, 157: 445-447, 1967.

- -acute radiation exposure to fallout (70-175 rads).
- -examined peripheral blood lymphocytes 10 years after fallout and found increased 2 break aberrations and acentric fragments (p less than 0.01) but no increase of other abnormalities versus unexposed controls. Significance unknown.
- -few controls not well matched for age and sex.

121) Martell, E.A., "Unresolved health effects of internal alpha emitters", Proceedings of a Congressional Seminar on Low-Level Ionizing Radiation, U.S. House of Representatives, 94th Congress, 2nd session, Nov. 1976.

- -"The magnitude of the contribution of internal alpha emitters to spontaneous mutations and genetic effects is a serious neglected question."
- -"Recent studies have shown higher concentrations of plutonium in human gonads and lymph nodes than in other soft tissue organs . . . distributed in a manner which gives a much higher dose to the sperm than to the testes as a whole."
- -"The microdistribution of alpha emitters in the gonads and at the important tumor sites . . . in high risk exposure groups" must be studied "before we are committed to further proliferation of nuclear energy. To do otherwise would be reckless and irresponsible . . . "

122) Merz, T., "Radiation-induced malformations in man", Birth Defects: A Regional Article Series, 12 (5): 19-22, 1976.

- -a good resume of the problem and reaffirms the conviction that "the most significant hazards to mankind are probably those which are related to very low doses fractionated over a long period of time".

123) Muller, H., "Radiation and Heredity", American Journal of Public Health, Volume 54, January 1964.

124) National Academy of Science, Advisory Committee on Biological Effects of Ionizing Radiation, The Effect on Populations of Exposure to Low-Levels of Ionizing Radiation, Washington, D.C., 1972. (BEIR Report)

- - uses predominantly the doubling dose method to quantify the risks.
- -doubling dose of genetic mutations is "between 20-200 rads".

(see following table)

Estimated Effect of 1 Rad Per Generation of Low Dose, Low Dose Rate, Low LET Radiation on 1 Million People

Recalculated BEIR Assessments
[*Taken from UNSCEAR Report - 77, See Number 127 this section*]

Disease Classification	Current Incidence	Effect of 1 rad per generation: 1st generation	Effect of 1 rad per generation: Equilibrium (≥ 5 gens.)
Autosomal dominant and x-linked diseases	10,000	20	100
Recessive and chromosomal diseases	10,000	slight	very slow increase
Congenital anomalies Anomalies later expressed Constitutional and degenerative diseases	40,000	2-20	20-200
TOTAL	60,000	25-40	125-300
Percentage of current incidence	100	0.04-0.07	0.21-0.50

[*These statistics do not apply to high-LET (linear energy transfer) radiation, e.g. alpha particles which have a relative biological effectiveness (RBE) of 5-20, depending on which authorities you read, compared to low-LET radiation, e.g. x-ray and gamma rays, which have an RBE of approximately 1*]

125) Neyman, J., "Public healt. hazards from electricity producing plants", Science, 195 (4280): 754-758, 25 February 1977.

-cannot extrapolate well from A-bomb studies and mice studies, therefore must take into account multipollutant and multilocality considerations.

-Rocky Flats Denver: Ranch complaints of increased malformations at birth among domestic animals. Query due to selenium entering the food chain; query local nuclear radiation.

126) Russell, W.L., "Studies in Mammalian Radiation Genetics", Nucleonics, 23: 53 (1965).

(-increased mutations vary with dose and rate, no definite linear relationship.

-female mice show recovery in genetic material at low dose and low dose rates, and have a threshold.

-male mice have no threshold.)

127) Sources and Effects of Ionizing Radiation, UNSCEAR (U.N. Scientific Committee on the Effects of Atomic Radiation), 1977 Report to the General Assembly, U.N. Publication E-77, IX.1.

- "Genetic effects of radiation are likely to be due predominatly to damage induced" in DNA.
- "Using the direct method the total rate of induction of recessive mutations by low-LET radiation is estimated as 60 per million per gamete per rad", for 1st generation.
- induction of dominant mutations is estimated as 20 per million per rad in males, for 1st generation.
- induction of chromosome aberrations is "2-10 congenitally malformed liveborn children per million conceptuses per rad, with about 5 times this number of recognizable abortions and about 10 times the number of losses at the early embryonic stage."
- the doubling dose method (the dose required to double the natural frequency of genetic abnormalities, which is approximately 100 rads for radiations such as x-rays, beta or gamma radiation- i.e. low-Linear Transfer Radiation) "the total genetic damage expressed over all generations (or the value in each generation reached after prolonged continuous exposure) is estimated to be 185/million/rad".

[*This does not take into account defect rate for high-LET radiation, e.g. alpha particles which have a relative biological effectiveness (RBE) of 5-20 depending on which authorities you read, compared to low-LET radiation.*]

128) Sternglass, E.J., "Radiation Risks", Bulletin of the Atomic Scientists, page 4-5, June 1972.

- " . . . it is the dose to the early developing embryo and fetus during the first few months of pregnancy that produces the greatest impact, both for a given family and for society as a whole."
- " . . . the dose required to double the incidence of serious defects in the genetic control mechanism of the human cell . . . is of the order of 100 millirads in the first trimester, compared to 10.0 to 100.0 rads . . . in the reproductive cells of the mature adult."
- "A typical chest x-ray . . . results in an average dose of about 50 millirads to the upper part of the body. However, the dose to the gonads from scattered radiation is only about 2 millirads."
- He points out that while medical diagnostic x-rays are rarely given to the embryo, radioactive fallout or releases from the nuclear fuel chain to the general environment will cause many more health problems than previously believed even at significantly lower doses than the present maximum permissible levels.

II - NUCLEAR FUEL CHAIN

1) American Institute of Architects, Energy and the Built Environment: A Gap in Current Strategies, and A Nation of Energy Efficient Buildings by 1990, Washington, D.C., 1975.

[*From Nader and Abbotts - Menace of Atomic Energy*]

-"A commitment to develop energy-efficient buildings by 1990 could alone save more energy than nuclear power is expected to supply even at historical growth rates."

2) A Public Report on Nuclear Power Plants, Environmental Education Group, Environmental Alert Group, 1543 N. Martel Avenue, Los Angeles, California, 90046, U.S.A., 1974.

-an excellent basic information and review book of the industry.

3) Bertell, R., Testimony before the Nuclear Regulatory Commission in the matter of Boston Edison Company et al, Pilgrim Nuclear Power Station Unit 2, Docket Number 50-471, Cambridge, Mass., April 19, 1977.

4) Bertell, R., Testimony before the Nuclear Regulatory Commission in the matter of the application of Public Service Company of Oklahoma, et al, for Black Fox Nuclear Generators Units 1 and 2, Docket Numbers STN-50-556 and STN-50-557, March 24, 1977.

5) Bertell, R., Testimony, Mines and Energy Management Committee, House of Representatives, Commonwealth of Pennsylvania, July 7, 1976.

6) Bertell, R., and Bross, I.D.J., Proceedings of a Congressional Seminar on Low-Level Ionizing Radiation, Subcommittee on Energy and the Environment of the Committee on Interior and Insular Affairs of the U.S. House of Representatives, U.S. Government Printing Office, Washington, 79-767-0, 1976.

7) Bross, I.D.J., Testimony to New York State Board on Electric Generation Siting and the Environment in the matter of Long Island Lighting Company (Jamesport Nuclear Power Station, Units 1 and 2), Riverhead, New York, May 2, 1977.

8) Caldicott, H., Nuclear Madness, Autumn Press, pp 120, 1978.

(-Dr. Caldicott, a pediatrician, presents a very informative discussion, for the layperson, of the biological impact of nuclear power.)

9) Energy Research and Development Administration, A National Plan for Energy RD&D, Report 48, Washington, D.C. 20545, June 28, 1975.

("Solar energy falling on about 3% of land, if utilized at about 10% efficiency could meet the total projected U.S. energy needs for the year 2,000.")

10) Environmental Analysis of the Uranium Fuel Cycle, EPA-520/9-73-003-D, (Environmental Protection Agency, Washington, D.C., 1973).

11) 40 Code of Federal Regulations (U.S.), 19439-Appendix I.

(-Numerical Guides for Design Objectives and limiting conditions to meet the criterion "as low as practicable" for radioactive material in light-water-cooled nuclear power reactor effluents.)

12) Gofman, J.W., "Nuclear Power - No", an address at the Nuclear Energy Forum, San Luis Obispo, California, October 17, 1973.

-"In our modern society the last refuge of the promotor is to threaten people with loss of jobs, loss of livelihood, lack of food, and a return to life in a cave."

-"The American Institute of Architecture proposed . . . a program for energy efficient buildings which . . . would result in savings . . . of some 12 million barrels of oil per day by 1990." (which equals 26 quads of thermal energy, enough to equal the projected increase of energy by 1990).

-John Gofman, MD, PhD, Professor Emeritus of Medical Physics at the University of California, Berkeley.

13) Gofman, J.W., On the Way to the Bank or Why There Will Never Be a Solution to the Radioactive Waste Problem, C.N.R. Inc., Report #1977-7, November, 1975. [*Available from C.C.N.R., #104 - 2127 West 40th, Vancouver, B.C., V6M 1W4*]

-"The real problem: losses of radioactivity on the way to storage."

-A good review of containment problems during "the handling of such radioactive substances in all parts of the entire nuclear fuel cycle . . . "

14) Gofman, J.W., Radiation Doses and Effects in a Nuclear Power Economy: Myths vs Realities, CNR Report 1976-2, April 1976. [*Available from Dr. Gordon Edwards, Canadian Coalition for Nuclear Responsibility, 2010 McKay Street, Montreal, Quebec*]

-"Weapons testing in the atmosphere deposited some 700 pounds of Plutonium on the lower 48 states of the U.S.A."

-"If a fabulous investment (mostly rate-payer's money) is sunk into nuclear power, and then late along the path, we realize we are fouling up the environment with radioactivity, there will be enormous pressure to continue in spite of unacceptable radiation doses, especially since the economy could by then be dependent upon the power output."

15) Gofman, J.W. and Tamplin, A.R., Poisoned Power, Rodale Press, Emmaus, Pa., 1971.

[*Taken from Nader and Abbotts, Menace of Atomic Energy.*]

"...the ' entire nuclear electricity industry had been developing under a set of totally false illusions of safety and economy. Not only was there a total lack of appreciation of the hazards of radiation for man, but there was a total absence of candor concerning the hazard of serious accidents'."

16) Hamel and Jennikens, Regulatory Control of Radioactivity and of the Nuclear Fuel Cycle of Canada, paper for the 1977 Salzburg Conference, Atomic Energy Control Board - 1100.

-A good descriptive outline of the current methods of control of the nuclear industry, with some not-very-courageous suggestions for future changes.

17) Hare, F.K. et al., The Management of Canada's Nuclear Wastes , Ottawa: Dept. of Energy, Mines and Resources, Report EP 77-6, 1977.

[*Publication obtainable from the Chairman, Standing Committee on national resources and public works, House of Commons, Ottawa, Ontario.*]

-This 'Green Paper' of the Canadian Government on waste management is to form the basis of public discussion in the area of nuclear wastes. It is particularly disturbing to see a recommendation that nuclear proliferation be allowed when no feasible disposal technology has been demonstrated.

[*The following is taken from the B.C.M.A. News, Sept. 1978.*]

-"A pamphlet prepared in less than 4 months by 3 men, none of whom had had any medical training. The report states that 'We have not had a medical expert in our team to contribute definitive views on the health hazards of radioactive materials.' One doctor, from the Radiation Protection Branch read the report. In spite of this deficiency the report is laced with optimistic statements best exemplified by the statement: 'We have not seen estimates of either health or environmental impacts likely to be associated with immobilization technology but believe these to be slight.' ... The present Green Paper, in the absence of these (health and environmental) considerations, is not a meaningful starting point for public discussion."

[*The B.C.M.A. and the C.M.A. have passed resolutions recommending that: "The present Green Paper be scrapped and that a new Green Paper be called for considering all aspects of the nuclear fuel cycle, including the best medical expertise available and encouraging full public participation."*]

18) Knelman, F.H., Nuclear Energy - The Unforgiving Technology, Hurtig Publishers, Edmonton, Alberta, 1976.

[*Available from the Hurtig Publishers, 10560-105th St., Edmonton*]

19) Morgan, K.Z., "The bases for standards and regulations", Paper delivered at Georgia Tech. School of Nuclear Engineering, Nov. 28, 1973.

20) Morgan, K.Z., "The dilemma of present nuclear power programs", Presented at an ERDA hearing, Sacramento, California, Feb. 1, 1977.

21) Nader, R. and Abbotts, J., The Menace of Atomic Energy, W.W. Norton and Co. Inc., New York, 1977.

-An extremely well written book that is as well documented as a legal case, with the source of hundreds of statements of fact footnoted.

IN GENERAL

-"...there are over 60 operating nuclear plants in the United States - each with one thousand times more radioactive material than the fallout from the Hiroshima weapon..."

-"...solar energy systems have major decentralizing potential, few security risks, and significant opportunities for self-sufficiencies at the energy consumption site."

-"...measures to increase energy efficiency can be implemented at less expense, in shorter time periods, and more economically than technologies to supply energy."

-"In choosing between energy alternatives, citizens in a democratic society should know about the maximum that can go wrong with each choice, both in terms of immediate and long-range impacts."

-They go on in the book to "explain why atomic fission is unsafe to an unacceptable degree, why it is unnecessary, and why it is economic folly".

THE PALEY COMMISSION

-In 1952 the Materials Policy Commission of President Truman (the Paley Commission) found that "only two sources of energy supply would be available to alleviate the demand for foreign oil - uranium and solar energies. The Paley Commission opted for the solar alternative, projecting an installation of thirteen million solar heating systems in commercial and residential dwellings by 1975. This would account for 10 percent of the nation's overall energy needs".

-However, billions of dollars have since been invested in nuclear energy development and very little for the 25 following years in solar, wind and tide, geothermal and biomass energy systems.

SOURCES OF RADIOACTIVE RELEASE FROM REACTORS & REACTOR WASTE

-1. "routine radioactive releases."
2. "accidental releases at the reactor
3. accidental releases during transport of spent fuel rods from reactors
4. planned and accidental releases from nuclear fuel reprocessing plants
5. environmental contamination from storage or disposal of high-level wastes

6. accidental releases through sabotage".

-Present standards for the nuclear industry set by the I.C.R.P. are 5 rem per year for workers and 0.025 rem per year for individuals.

-"A July 1976 report by the General Accounting Office concluded that 'tens of tons' of weapons-grade material could not be accounted for at 34 facilities operated under contract to the federal Energy Research and Development Administration.'

WASTE

-"While there are many speculative 'solutions' to the ultimate problem of nuclear waste, none has been demonstrated, and the history of attempted solutions is full of failure and false starts, raising serious questions about the ability of human institutions to manage nuclear waste for the centuries which may be required."

-They point out the problems with disposal in outer space, in salt mines, and waste solidification.

-"The amount of strontium-90 alone on the waste generated by one family's annual consumption of nuclear plant electricity is enough to contaminate one billion gallons of water beyond the NRC's (Nuclear Regulatory Commission's) maximum allowable concentrations in drinking water."

-"...the annual high level waste generated by each large nuclear power plant will become 10,000 gallons of liquid waste at a reprocessing plant. ...by the year 2000 accumulated wastes could be 25,000 metric tons - 40-60 million gallons in liquid form."

-"...it is unlikely that any method can be developed which can realistically guarantee the stability of geological formations as well as human institutions for the quarter-million years or more which may be necessary."

-"Nuclear electricity generated now could burden thousands of future generations with its lethal by-products."

REPROCESSING

-"...by the EPA's (Environmental Protection Agency's) own calculations, carbon-14 emissions from reprocessing plants through the year 2000 will eventually cause 12,000 cases of cancer, leukemia, and genetic disease."

TRANSPORTATION

-"The activities of greatest concern are the shipment of highly radioactive spent fuel from the reactor and subsequent shipments of waste from the reprocessing plant."

-"Between 1969 and 1972, there were 64 unreported instances in which the containers or the vehicles carrying them were contaminated beyond specified levels."

-"The AEC (Atomic Energy Commission) admitted that accidents at speeds over 50 miles per hour could rupture the fuel rods (in the transportation casks), resulting in a radioactive release."

-"The panel (of the Joint Committee on Atomic Energy) had recommended that air shipments of plutonium be banned because of the danger of an aircraft accident and resulting contamination."

-"...Marvin Resnikoff, professor of physics at the State University of New York at Buffalo, calculated that the release of 2.8 percent of the plutonium in a single (air) shipment could kill 30,000 persons from exposure at the airport, and 46,000 members of the general population could develop lung cancer."

THE INTERNATIONAL SPREAD OF ATOMIC POWER

-A provocative chapter outlining the difficulties in preventing the development of nuclear weapons from plutonium produced by nuclear reactors in foreign countries. Describes the poor controls of levels of radioactivity at India's Tarapur nuclear reactors.

-The General Accounting Office(GAO) of the U.S. in a recent report on the International Atomic Energy Agency (IAEA) concluded: "Although the global expansion of nuclear energy makes effective international safeguards crucial to U.S. and world security, international organizations have no authority to require physical protection measures, no authority to supervise, control, or implement such measures, and no authority to pursue and recover diverted or stolen material. Their inspectors have neither unlimited access nor authority to seek out possible undeclared or clandestine facilities of stockpiles of nuclear material. In addition, technical, political, financial, and staffing obstacles hamper the effective implementation of international safeguards."

THE RASMUSSEN REPORT

[The Nuclear Regulatory Commission, as of Jan. 1979, has withdrawn its endorsement of the executive summary of the Rasmussen Report - thus it is not a meaningful document in reassuring us of the safety of nuclear reactors, despite its continued use by the industry to justify its claims. Because of the latter, it is reviewed here.]

-The Reactor Safety Study (RSS) of the AEC, directed by N.C. Rasmussen (nuclear engineer) 1974 - First Draft:

"...the study covered only nuclear reactors themselves."

"The study predicted that the chances of a meltdown accident, on the average, would be 1 in 17,000 per reactor per year, but also concluded that most meltdown accidents would result in insignificant radiation exposure to the public."

"The worst accident which the RSS considered was predicted to occur once every billion years per reactor and would cause 2,300 immediate deaths, 5,600 immediate injuries, and $6.2 billion in property damage."

It was widely criticized by the Sierra Club and The Union of Concerned Scientists (SC-UCS) particularly for using "reliability estimating" techniques developed by the aerospace industry which had earlier abandoned them as a means of providing exact reliability estimates.

"SC-UCS tested the validity of the RSS estimating techniques by applying them to a reactor accident which had already occurred at the Dresden plant in Illinois in 1970. The result was an accident-probability prediction of one in a billion-billion. The fact that this accident had already occurred cast doubt on the study's methods, to say the least."

[It would be interesting to know what the RSS accident-probability prediction for the reactor accident at Three Mile Island in Harrisburg, Pennsylvania, would have been.]

"The SC-UCS review found that the RSS underestimated nuclear-accident health consequences by a factor of sixteen or more. This finding was generally supported by the Environmental Protection Agency and the AEC Regulatory Staff, a separate branch of the AEC which performed its own review."

"The American Physical Society, the national association of physicists, commissioned a review of reactor safety issues which included an examination of the RSS by a panel of twelve scientists. This review destroyed whatever credibility the Reactor Safety Study might have retained after the critiques by SC-UCS, EPA, and the AEC Regulatory Staff."

"The APS study also found that RSS had neglected cancers to the lungs and thyroid that would result from the inhalation of radioactive material."

"APS had felt the draft RSS underestimated cancers and genetic defects be factors of 25 to 60."

-"On October 30, 1975, the Nuclear Regulatory Commission, the AEC's successor, released its final version of the RSS."

"The worst accident considered by the final RSS would cause 3,300 'early'(as opposed to long-term) deaths, 45,000 early injuries, and $14 billion in property damage. The final RSS thus responded to criticisms by increasing early illness by a factor of 9 (i.e., multiplying by nine times), property damage by a factor of two, and early deaths hardly at all. These fell short of the revisions recommended by SC-UCS, EPA, and the AEC Regulatory Staff."

"The final Reactor Safety Study responded in a similar manner to the APS review. Estimates of latent cancer from the worst accident were revised upward by a factor of 14, to 1,500 per year. These latent cancers would occur during ten to forty years after the reactor accident, meaning that 45,000 total cancers would occur from the accident. The final RSS figures on genetic effects were also increased slightly. The worst RSS accident in the final version would cause 170 genetic defects per year, for a total of 5,100. Alarming though these figures on long-term effects are, they still fell short of the APS recommendations."

"Even some proponents of nuclear power such as Alvin Weinberg, former director of the AEC's Oak Ridge National Laboratory, acknowledge that for nuclear power to be a viable energy alternative it must be a technology free of catastrophic accident."

[It should be stressed that no study similar to the Reactor Safety Study has been undertaken in Canada "because the Rasmussen Study applies in a general way to CANDU". This question will be reviewed in the Porter Commission Report, #25, of this section.]

AEC STUDY 1965 (WASH-740 UPDATE)

- "...a 1965 study conducted for the Atomic Energy Commission concluded that the immediate effects of a reactor accident could be 45,000 people killed and 100,000 injured, with radioactivity contamination spread over an area as large as the state of Pennsylvania and causing $17 billion in property damage."

NUCLEAR POWER LIABILITY INSURANCE

- "Herbert S. Denenberg, former insurance commissioner of the state of Pennsylvania, ...used the results of the WASH-740 update to conclude that the damages from a nuclear plant accident could be $40.5 billion, a figure which includes the damages for health effects as well as property damage. ...and concluded that the premium necessary to cover a nuclear plant for this $40.5 billion accident would be $23.5 million per year."
- "Denenberg then noted that the annual operating costs for a nuclear plant - including fuel and maintenance costs - are about $23 million per year, by comparison."
- The Price-Anderson Act "set an absolute ceiling of $560 million on the damages which could be recovered by victims of an accident as a result of losses suffered".
- "On March 31, 1977, the Federal District Court for western North Carolina declared the Price-Anderson Act unconstitutional. The nuclear industry will appeal the ruling."

[In Canada, under the Nuclear Liability Act (1976), private insurance held by a plant must be $75 million. In the event of a more serious accident the Canadian Government, through the Nuclear Damages Claims Commission, will presumably pay the rest.]

OTHER TOPICS

- Thermal pollution, energy parks and decommissioning problems are discussed in detail.
- The book also discusses design problems of the Emergency Core Cooling System, nuclear economics, alternatives to nuclear energy, the corporations and institutions in the industry, and recommends numerous ways for individuals to become involved in the issue.

SUMMARY

- "This state of affairs surely warrants pause."
- "The facts on reactor technology and the fuel cycle point overwhelmingly toward the need for a nuclear power moratorium in this country. The facts just as overwhelmingly justify a moratorium on atomic exports."

22) Patterson, Walter C., Nuclear Power, Penguin Books, London and New York, 1976. [*Available from Penguin Books Canada, 41 Steelcase Road West, Markham, Ontario*]

-this is an excellent introductory source for the layman giving a balanced view of the processes and problems involved.

23) Policies and Poisons - The Containment of Long-Term Hazards to Human Health in the Environment and in the Workplace, Report No. 28 of the Science Council of Canada, October 1977.

-A good resume of the state of the art as regards the establishment of policies. This report underscores the importance of public participation in decisions relating to the nuclear fuel cycle in particular, but other hazards as well.

24) Pollard, R.D., (ed.), The Nuggets File, Union of Concerned Scientists, Cambridge, Mass., 1978.

(-From 1950 until 1976 when the U.C.S. made it public through the U.S.'s Freedom of Information Act, the Nugget File was the personal internal file of Dr. S.H. Hanauer (Nuclear Regulatory Commission's senior technical adviser). The file is composed of scores of reports of serious accidents and safety deficiences at reactors in the U.S. Pollard (a former NRC official and nuclear engineer) points out that the reports were initially headed "serious accidents" then became "abnormal occurrences" and now are labeled "licence event reports" and that the trend is not to embarrass the nuclear industry.)

25) Porter, A., Interim Report on Nuclear Power in Ontario, Royal Commission on Electric Power Planning, 1978.

[*AECL - Atomic Energy of Canada Limited - a crown corporation responsible for the "promotion and development of atomic energy." Eldorado Nuclear - a Canadian crown corporation responsible for the "promotion and development of uranium ore".*]

IN GENERAL

-"CANDU plants built in Canada and dedicated to the export of power to the United States deserve further study in light of arguments "for" and "against" this proposal."

-"There must be greater and freer public access to information."

-"There is a demonstrable - albeit complex - relationship between the growing world use of civilian nuclear power and the proliferation of nuclear weapons."

-"Nuclear energy should no longer receive the major portion of energy research funding."

-"Governments must recognize that decisions about nuclear power are fundamentally political in the widest sense of the word; they relate to quality of life and quality of the environment; they cannot be left to the utility alone."

REACTOR SAFETY

-"Assuming, for the sake of argument, that within the next 40 years Canada will have 100 operating reactors, the probability of a core meltdown might be in the order of 1 in 40 years, if the most pessimistic estimate of probability is assumed."

-" . . . it should be stressed that no study similar to the Rasmussen study has been undertaken in Canada to assess the reliability of the reactor system as a whole and the consequences of major CANDU reactor accidents. . . . It has been . . . argued by Ontario Hydro and AECL that, because the Rasmussen study applies in a general way to CANDU, and because an equivalent study, due to ongoing major design changes, would never be sufficiently up-to-date, such a study would not justify its high cost."

TRANSPORTATION OF SPENT FUEL

-"The hazards associated with transportation, in particular the possibility of accidents and the threat of hijacking, are real possibilities."

TERRORISM

-"While terrorist activity is relatively infrequent in Canada, it does seem prudent to assume that nuclear power stations may be regarded as attractive targets by terrorists in the future. The spread of nuclear facilities will increase the opportunity for some type of nuclear action by terrorists."

-"The object of terrorism is to create immediate, dramatic effects - unfortunately often through violence. We believe it is precisely this objective that may make nuclear terrorism appealing."

-"This problem arises . . . from the disturbing global growth of terrorism over the past decade and the simultaneous escalation in the sophistication of the tactics and weapons available to terrorists."

-"Although some members of the nuclear community have argued before this Commission that the threat represented by nuclear sabotage is "imaginary", the AECB clearly has taken the position that while the probability of terrorist attacks on nuclear facilities is low in Canada, Canada cannot consider itself immune from such events."

COST - BENEFIT

-"One recent study noted: ' . . . if we were to invest in projects with uncertain environmental effects, the result for future generations could be even worse than scarcity'. Frank P. Ramsey . . . argued for . . . not weighing the welfare of future generations less than that of the present one . . . "

26) Science Council of Canada, Report #27, Canada as a Conserver Society.

-this report outlines in concise fashion, options and obligations of the public and its institutions. This report points out the obvious, viz that our choices are not really among a number of odious alternatives to produce energy that we will continue to squander, but rather to convert ourselves and our nation to a conserver society with an accent on renewable resources and recyclable technology.

27) Teller, E., Journal of Petroleum Technology, May 1965.

("A gently seeping nuclear reactor can put its radioactive poison under a stable inversion layer, and concentrate it onto a few hundred square miles in a truly deadly fashion.")

28) Tsivoglou, E.C., and O'Connell, R.L., "Nature, volume and activity of uranium mill wastes", Radiological Health and Safety in Mining and Milling of Nuclear Materials, Vienna, International Atomic Energy Agency, Volume II: 101-121.

-" Toxicity of certain effluents is very high."

- Can "compute reliable estimates to which waste flows must be diluted by the receiving river in order to prevent adverse effects on the aquatic biota."

-"Liquid mill wastes contain concentrations of soluble Radium-226 and Lead-210 at levels which can present potential hazards of excessive internal radiation exposure to downstream water users."

29) Twenty-Third Pugwash Conference on Science and World Affairs, Report of Working Group 5, Page 11, Septemrer 4, 1973.

-"Owing to the potentially grave and as yet unresolved problems related to waste management, diversion of fissionable material, and major radioactivity releases arising from accidents, natural disasters, sabotage, or acts of war, the wisdom of a commitment to nuclear fission as a principal energy source for mankind must be seriously questioned at the present time."

30) Union of Concerned Scientists, press release, August 6, 1975.

-A petition signed by 2,300 scientists to Congress and the President called the dangers of nuclear power "altogether too great" and urged a "drastic reduction" in nuclear plant construction, along with greater efforts to develop a non-nuclear energy future for the nation.

31) Union of Concerned Scientists, The Nuclear Fuel Cycle: A Survey of the Public Health, Environmental and National Security Effects of Nuclear Power, Cambridge, Mass., MIT Press, 1975.

(PSR)-This book covers the entire nuclear fuel cycle, from uranium mining and milling, the possibility, mechanisms and consequences of catastrophic accidents, problems of diversion, the hazards of transportation through storage and disposal of high level radioactive wastes.

32) Varanini, E., Study of the California State Energy Commission, Sacramento, California, 1977.

-An excellent and exhaustive study of the current state of the art in nuclear waste disposal. No nuclear power plant licences can be granted in California until the Commissioners are convinced that a feasible waste disposal method is available. This study concludes that such a method is not available.

33) Zenz, C., Occupational Medicine: Principles and Practical Applications, Year Book Medical Publishers Inc., Chicago, Ill., 1975.

-List of Radiation Accidents Resulting in Lost-Time Injuries: 1945-1965, U.S.A.
Lists 17 accidents involving 3 fatalities, 6 burn cases, 3 finger amputations necessitated by plutonium lodged in finger.

-Lists Recorded Fatalities Resulting From Direct (External) Radiation Accidents (World): 1945-1967.
Total of 28 fatalities.

NRC Translation 520

DEPARTMENT OF ENVIRONMENTAL PROTECTION

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RADIOECOLOGICAL ASSESSMENT OF THE WYHL NUCLEAR POWER PLANT

May 1978

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1. Mathematical Basis of the Assessment

To calculate the radiation exposure levels that are to be expected, the Department of Environmental Protection used a mathematical model whose principles are described in USNRC Guide 1.109, 1976 and Baker, D.A. et al., 1976. Most assessments of radiation levels in normal operation that have been made in the last few years for nuclear reactors in West Germany have been based on this mathematical model, e.g., the exhaust gas evaluation of the Institute for Reactor Safety (GRS, October 1976) and the waste water evaluation of the Bavarian Biological Testing Institute (BBV, 1976) for the planned nuclear power plant Kernkraftwerk Süd. In the ecological model the radiation dose by a nuclide that passes into food via the exhaust gas of a nuclear power plant is determined by simple multiplication of five quantities, namely, the strength of the emission source, the average long-term dispersion factor (meteorological dilution), the transfer factor (passage from air into food), the food consumption rate, and the dose commitment factor (biological activity of the radionuclides in the body). The organ dose obtained in this way represents the radiation load by a nuclide through the consumption of a food. If we wish to determine the total organ dose for all nuclides and all pathways of radiation exposure (foods), we must add the individual organ doses of all nuclides for all pathways of exposure. The equation for determining the radiation load via the waste water is the same, except that the dilution by the river water must be taken into account instead of meteorological dilution. The formulas on which the ecological mathematical model are based and the assumptions that were made are described in detail in the sections which follow. The various routes of exposure are shown in Fig. 1-1.

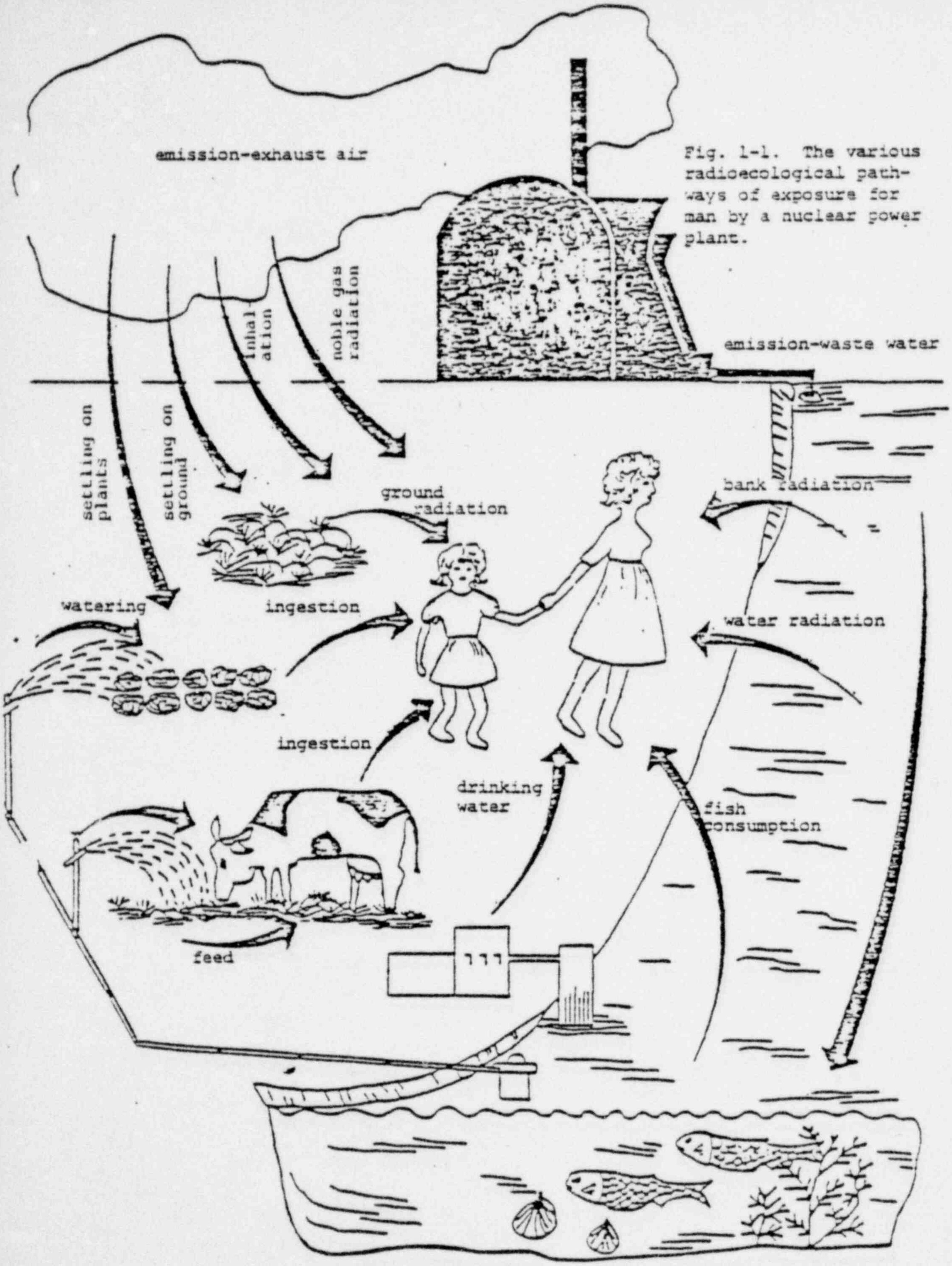


Fig. 1-1. The various radioecological pathways of exposure for man by a nuclear power plant.

2. Emissions

2.1. Planned Radioactivity Emission of the Kernkraftwerk Süd GmbH Nuclear Power Plant (Wyhl) with the Exhaust Air

In the safety report of Kernkraftwerk Süd (Kernkraftwerk Süd GmbH, 1973) and in correspondence of Kernkraftwerk Süd GmbH to the Institute for Reactor Safety (KKS, 9/13/1976), Kernkraftwerk Süd GmbH proposed the following values per block for leakage of radiotoxic substances with the exhaust air of the planned Wyhl nuclear power plant:

noble gases	80,000 Ci/yr
aerosols (half-lives greater than 8 days)	1 Ci/yr
iodine-131	0.3 Ci/yr

Additional limiting conditions were that the daily radioactivity emissions must be less than 1% of the yearly emission values and the quarterly emissions must be less than 25% of these values. Double emission values would be used for two blocks.

2.2. Planned Radioactivity Emission of the Wyhl Nuclear Power Plant With the Waste Water

The following maximum emission values per block were proposed for the planned Kernkraftwerk Süd nuclear power plant (according to the BBV assessment, 1976):

1,600 Ci tritium per year

10 Ci other radioactive decay products

Our calculations were based on these values.

3. Preexisting Emission Loads at the Site of the Plant

3.1. Preexisting Loads from Radioactive Emissions in the Air

The preexisting load from radioactive emissions in the air (mostly from the Fessenheim nuclear power plant) could not be taken into account due to lack of adequate meteorological data and would have to be added to the values determined in this study.

As measurements in the upper Rhine region have shown, these emissions are not negligible (see the discussion in section 5.1.4).

3.2. Preexisting Loads from Radioactive Emissions in the Water of the Rhine

In order to calculate the radiation load, it is also necessary to know the preexisting load of the Rhine with radioactive substances. Several different emission sources must be distinguished:

1. nuclear plants
2. hospitals (I-131, Tc-99 etc.)
3. scientific institutes and industry (P-32, S-35 etc.)

Regarding 1: The preexisting loads due to plants located on the Rhine upstream from the site of the Wyhl plant are given in Table 3.1.

Table 3.1.: Preexisting loads from nuclear power plants located on the Rhine upstream from the site of the Wyhl plant (BBV assessment, 1976)

Plant	Type	Nuclides without tritium (Ci/yr)	Tritium (Ci/a)
Fessenheim I+II	PWR	80	4,000
Kaiseraugst KWK	BWR	5	500
Leibstadt KKL	BWR	5	500
Beznau KKB I+II	PWR	30	5,000
Würenlingen EIR	PWR	30	500
Gösgen KKG	PWR	5	5,000
Mühleberg KKM	BWR	10	500
Graben KKW	BWR	5	500

Regarding 2: The values from the individual hospitals, most of which are on the French and Swiss side, are not available. According to information obtained from the National Bureau of Health in Berlin, the quantities of I-131 used in nuclear medicine under the conditions in that area average about 2.25 uCi per inhabitant per year. The Department of Environmental Protection therefore assumed a preexisting load of I-131 of 6.75 Ci/yr at Wyhl as a conservative estimate on the basis of the population of about 3 million in the Rhine drainage area above Wyhl). (According to model study Radioecology Biblis 3rd Colloquium Water Pathway 2).

Regarding 3: Additional preexisting loads by radioactive waste water from scientific institutes and industry could not be determined and would have to be added to the emissions specified above.

4. Nuclide Spectra

4.1. Composition of the Aerosol Emissions with the Exhaust Air

Previous experience with nuclear power plants shows that a large number of nuclides can escape as aerosols with the exhaust gas, namely, C-14, Cr-51, Mn-54, Fe-59, Co-57, Co-58, Co-60, Sr-89, Sr-90, Zr-95, Nb-95, Ru-103, Ru-106, Ag-110 m, Sb-124, Sb-125, I-131, Cs-134, Cs-137, Ba-140, La-140, Ce-141, Ce-144, and traces of alpha emitters such as Pu-239, Pu-240, Am-241 and Cm-242 (GRS, October 1976).

Isotopes that are particularly dangerous to human beings are those which pass readily through the food chain and at the same time exhibit a high level of radiotoxicity. This is especially the case with strontium-89 and 90, iodine-131, cesium-134, cesium-137, and to some extent with plutonium, so that these isotopes are generally very important.

I-131 is emitted mainly in gaseous form; only a small percentage, normally less than 10%, is emitted as a solid aerosol. The composition of the emitted aerosols, which, according to what has just been said, are relatively less dangerous for human beings, varies from reactor to reactor and can show strong variation with respect to time for an individual reactor. In West Germany measurements of the aerosol composition in the exhaust air of nuclear power plants have been available for only a few years (see, for example, M. I. Endrulat, I. Winkelmann, STH Reports).

For the calculations of radiation exposure via exhaust air, we used the nuclide compositions indicated in Table 4.1-1.

Table 4.1-1. Composition of radioactive aerosol mixtures in the exhaust air of nuclear power plants with light-water reactors.

Nuclide	Proportion	Half-life
Co 58	0.10	70.78 d
Co 60	0.15	5.27 a
Zn 65	0.10	244 d
Sr 89	0.01	50.5 d
Sr 90	0.01	28.5 a
Cs 134	0.15	2.06 a
Cs 137	0.40	30.1 a
Ce 144	0.08	284.8 d
Pu 239	$2 \cdot 10^{-4}$	24,400 a

The assumed nuclide composition differs from the composition assumed by GRS (October 1976) and GRS (1977) by a higher proportion of Cs-137. The following tables give the measured proportions of the Cs-137 nuclide in the nuclide composition of various nuclear power plants for various periods of time. It is apparent from the values compiled in these tables that the proportion of Cs-137 in the nuclide composition varies tremendously, so that the nuclide composition assumed in the calculations is necessarily somewhat arbitrary.

An important limitation that should be mentioned is that West Germany has had operational experience with large pressurized water reactors of the 1300-MW class only since 1974, while operating lives of 40 years are planned. It remains to be seen what effect the increasing wear of reactor components will have on the composition of the radioactive emissions.

Table 4.1-2. Proportions of the Cs-137 nuclide in the exhaust gas of various nuclear power plants (after Winkelmann, I. et al., 1975)

Stade nuclear power plant	1974	
First quarter	52.1 %	
Second quarter	20.0 %	
Third quarter	0.4 %	
Fourth quarter	0.0 %	
Annual mean	38.6 %	+
Lingen nuclear power plant	**1974**	
Third quarter	78.3 %	
Fourth quarter	78.3 %	
Annual mean	78.3 %	+
Gundremmingen nuclear power plant	**1974**	
First quarter	6.95 %	
Second quarter	30.39 %	
Third quarter	2.9 %	
Fourth quarter	23.42 %	
Annual mean	23.2 %	+ (relative to annual emissions)

Table 4.1-3. Proportions of the Cs-137 nuclide in 1974 at various nuclear power plants (after Winkelmann, I. et al., 1975)

Gundremmingen nuclear power plant	23.2 %
Stade nuclear power plant	38.63 %
Obrigheim nuclear power plant	0.17 %
Würgassen nuclear power plant	0.035 %
Biblis A nuclear power plant	2.4 %
Lingen nuclear power plant	78.3 %

4.2. Spectrum of Nuclides in the Waste Water

The relative proportions of the various nuclides is critical in calculations of the radiation dose that is to be expected. Previous experience with nuclear power plants indicates that a large number of nuclides can escape with the waste water, namely, H-3, C-14, P-32, S-35, Ca-45, Cr-51, Mn-54, Fe-55, Co-57, Co-58, Fe-59, Co-60, Ni-63, Zn-65, Sr-89, Sr-90, Y-90, Y-91, Zr-95, Nb-95, Ru-103, Ru-106, Rh-106, Ag-110 m, Sb-124, Sb-125, Te-125 m, I-131, Cs-134, Cs-137, Ba-140, La-140, Ce-141, Ce-144, Pr-144, Pm-147, Eu-154 (after Commission of the European Communities, 1975).

The proportions of the individual nuclides are subject to tremendous variation in some cases. For example, in 1974 the proportion of strontium isotopes in the waste water of the KRB (Gundremmingen, BWR) was more than 57% (Commission of the European Communities, 1975). It is impossible to predict what changes will occur in the composition of the waste water emissions in the course of the expected operating lives of 40 years.

The isotopes which pass readily through the food chain and at the time time exhibit a high level of radiotoxicity are particularly dangerous to man. This is expecially the case for Co-58, Co-60, Zn-65, Sr-89, Sr-90, I-131, Cs-134 and Cs-137 in waste water, so that these radionuclides may be regarded as very important in the determination of radiation exposure.

We therefore selected a nuclide mixture that could be considered conservative on the basis of past experience. No distinction was made between the emissions from pressurized water reactors and boiling water reactors since more than 85% of the preexisting load of nuclides without tritium comes from or will come from pressurized water reactors.

Table 4.2-1. Nuclide Composition in Waste Water

Nuclide	Proportion
Co 58	0.05
Co 60	0.15
Zn 65	0.05
Sr 89	0.10
Sr 90	0.05
I 131	0.10
Cs 134	0.15
Cs 137	0.35

Sources:- Commission of the European Communities, 1975
- BBV Assessment (1976)
- Radiation Protection Commission (1977)
- Model Study Radioecology Biblis 3rd Colloquium Water Pathway 2

Of course, it is impossible to know whether the above assumptions are safe for the entire operating time of the reactor since it is possible that there will be changes in the compositions in the future.

4.3. Nuclide Composition of the Noble Gases

Even in trouble-free operation of a nuclear power plant, it is impossible to retain all radioactive substances in the reactor. Quantitatively, the radioactive noble gases are the most important atmospheric emissions because they are produced in unavoidably large amounts in the fission process, are very volatile, and cannot be bound by any chemical reaction.

Since the radioactive noble gases escaping from a nuclear power plant endanger the human organism to varying degrees (e.g., krypton-88 is about 1000 times more dangerous than krypton-85), the radiation load depends critically on the composition of the emitted noble gas mixture. The noble gas nuclide spectrum has never been

The most accurate two-dimensional statistics from the southern upper Rhine region are those recorded by Weather Station No. 803 in Freiburg (Manier). These statistics were prepared in 1962 to 1966 and contain the wind speed in knots classified in 31 steps and the dispersion classes according to Klug's six categories. Statistics from other nearby stations had to be discarded because the data that was of interest to us was classified on too coarse a scale, so that the corresponding matrices are smaller in order than (31 x 6). Karlsruhe was used only for purposes of comparison because it is too distant. The distributions of the dispersion types are compiled in Table 5.1.2-1 for the three weather observation stations Freiburg Weather Bureau, Karlsruhe Nuclear Research Center and Breisach. The mean variation of the diffusion categories is determined from these values to be 25%. There is no reason to suppose that the proposed site of Wyhl deviates from the wind stability conditions in the Rhine Valley by more than this amount. The error inherent in the use of two-dimensional statistics that include the wind direction can be estimated at 15%. This determination was the result of a comparison of the three-dimensional sectoral calculation for Jülich (Vogt, Geiss) and the corresponding two-dimensional, integral values.

Table 5.1.2-1. Distribution of the diffusion categories in the upper Rhine Valley (relative proportions at each station)

Diffusion Type	Very unstable	Slightly unstable	Indiff. Unstable	Indiff. stable	Stable	Very stable	Total
After Pasquill	A	B	C	D	E	F	
After Klug	V	IV	III 2	III 1	II	I	
Freiburg	0.021	0.150	0.166	0.290	0.191	0.182	1.000
Karlsruhe	1.022	0.074	0.139	0.397	0.218	0.150	1.000
Breisach		0.075		0.588		0.337	1.000

The wind direction analysis was undertaken at the airport in Bremgarten (southwest of Freiburg), whose location in the Rhine Valley is similar to that of Wyhl. Breisach is less representative for Wyhl because the Kaiserstuhl (highlands), which is nearby, lies in the principal wind direction (SSW) and thus deflects the wind. Bremgarten, on the other hand, like Wyhl, is located on the open plain. Table 5.1.2-2 compares the wind rose data of the two stations.

Due to the Breisgau, the Kaiserstuhl and the indentation of the Black Forest (mountainous region) at Freiburg, the wind direction conditions in Freiburg, unlike the general weather situation, are not applicable to Wyhl.

The distribution of the two wind roses in Table 5.1.2-2 shows a margin of error of 25%, which also covers the site of the planned nuclear power plant.

16.29% calms and 0.64% variable winds were measured in Bremgarten. They were distributed isotropically on the wind rose.

In the fourth dimension the precipitation distribution shows how the washout (or wet deposition) is distributed. Wet deposition causes values four times greater than dry fallout (von Rudloff). Table 5.1.2-3 shows the directions of dispersion for fallout and washout.

We disregarded the direction-correlated washout in our computation of the long-term dispersion factor, but we did draw qualitative conclusions from Table 5.1.2-3 in our treatment of wet settling (section 5.1.7).

5.1.3. Wind Speed, Weak Wind

The modern method of wind speed measurement with the revolving-cup anemometer permits measurement of wind speeds of less than 0.5 m/s. Due to the especially high levels of radiation in the immediate vicinity of a radioactive emitter under weather conditions with light winds, we consider it absolutaly essential that light winds be accurately determined. Gradation of wind speed in knots (≈0.5 m/s) is absolutely necessary. In a computer study we demonstrated that a gradual increase in the size of the gradations of the wind speed scale results in underestimation of the radiation load from exhaust air by as much as 200% (!) (Department of Environmental Protection, 1978). After examining the meteorological data from the Kaiserstuhl region, we felt that this was another reason that the Breisach weather data should be discarded.

Table 5.1.2-2. Comparison of the wind roses of Breisach and Bremgarten in %

Wind Direction			East			South			West			North
sector	30	60	90	120	150	180	210	240	270	300	330	360
Bremgarten	9,35	2,97	2,84	1,09	3,94	12,19	25,98	6,22	2,85	1,52	5,50	8,62
Breisach	20,1		4,4		6,3	30,6		14,2	4,5		5,7	14,0

Table 5.1.2-3. Bremgarten wind rose as a function of the type of weather

	direction	30	60	90	120	150	180	210	240	270	300	330	360	var	calm
	average	9,4	3,0	2,8	1,1	3,9	12,2	25,0	6.2	2,9	1,5	5,5	8.6	,6	16.3
FALL OUT	fair weather	8,0	2,4	2,2	0,9	3,5	14,8	33,4	9,2	3,6	1,6	5,1	8,5	,7	6,4
WASHOUT	fog	10,9	3,3	3,0	1,3	1,9	3,5	4,6	1,9	1,8	1,3	[illegible]	8,9	0	48,6
	rain	5,6	1,6	2,0	0,7	3,4	17,1	36,9	7,2	2,9	1,7	7,2	6,6	0	7,0
	snow	14,2	2,7	1,3	1,2	1,9	6,5	16,8	3,1	1,7	1,4	14,7	11,5	0	23,0

In order to develop an idea of the variance of the wind speed for the Wyhl site, we compared the frequency distributions of the wind speed at the Freiburg and Bremgarten stations (Table 5.1.3-1).

Table 5.1.3-1. Comparison of the wind speeds according to the Beaufort wind scale. Frequency of occurrence per Beaufort force in %.

wind speed	in Beaufort	0, 1	2	3	4	5	6
	in m/sec	up to 1,5	1,6-3,3	3,4-5,4	5,5-7,9	8,0-10,7	>10,7
Bremgarten		41,7	21,2	17,9	12,8	5,1	1,3
Freiburg		41,2	30,3	14,7	9,5	3,3	1,0

A mean error of 12% between these stations can be calculated from these values.

The mean annual wind speeds at Bremgarten (3.0 m/s) and Freiburg Weather Station (2.3 m/s) approximately agree with this range of error. The percentage of weak-wind weather conditions for our dispersion calculations was by no means overestimated. On the contrary, it may be assumed that it is still too low since the data was recorded in the form of hourly means. In other words, light winds that last for less than one hour are averaged out. However, since there is visible drift (e.g., of a cloud of smoke) starting at Beaufort 1, and the maximum receiving point is reached in about 20 minutes at a wind speed of 0.5 m/s and in only 10 minutes at a wind speed of 1 m/s, recording wind data at one hour intervals is inadequate for calculation of the radiation load in the vicinity of a nuclear power plant. The wind speed measured at ground level (the measurements are generally made at a height of 10 m, although at Freiburg they are made at a height of 22 m above the ground) must be calculated high to about twice the emission height. The entire <u>wind profile</u> obtained in this way must be averaged in order to obtain an appropriate dispersion rate. Various formulas are possible for this integration over the wind profile. They differ in result by as much as 20%. According to Vogt (1977), previous experimental studies provide no information about the suitability of the integration models. Our experts proceed on the basis of a physical argument and regard the lower half-cone as relevant for the reflection of the exhaust gas plume on the ground and for the concentration near the ground according to the principle of superposition. They therefore integrate the wind speed from the ground ($\geq$ 10 m) to the height of emission.

5.1.4. Vertical Dispersion

The vertical dispersion of the cloud of exhaust gas is limited not only below by the ground, but also above when temperature inversions are present. Surface inversions were investigated in the Rhine Valley at Karlsruhe and Strasbourg.' The frequency of occurrence of surface inversions was obtained from Kleiss (Table 5.1.4-1.

Table 5.1.4-1. Inversion frequency in the Rhine Valley in %.

inversion frequency total per year	surface inversions ≦ 200 m	surface inversions ≦ 400 m
Karlsruhe	31,8 %	42,5 %
Straßburg	14,6 %	42,9 %

Allowance for inversion conditions in determining the dispersion of noxious substances is handled in various ways. While a general factor of 2 was originally used (BMBW, 1972), this factor is now rejected as too conservative. Therefore, our calculations need to be more realistic. Stable or very stable weather conditions occur in 37.3% of all cases at the site (Table 5.1.2-1). Surface inversions under a 400-m upper limit occur with similar frequency in the upper Rhine Valley, and a large percentage of these inversions have an upper limit of 200 m (Table 5.1.4-1). This suggests that the occurrence of the stable diffusion categories I and II (after Klug) and the occurrence of surface inversions should be equated. Therefore, in accordance with Lindackers et al. (1965), we assume a barrier layer correction factor of 2 only for weather classes I and II. This assumption is very optimistic and probably results in a serious underestimate of the radiation load via the air. In reality, simulation tests (Dunst, 1977) have shown that during an inversion the entire exhaust gas output can settle on the ground a few kilometers from the emission source within only a few hours, i.e., <u>before</u> changes in the stability conditions of the atmosphere can effect further attenuation. In this case no meteorological attenuation occurs for short periods of time, and when the inversion frequency is high (as is the case in the upper Rhine region), this can cause considerable change in the long-term dispersion factor.

Experimental studies conducted during the prolonged Rhine Valley inversion that occurred in the last week of October in 1975 (monthly weather report) revealed large quantities of Kr-85 emissions in Freiburg (Sittkus, Stockburger, 1976). The closest nuclear plant from which this Kr-85 can originate is the reprocessing plant in Karlsruhe 140 km away. A meteorological investigation of this incident is now being conducted by our department.

There is an urgent need for further studies on the long-term effects of the barrier layer intensification. In addition, in the wine-growing region around Wyhl the short-term radiation loads due to the frequent inversions in the fall, during the ripening of the grapes, must be investigated. These radiation loads can be considerable and may amount to as much as 100% of the emission source strength (see above); and this is true not only at the maximum receiving point, but also anywhere within a radius of 20 km, depending on the wind conditions.

5.1.5. Effects on the Meteorological Attenuation That Are not Considered

The following additional effects on the atmospheric diffusion cannot be reliably quantified at the present time. They are merely estimated as sources of error.

When light winds prevail, the gas is discharged with a greater effective stack height. For relatively cool sources, such as those in question here (about 10°C warmer than the ambient air), however, decreases in the effective stack height have also been observed. At greater wind speeds the exhaust gas plume may be drawn downward on the lee side of the chimney due to the sheltering effect of the chimney or of other buildings (downdraft effect). If we roughly estimate the uncertainty in the effective stack height as only about ± 10 m, the error in the dispersion calculation would be about 20%.

The initial attenuation of the exhaust air that occurs while the exhaust air is still inside the chimney is quite negligible at emission heights greater than 50 m.

The roughness of the topography is universally included in the empirically determined dispersion parameters and thus, strictly speaking, is applicable only at the location at which the parameters were measured (i.e., Jülich). Nester (1975) classifies the topography in four roughness categories and rearranges the diffusion classes according to roughness. At the Wyhl site we must consider a mixed topography with highly variable roughness, as is shown in Fig. 5.1.5-1.

Table 5.1.5-1. Topographical roughness in the region around Wyhl (10-km radius, inside West Germany)

roughness category	0	I	II	III	IV
roughness length in cm	0	0 - 3	3 - 30	30 - 150	>150
vegetation height	0	up to 10 cm	up to 1 m	up to 8 m	greater than 8 m
topography	water, asphalt	grass, pastureland	bushes, fields, vineyards	orchards, woods	timberland, cities
approximate percentage in area around Wyhl	3 %	10 %	50 %	30 %	5 %

The sectoral distribution of the topography around the site according to roughness is not isotropic. As far as the distribution of the radioactivity is concerned, this also results in weightings per sector, depending on the roughness, due to the variable wind profiles. This factor cannot be taken into account at the present time. Therefore, without more extensive studies in this area we are unable to assess the error resulting from disregarding this factor. The height above ground level at which wind shear occurs also depends on the surface roughness. At low wind speed, even at heights less than 100 m (emission height!), there is a shift in the mean wind direction, which is determined from wind rose measurements near the ground, toward the right in the direction of the geostrophic wind. This effect causes a shift in the sectors of maximum radiation load since the wind shear is not taken into consideration in the calculation of the wind profile. Present knowledge does not permit quantitative evaluation of this problem either. Furthermore, we have not considered any emissions except emissions from the exhaust air chimney. The ever-present leakage from the coolant circulation causes radioactive emissions through the machine house roof (low emission height) and through the cooling tower (large emission height, maximum receiving point more distant from the power plant).

The preexisting radiation load of the evaporated Rhine River water contributes to the emission of radioactivity into the air from the cooling tower. Aside from the radioactive emissions, the cooling towers have an adverse effect on the dispersion of the exhaust air from the chimney due to their great height (1 1/2 times the height of the chimneys) and large surface. The deviations caused by this are totally unknown. The clouds of steam disturb the diffusion of the plume of exhaust gas and alter air flow in general since thermodynamic processes are now at work as well. The entire spectrum of effects of a cooling tower on the dispersion due to

a) the design features themselves (wind-shielding, down-draft etc.)

b) the thermodynamic effects caused by mixing of the steam clouds with the exhaust air

c) cooling tower emissions from leakage and preexisting radiation load of the water

cannot be estimated closely enough at this time despite careful analysis of the work that has been started in this area.

Long-range changes in climate and their effects on meteorological factors should also be mentioned, although this is not one of our concerns in this assessment. The nuclear power plant would generate as much waste heat as a large city. At the same time, the amount of water that would be vaporized would be equal to about two thirds of the amount of water vapor released to the atmosphere by Lake Constance. The cooling towers would release this heat and water to the atmosphere at a point compared to the large surface area of a city or a large lake such as Lake Constance. This would certainly result in long-term changes in the local climate of the Wyhl - Weisweil area, which in turn would affect the continuous meteorological data. Therefore, the validity of long-range dispersion calculations for the planned operation of the nuclear power plant over a period of many years on the basis of data gathered before the plant is placed in operation is rather doubtful (see also section 5.1.1).

5.1.6. Determination and Error Analysis of the Long-Term Dispersion Factors

The data used in the dispersion calculation was subjected to critical examination in regard to its reliability in several places. It is now necessary to evaluate the reliability of the mathematical model itself.

The calculations were performed in strict accordance with the SSK's principles of calculation (BMI, 1977). The mathematical model described there is based on studies performed at the Jülich nuclear power plant. Since we have adopted these principles in their entirety, we see no need to describe the procedure of the calculations again. We have rejected the recommendations of the SSK only in regard to our treatment of inversions; our reasons for this are discussed above (section 5.1.4).

The mathematical model makes several fundamental assumptions that are incorrect. The question of whether or not the model even gives meaningful results will not be known until many years of experimental observation. In particular, the calculations are based on the following erroneous assumptions:

1. The model assumes a Gaussian distribution without justification.

2. The parameters are treated as mathematically independent, which is not true. Wind speed, wind profile, wind direction and weather class are interdependent parameters which also depend on other parameters, namely, pressure, temperature and humidity. However, the latter parameters are not even included in the calculations.

3. The mathematical model must be able to deal with turbulent atmospheric conditions. However, a mathematical description of turbulence (or at least a physical-phenomenological description) has not yet been found (Institute for Applied Mathematics, Heidelberg, 1978)

Consequently, the mathematical model of the SSK and other comparable models can only be regarded as rather unsatisfactory expedients that make it possible to obtain rough estimates.

For the purposes of our dispersion calculations we divided the horizon into 12 sectors of 30°C each. This is an appropriate division since the lateral width of the plume of exhaust air at the maximum receiving point is 15° to 38°, depending on the stability category.

The computation was performed by electronic data processing and had the following results:

A) Maximum Receiving Point

The maximum receiving point is located 500 m from the source in the 210° sector. The exact result is

(500 ± 50) m in sector (210 ± 15)°.

This gives a surface area of the receiving "point" of 2.6 ha in the direction NNE from the plant. The values for the critical receiving "point" are applicable in this area.

B) Concentration of Noxious Substances in the Air

The concentration of noxious substances at this point of maximum radiation load is

$$1.41 \times 10^{-6}\ s/m^3$$

in units of the source strength dose. This is the long-term dispersion factor. The behavior of the long-term dispersion factor in the principal wind direction is shown in Fig. 5-1. as an example of the results of our calculations.

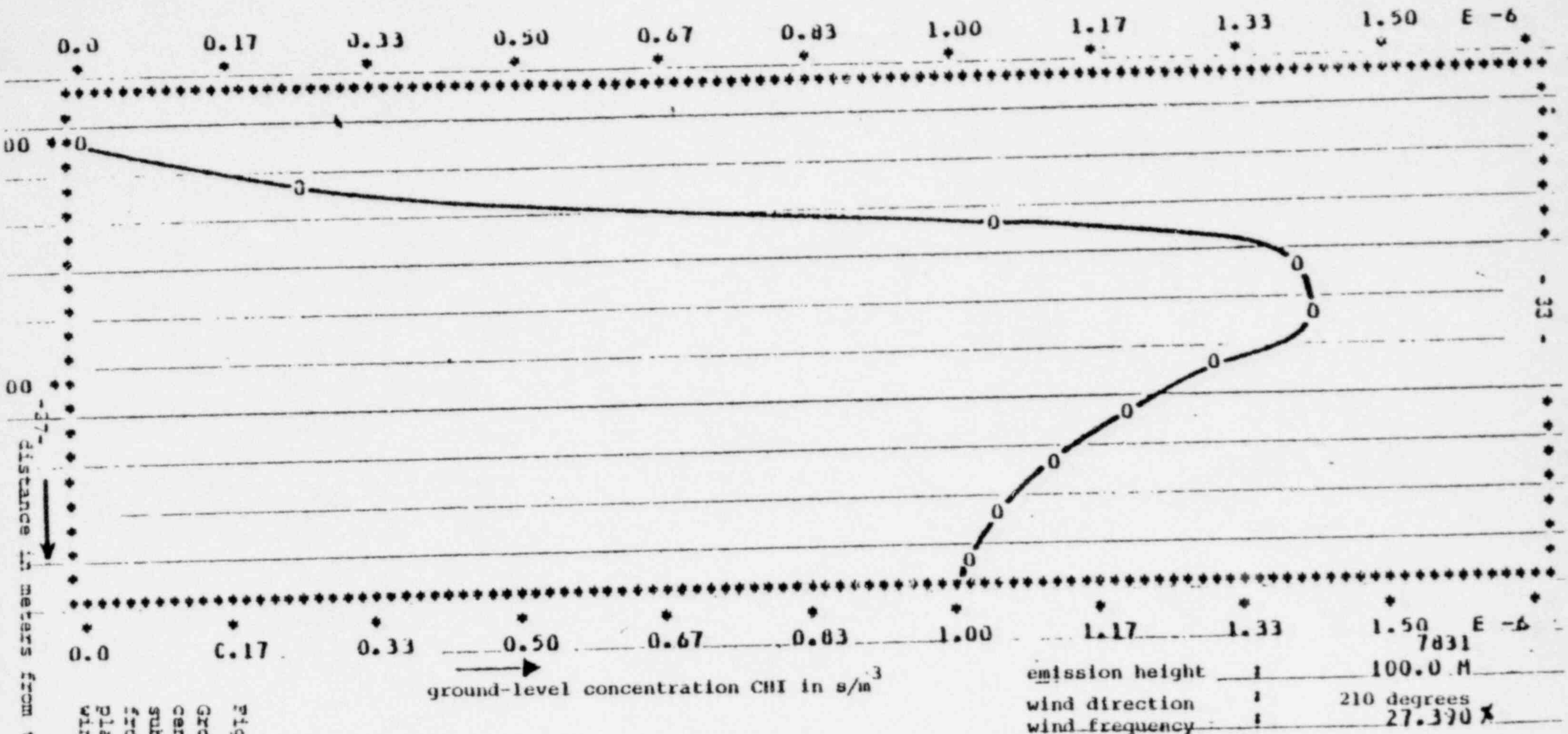


Fig. 5-1. Ground-level concentration of noxious substances emitted from the nuclear power plant in the principal wind direction.

C) Radiation Load in the Rest of the Surrounding Area

The subsequent calculations in this assessment of the radiation load via the various routes of exposure were performed with this value. In order to facilitate conversions to other areas of interest in the region around the emission source, we prepared a map (Fig. 5-2) showing the distribution of the radioactive exhaust air by relative isodose curves around the maximum receiving point (= 100%). Since the long-term dispersion factor enters linearly into the final dose, each individual result can be converted in this way to locations of special interest.

For flat terrain, in which the vertical distance to the emission source (mouth of the chimney) is the same at each point, there is only one maximum in the distribution of the radioactivity. For uneven terrain, such as the terrain in question, secondary maxima may occur. In the present case there is a second critical receiving point in Limberg, where the radioactivity is 50 to 100% of the maximum receiving point (see Fig. 5-2).

D) Gamma Submersion

We did not perform any calculations of our own for gamma submersion because our preliminary studies on allowance for the long-range gamma radiation from the neighboring sectors of the sector under consideration are still in progress. For the time being, therefore, we will adopt the data in the GRS assessment, in which the maximum gamma submersion 100 m from the source in a 30° sector in the principal wind direction NNE is

7.5×10^{-3} s/m^2.

For the maximum receiving point defined in A) at a distance of 500 m from the chimney, the following value is given:

3×10^{-3} s/m^2.

The GRS assessment includes no information at all about the mathematical models and assumptions that led to these results. Therefore, they must be considered very vague.

Until we are able to take into account the effect of the neighboring sectors on the gamma submersion, the error arising from failure to include it in our calculations can only be estimated. According to Hübschmann, Papadopoulos (1975), failure to allow for the neighboring sectors results in underestimation of the gamma dose by a factor of five at a distance of 100 m and by a factor of two at a distance of 500 m.

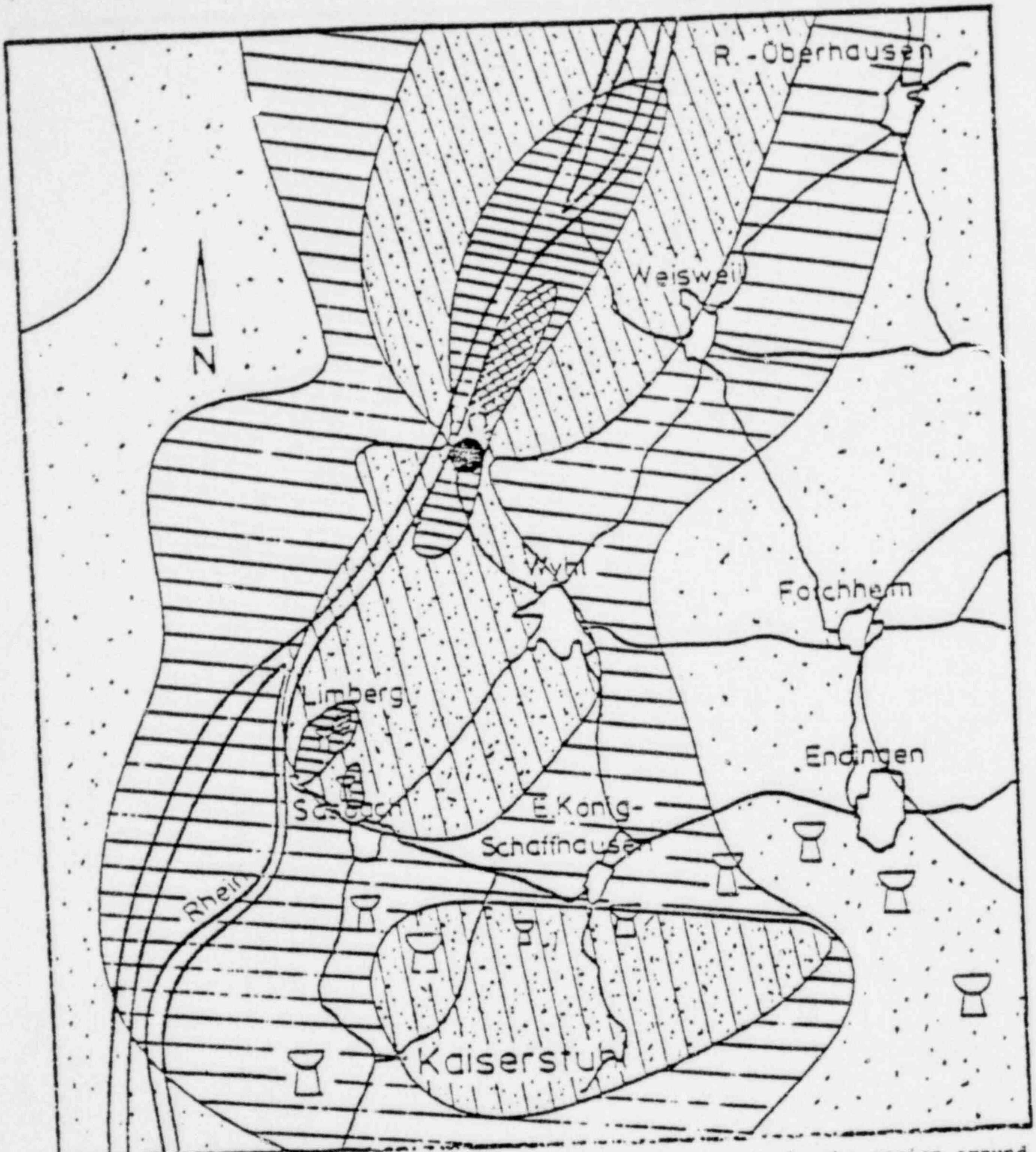


Fig. 5-2. Distribution of the radioactive exhaust air in the region around Wyhl.

- emission source (nuclear power plant
- principal winegrowing areas
- maximum receiving point = 100%
- 100 % to 50%
- 50 % to 25%
- 25 % to 10 %
- 10 % to 5 %
- 5 % to 2,5 %
- 2,5 % to 1 %

E) Calculation of Error Adjustment

The quantifiable errors contained in the calculations are compiled in Table 5.1.6-1.

Table 5.1.6-1. List of the quantitatively determinable errors in the dispersion calculation

Source of error	Discussed in:	Error range (relative to the final result, relative error)
Annual variations of the meteorological data, long-term means	5.1.1	1.00
Variations of the weather stability classes in the upper Rhine Valley, uncertainty in their determination	5.1.2	0.25
Variations of the wind rose in the region in question	5.1.2	0.25
Wind speed at ground level, anemometer measuring error	5.1.3	0.12
Type of wind profile to be assumed (power law), averaging of the wind profile	5.1.3	0.20
Error due to use of integral instead of sectoral diffusion class statistics	5.1.2	0.15
Error due to uncertain effective stack height	5.1.5	0.20
Only for gamma submersion: error due to failure to account for the radiation from neighboring sectors at the maximum receiving point	5.1.6	1.00

We assume these errors to be mathematically independent. Since it is statistically improbable that all parameters subject to err will assume the extreme values within the error range, we obtain a relative error of 1.2 for the long-term dispersion factor and of 1.6 for the gamma submersion at the maximum receiving point (500 m) in accordance with the rules for error adjustment (both values are relative to the final result).

F. Conservative Values

No conservative assumptions were made in our meteorological dispersion computations; we tried, rather, to come as close as possible to reality. We shall now discuss the conservative approach in order to compare our realistically calculated results with the corresponding conservative values. However, only the realistic values are used in the remainder of our calculations in this assessment.

Conservative values may also be regarded as realistic values in the sense that they are the values at the error limit determined by the error adjustment computation. This quantitative definition of "conservative" follows from our interpretation of the purpose of this type of assessment (which was discussed in section 5.1.1), for when we give an error range we are merely stating that the actual values vary around the theoretically computed values and sometimes reach the unfavorable error limit.

Table 5.1.6-2 is an overview of the final results of the meteorological dispersion computations.

Table 5.1.6-2. Overview of the results of the meteorological dispersion computations.

	Realistic value	Relative error	Conservative Value
long-term dispersion factor (ground-level concentration of noxious substances at the maximum receiving point in units of the source strength dose)	$1.4 \cdot 10^{-6}$ s/m^3	1.2	$3.1 \cdot 10^{-6}$ s/m^3
maximum gamma submersion (100 m)	$7.5 \cdot 10^{-3}$ s/m^2	4.2	$3.9 \cdot 10^{-2}$ s/m^2
gamma submersion at the maximum receiving point	$3 \cdot 10^{-3}$ s/m^2	1.6	$7.8 \cdot 10^{-3}$ s/m^2

G. Explanation of the Discrepancy with the GRS Assessment

The relatively low values that are given for the long-term dispersion factor in the GRS assessment cannot be considered useful because the meteorological data used in the calculations was too coarsely graduated. We were able to reproduce the results of the GRS by dividing the wind speed scale in larger intervals. However, a coarse classification of the wind speed could be avoided with our data material. The values given in the GRS assessment may therefore be considered outdated. Since the calculation of the gamma submersion (which we have tentatively accepted) was based on the same inadequate meteorological statistics, it is probable that the gamma submersion was also underestimated.

5.1.7. Deposition of Radioactive Substances

The noxious substances contained in the air descend to the earth by gravitation and adsorption during dry weather (fallout); during wet weather (rain, snow, fog) they are washed out. The rate of settling multiplied by the emission source strength and the long-term dispersion factor gives the amount of activity that is deposited per unit time for a smooth ground surface (in Ci/s m^2)

We prefer to use the term "wet deposition" instead of "wash-out" because it indicates that settling processes that cannot be characterized by the dry settling rate occur not only during rain, but also during snow and fog.

Since the number of water droplets per unit volume is about 16 times greater in fog than in rain, the probability that aerosols will be picked up and subsequently deposited is greater in fog. The fog droplets also act as nuclei and cause rapid growth of the size of the aerosol particles, thereby increasing the falling speed (Lilje-quist). The two effects together increase the rate at which the radio-active particles settle out to such a great extent that the rates of deposition are about the same for fog and rain, despite the fact that the sinking velocity of the fog droplets is roughly 10 times slower than that of rain droplets. More precise information cannot be given without further investigation in this area.

The same is true for gases (I_2) because the larger total surface of all fog droplets results in greater solubility in water. The situation with snow is about the same as that with fog; however, even less is known about snow washout. Consequently, rain, fog and snow are treated together as "wet deposition".

Table 5.1.2-3 shows that wet deposition of the radioactive emissions of the nuclear power plant will be heavy in the principal wind direction (from the SSW), i.e., the area to the NNE will have a high radiation load from wet deposition. However, other areas will also receive large amounts of radiation in this way, notably the areas to the S and SSW of the plant.

Due to the increased rate of deposition in fog, rain and snow, and due to the fact that fog and snow are very closely correlated with light winds, the area immediately around the nuclear power plant would be affected by greater radioactive contamination under these conditions (1 - 3 km from the plant; for a light wind of 0.5 m/s measured at a height of 10 m, any wind profile, and duration of the fog, rainfall or snowfall of 1 hour). In this case all directions would be affected to about the same extent.

Published values for deposition rates still vary by as much as 50% (see, for example, Vogt, 1970, or Villeque, Pelletier). In regard to German conditions, the most appropriate value is that given by Ludwieg, who determined a mean annual deposition rate of about 1.3 cm/s. This value represents an overall value that takes into account both dry fallout and rain washout. We allow for fog and snow, not by correcting the above value, but rather by including an additional, independent error of 20% (73 days of fog per year in the Weisweil- Breisach area). Therefore, for aerosols (solid contaminants) we use the following value:

$$(1.3 \pm 0.7) \text{ cm/s}.$$

The direct deposition of I-131, which is emitted mainly in gaseous form, is described by GRS (1976) and Vogt, K.J. et al (1973) by a deposition factor f_A in $m^3/kg \cdot s$. This reflects the rate of deposition with respect to a vegetation density of 1 kg dry weight/m^2. According to Vogt, K.J. et al. (1974), almost twice as much iodine settles on clover as on grass. In our calculations we therefore used the mean value for grass and clover, which is 0.12 $m^3/kg \cdot s$ according to Heinemann, K. and Vogt, K.J. (1975). For leafy vegetables (lettuce) we adopted the value f_A - 0.04 $m^3/kg \cdot s$.

Everything we have discussed so far in regard to deposition is applicable for a ground surface with a low level of <u>roughness</u>, namely, a roughness parameter of z_o - 0.03 m (after Baumgärtner et al.). This is equivalent to a vegetation height of 10 cm and thus applies to grass, clover, certain vegetables etc. (See table 5.1.5-1.).

In regard to the <u>deposition of radioactive material in vineyards</u>, which is an important consideration in the area around Wyhl, the deposition constants given above can only be used for the ground of the vineyards. The roughness parameter for the foliage and grapes (vegetation height 1 m) is z_o = 0.3 m (Baumgärtner et al.) According to Gudiksen et al., this causes an increase in the rate of dry deposition by a factor of 3 to 4. The same is true for wet deposition. Therefore, the following deposition rate applies to grapevine foliage and fruit and to other shrublike plants:

$$(4.0 \pm 3.3) \text{ cm/s}.$$

Table 5.1.7 is an overview of the results. The realistic values are used in our further computations; the conservative values are given only for comparison. Values greater than the conservative values can be ruled out on the basis of present knowledge.

Table 5.1.7. Deposition rates used in this study

Disposition of	Deposition on	mean value (realistic) in cm/s	mean error in cm/s	maximum value (conservative) in cm/s
Aerosol	grass, soil	[illegible].3	0.7	2.0
Aerosol	grapevine foliage, grapes	4.0	3.3	7.3

5.2. Dispersion via the Waste Water

In regard to the attenuation of the radioactive waste substances, we assumed that the emissions mix immediately with 25% of the river water, and that it is this water of which further use is made. According to information of Mundschenk (BfG) (Model Study Radioecology Biblis, 3rd Colloquium, p. 37), this is a perfectly realistic assumption.

Measurements at the Biblis nuclear power plant showed mixture with about 20% of the water 1 km below the point of entry with fresh-water cooling and mixture with about 10% of the water with recycle cooling. 6 km below the point of entry the mixture was about 50% for fresh-water cooling and 33% for recycle cooling. The emissions introduced into the river thus remain in a small part of the river for a long time. As far as the Wyhl site is concerned, a more precise experimental study would be required before anything definite could be said about possible effects of the barrage downstream from Wyhl on the mixing processes.

The calculations consider only the emissions of one block. For two blocks (as calculated in the BBV assessment, for example) the values would have to be increased accordingly.

In regard to the exposure pathway of fish consumption, we also considered the contamination of fish which swim chiefly at the cooling water outlet of the nuclear power plant. Experience at nucclear plants already in existance shows that increased numbers of fish are attracted to this area (and caught there) because of the oxygen enrichment of the cooling water. Therefore, this pathway represents a realistic source of contamination.

Exposure via consumption of fish was calculated for both possibilities (fish from the Rhine and fish from the cooling water outlet).

As in the BBV assessment (1976), our calculations were based on a cooling water discharge rate of 60 m^3/s (per block). We did not analyze the use of the cooling water for irrigation purposes or compute the higher radiation loads that one would expect from such use. The BBV assessment includes a conservative computation; if we wished to include this point in our assessment, we would expect a higher radiation load.

Volume Flow of the Rhine

According to the German Hydrology Yearbook (1971), the average volume flow of the Rhine at Rheinfelden is 1030 m^3/s (mean value for 1931 - 1970). The additional volume contributed by the Wiese and the Birse (small tributaries below Rheinfelden) justifies the assumption of a mean volume flow of 1050 m^3/s at Wyhl (the BBV assessment, 1976, uses the same assumption).

On the basis of these assumptions, the following values are obtained for the radionuclide concentration in the river water:

6.35 pCi/l	emissions excluding H-3
692.4 pCi/l	tritium
0.2 pCi/l	I-131 (medicine)

These values include the preexisting concentrations listed below:

5.15 pCi/l	emissions excluding H-3
499 pCi/l	tritium
0.2 pCi/l	I-131 (medicine)

For our calculations of the contamination of fish that are caught in the cooling water outlet, the radionuclide concentrations are:

10.4	pCi/l	emissions excluding H-3
1,344	pCi/l	tritium
0.2	pCi/l	I-131 (medicine)

This nuclide concentration was used as the basis of calculation for the various exposure pathways. Naturally, the concentration can change significantly at low water level. According to the German Hydrology Yearbook, the average low-water volume flow of the Rhine at Rheinfelden is 464 m^3/s in the winter and 610 m^3/s in the summer; in the dry summer of 1976 the lowest monthly mean volume flow rate was 385 m^3/s.

Furthermore, waste water discharge is not constant, but rather reaches a maximum at the time of the fuel element change, which is usually done in the summer months. According to GANS (BGA) (Model Study Radioecology Biblis, 3rd Colloquium, Water Pathway, p. 27), 40% of the year's activity was emitted during the 3 to 4 weeks of the fuel element change at the nuclear power plants in Stade and Obrigheim, and in 1976 in Stade 60% of the year's activity was discharged during the 4-week changing period. If the river water is used for irrigation or other purposes during this period, the radiation load is many times greater than the load determined in this assessment.

Low-water levels can also result in higher nuclide concentrations in the river water.

6. Passage of Radionuclides into Agricultural Products

6.1. Transport Factors for the Passage of Radionuclides from Soil into Plants

The transport factors for the passage of individual nuclides from the soil into plants are among the most important factors in the determination of radiation exposure by ingestion of foods. The following exposure pathways must be considered:

- ingestion of vegetable foodstuffs-exhaust air pathway
- intake of other vegetable matter (e.g., tobacco, tea, coffee) - exhaust air pathway
- forage plants - ingestion of animal products - exhaust air pathway

- irrigation - consumption of vegetable products
- irrigation - forage plants - ingestion of milk and meat

The unit of the transport factors is pCi/kg fresh plant per pCi/kg soil. In order to obtain a realistic estimate of the transport factors that should be used, we performed an extensive literature search. Pertinent information from the following journals (from about 1950 to the present) was analyzed: Nature, Science, Health Physics, Plant and Soil, Soil Science, Radiation Botany, Journal of Agricultural and Food Chemistry, various USAEC reports and conference reports of the International Atomic Energy Agency.

The analysis of this information revealed that the transport factors used and recommended by the TÜV, GRS, BBV and SSK are far too small in the most important cases, and that many of the experiments in which low transport factors were determined were performed under unrealistic conditions.

There are many natural factors that affect the magnitude of the transport factor, e.g., plant species, soil type, mineral content and water content of the soil, pH of the soil, biological activity of the soil, and the level of radioactive contamination of the soil.

Most of the work on which the present recommendations of the Radiation Protection Commission (SSK) and the computed values of the BBV, GRS and TÜV are based was performed at the end of the 1950's and early and middle 1960's at American atomic bomb research centers (reviews in USNRC, 1976; Baker, 1976; Fletcher, I.F. et al., 1971 and elsewhere). It was during this period that worldwide discussion began on the question of banning atmospheric testing of nuclear bombs because of the radioactive contamination of the environment that nuclear testing causes. The experiments for determination of transport factors for the absorption of radionuclides from the soil by crop plants were performed at that time mainly at the American atomic bomb centers. It is possible that the place of origin of these studies affected the way they were performed.

Evaluation of some of these studies revealed that unrealistic conditions had often been used. This resulted in underestimation of the transport factors. For example, in experiments of this type for determination of transport factors

- the soils were dried in ovens before the experiment was started; this destroyed the soil life which is capable of making radionuclides available to plants under natural conditions, i.e., soil life that can convert poorly soluble substances to soluble substances (e.g., Neel, J.W. et al., 1953; USAEC, 1953; Wilson, 1966);

- the radionuclides were added to the soil shortly before harvesting of the plants, so that it was not possible for an equilibrium state to become established, as actually occurs under realistic conditions in which the plants grow in contaminated soil from the very beginning (e.g., Jacobsen, L., Overstreed, R., 1948; Romney, G.M. et al., 1960; Nishita et al., 1961);

- a variety of soils was subjected to preliminary testing, and then the experiments were continued with those soils which had given the lowest enrichment factors (e.g., Scheffer, F., Ludwieg, F., 1959).

Experiments that were conducted under conditions of these kinds yielded significantly smaller enrichment factors than experiments conducted under realistic conditions.

6.2. Comparison of the Transport Factors Used by the GRS and SSK with Published Values

In this section we will compare the transport factors for the individual elements from soil to plant that were used by the GRS and recommended by the SSK with experimentally determined transport factors found in the literature. The only elements for which there was an extensive literature are strontium and cesium; very little has been published about the other elements. The elements will be discussed in alphabetical order.

6.2.1. Cerium

The fission products Ce-141 and Ce-144 are the principal representatives of the element cerium in the emissions of nuclear power plants (GRS, 1976). Their half-lives are 32.5 and 285 days, respectively (Seelmann-Eggebert, W. et al., 1974).

The transport factor recommended by the SSK is 0.0025. The GRS uses values between 0.0005 and 0.0068 in its assessments.

The literature contained two papers on the determination of transport factors for cerium (Romney, E.M. et al., 1954; Romney E.M., et al., 1957). These experiments yielded the following ranges of values, depending on the soils that were used:

for bean leaves	between 0.012 and 0.144
for bean seeds	between 0.003 and 0.028

for oats (grains)	around 0.015
for radishes (root)	between 0.014 and 0.032

(Romney, E.M. et al., 1954; Romney, E.M. et al., 1957)

The value recommended by the SSK and the largest value used by the GRS are at the lower end of the range of enrichment factors determined in these experiments. The even lower transport factors of 0.0003 and 0.00075 that were used in some cases by the GRS for pasture vegetation and leafy vegetables are many times smaller than the experimentally determined values.

6.2.2. Cobalt

The fission products Co-57, Co-58 and Co-60 are the principal representatives of the element cobalt in the emissions of nuclear power plants (GRS, 1976). They have half-lives of 270 days, 71 days and 5.3 years, respectively. (Seelmann-Eggebert, 1974).

Again there were only two published papers that gave transport factors for the absorption of cobalt from soil. The GRS and the SSK use a value of 0.00094.

Grummit, W.E., 1975, gives the following values as cobalt transport factors for the edible parts of plants:

oats	0.015
rye	0.003
radishes	0.032
carrots	0.011
turnips	0.043
beans	0.010
potatoes	0.020
tomatoes	0.011

(Grummit, W.E., 1975)

Menzel, R.G., 1967, gives values between 0.02 and 2 as the range of variation of cobalt transport factors from the soil into plants. The transport factor for cobalt that is used by the SSK and

GRS is thus at the lower end of the range of variation.

6.2.3. Ces'

The fission products Cs-134 and Cs-137 are the principal representatives of the element cesium in the emissions of nuclear power plants (GRS, 1976). They have half-lives of 2.1 and 30.1 years, respectively. (Seelmann-Eggebert, W. et al., 1974)

The literature contains a large number of papers in which experimentally determined transport factors for cesium are given. The results of these experiments are given below.

Marckwordt, U. and Lahr, J. (1971) give the following transport factors for cesium:

wheat grain	0.0015 - 0.38
alfalfa	0.0038 - 0.45
lettuce	0.0062 - 0.75
grass	0.0034 - 0.36

Guljakin, J.W. et al. (1974) determined the following values for the edible parts of plants:

wheat	0.04 - 0.48
oats	0.04 - 0.77
peas	0.08 - 0.71
beans	0.016 - 0.26

Frederikson, L. and Erikson, B. (1958) determined transport factors between 0.17 and 6.7 for red clover, depending on the type of soil that was used.

Nishita et al. (1958) also determined values between 0.05 and 0.36 for clover (Trifolium repens). Since these experiments were conducted over a period of 1.5 years, it was also possible to investigate the effect of time on the absorption of the radionucli It was found that the transport factor increased with time; after 1.5 years it was about five times greater than in the initial months of the experiment.

Barber (1964) obtained transport factors between 0.02 and 0.6 for ryegrass.

Souza et al. (1972) obtained values between 0.1 and 2.3 for grass, depending on the soil type.

Wiechen, A. (1972) investigated the contamination of pasture in Northern Germany by atomic bomb fallout and found a cesium transport factor of about 3 for grass growing on marshy soil.

Garret et al. (1971) determined the following transport factors for sandy soils:

various species of Bermuda grass	5
oats	5
crab grass	5.5
Dallis grass	5.5
Bahia grass	7
white clover	8

Berganini et al. (1970) determined transport factors between 0.11 and 33 in enrichment experiments with Trifolium pratense, a forage clover.

Sharitz, R. et al. (1975), in open-country measurements, found cesium-137 transport factors of 10.8 for Sagittaria latifolia and of 20.1 for Polygonum punctatum.

Polikarpov (1971) gives the following transport factors for grass, depending on the type of soil:

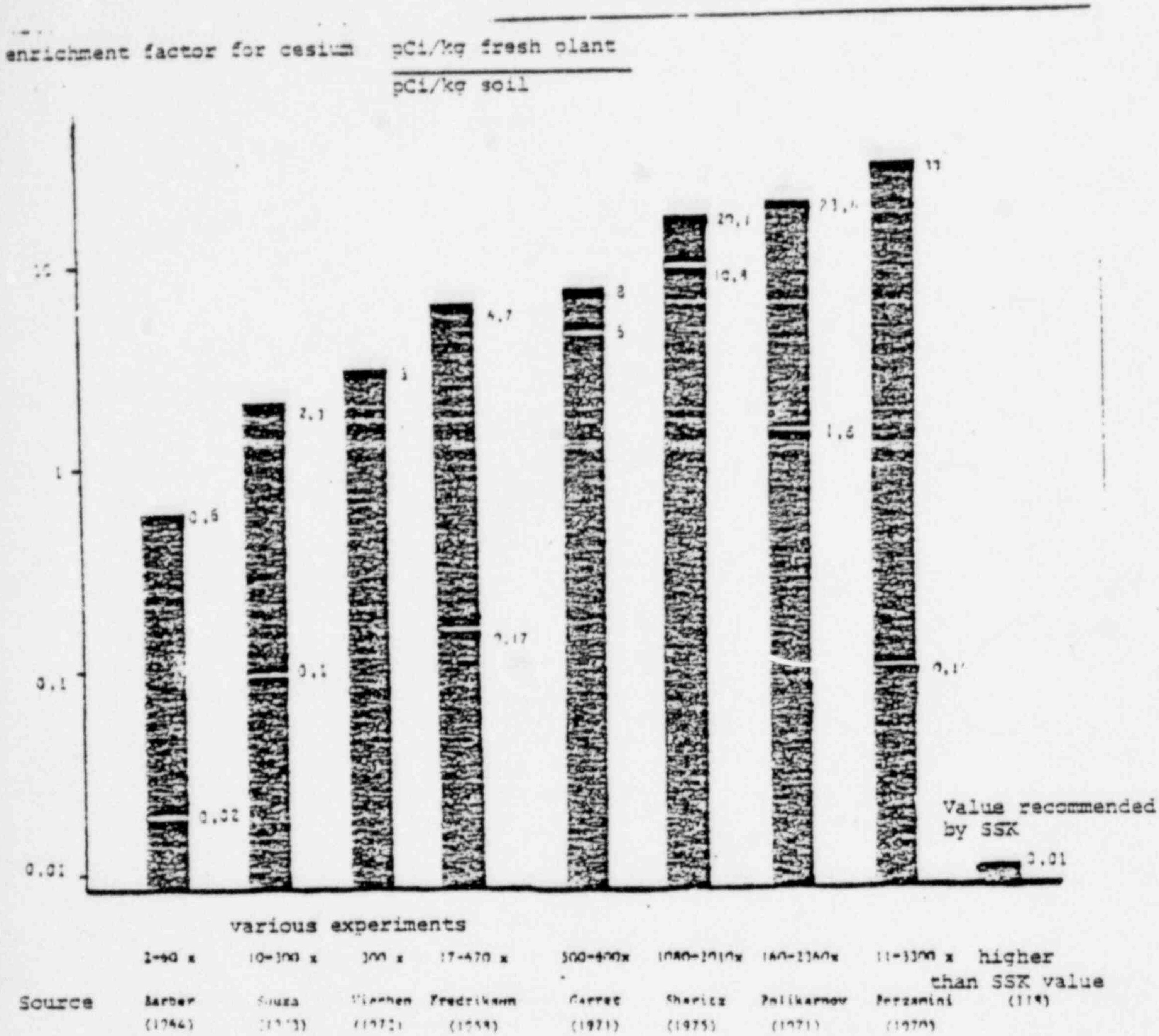
loamy sod-podzolic soils, chernozems	1.62
sandy-loamy sod-podzolic soils, sod-peat soils; silty-boggy soils	7.95
sandy sod-podzolic soils	23.6

(Polikarpov, 1971)

Grueter, H. (1971) reports on field measurements on mushrooms he determined a transport factor of 16.5 for cesium.

By comparison, the GRS uses cesium transport factors between 0.00064 and 0.019, and the SSK recommends a value of 0.01.

In the following graph the experimentally determined transport factors for cesium in grass, clover and leafy vegetable are compared with the value recommended by the SSK.



Comparison of enrichment factors for cesium in grass, clover and leafy vegetables: Results of various experiments and the value recommended by the SSK (logarithmic scale).

6.2.4. Iodine

The GRS and SSK use an iodine transport factor of 0.02 for all plants.

Cline, J. and Klepper, B. (1974) give values between 0.01 (barley) and 0.2 (radishes) for the iodine transport factor.

Menzel (1967) gives a range of variation of 0.02 to 2 for the transport factor of iodine.

Newton, H. and Toth, S. (1952) investigated enrichment factors for tomatoes and buckwheat as a function of the potassium chloride and potassium nitrate fertilization of the soil. They report the astonishing effect that the transport factor for iodine increases by about one power of ten when the concentration of potassium chloride and potassium nitrate in the soil increases (from 0.5 to 5 ppm). The values determined in the whole study ranged from 0.02 to 3.5.

Experiments performed by Cline, J. and Klepper, B. (1975) showed a similar effect of increase in the iodine transport factor, in this case with increasing soil concentration of stable iodine. These authors found transport factors between 0.01 and 120 (the higher values were obtained when the iodine concentration in the soil was increased to 10 - 1? ppm).

The iodine transport factor is especially important where the long-lived isotope I-129 is concerned (half-life 17 million years). This isotope is emitted mainly by fuel reprocessing plants. I-129 becomes enriched, in the soil in the course of the time and can result in considerable radiation exposure by ingestion following uptake by the roots of the plants. The short-lived isotope I-131 (half-life 8 days), on the other hand, which is emitted mainly by nuclear power plants, does not become enriched in the soil because its half-life is too short.

Comparison of the experimentally determined transport factors with the value used by the GRS and SSK shows that the latter falls at the lower end of the range of variation of possible iodine transport factors, which covers four powers of ten.

6.2.5. Manganese

The radioactive corrosion product Mn-54, which has a half-life of 312 days, is a relevant emission of nuclear power plants (GRS, 1976; Seelmann-Eggebert, W., 1974).

Jones, C.H.P. (1957) gives values between 0.125 and 0.675 for the manganese transport factor in oat grain. The higher values are obtained with low manganese concentrations in the soil.

Menzel (1967) gives values between 0.2 and 20 for the manganese transport factor in plants.

Prabhakaran Nair, K. and Prabhat, G. (1977) determined transport factors between 0.13 and 0.19 for corn.

The GRS and SSK use transport factors of 0.03 and 0.029, respectively, for manganese (GRS, 1976, and SSK, 1977).

6.2.6. Plutonium

Pu-238 and Pu-239 are the most relevant plutonium emissions of nuclear power plants and reprocessing plants (GRS, 1976). They have half-lives of 88 and 24,000 years, respectively (Seelmann-Eggebert, W., 1974).

The range of plutonium transport factors given in the literature is very large. The reason for this is that the plutonium emitted from nuclear power plants is usually present in a poorly soluble chemical form at first, so that it is not readily available to plants. With the passage of time, however, this poorly soluble form of plutonium can be converted to more easily dissolved forms that can be absorbed by plants; this conversion is probalby due to the activity of soil life. Lipton and Goldin (1976), for example, found that chelating agents, whether added to the soil with fertilizer or naturally occurring, cause a drastic increase in the uptake of plutonium by pea plants, namely, by more than three powers of ten.

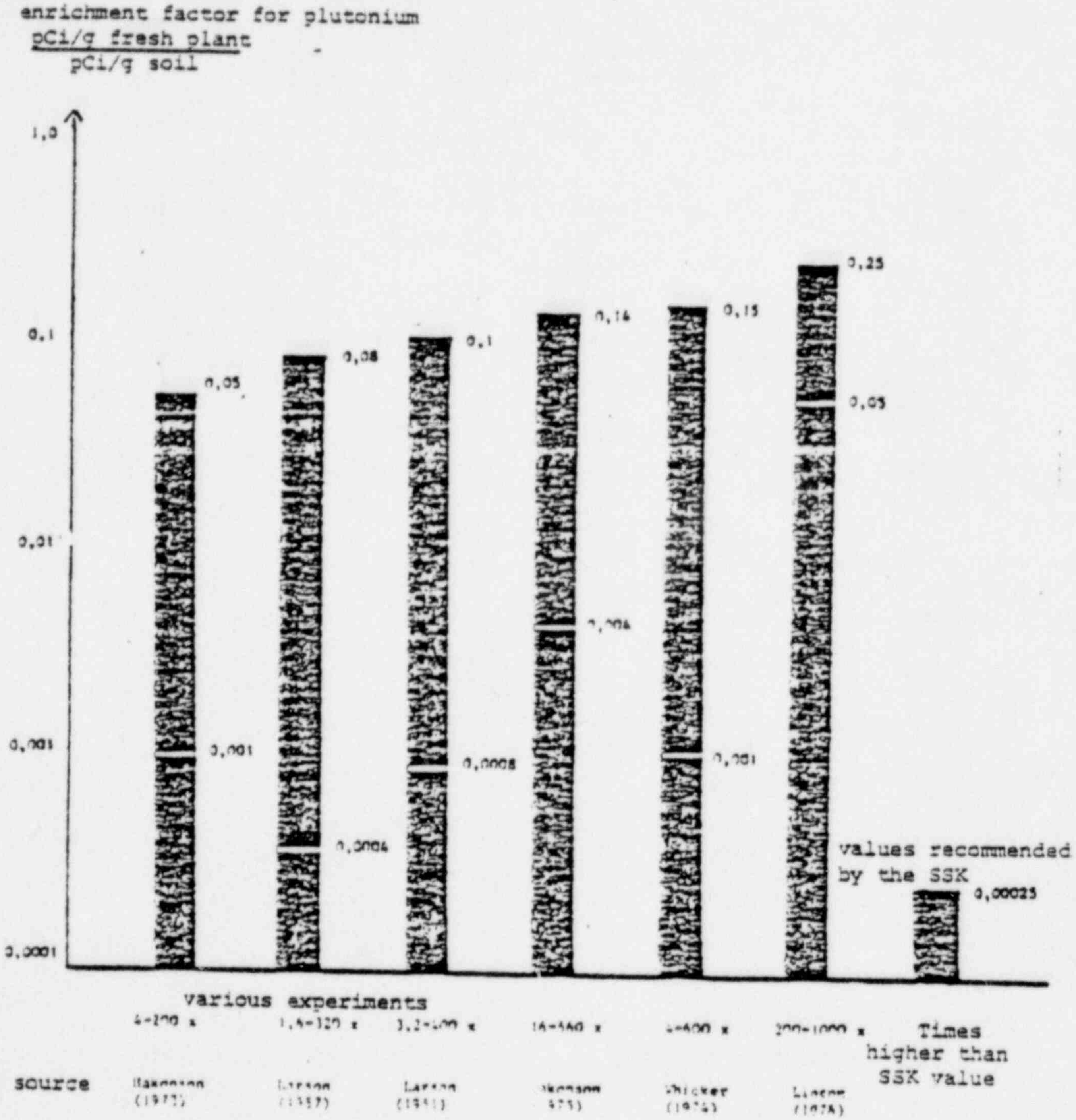
The GRS and SSK use a universal value of 0.00025 as the transport factor of plutonium for all plants. As the following published values show, this value is unrealistically low.

Larsson, K.H. (1951) found values between 0.0084 and 0.101 for plutonium transport factors. The mean value of various measurements was 0.025.

Larsson, K.H. et al. (1957) determined values between 0.00043 and 0.086.

Hakonson, T. E. and Johnson, L.M. (1973 I) studied various types of grass in the open country around a nuclear testing site 20 years after the last nuclear bombs had been detonated. They found transport factors between 0.03 and 4.7.

In an area of open country near Los Alamos where plutonium-containing waste had been dumped, Hakonson, T.E. et al. (1973 II) found values between 0.01 and 0.05 for grass and various meadow plants.



Comparison of the enrichment factors for plutonium in grass, clover and leafy vegetables: Result of various experiments and value recommended for purposes of calculation by the SSK (logarithmic scale).

Whicker (1974) measured plutonium transport factors between 0.001 and 0.15 in the open country around the Rocky Flats Nuclear Research Center. These measurements also revealed that the transport factors depend on the concentration: the lower the plutonium concentration in the ground, the higher the relative transport factor for plutonium from the soil to plants and small animals. It follows from this that the higher value is probably more realistic for the region surrounding nuclear power plants and reprocessing plants than the lower value.

Hakonson, T.E. (1975) determined transport factors between 0.004 and 0.14 in field experiments. The author states that higher transport factors are obtained under field conditions than in laboratory experiments. This may be related to the biological activity of the soil.

Lipton, W.V. and Goldin, A.S. (1976) determined transport factors between 0.05 and 0.25 in laboratory experiments on peas with addition of chelating agents as described above. Values around 0.00035 were determined when chelating agents were not added. Since the transport factors determined under field conditions are closer to the values determined in the laboratory experiment involving addition of chelating agents, it may be concluded that in nature plutonium is affected by processes (such as chelation) that facilitate uptake by plants in the course of time.

The preceding graph compares the measured transport factors for plutonium and the value used for computation by the GRS and SSK.

6.2.7. Strontium

The radioactive isotopes strontium-89 and strontium-90 are discharged into the atmosphere in the emissions of nuclear power plants (GRS, 1976). Their half-lives are 50.5 days and 28.5 years, respectively (Sellmann-Eggebert W., 1974).

A large number of papers have been published that deal with transport factors of strontium from soil to plants.

Romney, E.M. et al. (1954) determined the following values in laboratory experiments:

barley (grain)	1
barley (leaves and stems)	0.5 - 5
beans (leaves)	1.6 - 6
beans (stems)	0.9 - 5
beans (seeds)	0.35 - 3.5
radishes (part above ground)	1.8 - 14
radishes (part below ground)	0.6 - 16.7

(after Romney, E.M. et al., 1954)

Nishita, H. et al. (1958) determined transport factors between 1.2 and 1.93 for clover. They found that the transport factor increased slowly with increasing length of the experiment; the largest value of 1.93 was determined just before the experiments were terminated after 1.5 years.

Romney, E.M. et al. (1959) determined transport factors between 3 and 3.9 for clover. Although it had been expected that addition of inactive strontium to the soil would decrease the transport factor, it was found that it increased it slightly to as high as 5. The transport factor could not be significantly reduced until strontium was added in quantities equivalent to about 1.2 kg of strontium per m^2.

Vose, P.B. and Koontz, H.V. (1959) determined transport factors between 1.8 and 7 for grass and between 4.8 and 23.4 for legumes. However, the paper does not mention whether these transport factors are based on the fresh weight or the dry weight of the plants. If they are based on the dry weight, then the transport factors relevant to our study, based on the fresh weight, would be between 0.36 and 1.4 for grass and between 1 and 4.7 for legumes.

Evans, E.J. (1962) determined transport factors between 0.2 and 1 for various plants.

Andersen, A.J. investigated the effect of nitrogen and potassium fertilizers on strontium transport factors. This study yielded strontium transport factors between 0.36 and 2.9 for red clover. The mean values for 38 experiments in two soils were 1.39 and 1.53. It was concluded from the experiments that the effect of nitrogen and potassium fertilizers on the strontium transport factor is negligible. (Anderson, A.J., 1963)

Menzel, R.G. (1967) gives 0.2 to 20 as the range of variation of the strontium transport factors.

Polikarpov (1971) gives values between 0.7 and 2.3 for strontium transport factors in grass for various types of soil.

Garret, A. R. et al. (1971) determined the following transport factors:

Bahia grass	0.8
Bermuda grass	1.3
oats	1.5
Pangola grass	2
crab grass	2.1
white clover	3

(Garret, A. R. et al., 1971)

Souza, T. J. et al. (1972) determined transport factors between 2.2 and 9 for grass in various soils.

Measurements made by McIntyre, D.R. et al. (1977) yielded strontium transport factors of 0.64 in lettuce, 1.32 in the underground part of the turnip, and 3.6 in broccoli tops.

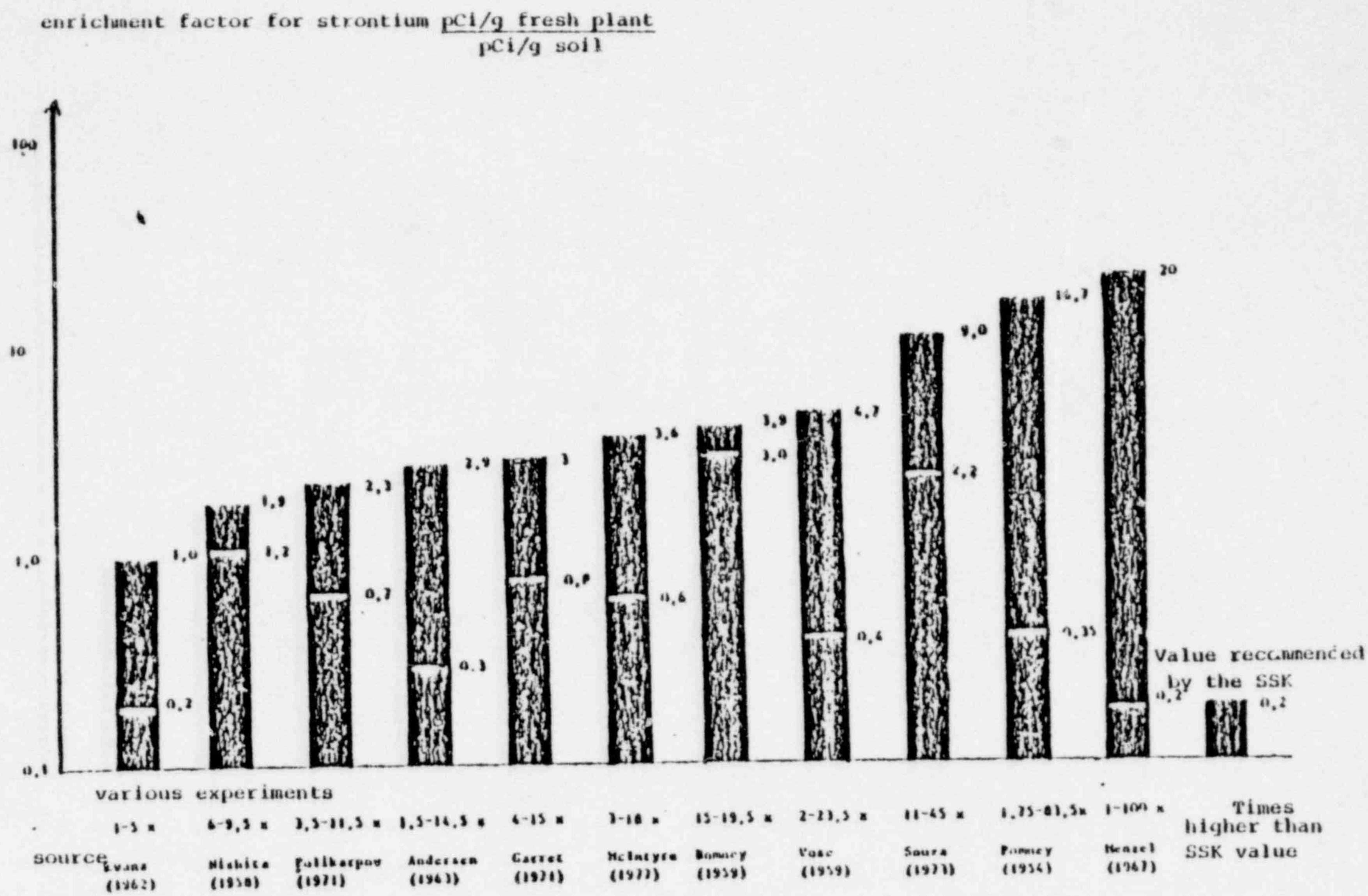
By comparison, the GRS uses the following transport factors for strontium

corn	0.064
pasture vegetation	0.2
leafy vegetables and fruit	0.32

(GRS, 1976)

The Radiation Protection Commission (SSK) recommends a value of 0.017 in (SSK, 1977 I) and a value of 0.2 in (SSK, 1977 II) for the strontium transport factor for all plants.

In the following graph we have compiled the results of the strontium enrichment experiments.



Comparison of enrichment factors for strontium in grass, clover and leafy vegatables: Results of various experiments and value recommended for computation purposes by the SSK (logarithmic scale).

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The graph shows that the values used by the GRS and recommended by the SSK are also too small for this important radionuclide.

6.2.8. Technetium

The emissions of Tc-99 have never been considered in calculations of the radiation load in the environs of nuclear plants, even though the fission yield of Tc-99 is 6.1% (i.e., Tc-99 is produced in about as much quantity as Sr-90 and Cs-137, it behaves much like iodine in the human body (and thus becomes concentrated in the thyroid gland), has a high transport factor from soil to plants, and has a half-life of 215,000 years (Wildung, R.E. et al., 1977).

Wildung, R.E. et al. (1977) determined transport factors of 22 to 130 for the uptake of Tc-99 by soybean plants and of 85 to 170 for the uptake of Tc-99 by wheat. The experiments revealed that the enrichment factor is clearly dependent on the concentration. The highest enrichment factors were found at the lowest radionuclide concentrations in the soil.

The SSK recommends a transport factor of 0.25 for Tc-99 from soil to all plants (SSK, 1977).

It can be said in summary that the transport factors for the passage of radionuclides from soil to crop plants that are recommended by the GRS, TÜV and SSK and that have been used in assessments (on which the licensing of the Wyhl nuclear power plant (Kernkraftwerk Süd) is based) by the Institute for Reactor Safety (October 1976, Exhaust Air) and by the Bavarian Biological Testing Institute (October 1976, Waste Water) (GRS, 1976; Bayr., 1976) in almost all investigated cases are either at the very lower end of the range of values given in the literature or are far below the values that may be regarded as realistic (in some cases they are too low by several powers of ten). It follows that the results of these assessments are unrealistically low and that the claim that the calculations are conservative (i.e., pessimistic) is not true. It also follows that any licensing granted on the basis of these assessments violates the Radiation Protection Law, especially section 45.

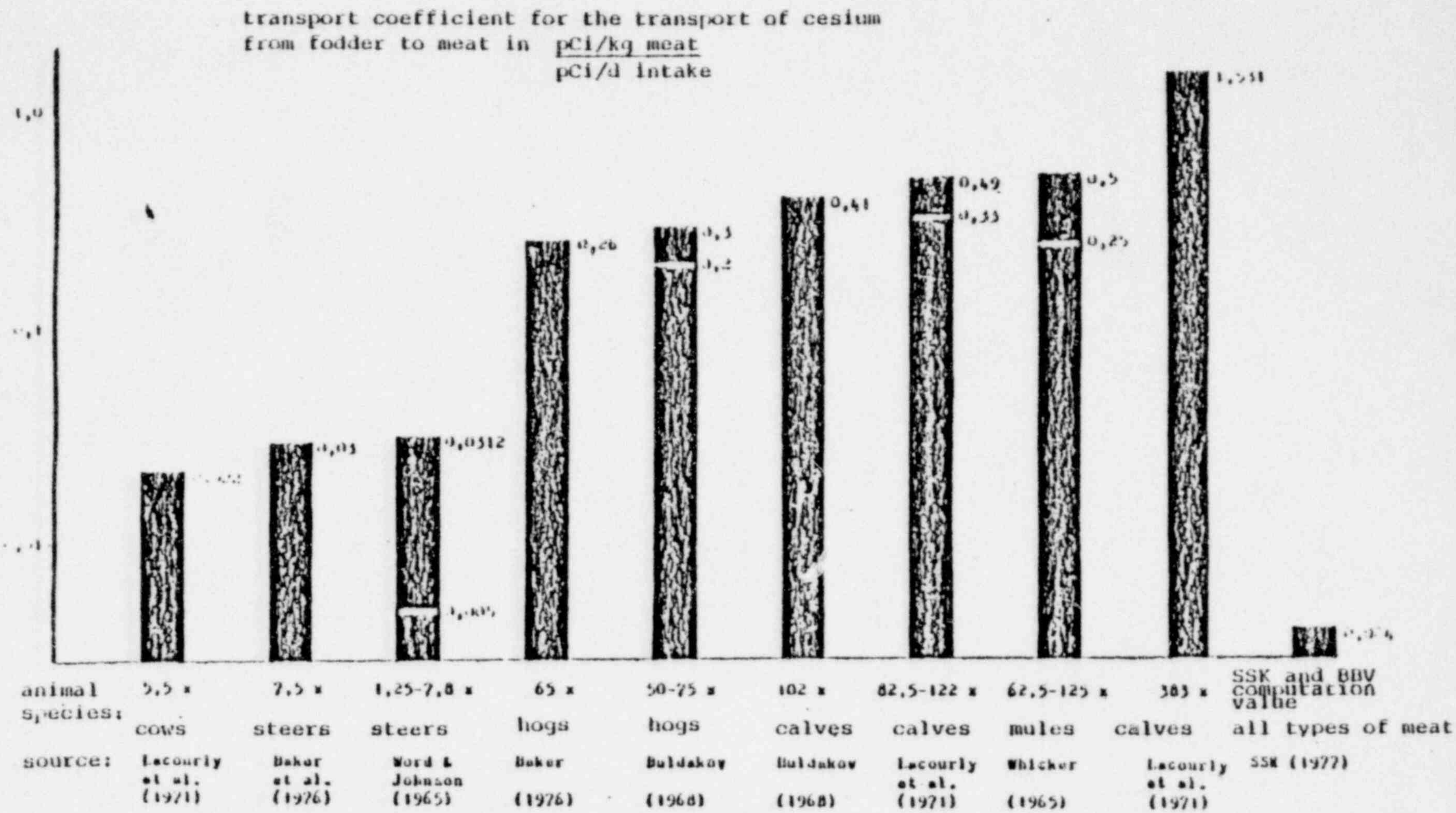
6.3. Transport Factors for Meat and Milk

The transfer factor is also important in determining expected levels of radiation exposure by ingestion of meat or milk. The transfer factor indicates the percentage of the daily intake of a given radionuclide that is found in 1 kg of meat or in 1 liter of milk. The magnitude of this value depends to a great extent on whether or not the radionuclide is in a state of equilibrium in the body; the type of forage and the age and species of the animals also affect this value.

The transfer coefficients that are recommended by the Radiation Protection Commission (SSK, 1977) for calculating radionuclide transport from the fodder to the meat and milk and that are used, for example, in assessments by the Bavarian Biological Testing Institute for the Wyhl plant (BBV, 1976) were compared by the Department of Environmental Protection with published values. The following graph shows the results of this study for the example of the radionuclide cesium and for the transport to meat.

The graph shows that the value recommended by the SSK is smaller than realistic values by a few powers of ten for this extremely important route of exposure as well.

For strontium Baker et al. (1976) gave a value of 0.003 for cattle and a value of 0.0073 for hogs. The SSK recommends a value of 0.0006, which is lower than Baker's values by about one power of ten.



Comparison of transport coefficients for the transport of cesium from forage to meat: Results of various experiments and the value recommended by the SSK for purposes of calculation (logarithmic scale.

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7. Analyzed Routes of Exposure

7.1. Exposure via Exhaust Air

7.1.1. Gamma Submersion by Noble Gases

Since noble gases are unable to enter the food chain to any significant extent due to their chemical nature, most of the radioecological load takes the form of direct gamma radiation from the radioactive cloud issuing from the chimney. The effect of this radiation on human tissue depends on the distance from the radioactive cloud, on the absorption of the radioactivity by the air, and on the dose factor of the nuclide in question, which gives the effect (in rem/s) of one curie on a unit area of human tissue.

We have the following:

$$sd = qu \cdot ch \cdot dc$$

where sd = radiation load

qu = source strength

ch = meteorological dispersion factor

dc = dose factor

If we accept the dose factors given in SSK (1977) for the individual noble gases and use the dispersion factors for gamma submersion calculated in section 5.1, we obtain the following doses (in mrem/yr) for one block:

Distance	100 m	500 m (maximum receiving point)
realistic value	77	31
conservative value	403	80

These values must be doubled for two power plant blocks.

It is well known that calculations of this sort are partly a matter of knowledge and fact and partly a matter of assumptions and estimates. As was shown above and discussed in greater detail elsewhere (5.1.6), merely the uncertainty in the dispersion factors results in a considerable difference between the realistic and the conservation value of dosage. Other uncertainties that can lead to an increase in dosage and that we were unable to examine further and make allowance for are therefore discussed briefly below:

a) the rates of liberation in the core of the reactor are not scientifically certain values, but rather were derived from a limited number of measurements and inferferences. The diffusion processes that occur in the reactor core are largely unknown. A change in the liberation rates can cause a considerable increase in dosage.

b) The possible effects of small disturbances, such as a problem in the exhaust gas system, were not considered.

c) Other routes of liberation, e.g., through the machine house roof, were not considered.

d) The dose factors taken from the literature (SSK, 1977), which are used as multiplicative factors in the calculation, were not checked.

e) The value of the dispersion factor, which is computed on the basis of simplified models and presents only an unsatisfactory picture of the real conditions, is also uncertain and questionable. For example, in the calculation of the gamma submersion the absorption coefficient is considered independent of the wavelength of the radiation, which is certainly incorrect.

f) The emitted noble gases disintegrate according to the following radioactive series:

$$\underset{1{,}79\,s}{Xe-141} \xrightarrow{\beta^-} \underset{24{,}7\,s}{Cs-141} \xrightarrow{\beta^-} \underset{18{,}3\,m}{Ba-141} \xrightarrow{\beta^-} \underset{3{,}93\,h}{La-141} \xrightarrow{\beta^-} \underset{32{,}51\,d}{Ce-141} \xrightarrow{\beta^-} \underset{\text{stable}}{Pr-141}$$

$$\underset{13{,}5\,s}{Xe-140} \xrightarrow{\beta^-} \underset{64\,s}{Cs-140} \xrightarrow{\beta^-} \underset{12{,}79\,d}{Ba-140} \xrightarrow{\beta^-} \underset{40{,}2\,h}{La-140} \xrightarrow{\beta^-} \underset{\text{stable}}{Ce-140}$$

Xe-139 (39,7 s) $\xrightarrow{\beta^-}$ Cs-139 (9,3 m) $\xrightarrow{\beta^-}$ Ba-139 (82,7 m) $\rightarrow$ La-139 stable

Xe-138 (14,1 m) $\xrightarrow{\beta^-}$ Cs-138 (32,2 m) $\xrightarrow{\beta^-}$ Ba-138 stable

Xe-137 (3,83 m) $\xrightarrow{\beta^-}$ Cs-137 (30,1 a) $\xrightarrow{\beta^-}$ Ba-137 stable

Xe-135 (9,17 h) $\rightarrow$ Cs-135 ($2\cdot10^6$ a) $\xrightarrow{\beta^-}$ Ba-135 stable

Xe-135m (15,3 m) $\rightarrow$ Cs-135m (53 m) $\rightarrow$ Ba-135m (28,7 h)

Kr-91 (8,6 s) $\xrightarrow{\beta^-}$ Rb-91 (58 s) $\xrightarrow{\beta^-}$ Sr-91 (9,5 h) $\xrightarrow{\beta^-}$ Y-91 (58,5 d) $\xrightarrow{\beta^-}$ Zr-91 stable

Kr-90 (32,3 s) $\xrightarrow{\beta^-}$ Rb-90 (2,6 m) $\rightarrow$ Sr-90 (28,5 a) $\rightarrow$ Y-90 (64,1 h) $\rightarrow$ Zr-90

Kr-89 (3,18 m) $\xrightarrow{\beta^-}$ Rb-89 (15,2 m) $\rightarrow$ Sr-89 (50,5 d) $\rightarrow$ Y-89 stable

Kr-88 (2,80 h) $\xrightarrow{\beta^-}$ Rb-88 (17,8 m) $\rightarrow$ Sr-88 stable

Kr-87 (76,3 m) $\xrightarrow{\beta^-}$ Rb-87 ($4{,}7\times10^{10}$ a) $\rightarrow$ Sr-87 stable

In the calculation of the radiation load, only the noble gases were considered. As the radioactive series show, however, most of the noble gases disintegrate into some highly radioactive nuclides of the elements cesium, strontium, rubidium, barium and cerium. None of these radioactive decay products were considered even though they cause an increase in the calculated radiation load.

7.1.2. Ground Radiation by Deposited Radionuclides

A portion of the radionuclides discharged into the atmosphere by the nuclear power plant is deposited on the ground in the immediate and distant area around the plant by the processes of fallout and washout (dry and wet deposition). This produces an external radiation source for human beings in this area by the gamma emission of the nuclides. Since the contamination of the ground and thus the radiation load increase in the course of time, the SSK calculated the radiation load for the 50th year of reactor operation (SSK, 1977).

The gamma submersion dose from radionuclides that have settled onto the ground is determined by the following formula:

$$D_{io} = Q \cdot f \cdot \chi \cdot v_G \cdot S \cdot \frac{(1 - e^{-\lambda i \cdot t})}{\lambda i}$$

where D_{io} = gamma submersion dose in mrem/yr by nuclide i

Q = emission source strength in Ci/yr

f = nuclide fraction of the nuclide in question

χ = meteorological long-term dispersion factor

v_G = rate of deposition by dry and wet deposition

S = dose factor for gamma submersion (ground) in $\frac{rem \cdot m^2}{Ci \cdot s}$

λ_i = decay constant of the nuclide i

Table 7.1.2-1 : Gamma submersion dose factors (ground) in $\frac{rem \cdot m^2}{Ci \cdot s}$

Nuclide	Dose factor (ground)
Co-90 [sic]	2.20 E - 03
CO-60	6.00 E - 03
Zn-65	1.90 E - 03
Sr-90	0.00 E + 00
Cs-134	3.90 E - 03
Cs-137	1.40 E - 03
Ce-144	7.30 E - 05
Pu-239	6.10 E - 06
I-131	1.10 E - 03

(after SSK, 1977)

For an individual staying in this area for an entire year, we obtain a radiation load by this route of exposure of 14.6 mrem/yr as the sum of the investigated radionuclides. This radiation dose is applicable for a height of one meter above the ground according to the SSK (1977).

The exhaust gas assessment of the Association for Reactor Safety for the Wyhl plant (Kernkraftwerk Süd) (GRS, 1976) did not consider the radiation dose to be expected by this route of exposure, although the statement "external γ-radiation = 12.6 mrem/yr" in Table 7.5 (p. 13-22) gave the impression that this route of exposure had been taken into account. An examination will show that the 12.6 mrem/yr refers only to the gamma radiation dose from the cloud of noble gas.

7.1.3. Ingestion of Vegetable Foodstuffs

The land of the planned nuclear power plant is located within a wooded zone that is about 1000 to 1500 meters wide at the proposed site. Outside of this wooded zone, both sides of the Rhine Valley are used mainly for farming. Wine, fruit and tobacco are the main agricultural products in the Rhine plain, in the Kaiserstuhl (mountainous region south of Wyhl) and in the foothills, while grain crops, root crops, forage crops and timber are import--t in the remaining areas.

In the area of 10-km radius around the site there were farming and forestry operations on the German side of the river with a total area of 18,222 ha in 1975. The land-use data is given below:

- pasture land (meadows, ields etc.)	10%
- tilled land	34%
- forest	29%
- vineyards	9%
- orchards	2%

The following table shows the exact distribution of land use in the Emmendingen district.

Emmendingen district	total commercially exploited area	area used for agriculture	tilled land	pasture land	forest area	vineyards	orchards
total	65 496	28 710	13 025	12 156	23 240	2 425	679
Endingen	2 735	1 907	839	283	360	681	172
Forchheim	1 437	1 124	948	121	331	46	7
Herbolzheim	3 377	1 760	893	446	805	323	66
Kenzingen	4 050	1 150	672	165	2 336	264	22
Riegel	870	652	471	124	113	51	1
Leiselheim	261	197	86	12	40	78	19
Jechtingen	803	437	177	32	190	179	44
Weisweil	1 040	677	531	135	122	2	3
Wyhl	1 545	851	622	207	322	3	4
Rheinhausen	2 054	1 209	875	317	512	0,2	3

Table 7.1.3-1. Land use in 1975 in the Emmendingen district (areas in ha) (GRS, 1976)

Even in normal operation the planned nuclear power plant would release radioactive substances to the environment which would be dispersed by meteorological processes and deposited on agriculturally exploited land in the immediate and more distant areas around the plant. In this case radioactive substances would reach human crop plants by two routes:

- by settling directly onto crop plants
- by settling onto the ground, physical enrichment of the deposited nuclides as deposition continues over a period of years, and transport of the radionuclides from the soil to the edible parts of the plants via the root system.

The assessment therefore calculates the radiation exposures to be expected from ingestion of the following vegetable foods:

- leafy vegetables
- root vegetables
- potatoes
- grains
- grass and
- clover as forage plants for animals
- wine (section 7.1.5.)

The transfer factor describing the transfer of a radionuclide from the air at ground level to the edible part of a crop plant is calculated with the following formula:

$$f_i = V \cdot 86\,400 \cdot \left[\frac{r \cdot T_v \cdot F \cdot (1-e^{-\lambda_{Ei} \cdot te})}{\lambda_{Ei} \cdot Y_v} + \frac{B_{iv} \cdot (1-e^{-\lambda_i \cdot te})}{\lambda_i \cdot P} \right] \cdot e^{-\lambda_i \cdot th}$$

The transfer factor for the deposition of I-131 from ground-level air onto plants is calculated with the following equation:

$$f_{I\text{-}131} = \frac{f_A \cdot 86400 \cdot F}{\lambda_{Ei\,(I\text{-}131)}}$$

where f_i = transfer factor for nuclide i in pCi/kg fresh plant : pCi/m^3 air

V = total rate of deposition of the radionuclides by fallout and washout

r = retention factor, dimensionless

The retention factor indicates the fraction of the deposited radioactivity which is initially retained on the part of the vegetation that is above ground.

T_v = translocation factor, dimensionless, indicates the fraction of activity deposited on the leaves which enters the edible part of the plant in the course of time.

F = factor describing the loss of externally deposited activity during preparation of the plants in the kitchen, dimensionless.

λ_{Ei} = effective decay constant for isotope i in 1/d. λ_{Ei} is a measure of the rate at which superficially adsorbed radionuclides disappear from the surface of the plant by weathering processes and physical decay.

Y_v = vegetation density of the plants in kg fresh weight/m^2

t_e = exposure time in d
t_e is the time from sprouting of the plants until harvest.

B_{iv} = transport factor for a nuclide i in pCi/kg fresh plant : pCi/kg soil by root uptake from the soil.

P = 224 kg/m^2 mass of the earth in the plowed layer under one square meter of ground surface

λ_i = physical decay constant of a nuclide i in 1/d

$\lambda_i = \frac{\ln 2}{t_{1/2\ i}}$, where $t_{1/2\ i}$ is the half-life of the nuclide

t_B = reactor operating time

t_B is also the period of time in which radionuclides can accumulate in the soil

t_h = storage time of the products

f_A = see section 5.1.7.

(after: USNRC, 1976, and Baker, D.B., 1976)

The first term inside the brackets of the equations for computation of the transfer factor gives the direct deposition of radioactivity on the surface of the plant, and the second term inside the brackets gives the enrichment of radionuclides from the soil into the plants. The expression $e^{-\lambda_i \cdot t_h}$ takes into account the decay of the radionuclides during storage.

The following values are used in the calculation of the transfer factors for vegetable foods:

Retention factor for deposition on plants

The value of r = 0.33 was adopted from the GRS assessment for use in this calculation.

Loss factor during kitchen preparation

The loss factor F gives the loss of externally deposited radioactivity during harvesting and kitchen preparation. A loss factor of 0.28 is used in the GRS assessment.

The literature contained only one paper in which this question was explored in detail. Rohleder employed various decontamination measures in an effort to reduce the amount of artificial fission products contained in kale from normal atomic bomb fallout. After washing kale in cold water for 1 hour, this author still found 91% of the cesium-137 and 87% of the zirconium-95 and niobium-95 that were originally contained in the kale. After treating the kale for three hours in warm water (35°C), he still found 62% of the cesium-135 and 74% of the zirconium/niobium-95 (Rohleder).

A loss factor of 0.4 is used in the calculation for leafy vegetables and grains, and a factor of 1 is used for potatoes and root vegetables. The factor of 1 takes into account the fact that for these vegetables the radioactivity is not the result of external contamination, but rather of root and leaf uptake and subsequent transport to the edible part of the plants (potatoes and root vegetables).

Vegetation Density

The following values (in kg fresh weight per square meter) are taken from Fletcher, I.F. et al. (1971) as the vegetation density of the plants:

leafy vegetables	1.5 kg/m^2
root vegetables	4.0 kg/m^2

potatoes 1.8 kg/m^2

grains 0.34 kg/m^2

Exposure time of the plants

An exposure time of three months is used for leafy vegetables, root vegetables, potatoes and grains (after Fletcher, I.F., 1971). An exposure time of 30 days is used for pasture vegetation. According to Baker, D. A. et al. (1976), this is the typical amount of time that passes before cows return to graze in the same part of the pasture. In the assessment by the GRS and the recommendations of the Radiation Protection Commission, the value for pasture plants is also 30 days. However, an exposure time of only 2 months is applied to all other crop plants.

Translocation factor

This factor indicates the fraction of activity deposited on the leaves which enters the edible part of the plant in the course of time.

T_v = 0.1 for potatoes and root vegetables

T_v = 1 for pasture vegetation and leafy vegetables

(after Baker, D.A. et al., 1976)

According to the GRS (1976), the product $r \cdot T_v$ is 0.05 for cereal grains. This means that 5% of the deposited radionuclides are directly adsorbed on the grains of the cereal plants.

We used the same values as in the GRS assessment for the mass of the earth in the plowed layer under one square meter of ground surface (224 kg/m^2), for the wash-off half-life, i.e., the time required for 1/2 of deposited radioactive substances to be removed from the surface of the plant by meteorological processes (14 days), and for the storage time of potatoes, grains and stall fodder (1/2 year).

We used the reactor operating time recommended by the SSK (1977) for this type of calculation (50 years = 18,250 days).

Table 7.1.3-2. Transport factors for plants in pCi/kg fresh plant over pCi/kg soil.

nuclide	grass	clover	leafy veg.	potatoes
Co	0,0094	0,02	0,02	0,02
Zn	0,4	0,4	0,4	0,4
Sr	3,2	7,2	2,5	0,75
I	0,2	0,2	0,2	0,2
Cs	5,9	8,5	0,75	15
Ce	0,0005	0,0005	0,00075	-
Pu	0,1	0,1	0,1	0,1

nuclide	root vegetables	cereal grains
Co	0,032	0,015
Zn	0,4	0,4
Sr	15	1,67
I	0,2	0,2
Cs	0,07	0,48
Ce	0,032	0,015
Pu	0,1	0,1

(Baker, D.A. et al., Food, 1976; Bergamini et al., 1970; Fletcher, I.F., 1971; Garett, A.R. et al., 1971; GRS, 1976; Grummit, 1975; Guljakin, J.W. et al., 1974; Hakonson Th. E. et al., 1973, 1974; Herbst, W., 1976; Lipton, W.V., Goldin, A. S., 1976; Marckwordt, U., 1971; Romney, E.M. et al., 1954, 1957 and 1959; Souza, T.J. et al., 1972; Teufel, D., 1977; Vose, P.B., Koontz, H.V., 1959; Whicker, 1974; UCRL, 1968; USNRC, Guide 1.109, 1976).

The transfer factors (f_i) determined by the method described above are compiled in Table 7.1.3-3.

Table 7.1.3-3. Transfer factors in pCi/kg fresh plant : pCi/m^3 air

nuclide	leafy vegetable	potatoes	root vegetables	cereal grains
Co 58	1 669	61	30	472
Co 60	2 237	643	588	3 233
Zn 65	2 577	657	529	2 280
Sr 89	2 471	51	476	269
Sr 90	134 325	39 638	784 836	90 580
I 131	2 037	0	0	0
Cs 134	6 019	69 468	477	4 929
Cs 137	42 755	806 883	3 946	29 031
Ce 144	1 887	254	157	2 033
Pu 239	11 118	9 556	9 329	12 409

The following rates of consumption were used:

Table 7.1.3-4. Annual consumption of vegetable foodstuffs.

	adults
leafy vegetables	50 kg
root vegetables	50 kg
potatoes	90 kg
grains	90 kg

The radiation doses to be expected from the ingestion of vegetable foodstuffs are given in section 9.

7.1.4. Ingestion of Animal Foodstuffs

Table 7.1.4-1 lists the numbers of different types of animals raised in the various farming communities in the Emmendingen district. Quantitatively, the most important animals are cattle and hogs, which we shall discuss below in regard to their contribution to the possible radiation dose received by human beings from the planned nuclear power plant.

	ho[illegible]	cattle	including milk cows	hogs	chick-ens	ducks	geese	turkeys	bee swarms	sheep	goats
total for Emmendingen district	764	26 144	9 247	33 368	146 400	947	974	21	2 047	2 268	230
Endingen	52	776	106	1 472	4 625	20	-	2	23	-	2
Forchheim	13	737	231	2 307		-	-	-	2	-	-
Herbolzheim	62	1 030	290	1 650	5 443	-	16	-	80	21	14
Kenzingen	47	306	103	1 054	4 258	145	34	6	-	43	5
Riegel	9	541	229	747	1 772	17	4	-	20	807	2
Leiselheim	2	26	11	195	497	-	-	-	-	1	2
Jechtingen	-	208	21	122	825	8	4	-	-	-	1
Weisweil	22	346	109	2 705	3 830	30	3	6	-	12	-
Wyhl	16	437	129	1 203	1 233	26	-	-	-	-	-
Rheinhausen	44	674	184	1 548	2 473	67	4	9	-	63	-

Table 7.1.4-1. Animal raising in the Emmendingen district (number of head) (after GRS, 10/1976)

It has been known for many years that radioactive substances reach the human body by the pathway pasture - cow - milk. Since babies drink relatively large quantities of milk and are thus an especially endangered group, this exposure pathway is extremely important.

The quantity of short-lived radionuclides, such as I-131, which is absorbed by the body from milk in one year depends on the length of the grazing season. The grazing season in Germany is variable, but according to Hoffman, F.O. (1973), it is up to 200 days for pasture land located at low altitudes. According to measurements on American reactors, 30 to 70% of I-131 is emitted in gaseous form. However, since no measurements of this sort have been made for German pressurized water reactors, the Department of Environmental Protection, in agreement with IRS-W-13 (IV, 1975), based its calculations on the conservative assumption that 100% of the iodine emissions consists of elemental gaseous iodine. The transfer of radioisotopes from the air to grass and clover was discussed in the preceding section. Clover generally absorbs larger percentages of radionuclides than does grass. The enrichment factors for clover and grass are compiled in Table 7.1.3-2. The forage consumption of the cows must also be known before we can compute the percentages of the radioisotopes that find their way into 1 liter of milk. For this parameter we assumed (after Baker, D.A. et al., 1976) a daily consumption of 75 kg of fresh pasture vegetation during the grazing season and a daily consumption of 10 kg of silo fodder (consisting of 5 kg of hay and 5 kg of clover) during the stall-feeding period. Five kg of stall fodder is equivalent to an initial fresh weight of 18 kg. Our calculations were based on an average storage time of 1/2 year for the stall fodder. Another parameter that enters into the calculation is the transfer coefficient, which indicates what fraction of the radioactivity ingested by the cows each day with their fodder reappears in one liter of milk. The values used in our computations are compiled in Table 7.1.4-2. It should be mentioned that the especially critical isotope I-131 is contained in sheep's milk and goat's milk in significantly higher concentrations than in cow's milk. Therefore, babies who drink fresh sheep's milk or goat's milk are exposed to significantly higher radiation doses than babies who drink cow's milk. We therefore calculated the expected radiation dose for babies from ingestion of sheep's milk and goat's milk on the basis of the assumption that daily milk consumption is 0.5 liters during the grazing season of these animals (0.75 yr). We further assumed that the daily consumption of fresh forage is 8 kg for sheep and 6 kg for goats.

The Department of Environmental Protection also considered the radiation doses that could be expected from ingestion of meat. We performed complete computations for the radiation exposure to be expected from ingestion of beef and pork.

The transfer factor for the transfer of radionuclides from the fodder to beef and milk is given by the following formula:

$$f_i = f_{iv} \cdot V \cdot S_d$$

where f_{iv} = transfer factor for grass or stall forage (see section 7.1.3).

V = forage consumption in kg fresh weight/day (see above).

S_d = transfer coefficient in $\frac{\text{pCi/l milk}}{\text{pCi/d intake}}$ and $\frac{\text{pCi/kg meat}}{\text{pCi/d intake}}$

S_d gives the percentage of activity absorbed per day which is receovered in one liter of milk or in one kilogram of beef (Table 7.1.4-2.)

In regard to the hog forage, the possible contamination was calculated as follows:

It was assumed that young pigs weighing 20-25 kg are obtained from a breeding farm with no radionuclide exposure. An average quantity of feed per day of

10 l whey

3 kg potatoes and

1 kg cereal grain

was assumed for the five-month fattening period until slaughter maturity was reached (after Kirchgaessner, 1973).

According to Karavaer et al. (1973), about 85% of the radionuclides contained in whole milk remain in the whey. The radionuclide load of the fodder was calculated as described above.

Therefore, the transfer factor for pork is given by the following formula:

$$f_i = (f_{iv\ whey} \cdot V_{whey} + f_{iv\ potatoes} \cdot V_{potatoes} + f_{iv\ grain} \cdot V_{grain}) \cdot S_d$$

where f_i = transport factors of the fodder ingredients

V = fodder consumption per day

S_d = transfer coefficient for pork

The transfer coefficients for the transport of radionuclides into beef, pork and milk are compiled in Table 7.1.4-2.

Table 7.1.4-2. Transfer coefficients for the transport of radionuclides into beef, pork and milk

nuclide	beef pCi/kg meat / pCi/d intake	pork pCi/kg meat / pCi/d intake	milk pCi/l milk / pCi/d intake
Co	0,013	0,013	0,001
Zn	0,05	0,14	0,039
Sr	0,003	0,0073	0,0029
I	0,02	0,09	0,01
Cs	0,1	0,26	0,012
Ce	0,0012	0,005	0,0006
Mn	0,005	0,02	0,00025
Pu	0,005	0,01	0,000002

Transfer factor for I in sheep's milk = 0.40 and in goat's milk = 0.47

After: Buldakov, L.A. et al., 1968; Ward, G.M., Johnson, J.E., 1965; Baker, D.A. et al., 1976; Strahlenschutzkommission, 1977; Annekov, B.M., 1971; Hoffman, F.O., 1975)

The transfer factors determined in this way are compiled in Table 7.1.4-3.

Table 7.1.4-3. Transfer factors in pCi/kg meat (or pCi/l milk) : pCi/m^3 air

nuclide	Beef	Milk	Pork
Co 58	3 479	268	38
Co 60	5 049	388	110
Zn 65	18 477	14 412	17 745
Sr 89	896	866	57
Sr 90	35 055	33 886	3 632
I 131	12 600	6 300	4 820
Cs 134	221 462	26 575	114 197
Cs 137	1 973 473	236 817	1 160 282
Ce 144	408	204	23
Pu 239	4 548	2	411

The following values were used as consumption rates:

Table 7.1.4-4. Annual food consumption.

	Adults	Babies
Milk	360 liters	320 liters
Beef	100 kg	
Pork	40 kg	

The radiation doses to be expected from the ingestion of animal foodstuffs are given in section 9.

7.1.5. Exposure Pathway Grapevines - Wine

Wine was taken into account as a relevant foodstuff in the 1976 assessment of the Association for Reactor Safety (GRS); however, recalculation with the individual parameters that were given showed the following disparity between the result of the multiplication and the final values in Table 11.2 of the GRS assessment:

	whole body	bone	liver	kidney
GRS (Tab. 11.2.)	0,08 mrem	0,4 mrem	0,1 mrem	0,04 mrem
results of the recalculation	1,93 mrem	5,89 mrem	0,9 mrem	0,27 mrem
the radiation doses given in the GRS assessment (Table 11.2) were too small by the following factors.	24 x	14,7 x	9 x	6,7 x

We therefore felt that it was necessary to reexamine the individual parameters, especially the transfer factors of the grapevine - wine exposure pathway.

In this case three transfer factors must be determined:

(f_1) : air - leaf surface - grapes - wine

(f_2) : air - grape surface - grapes - wine

(f_3) : air - soil - plant - wine

The determination was based on the following mathematical model:

$$(f_1) : V_1 \times 86\,400 \times T_{V1} \times \frac{r_1'(1-e^{-\lambda_{ei} \cdot t_{ei}'}) + r_1''(1-e^{-\lambda_{ei} \cdot t_{ei}''})}{\lambda_{ei} \cdot Y_{V1}} \times$$

$$\times \frac{\text{kg Leaf}}{\text{l wine}} \times e^{-\lambda_i \cdot t_h}$$

$$(f_2) : V_2 \times 86\,400 \times T_{V2} \times \frac{r_2 (1-e^{-\lambda_{ei} \cdot te_2})}{ei \cdot Y_{V2}} \times e^{-\lambda_i \cdot t_h}$$

$$(f_3) : V_3 \times 86\,400 \times \frac{B_{iv} \cdot (1-e^{-\lambda_i \cdot t_3})}{\lambda_i \cdot P} \times 0{,}72 \times e^{-\lambda_i \cdot t_h}$$

A value of 0.04 m/s is used for the rates of deposition V_1 and V_2; this value takes into account the greater surface roughness and the filter effect caused by the shrublike nature of the grapevines (see 5.1.7).

The retention factors r_1 and r_2 take into account both the distance separating the individual grapevines and the proportion of nuclides deposited on the surface of the leaves and grapes. Two retention factors r_1' and r_1'' were determined for (f_1); this is necessary because the vines only have leaves at the beginning of the growing season, and later in the season they have both leaves and grapes on which nuclides are deposited. The separation of the grapevines is taken into account with a factor of 0.4 since about 44 vines grow on 100 m^2 of vineyard area. (National Viniculture Institute in Freiburg, 1977).

The grapevines begin to sprout at about the beginning of May; within three months the leaf surface area reaches 320 m^2/100 m^2. The first pruning is performed at the end of July; this reduces the leaf surface area to 250 m^2/100 m^2. Before the second pruning in the second half of August, the leaf surface area increases to 280 m^2/100 m^2; the second pruning reduces it to 250 m^2/100 m^2 and it remains at this value for the rest of the season (National Viniculture Institute, Freiburg, 1978). Since the leaves are very small at the beginning of the season, the first month of exposure time was disregarded.

During the following months ($t_{e1}' = 60$ days) the total surface area of the grapes is considered negligible; the nuclides are distributed over the available leaf surface. This is taken into account in r_1'.

Once the grapes have become so large that it is necessary to include their surface area in the calculation, this is expressed in terms of its ratio to the leaf surface area r_2 to r_1''.

The grape surface area is 60 m^2/100 m^2 (GRS, 1976). Accordingly, in the months of August and September (t_{e1} = 60 days) the nuclides are distributed on the grapes and leaves in a ratio of 0.2 to 0.8.

In regard to the exposure time of the grapes (te_2), we disregard the first six weeks of the 100-day period from flowering to harvesting during which the grapes are hanging on the vine (National Viniculture Institute, Freiburg, 1978).

The meteorological half-life of the nuclides on the leaves and grapes is assumed to be 30 days because the surfaces are covered with adhering spray agents.

The translocation factor Tv_1 indicates the percentage of the nuclides which passes from the surface of the leaves into the plant and then into the grapes. This factor is nuclide-specific and was obtained from the following sources: Aarkrog, A., 1975; Rohleder, U., 1972; Middleton, L.J., Squire, H.M., 1963.

The translocation factor Tv_2 indicates the percentage of the nuclides remaining on the grapes despite wind and rain which eventually passes into the wine. This factor is 0.5 (GRS, 1976).

The leaf mass Yv_1 is subject to the same variation as the leaf surface area as a result of the prunings and has a mean value of 0.5 kg/m^2. In this case the low weight of the younger leaves is taken into consideration (National Viniculture Institute, Freiburg, 1977).

With an average grape yield of 1.1 kg/m^2, the wine yield Yv_2 is 0.825 l/m^2 (assuming that 0.71 l of wine is produced from 1 kg of grapes) (GRS, 1976). It is assumed that 100% of the nuclides present inside the grapes passes into the wine.

Since the literature contains no values for enrichment factors (Biv) of wine, we adopted the values that were available for the most closely related plants.

P gives the mass of the earth in the plowed layer under one square meter of ground surface area. Its value is 224 kg/m^2.

The reactor operating time t_B is 50 years (Basis of Calculation of the Radiation Protection Commission, 1977).

The expression $e^{-\lambda i \cdot th}$ gives the decay of the radionuclides during storage of the wine.

The decay time t_h gives the minimum storage time of the wine, which is 120 days (GRS, 1976); however, this value does not take into consideration the fact that a small portion is consumed as grape must before the end of the 120-day storage period.

The rate of consumption was assumed to be 400 l of wine per year (after GRS, 1976).

In our determination of the radiation dose to be expected by this pathway, we considered the fact that the nearest wine-growing area is not located at the maximum radiation receiving point, but rather at Limberg. Consequently, the long-term dispersion factor for the maximum receiving point was not used. We adopted a more realistic value for Limberg (according to section 5.1.6).

The transfer factors for wine are compiled in Table 7.1.5-1. Due to a lack of utilizable translocation factors for Zn, Ce and Pu, exposure via the leaves (f_1) was calculated only for Co, Sr and Cs.

Table 7.1.5-1. Transfer factors in pCi/l wine : pCi/m^3 air.

Nuclide	Transfer factor
Co 58	3 015
Co 60	11 578
Zn 65	3 986
Sr 89	1 027
Sr 90	44 559
I 131	0
Cs 134	71 242
Cs 137	150 344
Ce 144	3 875
Pu 239	12 023

The radiation doses to be expected from consumption of wine are given in section 9.

7.2 Exposure via Waste Water

As in the SSK Recommendations (SSK, 1977), it is necessary to make a basic distinction between internal and external exposure in our discussion of the radiation doses to be expected by the waste water pathway.

The pathways of internal exposure include the following:

- drinking water
- ingestion of fish
- irrigation - ingestion of vegetable foodstuffs
- irrigation - forage plants - ingestion of milk (ingestion of meat)
- livestock watering - ingestion of milk/ingestion of meat

The above pathways of exposure were computed with respect to their significance for the radiation dose of the most unfavorable location. They are discussed in detail below. We did not consider external exposure from direct radiation while swimming and boating and from sediment radiation (recreational outings on the banks of the Rhine etc.). The radiation doses resulting from these activities would have to be added to the dose from internal exposure.

7.2.1. Exposure by Ingestion of Fish

The radiation dose from ingestion of contaminated fish was determined with the following formula:

$$D_{io} = Q_i \cdot \frac{1}{W} \cdot f_i \cdot d_{io} \cdot V$$

where D_{io} = radiation dose for an organ o caused by isotope i (in mrem/yr)

V = rate of consumption (in kg/yr)

d_{io} = dose commitment factor for organ o and nuclide i (in mrem/pCi)

Q_i = source strength of the nuclide (in pCi/s)

W = volume flow rate of the river (in l/s)

f_i = transfer factor for nuclide i (in $\frac{\text{pCi/kg fi[illegible]}}{\text{pCi/l water}}$)

The transfer factors in Table 7.2.1-1 were obtained from the recent technical literature. There were large variations in the factors given in the literature for the critical nuclides.

In the case of strontium values of up to 370 were given (Hübel, Ruf and Herrmann, 1973). Kohlemainen et al. (1966) and Hakonson and Whicker (1975) determined maximum transfer factors for cesium of $6840/(K)_w$ and $13,000/(K)_w$, respectively. ($(K)_w$ gives the content of stable potassium in mg/l water.)

In the case of cesium it is necessary to consider the dependence of the enrichment on the potassium concentration of the water because cesium and potassium behave similarly in the organism of the fish and relatively more cesium is absorbed when the potassium concentration of the water is low.

Table 7.2.1-1. Transfer factors for fish in $\frac{\text{pCi/kg fish meat}}{\text{pCi/l water}}$

Nuclide	Factor
H 3	1
Co 58	400
Co 60	400
Zn 65	1 000
Sr 89	40
Sr 90	40
I 131	520
Cs 134	$4\,000/K_{(w)}$
Cs 137	$4\,000/K_{(w)}$

after BBV, 1976; Blanchard, R.L. & Kalm, B. jun., 1971; Hermann, H. et al., 1975; Hakonson & Whicker, 1975; Kohlemainen et al., 1966; Vanderploequ et al., 1975

The assessment of the Bavarian Biological Testing Institute (1976) uses a potassium concentration of 6 mg/l as the annual average of the Rhine at Weisweil. In the opinion of our experts, this is an unacceptable value for a conservative estimate of the radiation dose that is to be expected. Since the estimation of the radiation dose to be expected is performed on the assumption of an operating time of 50 years, and since we can assume that the level of potassium pollution of the Rhine (especially from the Alsatian potash mines) will drop off sharply in the years to come as a result of increasing environmental protection measures, a value of 6 mg/l is clearly too high.

Measurements by Egger (1887) at Mainz showed a concentration of 1.9 mg K/l, and measurements by Pagenstecher (1837) at Basel showed a concentration of 1.2 mg K + Na/l (cited by Livingstone, 1963). The Department of Environmental Protection therefore assumed a potassium concentration in the Rhine of 1 mg/l for the purpose of making a conservative estimate of radiation doses that can be expected.

However, due to the uncertainties in regard to the transfer factors, it is debatable whether our assumptions put us on the safe side.

The chosen consumption rate of 50 kg/yr can be regarded as realistic for a critical population group (see the survey by Schaefer, BGA, of sport fishermen and professional fishermen, Model Study Radioecology Biblis, 3/17/1977), especially since we must expect increasingly large catches as a result of the possible improvement of the water quality of the Rhine.

7.2.2. Irrigation - Ingestion of Vegetable Foodstuffs

Due to the steady lowering of the water table in the upper Rhine region as a result of the canalization of the Rhine, and due to the relatively dry climate, the irrigation of farmland in the Rhine plain below the planned nuclear power plant is a realistic source of contamination.

Since it is very likely that the water quality of the Rhine will be improved by intensification of environmental protection measures, it must be assumed that Rhine water will be used to an increasing extent for irrigation of agricultural land.

Irrigation is performed mostly in the summer months. As was mentioned in section 5.2, a large percentage of yearly nuclear power plant emissions is also discharged in the summer months (during the changing of the fuel elements). Consequently, calculations of expected radiation dose that are based on uniform discharge of emissions would result in underestimation of the dose. A more exact study is necessary.

The following formula is used to compute the radiation exposure due to ingestion of crop plants grown in irrigated soil:

$$D_{io} = Q_i \cdot \frac{1}{W} \cdot f_i \cdot V \cdot d_{io}$$

where V = consumption rate in kg/yr

f_i = transfer factor for the nuclide i

The transfer factor f_i is determined by the following formula; this formula is similar to the equation in section 7.1.3 for the transfer of radionuclides from ground-level air to plants, the difference being that the rate and duration of irrigation must be considered instead of the rate of deposition of aerosols.

See section 7.1.3 for explanation of the meanings of the symbols.

$$f_i = R \cdot \left[\frac{r \cdot T_v \cdot F \cdot (1 - e^{-\lambda_{Ei} \cdot t_e})}{\lambda_{Ei} \cdot Y_v} + \frac{t_w \cdot B_{iv} \cdot (1 - e^{-\lambda_i \cdot t_e})}{12 \cdot \lambda_i \cdot P} \right] e^{-\lambda_i \cdot t_h}$$

where R = irrigation rate for garden vegetables 3 $1/m^2 \cdot d$

pasture land 1 $1/m^2 \cdot d$

potatoes 1.25 $1/m^2 \cdot d$

(after: Ruhr-Stickstoff-AG, 1978; Perrot, 1949)

r = retention factor = 0.33

T_v = translocation factor for pasture vegetation and leafy vegetables = 1

for potatoes and root vegetables = 0.1

F = loss factor for leafy vegetables = 0.4

for all other plants = 1

λ_{Ei} = effective decay constant for isotope i in d = $\lambda_i + \lambda_w$

t_e = exposure time in d for pasture vegetation = 30 days for vegetables and potatoes = 90 days

Y_v = vegetation density in kg fresh weight/m^2

for pasture plants = 0.85

leafy vegetables = 1.5

root vegetables = 4.0

potatoes = 1.8

B_{ir} = enrichment factor from the soil to the plant for nuclide i; (Table 7.1.3-2)

P = mass of the earth in the plowed layer (224 kg/m^2)

t_r = duration of irrigation = 4 months for vegetables and potatoes

= 5 months for pasture land

t_B = 18,250 days

t_h = 180 days (for potatoes and stall forage)

λ_i = physical decay constant

Leafy vegetables, root vegetables and potatoes were regarded as possible exposure pathways. The assumed rates of consumption are given in Table 7.1.3-3.

In our determination of the transfer factors, we departed from the recommendations of the Radiation Protection Commission (SSK) in several points.

For example, the SSK's determination of the amount of additional water that must be supplied by irrigation, which is based on mean precipitation values (SSK, 1977 II, p. 41), is scientifically unsatisfactory.

It must be realized that during irrigation part of the water immediately evaporates. Also, according to Ruhr-Stickstoff-AG (1978), significantly higher irrigation rates than 1 l/m^2·d are advisable for vegetable cultivation. 600 l/m^2 per year is given for intensive outdoor vegetable cultivation, and 150 l/m^2 per year is given for field vegetable cultivation (Ruhr-Stickstoff-AG p. 506).

On the basis of the vegetation period of 4 months for vegetable growing and the recommendations for agricultural practice (Ruhr-Stickstoff), we determined mean values of 1.25 to 5 l/m^2 per day. For the purpose of obtaining realistic estimates, we based our calculations on a mean value of 3 l/m^2 per day.

Our calculation of the nuclide concentration that accumulates in the soil in the course of the operating life of the reactor was based on the irrigation time of 4 months per year. This fact is not taken into consideration in the SSK recommendations; the SSK assumes a continuous irrigation rate of 1 l/m^2 per day over the entire year.

Consequently, the calculations of the SSK and Department of Environmental Protection give equivalent results in regard to the radionuclides accumulated in the soil at the end of the reactor operating time from irrigation with river water. The difference is that in the first part of the formula, for the portion of radioactivity that reaches the plants directly with the irrigation, we obtain higher values as a result of our more realistic approach (irrigation only in the summer).

Naturally, we cannot rule out the possibility that in especially dry years, when irrigation rates are higher, or during fuel element changes, when emission rates are higher, irrigated crop plants may cause higher radiation doses than are calculated in this study.

The transfer factors determined in this way are compiled in Table 7.2.2-1.

Table 7.2.2-1. Transfer factors in pCi/kg fresh plants : pCi/l irrigation water.

nuclide	leafy vegetables	root vegetables	potatoes
H 3	1	1	1
Co 58	4,4	0,1	0,1
Co 60	5,5	0,8	0,5
Zn 65	5,6	0,7	0,4
Sr 89	5	0,4	0
Sr 90	121,8	691,4	14,8
I 131	2	0	0
Cs 134	8,8	0,7	25,7
Cs 137	41,2	3,8	296,3

7.2.3. Irrigation - Forage Plants - Ingestion of Milk and Meat

This exposure pathway concerns the possibility of contamination by ingestion of milk and beef from cattle which have grazed in pastures irrigated with Rhine water or which have been fed in the winter with stall fodder from irrigated pastures.

The following formula was used in our calculations:

$$D_{io} = Q_i \cdot \frac{1}{W} \cdot f_{iv} \cdot s_d \cdot d_{io}$$

where f_{iv} = transfer factor for grass or stall fodder for the passage of

radioactivity from the irrigation water to the plant in

$\frac{\text{pCi/kg plant}}{\text{pCi/l water}}$

(calculation analogous to sections 7.2.2 and 7.1.4)

s_d = transfer coefficient for the passage of daily ingested radioactivity from the forage into the milk or meat

(Table 7.1.4-2)

The transfer factors determined in this way are compiled in Table 7.2.3-1.

Table 7.2.3-1. Transfer factors in pCi/kg beef or pCi/l milk : pCi/l irrigation water

nuclide	beef	milk
H 3	1	1
Co 58	3,1	0,2
Co 60	4,4	0,3
Zn 65	15,4	12,0
Sr 89	0,7	0,7
Sr 90	11,0	10,6
I 131	2,3	1,1
Cs 134	86,9	10,4
Cs 137	602,2	72,3

7.2.4. Livestock Watering - Milk (Meat)

This pathway concerns the possibility of contamination by ingestion of milk and beef from cattle which have been watered with radioactively contaminated water. The calculations were performed in accordance with SSK recommendations.

The following formula was used:

$$D_{io} = Q_i \cdot \frac{1}{W} \cdot L \cdot S_d \cdot d_{io}$$

where L = daily water consumption of the cow (75 l/d)

S_d = transfer coefficient for the passage of daily ingested radioactivity into the milk or meat

(see Table 7.1.4-2)

The transfer factors determined in this way are compiled in Table 7.2.4-1.

Table 7.2.4-1. Transfer factors in pCi/kg beef or pCi/l milk : pCi/l water.

nuclide	beef	milk
H 3	1	1
Co 58	1	0,1
Co 60	1	0,1
Zn 65	2,9	3,8
Sr 89	0,2	0,2
Sr 90	0,2	0,2
I 131	1,5	0,8
Cs 134	7,5	0,9
Cs 137	7,5	0,9

7.2.5. Annual Consumption Rates (Waste Water Pathway)

The following consumption rates were assumed for the waste water pathway.

The annual consumption rates were used for the exposure pathways irrigation - forage plants - milk/meat and livestock watering - milk/meat.

Table 7.2.5-1. Annual consumption of foodstuffs used in the waste water pathway calculations

	Adults
cow's milk	360 l
leafy vegetables	50 kg
root vegetables	50 kg
potatoes	90 kg
beef	100 kg
fish	50 kg

The radiations doses to be expected from exposure by the waste water pathway are given in section 9.

8. Examination of the Dose Factors

8.1. Dose Factors - Mathematical Basis

The dose factor or dose commitment factor gives the radiation dose in mrem/yr whi is produced per quantity of radioactivity in pCi/a absorbed by ma:

The radiation exposure in an organ depends on the following factors:

- quantity of nuclide absorbed
- type of radiation emitted
- energy of the radiation
- relative biological activity of the radiation
- effective half-life of the nuclide in the organ
- selection or enrichment factor of the organ
- mass and form of the organ
- microdistribution of the activity in the organ

These factors depend in turn on the following factors (among others):

- chemical composition of the incorporated substance
- quantity of the stable element in the diet
- age and state of healty of the individual
- genetic constitution

The dose commitment factor is calculated by the following formula:

$$\frac{dD}{dt} = 0{,}05115 \frac{E_{eff} \cdot f_a}{m \cdot \lambda_{eff}} \left(1 - e^{-\lambda_{eff} \cdot 50\ a}\right) \frac{mrem}{a}$$

where E_{eff} = effective energy in MeV

f_A = fraction of the absorbed activity which reaches the organ

m = mass of the organ in g

λ_{eff} = effective decay constant, takes into account the physical and biological half-life

For very long-lived nuclides the dose commitment factor gives the dose which is active in the fiftieth year of continuous radionuclide absorption (dose commitment). For nuclides with short and medium effective half-life the yearly dose and the dose commitment are the same.

The dose commitment factors used by the Association for Reactor Safety (GRS) and recommended by the Radiation Protection Commission (SSK) have a number of deficiencies. These deficiencies are set forth below, and, when possible, more realistic dose commitment factors are calculated.

8.2. State of Health and Genetic Constitution

The dose commitment factor applies to the so-called average human being, who weighs 70 kg, is healthy, and has a "normal" genetic constitution. Diseases or environmental influences which might lead to an increase in the rate of absorption of radionuclides or to a higher biological half-life of radionuclides are not taken into consideration. Lack of time prevented us from investigating this area in greater detail. However, it may be expected that these factors would have a considerable effect on the dose commitment factor. The content of the stable element in the diet is an example of such a factor; the dose commitment factor would be strongly affected by iodine deficiency, for example.

A paper on the measurement of plutonium in cows in the vicinity of an American nuclear research center seems very important in this connection. In this study plutonium values of 0.5 to 10 pCi/kg were found in beef. However, a concentration of 100 - 200 pCi/kg Pu-239 was found in one of the cows, although the cow was subject to the same environmental conditions as the other cows. The author of this report states that this cow had a genetic abnormality, and although this abnormality did not adversely affect the cow's viability, it did represent a possible explanation for the high plutonium concentration. (Smith, D.D., 1973)

Since man does not have a uniform genotype, and since not all individuals are healthy, some individuals may be exposed to significantly higher radiation doses than those calculated here for a normal, healthy person; this will depend on an individual's genetic constitution and state of health.

8.3. Chemical Form of the Radionuclide

Depending on the chemical form in which the radionuclide is present in the diet, the dose commitment factor (and thus the radiation dose resulting from absorption of the radionuclide) may vary by several powers of ten.

This will be discussed with the example of cobalt-60 (half-life 5.2 years), which is emitted as a corrosion product by nuclear power plants.

The dose factor used by the GRS and recommended by the SSK for Co-60, e.g., in the liver, is 2.15×10^{-6} mrem/pCi. Although this dose factor is valid only when the Co-60 is present in inorganic form (as a salt), it is used for all exposure routes. If the Co-60 is present as vitamin B_{12}, for example, the dose factor would be between 3000×10^{-6} and 6100×10^{-6} mrem/pCi (ICRP, 1969). The dose factor for this organic form of Co-60 is thus 1400 to 3800 times greater than the dose factor used by the GRS and SSK. This aspect was not investigated either. However, we are afraid that the exclusive use of dose factors that are valid only for the inorganic form of the radionuclide will result in significant underestimation of the radiation dose since animal and vegetable foodstuffs are the source of the radionuclide.

8.4. Transferability of Animal Experiments to Man

In the great majority of cases the values used to determine the dose factors are results of animal experiments that are applied to man. The most commonly used experimental animals are rats, mice and guinea pigs, that is to say, animal species whose organisms are much smaller than the human organism. As a rule, the smaller an organism is, the faster is the rate at which physiological processes occur in it. A readily apparent example of this is the higher respiratory rate and heart rate in the smaller organism. Furthermore, due to the smallness of the organs, the metabolic exchange processes occur more rapidly, so that the biological half-lives of elements in a given organ are shorter than they are in larger organisms. In regard to the application to human beings of radionuclide biological half-lives determined in animal experiments, as has been done in many cases, e.g., by the International Commission on Radiological Protection, there is a definite danger that the dose factors, and thus the radiation exposure, will be systematically and significantly underestimated.

8.5. Transfer Factors Gastrointestinal Tract - Organ

The investigation of the transfer factors for the passage of radionuclides from the gastrointestinal tract to the various organs resulted in an incorrect calculation of the dose factors for the most important radionuclides by the International Commission on Radiological Protection and the Association for Reactor Safety.

The transfer factor f_A consists of two parts: f_1 describes the passage of radionuclides from the gastrointestinal tract into the blood, and f_2 describes the passage of the radionuclides from the blood into the individual organs ($f_A = f_1 \cdot f_2$).

Example: Strontium

The International Commission on Radiological Protection gives the values necessary for calculation of the dose factors in "Recommendations - Permissible Dose in Incorporation of Radionuclides" (ICRP, 1966). On p. 96 a value of 0.21 is given as the transfer factor for the transfer of the radionuclides Sr-85 m, Sr-85, Sr-89, Sr-91 and Sr-92 from the food into the bones. These strontium isotopes are short-lived and thus relatively undangerous nuclides. Although the individual isotopes of an element show exactly the same chemical behavior, a significantly smaller value (0.09) is assigned to Sr-90, which has a half-life of 28.5 years and is thus by far the most dangerous isotope of strontium.

The value of 0.21 is based on a scientific paper (Jowsey, J. et al., 1953) and can therefore be regarded as scientifically acceptable. The low value of 0.09, on the other hand, is taken from a personal communication (Durbin to Morgan, 8/7/1958) which cannot be checked and which apparently is unpublishable. Consequently, there is no reason to pay further attention to this value.

Example: Plutonium

Depending on the chemical form in which it is present, plutonium is absorbed in highly variable quantities in the gastrointestinal tract. While only about one millionth of the plutonium present in the food in the form of the insoluble, inorganic compound plutonium dioxide is absorbed in the gastrointestinal tract, the absorption rate increases by a factor of about 10,000 for soluble or organic plutonium compounds. As the operating time of a reactor increases, an increasingly large percentage of the plutonium deposited on the ground is made available to plants by the action of microorganisms and is able to reach man via the metabolism of food plants. Therefore, it is totally unrealistic to base calculations of plutonium dose factors on insoluble plutonium dioxide (as has been done by the GRS and SSK). In a basic study in which plutonium dose factors are calculated, the GRS writes the following on p. 18: "For poorly soluble material like PuO_2 we assume a blood-absorbed fraction of $f_w = 10^{-4}$% in man. For soluble plutonium compounds, particularly plutonium citrates and nitrates, transfer factors of up to about 2% have been measured. The present model computation assumes poorly soluble material for all actinides and uses an absorption value of $f_w = 10^{-4}$%." (GRS-I, p. 18, 1977). Although the GRS is acquainted with the fact that the absorption of organic and soluble plutonium compounds is significantly greater than that of inorganic and insoluble plutonium compounds, it bases its calculation of plutonium dose factors on a transfer factor that is too low by a factor of 20,000. This transfer factor enters linearly into the calculation of the dose factor and thus into the calculation of the plutonium radiation exposure.

8.6. Microdistribution of the Radionuclides

A uniform distribution of the radionuclide in the organ is normally assumed in calculations of dose factors. However, this can result in considerable underestimation of the radiation exposure.

An example is plutonium:

It was formerly assumed that plutonium distributes itself uniformly in bone. However, recent studies show that plutonium becomes concentrated entirely in the organic parts of bone, especially in the osteogenetic cells, and is not incorporated in the mineral phase of the bone (Priest, 1977). Consequently, the radiosensitive part of the bone is exposed to significantly higher radiation doses than would be expected by assuming homogeneous distribution.

8.7. Organs Investigated

Only a few organs are considered in the assessments of the GRS and in the mathematical models of the SSK (whole body, thyroid, liver, kidney, gastrointestinal tract and bone). However, it is precisely these organs which are either only moderately radiosensitive (bone and thyroid) or actually relatively radioresistant (liver, kidney, lung, muscle) (Pabst et al., 1976; Barth, G. et al., 1968). The radiosensitive organs (Pabst, 1976; Barth, 1968) are systematically disregarded:

- embryonal tissue
- lymphatic tissue
- thymic tissue
- bone marrow
- testis
- ovary

8.8. Radiation Exposure of Embryos

One of the most serious radiobiological problems is the accumulation of radioactive substances during pregnancy and the irradiation of the human embryo, which is by far the most radiosensitive stage of human life due to the rapid rate of cell division and the determinant development of all organs. Various studies show that human embryos are 100 to 1000 times more radiosensitive than human adults (e.g., Stewart, A., 1973).

The formation and destruction of cells in the adult human body are in a state of transient equilibrium. Therefore, the biological half-life of absorbed radionuclides is shorter in the adult than in the embryo. Embryonal and fetal tissue are formed at a relatively fast rate, while the occurrence of destructive processes is very limited. This high rate of formation results in a high rate of assimilation. Radionuclides are also assimilated at a fast rate; they are incorporated with a high biological half-life in the body of the embryo and later the child. It follows, therefore, that the embryo receives the highest radiation dose at a given concentration of radionuclides in the environment.

Although this has been known for a long time, the embryonal radiation exposure has never been considered in any assessment for nuclear power plants in West Germany. Even the mathematical models of the Radiation Protection Commission (SSK), which will be included in the legal regulations in the future, do not consider the embryonal stage in any way. As in many other cases, therefore, we are confronted with an intolerable discrepancy between the actual licensing procedure for nuclear power plants and the explicit requirement stated in section 45 of the Radiation Protection Law that radiation exposure be considered at the "most unfavorable points of exposure" and that "all relevant exposure pathways" be taken into account.

The following table gives the dose factors used for children and adults.

Table 8-1. Dose commitment factors, ingestion (in mrem/pCi)

	H 3	Co 58	Co 60	Zn 65	Sr 89	Sr 90	J 131	Cs 134	Cs 137	Ce 144	Pu 239
bone	0	$1,12\cdot10^{-5}$	$3,64\cdot10^{-5}$	$1,71\cdot10^{-5}$	$4,40\cdot10^{-4}$	$9,6\cdot10^{-2}$	$4,16\cdot10^{-6}$	$1,25\cdot10^{-4}$	$2,03\cdot10^{-4}$	$5,3\cdot10^{-7}$	5.78
whole body	$1,3\cdot10^{-7}$	$1,12\cdot10^{-5}$	$3,64\cdot10^{-5}$	$3,34\cdot10^{-5}$	$1,11\cdot10^{-5}$	$2,26\cdot10^{-3}$	$3,52\cdot10^{-6}$	$1,47\cdot10^{-4}$	$9,21\cdot10^{-5}$	$2,62\cdot10^{-8}$	$1,28\cdot10^{-2}$
liver	$1,3\cdot10^{-7}$	$8,79\cdot10^{-6}$	$2,88\cdot10^{-5}$	$7,67\cdot10^{-5}$	-	-	$5,96\cdot10^{-6}$	$2,2\cdot10^{-4}$	$1,36\cdot10^{-4}$	$2,06\cdot10^{-7}$	$7,12\cdot10^{-2}$
kidney	$1,3\cdot10^{-7}$	$8,73\cdot10^{-7}$	$2,04\cdot10^{-6}$	$5,13\cdot10^{-5}$	-	-	$1,02\cdot10^{-5}$	$1,59\cdot10^{-3}$	$1,44\cdot10^{-3}$	$1,22\cdot10^{-7}$	$5,45\cdot10^{-2}$
lung	$1,3\cdot10^{-7}$	$1,12\cdot10^{-5}$	$3,64\cdot10^{-5}$	$3,34\cdot10^{-5}$	-	-	-	$1,9\cdot10^{-5}$	$1,25\cdot10^{-5}$	$2,62\cdot10^{-8}$	-
thyroid	$1,3\cdot10^{-7}$	$1,12\cdot10^{-5}$	$3,64\cdot10^{-5}$	$3,34\cdot10^{-5}$	-	-	$1,95\cdot10^{-3}$	$1,47\cdot10^{-4}$	$9,21\cdot10^{-5}$	$2,62\cdot10^{-8}$	-
bone marrow	$1,9\cdot10^{-7}$	$1,12\cdot10^{-5}$	$3,64\cdot10^{-5}$	$3,34\cdot10^{-5}$	-	$8,86\cdot10^{-4}$	-	$1,47\cdot10^{-4}$	$9,21\cdot10^{-5}$	$2,62\cdot10^{-8}$	-

The relevant dose factor for babies for the thyroid gland (I-131) was assigned a value of 2.8×10^{-2};

after (Bacher D., Müller W., 1977; Bonka H., Brüssermann K., 1973; Cooper W., 1972; Eisenbud M., 1973; ICRP, 1966; ICRP, 1974; ICRP, 1969; Priest N.D., 1977; SSK, 1977; Thorne U.C., 1976; UCRL, 1968;)

9. Results of the Radioecological Computer Program

The radiation doses to be expected from consumption of foodstuffs from the area around the planned nuclear power plant in Wyhl are compiled in the following tables. All values are given in the unit millirems per year.

Table 9-1. Expected radiation exposure for adults by the exhaust air pathway at the maximum radiation receiving point (the values given for wine refer to Limberg)

	bone	whole body	liver	kidney	lung	thyroid	bone marrow
leafy vegetables	121.1570	10.66019	[illegible]	58.2101	6.5416014	[illegible]	6.490274
root vegetables	1669.026	15.32492	0.9213534	5.516095	0.05430139	3.15755	15.81039
potatoes	563.7017	179.7135	[illegible]	1925.761	15.95561	125.3524	126.4571
grains	415.0591	11.13156	[illegible]	17.19167	4.7400115	[illegible]	8.026098
pork	178.4931	85.73359	113.1302	1236.784	10.39377	45.39655	80.63095
beef	[illegible]	348.8275	[illegible]	[illegible]	41.47425	173.0332	346.6206
milk	916.7600	162.1351	227.1173	2295.490	23.16735	234.7613	154.5775
wine	[illegible]	109.7058	153.7951	1111.262	13.30273	[illegible]	101.1307
grand total	5157.415	833.7912	[illegible]	12255.75	111.1564	[illegible]	839.7419

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POOR ORIGINAL

	bone	whole body	liver	kidney	lung	thyroid	bone marrow
leafy vegetables							
CO 58	[illegible]	[illegible]	[illegible]	[illegible]	0.0461519[illegible]	[illegible]	0.0961[illegible]1952
CO60	[illegible]	[illegible]714225	[illegible]	0.01152115[illegible]	0.02714225	[illegible]	0.32714225
ZN65	[illegible]	[illegible]	[illegible]	0.0293777[illegible]	0.01912735	0.01912735	0.01912705
SR89	[illegible]	[illegible]	0	0	0	0	0
SR90	[illegible]	6.716099	0	0	0	0	2.644109
I-131	[illegible]	0.0043[illegible]0135	0.0310[illegible]	0.01365159	0	2.6[illegible]9097	0
CS134	0.2537516	[illegible]	[illegible]	1.153065	0.33812[illegible]	3.2759309	0.2959309
CS137	7.714931	3.5[illegible]0704	5.168601	54.12618	0.4750855	1.503204	1.503203
CE144	[illegible]	[illegible]E-06	6.510611E-05	4.072651E-05	8.789224E-06	6.7[illegible]224E-06	8.799224E-06
PU239	23.56[illegible]	0.0632[illegible]	0.3519227	0.2693026	0	0	0
total	[illegible]3.1570	13.66013	6.018619	59.23085	0.5636673	6.[illegible]93659	6.493278
root vegetables							
CO 58	7.465663E-05	7.466663E-05	5.859797E-05	5.419958E-05	7.466663E-05	7.466661E-05	7.466663E-05
CO 60	0.007134191	0.007134191	0.005644775	0.0041949196	0.007134191	0.007134191	0.007134191
ZN 65	0.032013195	0.001926352	0.009016505	0.006030597	0.001926352	0.001926352	0.001926352
SR 89	0.005554216	0.0001174133	0	0	0	0	0
SR 90	1674.315	19.41623	0	0	0	0	15.45254
I 131	0	0	0	0	0	0	0
CS134	0.31637499	0.02117303	0.01607737	0.2328697	0.003070937	0.02117303	0.02117300
CS137	0.7123117	0.3210654	0.4710715	5.050979	0.0430[illegible]	0.3210655	0.1210658
CE144	1.479283E-05	7.312709E-07	5.767697E-06	3.405154E-06	7.312709E-07	7.312709E-07	7.312709E-07
PU239	23.96515	0.05307163	0.2952138	0.2259651	0	0	0
total	1699.926	34.82692	0.821[illegible]	5.536096	0.05[illegible]30153	[illegible]0.3575547	15.81009
potatoes							
CO 58	0.0002712778	0.0002712798	0.0037144759	2.110111E-05	0.0002712[illegible]	0.0002712798	0.0002712795
CO 60	0.01404311	0.01404311	0.01111101	0.0007070311	0.01404311	0.01404311	0.01404311
ZN 65	[illegible]	0.008777815	0.02015675	0.01358163	0.008777514	0.008777514	0.008777514
SR 89	0.0003975924	2.264359E-05	0	0	0	0	0
SR 90	152.2098	1.503275	0	0	0	0	1.404770
I 131	0	0	0	0	0	0	0
CS134	[illegible]	6.127376	9.159774	66.27246	0.7919353	6.127016	6.127016
CS137	262.0754	118.9022	175.5777	1059.051	16.13765	118.9022	118.9022
CE144	4.307932E-05	2.129535E-06	1.674367E-05	9.916154E-06	2.129535E-06	2.129535E-06	2.129535E-06
PU239	44.19694	0.09705331	0.554309[illegible]	0.4166415	0	0	0
total	[illegible]3.7017	128.7335	195.4732	1925.761	16.95257	125.0524	126.4571

		bone	whole body	liver	kidney	lung	thyroid	bone marrow
grains								
	Co 58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Co 60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Zr 95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.01056074
	Sr 89	[illegible]	[illegible]	0	0	0	0	0
	Sr 90	[illegible]	0.144533	0	0	0	0	1.210155
	I 131	0	0	0	0	0	[illegible]	0
	Cs134	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Cs137	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Ce144	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.704666*-05
	Pu239	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0
	total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.025098
pork								
	Co 58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	7.565219*-05
	Co 60	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Zr 95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	1.1051658
	Sr 89	[illegible]	[illegible]	0	0	0	0	0
	Sr 90	[illegible]	[illegible]	0	0	0	0	0.05720802
	I 131	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	0
	Cs134	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4.476521
	Cs137	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	75.93372
	Ce144	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	8.570105*-05
	Pu239	[illegible]	[illegible]	[illegible]	[illegible]	0	0	0
	total	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	83.61395
beef								
	Co 58	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.31731768
	Co 60	[illegible]	[illegible]	[illegible]	[illegible]	0.1225221	[illegible]	0.1225221
	Zr 95	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.2742306
	Sr 89	[illegible]	[illegible]	0	0	0	0	0
	Sr 90	[illegible]	[illegible]	0	0	0	0	1.393387
	I 131	[illegible]	[illegible]	[illegible]	[illegible]	0	[illegible]	0
	Cs134	[illegible]	21.70326	[illegible]	[illegible]	[illegible]	[illegible]	21.70326
	Cs137	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	323.1230
	Ce144	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Pu239	[illegible]	0.05174612	[illegible]	[illegible]	0	0	0
	total	[illegible]	[illegible]	514.7510	[illegible]	[illegible]	[illegible]	345.6206

		bone	whole body	liver	kidney	lung	thyroid	bone marrow
milk								
	CO 58	0.004802555	0.004802555	0.003176150	0.003376471	0.004802555	0.004802555	0.004802555
	CO 60	0.03383566	0.01389566	0.02698135	0.01399647	0.01345566	0.01389565	0.01389566
	ZN 65	0.3943171	0.7731763	1.763643	1.182536	0.7701761	0.7731751	0.7701768
	SR 89	0.04096633	0.001538016	0	0	0	0	0
	SR 90	570.4485	12.25117	0	0	0	0	4.833678
	I131	0.1257993	0.1064447	0.1992103	0.1084479	0	58.95797	0
	CS134	7.932439	9.375658	14.33159	101.4101	1.211823	9.375659	9.375658
	CS137	307.6726	119.5931	206.8254	2182.504	15.94536	139.5891	139.5893
	CE144	0.0031383915	6.841342E-06	5.379070E-05	1.195652E-05	6.841342E-06	6.841342E-06	6.841342E-06
	PU239	0.03655199	8.191598E-05	0.0004556756	0.0003487999	0	0	0
	total	836.7930	162.1351	222.1370	2285.409	20.96605	205.7617	154.5775
wine								
	CO 58	0.04502398	0.04502391	0.03513573	0.003509459	0.04502378	0.04532134	0.04502395
	CO 60	0.8501579	0.6501579	0.6776526	0.04764627	0.4501573	0.4531573	0.8531579
	ZN 65	0.09083375	0.1775341	0.4376347	0.2726423	0.1775097	0.1775097	0.1775097
	SR 89	0.02025063	0.001519960	0	0	0	0	0
	SR 90	570.3547	13.42710	0	0	0	0	5.263902
	I131	0	0	0	0	0	0	0
	CS134	17.61049	20.94514	31.35647	226.5595	2.737135	20.94514	20.94514
	CS137	162.7726	73.84895	109.0595	1154.641	10.02291	73.84695	73.84895
	CE144	0.002190666	0.0001082913	0.0004514563	0.0005042667	0.0001082933	0.0001082511	0.0001082933
	PU239	165.3144	0.4103850	2.282765	1.747342	0	0	0
	total	917.2998	104.7058	143.7951	1383.262	13.80297	55.96688	101.1307

Table 9-2. Expected radiation exposure for adults by the waste water pathway from utilization of Rhine water.

values given in mrem/yr

	bone	whole body	liver	kidney	lung	thyroid	bone marrow
fish consumption	176.2276	71.57474	134.0445	951.5821	10.44731	112.4420	70.62006
leafy vegetables	186.1969	4.860232	0.7327037	7.253519	0.08275450	0.6627634	2.280464
root vegetables	1951.023	24.79065	0.07104920	0.6644819	0.01215461	0.0499154	9.751193
potatoes	52.76889	6.730520	8.532324	48.62357	0.7906929	5.737252	6.1[illegible]
irrigation – milk	128.2620	8.652532	8.771427	90.84274	0.8707602	6.564141	7.06[illegible]
irrigation – meat	61.61485	14.33774	20.03394	205.3853	1.867026	13.92429	13.65211
livestock watering – milk	2.402912	0.2124233	0.2334457	1.580675	0.06297459	0.6290392	0.1946537
livestock watering – meat	1.046027	0.2806032	0.4026296	3.542059	0.05087297	0.5182378	0.2834612
grand total	1659.538	131.4510	192.8195	1337.467	14.18433	140.5671	110.0003

The following values were obtained for the consumption of fish from the cooling water outlet

fish consumption	288.8582	117.3215	173.5316	1541.407	17.12603	172.9997	115.7621

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POOR ORIGINAL

	bone	whole body	liver	kidney	lung	thyroid	bone marrow
fish consumption							
H 3	0	0.004497164	0.004497164	0.004497164	0.004497164	0.004497164	0.006558165
CO 58	0.07093329	0.07093323	0.03556700	0.005525393	0.07093328	0.07093328	0.07093328
CO 60	0.6915997	0.6915997	0.5471797	0.3147599	0.6515997	0.6915997	0.6915997
ZN 65	0.2707590	0.5288332	1.214417	0.9172533	0.5288332	0.5288332	0.5288332
SR 89	0.5571330	0.01435990	0	0	0	0	0
SR 90	63.79997	1.431333	0	0	0	0	0.5611333
I 131	0.09042174	0.03651047	0.1235465	0.2217071	0	42.38519	0
CS134	21.74998	27.92999	41.79999	332.0999	3.609999	27.92999	27.92999
CS137	65.59666	40.93099	60.29332	638.3999	5.541666	40.93099	40.83099
total	176.2276	71.57874	104.0446	961.5823	10.44731	112.4420	70.62004
leafy vegetables							
H 3	0	0.004497164	0.004497164	0.004497164	0.004497164	0.004497164	0.006558165
CO 58	0.0007802665	0.0007802665	0.0006123697	6.081999E-05	0.0007802665	0.0007802665	0.0007802665
CO 60	0.009509493	0.009509493	0.007521995	0.005324456	0.009509493	0.009509493	0.009509493
ZN 65	0.031514200	0.002961466	0.006800730	0.004540599	0.002961466	0.002961466	0.002961466
SR 89	0.06966662	0.001757503	0	0	0	0	0
SR 90	185.1358	4.158609	0	0	0	0	1.708651
I 131	0.0003477759	0.0002942719	0.0004932557	0.0008527156	0	0.1610703	0
CS134	0.05274999	0.06144599	0.04125995	0.6446109	0.007941935	0.06144599	0.06144599
CS137	0.9269655	0.4205592	0.6210212	6.575519	0.05707916	0.4205592	0.4205592
total	186.1969	4.860202	0.7329037	7.250619	0.08275950	0.6627614	2.210464
root vegetables							
H 3	0	0.004467164	0.004497164	0.004497164	0.004497164	0.004497164	0.006558165
CO 58	1.773331E-05	1.773331E-05	1.351769E-05	1.382249E-06	1.773331E-05	1.773331E-05	1.773331E-05
CO 60	0.001383199	0.001383199	0.001094359	7.751956E-05	0.001383199	0.001383199	0.001383199
ZN 65	0.003145249	0.0003701830	0.0008500915	0.0005685758	0.0003701830	0.0003701830	0.0003701830
SR 89	0.09553329	0.0001405999	0	0	0	0	0
SR 90	1050.927	24.74059	0	0	0	0	9.699188
I 131	0	0	0	0	0	0	0
CS134	0.004156247	0.004887749	0.007314995	0.05296749	0.0006317497	0.004887749	0.004887749
CS137	0.08549678	0.03878944	0.05727865	0.6065798	0.005264580	0.03878944	0.03878944
total	1051.023	24.79065	0.07103920	3.664019	0.01215461	0.04991546	9.751193

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	bone	whole body	liver	kidney	lung	thyroid	bone marrow
potatoes							
H 3	0	0.000017879	0.005076899	[illegible]	0.008076833	0.008076899	0.01180670
CO 58	3.191998E-05	3.191998E-05	2.505164E-05	2.576046E-06	3.191998E-05	3.191994E-05	3.191998E-05
CO 60	0.001556099	0.001556099	0.001711139	8.720496E-05	0.001556091	0.001556079	0.001556099
ZN 65	0.0001942190	0.0003507578	0.000174175	[illegible]	0.0001807558	0.000343759	0.0001837598
SR 89	0	0	0	0	0	0	0
SR 90	40.49277	0.5512619	0	0	0	0	0.3737147
I 131	0	0	0	0	0	0	0
CS134	0.2346606	0.3210105	0.4835167	3.493796	0.04175565	0.3210105	0.3210105
CS137	11.59969	5.444197	8.039206	85.17049	0.7348976	5.444197	5.444197
total	52.76839	6.330523	8.537929	68.67352	0.7906929	5.777252	6.156695
irrigation-milk							
H 3	0	0.03230760	0.03230760	0.03710760	0.03230760	0.03230760	0.04721880
CO 58	0.0002551598	0.0002551594	0.0002004117	1.936419E-05	0.0002551571	0.0002551594	0.0002551598
CO 60	0.003734618	0.003734634	0.002956474	0.0005239193	0.003734634	0.003734613	0.003734636
ZN 65	0.02139230	0.04569117	0.104975	0.07317919	0.04569119	0.04569119	0.04569119
SR 89	0.07022381	0.001731557	0	0	0	0	0
SR 90	116.0063	2.730986	0	0	0	0	1.070642
I 131	0.001377202	0.001145116	0.001277102	0.001376769	0	0.6455517	0
CS134	0.6665999	0.5228495	0.7474959	5.555311	0.06757915	0.5228495	0.5228495
CS137	11.71216	5.313765	7.066572	83.08136	0.7211921	5.313765	5.313765
total	128.2620	8.652532	5.771573	88.84275	0.8707632	6.564151	7.006136
irrigation - meat							
H 3	0	0.00607431	[illegible]	[illegible]	[illegible]	[illegible]	0.01311613
CO 58	0.001099666	0.001099665	0.000445258	8.56994E-06	0.001099665	0.001099666	0.001099666
CO 60	0.01521519	0.01521519	0.01233119	0.0004527154	0.01521519	0.01521519	0.01521519
ZN 65	0.005339100	0.01628806	0.03750601	0.02501743	0.01628806	0.01628806	0.01628806
SR 89	0.01950665	0.0005520997	0	0	0	0	0
SR 90	13.43997	0.7872136	0	0	0	0	0.3086231
I 131	0.0007978541	0.00006726249	0.001145988	0.001961255	0	0.3749456	0
CS134	1.031937	1.213558	1.312709	13.12624	0.1560545	1.213559	1.213558
CS137	27.09749	12.29421	18.15531	192.2221	1.668595	12.29421	12.29421
total	61.61505	14.33776	20.33396	205.3853	1.867026	13.92429	13.86211

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	bone	whole body	liver	kidney	lung	thyroid	bone marrow
livestock watering - milk							
H 3	0	0.01210760	0.01210760	0.01210760	0.01210753	[illegible]	0.04726600
CO 58	0.0001276779	0.0001276779	0.0001007059	9.952196E-05	0.0001276753	0.0001276779	0.0001276799
CO 60	0.001244575	0.001244575	0.0005932551	4.935796E-05	0.001244473	0.001244373	0.001244533
ZN 65	0.03340717	0.01446933	0.03373663	0.02222315	0.01446487	0.01446487	0.01446267
SR 89	0.02006399	0.0005821595	0	0	0	0	0
SR 90	2.189799	0.05157800	0	0	0	0	0.02920080
I 131	0.001001595	0.0008475028	0.001414977	0.002455411	0	0.4695975	0
CS134	0.01047599	0.04524659	0.06771554	0.4336014	0.003543537	0.04524659	0.04524659
CS137	0.1457956	0.06614619	0.09767514	1.014207	0.008577599	0.06614619	0.06614619
total	2.402917	0.2174233	0.2314452	1.580675	0.06297469	0.6290392	0.1946537
livestock watering meat							
H 3	0	0.008974312	0.001974312	0.008974312	0.008974312	0.008974312	0.01311633
CO 58	0.0001546665	0.0001546665	0.0002731500	2.765490E-05	0.0001546665	0.0001546665	0.0001546665
CO 60	0.001457998	0.001457994	0.001715999	0.0001917999	0.001457549	0.001457999	0.001457998
ZN 65	0.001570350	0.003067232	0.007343611	0.004711061	0.003067232	0.003067232	0.003067232
SR 89	0.005513329	0.0001405999	0	0	0	0	0
SR 90	0.6079997	0.01431333	0	0	0	0	0.005651330
I 131	0.0005216618	0.0004414078	0.0007573419	0.001277080	0	0.2445297	0
CS134	0.08906245	0.1047375	0.1567503	1.112874	0.01353750	0.1047375	0.1047375
CS137	0.3374875	0.1531162	0.2261000	2.393499	0.02078125	0.1531162	0.1531162
total	1.046027	0.2806017	0.4026296	3.542059	0.05017297	0.5187378	0.2834612

The following values were obtained f&r the consumption of fish from the cooling water outlet

fish consumption							
H 3	0	0.008704951	0.008704951	0.008704951	0.008704951	0.008704951	0.01272262
CO 58	0.1162736	0.1162736	0.09125436	0.009061117	0.1162736	0.1162736	0.1162736
CO 60	1.133668	1.133658	0.5769679	0.04351521	1.133658	1.133668	1.133668
ZN 65	0.4430125	0.8668617	1.990667	1.311637	0.8668617	0.8668617	0.8668617
SR 89	0.9135704	0.02334710	0	0	0	0	0
SR 90	99.66312	2.346236	0	0	0	0	0.9198079
I 131	0.1347445	0.1140136	0.1939475	0.3303032	0	63.16150	0
CS134	38.73091	45.78276	63.51959	455.2312	5.917533	45.78276	45.78276
CS137	147.5222	66.93002	98.83261	1046.467	9.083843	66.93002	66.93002
total	288.8502	117.3215	170.5316	1543.407	17.12683	177.9997	115.7621

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10. Emission Sources, Exposure Pathways and Factors Not Considered

10.1. Emissions from the Secondary Circulation

Complete tightness of heat exchangers cannot be guaranteed. Therefore, there is the danger that radioactive substances from the primary circulation, which is under high pressure and which is radioactively contaminated after even short operating times, will leak into the secondary circulation. Heating pipe damage in the steam generators was observed in 22 of the water-cooled power reactors inspected in 1975 (GRS, no. 19). "It is usually the result of uniform corrosion" (GRS, no. 21). It can be assumed, therefore, that this type of damage will occur more and more frequently with increasing length of operation. According to figures given in the GRS assessment (GRS, 1976, pp. 3-6), about 12,000 tons of steam per year are discharged to the environment from the secondary circulation without first passing through exhaust gas systems or filtration systems. Since the secondary circulation contains about 600 tons of water, this means that a quantity of water or steam equivalent to the capacity of the secondary circulation is discharged from the secondary circulation to the environment once every 18 days on the average. This means that a considerable quantity of radioactive emissions may leave the nuclear power plant in this way without being filtered or controlled. Moreover, these emissions occur at a low emission height, which means that there is about ten times less meteorological attenuation of these emissions than of the smokestack emissions.

Although the GRS is aware of this problem, the GRS assessment (1976) does not include a determination of the radiation exposure to be expected from these emissions.

The Department of Environmental Protection is preparing a study of this problem.

10.2. Fruit and Other Foodstuffs Not Considered

Considerable quantities of fruit of all types are cultivated in the immediate vicinity of Wyhl (see Table 7.1.3-1).

Satisfactory determinations of the radiation exposure that might be expected from consumption of this fruit is not possible because no studies have been performed for determination of transfer factors.

In this case it does not seem advisable to use any one variety of fruit as a representative for all other varieties, as was done in the 1976 assessment of the Association for Reactor Safety. Neither does it seem appropriate to transfer the required data from other plants since it must be assumed that fruit, in view of its peculiar morphology, also exhibits physiologically specific behavior. There is evidence in the literature that certain varieties of fruit show characteristic enrichment with certain elements.

Raspberries, black currants and gooseberries contain relatively large concentrations of Zn, Mn and Co; these concentrations are correlated with the supply of these elements in the soil (Krupyshev, P.V., 1967). It was also shown that in these types of fruit the Mn content increases during the period of flowering and fruit growth, so that aside from the leaves, the highest concentration is found in the carpels (Krupyshev, P.V., 1969). Apples contain high concentrations of Fe, Mn, Co and Sr (Vigorov, L.I., Sumenkova, T.N., Pashilov, V.A., 1972, and Shkvaruk, N.M., Moiseichenko, V.F., Shkvaruk, R.N., Khanchak, N.E., Shinyan, O.I., 1972). Furthermore, a correlation was found between the surface texture of fruits and their capacity for absorption of radiostrontium (Merten, D., Buchheim, W., 1967).

These references strengthen our suspicion that for individual varieties of fruit there may be both a high level of enrichment of certain nuclides and high nuclide-specific absorption through the surface. It therefore seems critically important that further studies be performed and that separate calculations be performed for the transfer factors of the following fruits:

Apples
pears
quinces
plums
mirabelle plums
peaches, apricots
red and black currants
gooseberries
strawberries
raspberries
blackberries
bilberries
whortleberries
sea buckthorn
sloes

hips

elderberries

rhubarb

In addition, it is necessary to expand the list of foods considered in the GRS assessment since most people have a somewhat more varied diet. The expanded list should include the following:

beans

peas

tomatoes

cucumbers

paprika

eggplant

zucchini

gourd

mangel-wurzel

onions

garlic

horseradish

celery

red beets

comfrey

asparagus

mushrooms (some mushrooms, especially boletus. are known for their high Cs-137 content (BMI, 1974)

nuts (hazelnuts, walnuts, chestnuts, almonds)

spices (parsley, chives, savory, balm; seed spices: fennel, caraway, anise, mustard)

teas: peppermint, sage, chamomile

lamb meat

poultry

snails

game meat

Important radioecological data is presently lacking for almost all of these previously unconsidered foods. The universal factors, e.g., for all plants, that are recommended by the SSK (1977) are scientifically unacceptable.

Consequently, nothing can be said at this time about radiation exposure via possibly important exposure pathways due to lack of basic knowledge.

10.3. Other Factors Not Considered

The following factors were also disregarded:

sediment radiation at the banks of the Rhine from radionuclides that have settled out of the waste water

radiation exposure by iodine-131, tritium in the exhaust air, carbon-14 and all radioactive decay products of the noble gases emitted from the nuclear power plant

radiation exposure for babies (other than by I-131) and embryos.

11. Summary

1. In its calculation of expected radiation exposure, the Department of Environmental Protection used an ecological model of computation on which most such assessments for nuclear power plants are based (e.g., exhaust air assessment of the Institute for Reactor Safety, waste water assessment of the Bavarian Biological Testing Institute for the planned nuclear power plant in Wyhl).

2. The Department of Environmental Protection made an effort to proceed on the basis of realistic assumptions that would make it possible to obtain a realistic estimate of the radiation exposure that might be expected from the planned nuclear power plant (Kernkraftwerk Süd, Wyhl).

Overly conservative assumptions were avoided. For example, our expert analysts thought it unrealistic to assume an annual consumption of 880 l of Rhine water below the nuclear power plant. Such an assumption, the conservativeness of which is emphasized by the SSK and the BBV, would, in the estimation of the Department of Environmental Protection, result in a whole body dose of only about 1.8 mrem/year anyway.

Furthermore, the Department of Environmental Protection considers it unrealistic to assume that many totally unclothed persons would loiter near the fence surrounding the nuclear power plant. This assumption would be relevant only for the beta submersion dose, which was calculated to be 0.8 mrem/year in this unrealistic case. As in other cases, examination of this case showed that in the recommendations of the Radiation Protection Commission and in the assessments of the GRS and BBV, overly conservative assumptions were made mainly in regard to exposure pathways whose contribution to the total radiation exposure is rather insignificant.

Our experts at the Department of Environmental Protection therefore proceeded on the basis of realistic assumptions.

3. It was found that the uniform bases of calculation used by the SSK, BGA, BMI, TÜV, GRS, BBV and the Jülich and Karlsruhe nuclear power plants, which produce the well-known result that the maximum radiation dose in the vicinity of a nuclear power plant is below the level specified in section 45 of the Radiation Protection Law, are incomplete and incorrect and do not meet the requirements set forth in section 45.

In particular, we found the following errors:

The meteorological long-term dispersion factor assumed in the GRS assessment was about 2.5 times too low, so that the meteorological attenuation was about 2.5 times too high. This factor enters linearly into the calculation of the radiation doses. The principal cause of this error is an overly coarse gradation of the wind speed classes in the GRS assessment, with the result that weather situations involving light winds, in which radioactive emissions are only slightly attenuated, were averaged out.

The assumed nuclide spectrum for radioactive aerosols was not conservative. In particular, the percentage of cesium-137 that was used was too small.

The enrichment factors for the passage of radionuclides from the soil into crop plants were between 10 and 1000 times too low in the most critical cases (see, for example, the figures on pp. 41, 44 and 48).

The transfer coefficients for the passage of radionuclides from forage into beef, pork and milk were between 10 and 100 times too low in the most critical cases (see, for example, the figure on p. 51). These transfer coefficients enter linearly into the calculation of the radiation exposure by these exposure pathways.

The transfer factors for the passage of radionuclides from foodstuffs into the bloodstream via the gastrointestinal tract were between 10 and 20,000 times too low (see, for example, plutonium on p. 91). These transfer factors enter linearly into the calculation of the radiation exposure.

The value assigned for the biological half-lives of radionuclides in the human organism were too low for some radionuclides.

The nuclide composition of the radioactive noble gases was totally unrealistic. Consequently, the calculated radiation exposure from radioactive noble gases was about 5 times too low.

The errors listed above apply to an equal or similar extent to the bases of computation of radiation exposure that are recommended by the Radiation Protection Commission (SSK, 1977).

It was also found

that important exposure pathways, such as the submersion radiation exposure from radionuclides from the exhaust air emission deposited on the ground, were not calculated in the GRS assessment.

4. In the present assessment the Department of Environmental Protection calculated the radiation exposure to be expected from the following exposure pathways:

radiation exposure from noble gases

radiation exposure from ground radiation

radiation exposure from consumption of the following foodstuffs: milk, beef, pork, cereal grains, potatoes, leafy vegetables, root vegetables, wine and fish.

5. These calculations show that the permissible maximum values specified in section 45 of the Radiation Protection Law would be clearly and sometimes greatly exceeded.

The most important results are summarized below. The complete results of the computer programs are given in section 9 above.

Radiation Doses from Radioactive Exhaust Air

ADULTS (All values in mrem/yr)

	whole body	thyroid	kidney	bone
noble gas radiation	31	31	31	31
ground radiation	15	15	15	15
total of various food-stuffs	784	809	10,872	4,820
wine	110	96	1,383	937
Total	940	951	12,300	5,803
maximum value in accordance with section 45 of the Radiation Protection Law	30	90	90	180

Babies (only iodine-131

	thyroid
cow's milk	753
goat's milk	2,204
sheep's milk	2,501
maximum value in accordance with section 45 of the Radiation Protection Law	90

Radiation Dose by Radioactive Waste Water with Utilization of Rhine water

Adults

	whole body	thyroid	kidney	bone
fish+	72 (117)	112 (178)	942 (1,543)	176 (289)
other foodstuffs	60	28	396	1,483
Total	131	141	1,338	1,660
Maximum value in accordance with section 45 of the Radiation Protection Law	30	90	90	180

+The values in parentheses give the radiation doses for consumption of fish from the cooling water outlet.

The radiation doses given above are based on only one of the two nuclear power plant blocks that are planned for Wyhl.

6. The following factors, influences and exposure pathways, all of which cause an increase in the radiation exposure, have not been taken into consideration in the above results:

discharge of unfiltered radioactivity through safety valves and steam valves and from the machine house

discharge of radioactivity from the fuel element storage tanks, in which the consumed fuel elements presumably would have to be stored for very long periods of time due to difficulties with the planned reprocessing emissions of the radionuclides iodine-131, tritium (exhaust air), carbon-14 and all radioactive decay products of the emitted noble gases

exposure pathways fruit, nuts, mushrooms, spices, game meat etc.

sediment radiation at the banks of the Rhine from radionuclides that have settled out of the waste water

radiation exposure by inhalation (inhalation of radionuclides)

effects of the structure and water release of the planned cooling towers (reduction of the meteorological attenuation and increase in the wet deposition)

increase in the nuclide concentration of the Rhine during the irrigation period in the summer due to above-average quantities of emissions while the fuel elements are being changed

the calculation of the radiation exposure was performed only for adults. For babies it was performed only for radiation exposure by iodine-131. It was not performed for the most sensitive stage of human life, i.e., the embryonal stage, because important radiological bases of calculation are unavailable.

preexisting radiation loads from radioactive emissions of other nuclear power plants and nuclear facilities with the exhaust air.

Although none of these problems has yet been taken into consideration (mainly because of a lack of scientific data), it can definitely be said on the basis of the effects calculated in this assessment, that the legally stipulated maximum permissible values will be significantly exceeded with the design of the planned pressurized water reactor in Wyhl, even if the plant is properly operated as authorized.

Appendix

Biological Effect of Ionizing Radiation

1. Basic introduction
2. Excursus: Radiation damage on the molecular level
3. Statistical studies on radiation damage in man
4. Discussion of the tolerance limit
5. Discussion of the dose factors
    a) calculation, average person
    b) radiosensitivity of the tissues
    c) inhomogeneous microdistribution
6. Radiation damage in the embryo and fetus
    a) elevated organ concentration
    b) dependence on the stage of development
    c) threshold value, late damage
    d) statistical studies on the human embryo

1. Basic Introduction on the Effects of Radiation on Man

Due to its ionizing effect, the radiation emitted in radioactive disintegration causes damage to or destruction of human cells, organelles and biological molecules. The extent of the damage depends on the penetrating power of the radiation, the duration of the irradiation, whether the whole body is irradiated or only parts of it, and on other factors. We can distinguish between latent and manifest damage, i.e., early and late damage.

We shall be concerned to discuss the somatic effects of low doses of radiation to which people are exposed from the "normal" operation of nuclear power plants, rather than the effects of a nuclear accident (which are death, acute radiation sickness and early damage).

Even small radiation doses (mrem range) are able to cause impairment of vital organs and manifest and fatal disorders of the organism. Many results of radiobiological experiments and extensive statistics prove this. In particular, many irradiation experiments have been performed on animals in order to determine the risk to man of radiological testing and handling methods.

2. Excursus: Radiation Damage on the Molecular Level

Radioactive radiation has a variety of biological consequences. Independent of the location of the radiation source (i.e., inside or outside a cell), the following types of damage may occur:

1. Damage to the cell membrane (e.g., Petkau, A., 1972; Scott, K.G., et al., 1973)

2. Changes in the enzyme pattern (e.g., Mintzel-Landbeck, L. Hagen, U., 1976; Cerutti, P.A., 1974)

3. Effects on the genetic substance of DNA (deoxyribonucleic acid) (e.g., Weish, P., Gruber, E., 1975; Várterész, V., 1966).

Radiobiology is concerned especially with effects on the genetic substance because changes in this molecular area and all of the consequences of these changes are passed on to the daughter cells during cell division (e.g., mutations, transformation of a healthy cell into a cancer cell). Although the probability that damage will be caused is greater when large doses are involved, the disintegration of a single radionuclide can be enough to cause the mutation of one or more cells. For example, the disintegration of one tritium particle incorporated in the DNA can cause an average of 2.1 strand breaks in the DNA (Cleaver, J.E., et al., 1972). As the discussion of the molecular events shows, any determination of a dose threshold value must be considered arbitrary.

Unfortunately, only a few papers have been published on the biological effects of natural radiation and on synergistic environmental effects. It has been experimentally demonstrated that a decrease in the natural background radiation induces a decrease in the cell growth rate (IAEA, 1976), which is concrete evidence that even natural radiation affects cellular mechanisms. This conclusion is supported by the results of epidemiological studies in Kerala (India), where a high level of background radiation caused by thorium-containing rock is associated with a high incidence of mongolism (Down's syndrome) and other mental deficiencies of genetic origin (Kochupillai, N., 1976).

The question of the reversibility of radiation damage has been under discussion for several years. Enzymatic mechanisms are known which are able to repair the DNA strand breaks mentioned above. In in vitro experiments the best results that have been achieved so far have been repair of 80% of artificially induced strand breaks (Mitzel-Landbeck, L. et al., 1976).

The efficiency of these mechanisms in vivo depends on the type of radiation source. The strand breaks produced by UV radiation are not repaired by the same enzymes as strand breaks caused by gamma rays (Hariharan, P.V., Carutti, P.A., 1976). I-125 incorporated in DNA produces strand breaks, a maximum of 50% of which can be repaired (Painter, R.B. et al., 1974). Little is known about the consequences of unrepaired strand breaks. In most cases they probably result in the death of the cell. An error in the repair can have disastrous results (mutations).

Ionizing radiation can produce not only strand breaks, but also chemical changes in the subunits of the DNA (Cerutti, P.A., 1974). This damage can be identical to damage produced by alkylating agents (including such environmental poisons as benzpyrene and nitrosamines) (Trosko, J.E., Chu, E.H.Y., 1975). The carcinogenic effect of ionizing radiation is demonstrable by the identity of damage produced by ionizing radiation and alkylating agents (so-called radiomimetic substances).

3. Statistical Studies on Radiation Damage in Man

The most important result of these molecular biochemical experiments and of many animal experiments is the significant increase in cancer as a late consequence of low-level radiation (Little, J.B. et al., 1975). There is a linear relationship between the amount of time by which life is shortened and radiation dose (Bacq, Z.M., Alexander, P., 1955); this linear relationship can also be observed in the mrem dose range. The shortening of life is a result of many kinds of late damage, e.g., loss of vitality with diminished resistance to disease, early onset of aging processes, and diminished power of regeneration.

Statistics from the United States and Japan confirm the results of these experiments. Some of the problems in this area which have been statistically analyzed are the following: Disease status of workers in nuclear power plants (Mancuso, T.F. et al., 1976; Wagoner, J.K. et al., 1963), effects of increased natural radioactivity (Gentry, J.T. et al., 1959; Kochupillai, N., 1976; Pincet, J., Marsé, L., 1975), atomic bomb victims of Hiroshima and Nagasaki (Jablon, S. et al., 1965; Brill, A.B. et al., 1962), radiation injury in pregnant women (Stewart, A., Kneale, G.W., 1970). A common finding in these studies was a significant increase in morbidity and mortality of the individuals involved, primarily in regard to cancer.

A few examples:

Among workers in nuclear power plants the incidence of cancer is clearly a function of radiation exposure (Mancuso, T.F. et al., 1976). The incidence of congenital deformities is directly dependent on the radiation dose from natural radiation (study on 1.24 million infants in New York State) (Gentry, J.T. et al., 1959). In a study on 19 million children in Great Britain, Stewart at Oxford University determined that a doubling of the number of radiographs of pregnant women is associated with a doubling of the risk of leukemia and other forms of cancer in their offspring, and that irradiation with 80 mrem in the first trimester is enough to double the incidence of leukemia and cancer in children up to 10 years old (Stewart, A., Kneale, G.W., 1970). In West Germany a dose of 60 mrem/year by nuclear power plants is allowed; the thyroid dose for children may be 90 mrem/year. The risk of irradiation of unborn children and newborns is discussed in greater detail in section 6.

A comprehensive study by the National Academy of Science in America, which was commissioned by HEW (BEIR report, 1976), contains estimates of the risk for cancer, leukemia and hereditary diseases from chronic low doses of radiation. On the basis of the data in this report, we have determined the following results of an additional radiation dose of 60 mrem/year in West Germany (the legally permitted dose):

a) an additional 40 to 700 cases per year of serious dominant hereditary disease in the first generation,

b) a fivefold increase in the number of cases of hereditary disease after a few more generations, and

c) an additional 500 - 1400 cancer deaths per year.

In a risk assessment performed for the AEC, Gofman, J.W. et al. (1971) estimate even higher values (2000 to 12,000 cancer cases per year at 60 mrem additional radiation exposure for West Germany).

The BEIR report contains a critical discussion of the validity of this type of risk assessment:

"It is clear that these estimates are subject to great uncertainty. The range of credible values is large, and there is no guarantee that the actual values fall within this range. We are well aware that future information will necessitate revisions. The estimates that have been given are not exact scientific values (as scientists we would prefer to reserve judgment until reliable information becomes available), but they are reasonable values that are based on present scientific knowledge, and however rough and uncertain these estimates may be, they are better than no estimates at all since some degree of orientation is advisable when we are dealing with radioactivity."

The population that will be affected and the politicians have to have some idea of the risk; the known qualitative effects of radioactive radiation must be quantified. The presently available estimates are the only quantifications that are possible at this time. In the course of this discussion we shall elaborate on the difficulties that prevent absolutely certain knowledge of these relationships (no radioactive irradiation experiments on man, observation time too short, sometimes difficult diagnosis of the diseases caused by radiation, cause-and-effect relationships difficult to survey, etc.).

The quantifications of the radiation risk from nuclear power plants that are given in the large studies (e.g., BEIR report, UNSCEAR report, papers by Gofman or Tamplin) are not overestimates since only the mean values were taken from the possible risk range. This fact is illustrated by the BEIR report, in which various mathematical models and various parameters were used to estimate the cancer death risk in the United States if the maximum permissible radiation levels were reached; values of 2000 to 9000 deaths per year were obtained from these calculations, but the final estimate that was given was 3000 to 4000 deaths per year. If conservative assumptions are desired, i.e., if we wish to consider the greatest possible damage that could result from the use of nuclear technology, then we would have to work with figures from the upper range of these estimates.

4. Discussion of the Tolerance Limit

In light of present knowledge, it is no longer possible for any radiologist to determine a so-called threshold value, below which genetic and somatic damage will not occur. Stokke et al. found damage of bone marrow cells at a dose of only 8 mrem (Stokke, T. et al., 1968).

Although radiation doses in the mrem range had at one time been demonstrated to have biological effects only on fungi, damage to rat bone marrow has now been observed after doses of only a few mrem Sr-90 per week. Lung cancer has been induced in hamsters with Po-210 doses of only a few mrem (Little, J.B. et al., 1970). The eminent radiation geneticist H.J. Muller stated on the basis of his experiments with fruit flies (Drosophila), that there is no threshold value below which ionizing radiation is ineffectual. To a certain degree of probability, every single ionization must be regarded as effectual (Beck et al., 1959). This is especially true where the development of cancer is concerned. It could well be that it is precisely low radiation doses that are capable of giving rise to cancer since high doses damage the cells so severely that they die and are then usually dissimilated by the organism, so that cancer cannot develop. Low doses also damage the cells, but usually not so severely that the cells are unable to continue living and dividing. Multiplication of the cells results in multiplication of the cell damage, which in turn may result in the development of a malignant tumor. There is no minimum dose below which radioactivity can be regarded as definitely not cancer-inducing (Oberling, C., 1944).

In regard to carcinogenesis, it must be considered that the disease is usually triggered by several factors (BEIR report, 1972), and that the induction of a tumor must be regarded as the result of radiation damage to one or only a few cells. The BEIR report therefore assumes a linear dose-effect relation with no threshold value for carcinogenesis and leukemogenesis. The threshold value is a hypothetical quantity that is not supported by any theory of tumor induction or empirical evidence.

There is still another difficulty. Cancer often does not appear until many years after the causative damage has occurred. There may be a latent period of 5 to 30 years (Cleaver, J.E. et al., 1972). The long dormancy of the cancer makes it much more difficult to establish causal connections between irradiation (cause) and cancer (effect), i.e., many cancer patients will never know that their disease was caused by the action of radiation (including, for example, x-ray examinations).

5. Discussion of the Dose Factors

a) By definition, the dose factors establish a connection between organ dose and the time integral of the concentration, i.e., they express the biological radiation load by a given quantity of radioactivity, specifically in the organs of the human body, in the form of a single numerical value. The following list of the parameters that have to be considered shows how many imponderables and individual differences cannot be taken into account.

The radiation dose in an organ depends on the following factors:

1. Quantity of the absorbed nuclide
2. Type of radiation emitted
3. Energy of the radiation
4. Half-life of the nuclide in the organ, dwell time
5. Selection factor of the organ
6. Mass and form of the organ
7. Distribution of the activity in the organ
8. Chemical compound of the incorporated substance

These parameters depend in turn on the following:

age

sex

state of health

genetic constitution

food composition

In estimating the radiation exposure from a nuclear facility, the estimate is based on the "critical" points, e.g., on the "critical" population group, i.e., the group which will be affected most strongly by the radiation exposure.

These risk calculations are based on the so-called "average" person, i.e., on a model of the adult human being in which rigid physical and physiological parameters are used (e.g., 70 kg body weight, 1.2 l fluid intake per day etc.). However, this does not represent the critical population group, for there are population groups whose physical and physiological characteristics lead to greater radiation exposure.

For example, liquid intake is higher in certain metabolic diseases (e.g., diabetes mellitus). All metabolic diseases result in changes in the normal parameters due to changes in metabolic processes, so that, for example, the dwell time of incorporated radionuclides in the organism may be increased. The radiation dose is thus increased. (Belcher, E.H. et al., 1971; Barth, G. et al., 1968).

Furthermore, population groups in which previous damage has been caused by other noxae must also be regarded as critical groups. This means that the effect of the additional radiation exposure will be greater in these groups than in groups in which there is no preexisting damage. The following examples illustrate this:

Previous damage to an organ (the lungs of smokers, the skin of photosensitive individuals) enhances the effect of ionizing radiation and thus increases the danger of radiation damage.

A number of chemical compounds, e.g., certain antibiotics, sex hormones and the like, increase the radiosensitivity of tissues, which are then more susceptible to damage.

Metabolic changes, such as diabetes mellitus, nephrosis, hyperthyroidism and the like, result in greater radiosensitivity of the organism due to previous injury of the tissues, increased dwell time of the radionuclide, or restriction of possible r pair mechanisms. (It is precisely the metabolic changes characteristic of a metabolic disease and the associated changes in the radionuclide distribution in the organism and tissues which are utilized in nuclear-medical diagnostics.). (Belcher, E.H. et al., 1971; Emrich, D., 1971; Barth, G. et al., 1968)

These effects show that our calculations should not be based on the group of average persons, but rather on the population group in which deviations from the normal parameters of the average person result in an increase in radiation dose. The customary procedure of basing these calculations on the normal population does not conform to present knowledge in medical science, which is now concerned mainly with cybernetic control systems and multifactorial cause-effect analyses, and which for the most part now rejects schematic-mechanical approaches to the human body.

b) Radiosensitivity of the Tissues

The dose factors that have been calculated in the past have generally been for the bone, lung, liver, kidney, and gastrointestinal tract, and in some cases for the spleen, thyroid and muscle. The testbooks on nuclear medicine and radiation protection judge most of these tissues to be moderately radiosensitive (bone, thyroid) or even relatively radioresistant (liver, kidney, muscle) (Pabst et al., 1976; Sauter, 1971; Barth, G. et al., 1968). Only the spleen and gastro-intestinal tract exhibit a high degree of radiosensitivity. The other highly radiosensitive tissues are the following:

embryonal tissue

lymphatic tissue

thymic tissue

bone marrow

testicular tissue

ovarian tissue

(Pabst et al., 1976)

Specific dose factors are not used for these highly radiosensitive tissues, i.e., the moderately radiosensitive tissues and relatively radioresistant tissues are considered in most calculations of the relative biological activity of nuclear power plant emissions, while the highly radiosensitive tissues are not included in the calculations. The radiosensitivity of cells increases with their reproductive activity and decreases with their degree of differentiation (Barth, G. et al., 1968). The more frequently and faster a cell multiplies and divides (the process of cell division is the most radiosensitive), the less specialized it is and the more radiosensitive it is. This is true of embryonal tissue, hematopoietic tissue (lymph nodes, spleen, thymus, bone marrow), white and red blood cells, and gonadal tissues (testis, spermatozoa, ovary, and follicle). This provides the pathophysiological explanation of the fact that primarily embryonal damage, carcinoma of the hematopoietic tissues, especially leukemia (i.e., cancer of the white blood cells), and genetic defects occur in individuals who are exposed to radioactivity.

c) Inhomogeneous Microdistribution

Furthermore, it is necessary to distinguish not only among the various radiosensitive tissues, but also to consider the specific exposure within each organ. Bone is an example. It consists of marrow, compact substance (shaft), spongy substance (epiphysis), a layer of cartilage (covering the articular surface of the bone), and the endosteum (tissue lining the medullary cavity) and periosteum (tissue covering the outside of the bone). Radionuclides are not uniformly distributed in this bone system (Sugahara and Hug, 1971):

> Alkaline earths are deposited principally in the epiphysis and the calcification zones during the growth period; in adults they are deposited mainly in the mineral zone under the periosteum, in the endostium, and in newly formed compact substance and spongy substance. This applies to the elements calcium, radium, strontium, barium and phosphorus.
>
> Depending on their manner of incorporation and chemical structure, plutonium and thorium are deposited in bone, especially in the periosteum, endosteum and bone marrow.
>
> Americium, rare earths and transuranium elements become concentrated in the bone marrow and at the surface of the bone.

Our criticism of the dose factors can be expanded. Other problems include the following: important radionuclides are disregarded, there is no specific evaluation of the organic damage with respect to effects on the total organism, undiscoverable damage, e.g., of the immune system, synergism, potentiating effect of damage to more than one organ. However, the questions that have been raised should be reason enough to regard the use of the customary dose factors for calculations of the radiation exposure as completely unsatisfactory.

6. Radiation Damage in the Embryo and Fetus

The greatest radiological problem is without doubt the accumulation of radioactive substances during pregnancy and subsequent irradiation of the human embryo.

a) Elevated Organ Concentration

The formation and destruction of cells are in transient equilibrium in the adult human body. This means that radionuclides absorbed by the adult human body have a shorter biological half-life than radionuclides absorbed by the embryo. Embryonal and fetal tissue is formed at a relatively fast rate; destructive processes occur only to a limited extent. This high rate of formation results in a high rate of substance absorption, including radioactive substances; the absorbed radionuclides are then incorporated in the body of the embryo and later the child with a high biological half-life. It follows that for a given concentration of radionuclides in the environment, the embryo has by far the greatest radiation exposure.

Experiments on rats and dogs have shown that 38% of the strontium and 66% of the cesium intake of the mother animal reaches the fetus transplacentally ~~and is deposited in it~~ (Sikov, M.R., Mahlun, D.D., 1969). In the pig (the experimental animal whose physiology is closest to human physiology) the deposition of radiostrontium in the fetuses is ten times greater than in the uterus and placenta. Thus, radiostrontium is able to pass through the placental barrier (Werner, H., 1971). Long-term studies on large and small mammals with extremely low doses of radioactive iodine (I-131), e.g., absorbed from atmospheric radioactive fallout, showed absorption rates of mother to fetus of 1 : 3 (Book S.A., Goldman, M., 1975; Eisenbud, M., 1968). A fetal thyroid gland contains 4 to 5 times the dose of I-131 as the thyroid of an adult.

The artificial plutonium radioisotope becomes distributed through the entire body in the course of fetal development, but especially large amounts are deposited in the bones and liver. Pu-239 is present in the newborn's liver in amounts 20 times greater than in the adult liver. Calculation of the Pu-239 radiation dose required to induce cancer showed that the value for adults is 11 times greater (45 times greater in the case of leukemia) than the dose that is sufficient for tumor development in the newborn (Sikov, M.R. and Mahlun, D.D., 1972).

When these high absorption rates are converted for the body weight of a fetus (e.g., a fetus weighing 1 g compared to a woman weighing 60 kg), we find that the child in utero is exposed to a radiation dose that is several powers of ten greater.

b) Dependence on the Stage of Development

Comprehensive experiments performed by Wilson and Russell on rats and mice show that the radiosensitivity is much greater in the early stages of embryonal development than in the later stages (Braun et al., 1973; Hug, Zuppinger, 1972; Wilson, J.G., 1973). The zygote (the fertilized ovum before implantation in the uterus) is extremely radiosensitive; it is destroyed by relatively low doses of radiation and then resorbed; if it survives, exencephaly (brain located outside the skull) and cataract are likely to occur. Irradiation during the organ-forming stage (in the human embryo in the second and third weeks) causes (according to the authors cited above) a lower resorption rate but a high incidence of deformities, e.g., hydrocephalus, microphthalmia (abnormal smallness of the eyes), anencephaly (absence of a brain), micrencephaly (abnormal smallness of the brain), deformities of the teeth, nose, retina and herniation. In the fetal phase (in man, from the fifth week after conception until birth) the CNS (especially the cerebellum) and the eyes are highly radiosensitive; total absence and defective development of these organs have been observed.

c) Threshold Value, Late Damage

In experiments with relatively low radiation doses (5 R) (e.g., wholebody dose allowed by the West German Radiation Protection Law for occupationally exposed persons, women in nuclear power plants), investigators have found significant genetic damage, growth retardation, accelerated aging processes and skeletal changes (Wilson, J.G., 1973; Jacobsen, L., 1968; Medical Memorandum on the Industrial Use of Nuclear Energy, 1976). In various experimental animals (e.g., rat, cow) radionuclide concentrations of 4 nCi/g body weight increase the death rate of newborns and reduce their weight and fertility.

Another important problem must be considered in this connection. Many types of embryological radiation damage are undiscoverable, especially after irradiation with small doses over long periods of time. (Quote from Braun et al., 1973: "Our knowledge about radiation damage in the fetal stage is unsatisfactory. Developmental anomalies induced by ionizing radiation in the late fetal period show definite morphological/anatomical manifestations only in a very small number of cases and can be discovered only by histological and biochemical methods. Radiation damage of this sort is no less important than "drastic" deformities; the damage simply may not manifest itself until the postnatal stage, by which time it has become difficult to recognize the qualitative connections between cause and effect.")

The types of damage involved here are growth retardation, losses of activity, nervous disorders and biochemical defects (Wilson, J.G., 1973; Medical Memorandum on the Industrial Use of Nuclear Energy, 1976).

The animal experiments prove that there is also no threshold value or tolerance limit for embryonal radiation damage (Jacobsen, L., 1968). Genetic defects, chronic changes and cancer can be caused by even the smallest doses of radiation (Wilson, J.G., 1973).

d) Statistical Studies on the Human Embryo

It is becoming increasingly apparent that the results of animal experiments very probably are valid in man as well. The evaluation of data from the initial phase of radiotherapy, consequences of radiography, studies on the atomic bomb victims of Hiroshima and Nagasaki, and extensive statistics from recent years show significant effects of radiation on embryos and infants.

Stewart found an almost 100% increase in leukemia and other cancers in children whose mothers had had x-rays of the abdomen during the first trimester of pregnancy compared to children whose mothers had not had obstetric x-rays (Stewart, A., 1973; Stewart, A., Hewitt, D., 1965; Stewart, A. and Kneale, G.W., 1970; Stewart, A. et al, 1958). Studies by MacMahon and Kneale confirm this (MacMahon, B., 1962; Kneale, G. W., 1971). Even children whose parents had been x-rayed 5 to 15 years before the mother's pregnancy had a significantly greater chance of developing leukemia (Gibson, R.W. et al., 1968; Kessler, I.I. and Lilienfeld, A.M., 1969).

Many other studies could be cited. However, the results that have been given are sufficient to show that the child in utero represents by far the most radiosensitive stage of human life and the stage that is most threatened by radiation. This fact has not been considered in any way in the licensing procedure for nuclear power plants.

According to the presently lawful West German Radiation Protection Law, the radiation exposure resulting from leakage of radioactive substances into the air or water from nuclear power plants must be kept "as low as possible" and may not exceed 30 mrem/yr for the whole body or 90 mrem/yr for the thyroid. In addition, section 45 of the Radiation Protection Law stipulates: "This radiation exposure must be computed for the most unfavorable cases and points of exposure, with due consideration being given to all relevant exposure pathways, including the food chains."

Therefore, calculations of the radiation exposure expected for man must be submitted as part of the licensing procedure for nuclear power plants. However, these calculations are based on the physiological conditions in a "healthy, average person". Unfavorable cases, such as sick and old persons, children, and especially children in utero, are not taken into consideration. This procedure does not comply with the explicit demands of the law.

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ABBREVIATIONS USED IN THE TEXT

BBV = Bavarian Biological Testing Institute.

Ci = Curie. Unit for the quantity of a radioactive substance in which 37 billion disintegrations per second occur.

GRS = Association for Reactor Safety, a private company which prepares assessments for nuclear power plants. Financed by the federal government and by the TÜV.

KWS = Karnkraftwerk Süd GmbH, Karlsruhe.

mrem = Unit of Radiation Dose.

pCi = picocurie = 10^{-12} Curie.

RSK = Reactor Safety Commission. Advises the Secretary of the Interior. 13 members, exclusively advocates of nuclear energy.

SSK = Radiation Protection Commission. Advises the Secretary of the Interior. 13 members, exclusively advocates of nuclear energy.

SSVO = Radiation Protection Law.

TÜV = Industrial Supervisory Association. Industrial association whose members include, for example, all nuclear power plants and manufacturers of nuclear power plants.
Prepares assessments on nuclear power plants by commission of the licensing authorities.

BMI = Federal Department of the Interior.

BMBW = Federal Department of Education and Science.

BGA = Federal Bureau of Health.

IRS = Institute for Reactor Safety.

DWD = German Weather Service.

RS

TDR-TMI-116

Revision 0

July 31, 1979

ASSESSMENT OF OFFSITE RADIATION DOSES FROM THE THREE MILE ISLAND UNIT 2 ACCIDENT

[PRINCIPAL PORTIONS OF TOTAL REPORT, EXCEPT FOR SOME TABLES AND APPENDIXES)

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Assessment of Offsite Radiation Doses
from the Three Mile Island Unit 2 Accident

EXECUTIVE SUMMARY

Estimates of offsite radiation doses from the accident at Three Mile Island are summarized in the table on page v. The most significant doses are from the release of airborne radioactive noble gases. The best estimate of maximum potential whole body dose from noble gases at any offsite location is 76 millirem. The analogous estimate of cumulative population dose within a 50-mile radius is 3500 person-rem.

Based on techniques used in this analysis, dose estimates are consistent with the release of about seven million curies of noble gases in the first one-and-one-half days of the accident, two million in the next two days and one million in the next three days, and a relatively small amount thereafter.

The estimates were made by Pickard, Lowe and Garrick, Inc. based on radiation measurements made in the plant and in the field by Metropolitan Edison and Porter-Gertz Consultants, Inc., and on meteorological data from the Three Mile Island weather tower.

EXPOSURE FROM NOBLE GASES

Strip chart records from all noble gas radiation monitors in the plant ventilation exhaust show no significant radiation levels during the first three hours of the accident.

Since these monitors are in the most probable pathway for release, it is concluded that no significant releases occurred before 0700 on March 28. Shortly after 0700, however, these monitors, which are designed to read normal low levels, indicated rapidly increasing radiation concentrations. Within a few minutes, they went off scale on the high side. At about the same time, the in-plant building area monitors which measure radiation levels inside the fuel handling and auxiliary buildings began to record increasing levels from about 1 milliroentgen per hour at 0700 to 100 milliroentgen per hour at 0740. At about 0900, the readings began to increase again and reached about 1000 milliroentgen per hour at 1000 hours. They continued to fluctuate at high levels for about four days. One or more of these area monitors continued to read on scale during the course of the accident.

Gamma doses outside plant buildings and offsite were measured by thermoluminescent dosimeters (TLDs) at 20 stations located around the plant at distances from 260 to 24,000 meters. The TLDs were in place as part of the routine environmental monitoring program when the accident started. They were used to measure integrated gamma dose over selected time intervals during the course of the accident.

Measurements from the TLDs and in-plant area monitors were used to estimate offsite doses from the release of radioactive noble gases. First, it is assumed, for reasons discussed in the body of this report, that radiation levels measured by area monitors in the auxiliary and fuel handling buildings are proportional to the rate at which airborne gamma activity was released to the environment. These assumed relative release rates were combined with contemporaneous atmospheric dispersion estimates to calculate gamma doses for the exposure time period and location of each TLD. Then release rates were adjusted so that calculated doses best matched the TLD dose measurements. Once the release rates were defined in this way, they were used along with the same atmospheric dispersion model and weather data to calculate doses at all offsite locations out to 50 miles.

EXPOSURE FROM AIRBORNE IODINES

The best estimates of potential maximum individual thyroid dose from airborne iodine are about 10 millirem from air inhalation, and 1.1 millirem from drinking milk. The best estimates of population exposure within 50 miles of the site due to iodine inhalation and drinking milk are, respectively; 180 and 1100 person-rem to the thyroid.

Air leaving the plant vent was sampled continuously to measure radioactive iodine during the course of the accident. These measurements indicate about 14 curies of iodine-131 were released from the station vent through April 30th. Airborne iodine-131 concentrations were also measured at eight offsite locations. The offsite concentration measurements were compared with concentrations calculated using measured release rates and weather data. The measurements and calculations were used to estimate the offsite doses.

Preliminary evaluations of particulate radioisotopes in airborne effluents indicate that these isotopes did not contribute significantly to offsite doses.

EXPOSURE FROM LIQUID RELEASES

The maximum individual dose from radioactive materials in water released from the plant during the course of the accident is estimated to be much less than one millirem. The corresponding population dose from drinking water, eating fish, and recreational uses of the river is less than one person-rem.

Analyses of samples from discharged water and the river indicate that iodine-131 is the only significant ? accident-generated isotope released from the plant. The best estimate is that 0.24 curies were released from March 28 through April 30.

Samples of river water collected downstream have shown no increase over normal background concentrations of radioactive materials except for four samples. Three of these are from the Columbia Water Treatment plant, about 17 miles downstream. These three samples were taken within the first five days after the accident started. They showed iodine-131 concentrations slightly above detectable levels but far below allowable limits. Iodine-131 was also detected just above minimum detectable limits in one sample collected on April 27 from the Wrightsville Water Treatment Plant about 16 miles downstream.

+Composite began 4/10

*Composite began 2/28

TABLE D-6

Air Particulates - Air Iodine
(Gross Beta) (Iodine-131)
pCi/m³

		Station	3/21-3/29	3/29-3/31	3/31-4/3	4/3-4/6	4/6-4/9	4/9-4/12	4/12-4/15	4/15-4/18	4/18-4/21	4/21-4/24	4/24-4/27	2/2-4/3
North Weather Station	AP-GROSS BETA	1S2	0.033	0.17	0.035	0.043	0.058	0.057	0.058	0.030	0.091	0.10	0.067	0.0
Falmouth Sub.	AP-GROSS BETA	8C1	<0.002	0.0387	0.013	<4.17	-	0.220+	0.071	0.028	0.069	0.076	[illegible]	0.034
Observation Cntr.	AP-GROSS BETA	5A1	0.025	0.21	0.026	0.073	0.047	0.040	0.028	0.160	0.040	0.040	0.039	0.053
West Fairview	AP-GROSS BETA	15G1	0.035	0.12	0.032	0.039	0.047	0.041	0.047	0.042	0.074	0.074	0.060	0.035
Drager Farm	AP-GROSS BETA	7F1	0.065*	0.19	0.084	0.074	0.110	0.096	0.070	0.069	0.140	0.140	0.092	0.073
Drager Farm	AP-GROSS BETA	7F1Q	0.124*	0.155	0.202	0.04	0.06	0.04	0.05	0.04	0.09	0.08	0.051	0.033
Middletown	AP-GROSS BETA	1C1	0.039*	0.24	0.035	0.044	0.06	0.065	0.047	0.041	0.110	0.060	0.053	0.039
Middletown	AP-GROSS BETA	1C1Q	0.124*	0.212	0.184	0.04	0.06	0.03	0.05	0.03	0.09	0.05	0.044	0.030
Goldsboro Air Station	AP-GROSS BETA	12B1	0.049*	0.22	0.038	0.045	0.038	0.061	0.053	0.027	0.089	0.073	0.053	0.051
North York Sub.	AP-GROSS BETA	9G1	0.034*	0.10	0.045	0.038	0.048	0.046	0.038	0.029	0.069	0.058	0.052	0.042

		Station	3/21-3/29	3/29-3/31	3/31-4/3	4/3-4/6	4/6-4/9	4/9-4/12	4/12-4/15	4/15-4/18	4/18-4/21	4/21-4/24	4/24-4/27	2/2-4/3
North Weather Station	AI-IODINE 131	1S2	0.468	22.6	0.110	0.317	0.364	0.412	0.346	< 0.07	0.611	0.963	0.253	<0.046
Falmouth Sub.	AI-IODINE 131	8C1	< 0.02	20.1	1.39	< 5.27	-	0.152+	0.449	0.057	0.172	0.086	<0.050	<0.17
Observation Cntr.	AI-IODINE 131	5A1	< 0.02	20.3	0.279	3.87	0.666	0.627	0.197	8.39	0.082	0.105	<0.027	0.647
West Fairview	AI-IODINE 131	15G1	< 0.03	1.83	<0.024	<0.047	<0.052	<0.01	0.065	< 0.04	< 0.07	<0.065	<0.078	<0.14
Drager Farm	AI-IODINE 131	7F1	< 0.04*	0.266	0.155	0.090	0.039	0.205	<0.03	0.39	0.233	0.061	<0.065	<0.23
Drager Farm	AI-IODINE 131	7F1Q	< 0.02*	0.09	<0.09	0.08	<0.07	0.09	<0.07	0.17	0.09	0.078	<0.051	<0.076
Middletown	AI-IODINE 131	1C1	0.082*	12.7	0.051	0.167	0.202	0.098	0.381	<0.06	0.069	0.184	<0.035	<0.042
Middletown	AI-IODINE 131	1C1Q	0.05*	9.8	< 0.05	0.1	0.15	<0.07	0.15	<0.06	0.12	0.049	<0.068	<0.05
Goldsboro Air Station	AI-IODINE 131	12B1	0.295*	23.9	0.068	0.368	0.687	0.675	0.462	<0.06	0.168	0.130	<0.046	< 0.16

Summary Table

Summary of Estimated Offsite Radiation Doses from the Accident at TMI Unit 2

Release Mode	Pathway	Organ Affected	Estimated Integrated Dose: Maximum Individual Dose (millirem) from Release & Environmental Dispersion Models	Estimated Integrated Dose: Maximum Individual Dose (millirem) from Environmental Measurements	Estimated Integrated Dose: Population Dose (person-rem) FOR 50 MILES [illegible]	Reference Section in Report
Liquid	Drinking water	Thyroid	(6)	<0.04 (1)	<1.0	Section 3.3 & Apx E
	Fish ingestion	Thyroid	(6)	<0.02 (1)	<1.0	Section 3.3 & Apx E
	Swimming, boating and shoreline activities	Whole body	(6)	<<0.01 (1)	<1.0	Section 3.3 & Apx E
Gaseous	Noble gases in plume	Whole body	75	76	3500	Section 4.3
	Noble gases in plume	Skin (5)	200	(2)	7170	Section 4.3
	Iodine inhalation	Thyroid(child)	9.8	5.0	180	Section 5.3
	Iodine uptake through cow milk ingestion	Thyroid(infant) *	(4)	1.1	1100	Section 5.3
	Particulate isotope inhalation or ingestion	(3)	(3)	(3)	(3)	Section 5.3

*NOTE. NOT FOR [illegible]

(1) Iodine-131 was detected in only a few of the water samples collected and none of the other samples. Concentrations used in dose assessments are assumed to be the minimum detectable level.

(2) No environmental information is available for this pathway.

(3) Preliminary evaluations indicate that particulate isotopes did not contribute significantly to offsite doses.

(4) No estimate from effluent release data is included since environmental samples give more accurate results (Section 5.3).

(5) Includes β and γ dose to skin.

(6) Calculations based on estimated releases and river dilution are consistent with calculations based on environmental measurements.

X = result by radiochemistry
(X) = result by gamma spec.

40 gm/gal $NaHSO_3$ to each sample

Milk
Iodine - 131 (pCi/l)

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Map Loc	Page 3 of 4	Sample	4/22	4/23	4/24	4/25	4/26	4/27	4/28	4/29	4/30	5/1	5/2	5/3
18	Alwine Farm	4B1	<0.2	0.19	<0.2	<0.4	<0.2	<0.2	<0.4	<0.4	<0.3	<0.3	<0.2	< 0.2
20	Becker Farm	7B3	0.57	0.72	<0.4	0.42	0.86	0.49	<0.5	3.6	4.7	3.6	2.9	2.7
20	Becker Farm	7B3Q	1.7	<0.8	<2.2	0.5	<0.5	<0.7	<0.4	4.5	5.2	5.4	2.2	1.6
-	Fisher Farm	14D1	0.31	0.40	1.0	0.77	2.1	-	.89 / <.5	<0.3	-	<0.4	<.3 / <.2	-
36	Oellig Farm	2G1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.3	<0.5	<0.5	<0.3	<0.3	<0.2	<0.1
45	Hardison Farm	1B1	-	-	-	110. (97.6)	57. (60.8)	39. (46.8)	22. (28.9)	37. (50.8)	26. (21.6)	49.	46.	37.

X = result by radiochemistry
(X) = result by gamma spec.

Effective 4/18 - 40 gm/gal $NaHSO_3$ to each sample

Milk
Iodine - 131 (pCi/l)

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Page 2 of 4

Map Loc		Sample	4/10	4/11	4/12	4/13	4/14	4/15	4/16	4/17	4/18	4/19	4/20	4/21
18	Alvine Farm	4B1	<0.3	<0.2	<0.3	0.24	<0.1	<0.2	0.39	0.34	0.59	0.54	0.35	0.27
20	Becker Farm	7B3	0.58	1.3	1.1	1.8	0.94	0.57	3.4	3.7	5.6	6.6	3.1	2.1
20	Becker Farm	7B3Q	2.4	1.6	1.4	1.8	1.3	1.1	5.2	4.4	11.5	7.8	4.4	2.8
-	Fisher Farm	14D1	-	<0.3	<.3, 0.84	-	0.73	0.26	0.27	<0.2	< 0.1	<0.2	<0.1	<0.3
36	Oellig Farm	2G1	<0.3	<0.2	<0.3	<0.3	<0.2	<0.1	<0.2	<0.2	<0.2	<0.2	<0.2	<0.3
45	Hardison Farm	1B1	4.2	6.0	34.0	10.0	4.1	8.0	3.3	13.0	-	-	-	-
	(NORTH, 1-2 MILES)				(47.1)					(28.4)				

X = result by radiochemistry
(X) = result by gamma spec.

40 gm/gal $NaHSO_3$

MAY 4, 1979 – MAY 15, 1979

Milk
Iodine - 131 (pCi/l)

	Page 4 of 4	Sample	5/4	5/5	5/6	5/7	5/8	5/9	5/10	5/11	5/12	5/13	5/14	5/15
8	Alwine Farm	4B1	<0.3	<0.2	<0.5	<0.3	<0.3	<0.3	<0.3	<0.4	<0.4	<0.4	<0.3	<0.3
0	Becker Farm	7B3	1.9	1.4	4.7	1.8	1.9	2.3	0.86	1.4	1.4	1.1	1.0	1.0
0	Becker Farm	7B3Q	1.7	1.6	5.3	3.7	2.3	2.3	1.5	1.5	1.8	1.4	1.8	0.65
-	Fisher Farm	14D1	<0.2	<0.2	<0.2	<0.3	0.72	0.65	0.34	<0.4	0.43	<0.4	<0.3	<0.4
36	Oellig Farm	2O1	<0.3	<0.2	<0.3	<0.5	<0.3	<0.3	<0.3	<0.5	<0.4	<0.5	<0.4	<0.4
45	Hardison Farm	1B1	35.0	-	19.0	14.0	13.0	9.7	16.0	17.0	16.0	6.9	6.4	7.1

1.0 PURPOSE AND SUMMARY

When a general emergency was declared at 7:24 a.m. on March 28, 1979, Metropolitan Edison in conformance with the emergency plan, sent radiation monitoring teams into the field and initiated an augmented environmental radiation measurement program. The objective was to provid information for those who had to make decisions concerning stabilization of the plant and protection of the public. When this first priority objective was being well served, an organized effort was started within the first two days to assemble all pertinent plant and environmental data as a basis for a more refined estimate of integrated radiation doses in the environment as a function of time and location. These dose estimates have been made and are reported herein. They are based on releases through April 30, 1979.

The report is divided into three parts: the first evaluates offsite doses from radioactive liquids; the second, doses from noble gases; and the third, doses from radioactive iodine and particulates. A compilation of all pertinent data is included in the Appendices.

2.0 REFERENCES

The dose estimates reported herein are based primarily on data from radiation and weather measurements made by and for Metropolitan Edison Company during the full course of the accident. Most of the radioactive releases to the environment occurred before extensive monitoring programs were implemented by other groups. For this reason, only a small portion of the large number of measurements made by other groups has been evaluated. The data used are sufficiently comprehensive to support a reasonably accurate assessment of offsite radiation doses.

Each of the data sources used is discussed in the following sections.

2.1 Measured Releases

Metropolitan Edison Company operates a program to measure the radioactivity in liquids and gases released to the environment from the Three Mile Island plant. The program includes continuous automatic radioactivity measurements and periodic sampling and analysis of all potentially-radioactive liquid and gas effluent streams. Sample analysis results are used where available for quantitative assessments in this report. Measurements made with automated monitoring equipment are, in most cases, less accurate and/or less sensitive than those made by sampling and laboratory analysis.

Measured effluent data used to develop dose evaluations include:

(1) Noble gas: Measurements of radioactive noble gas concentration in samples of air leaving the Unit 2 vent.

Continuous measurements of radioactive noble gas concentrations in air leaving the Unit 2 vent (after April 22).

(2) Iodine: Measurement of radioactive iodine concentration in air leaving Unit 1 and 2 vents (by passing a small continuous side stream through charcoal filter cartridges.)

(3) Particulates: Measurement of radioactive particulate concentration in air leaving the plant vents (by passing a small continuous side stream through filter cartridge collectors.)

(4) Isotopic content: Measurements in the airborne plume made with helicopter-mounted instruments (DOE data).

Measurements of radioactive isotopes in samples from the large charcoal bed filters in the plant ventilation system.

(5) Ventilation System Flow: Records of ventilation system operating status.

(6) Liquid Effluent Radio Isotope Concentration: Measurement of radioisotope concentration in samples of liquid batches.

(7) Liquid Effluent Radioactivity Concentration (cont'd) — Continuous measurements of radioactivity concentration in flowing liquid effluent streams.

(8) Liquid Effluent Flow: — Records of operating status, tank volume changes and effluent flow rates.

Data from these sources is summarized in Appendix C.

2.2 Estimated Release Rates

For periods when measurements of the radioactivity concentration in releases were not available, estimates were made using radiation levels measured in the environment along with weather conditions measured at the meteorological tower, and/or radiation levels measured by the area monitors inside the Unit 2 auxiliary and fuel handling buildings.

2.3 Meteorological Data

Metropolitan Edison Company maintains a meteorological tower located at the north end of the island to support normal plant operation and accident control. Data from this tower were continuously available via redundant sensors before, during and after the accident. They were used with atmospheric dispersion models to estimate noble gas releases and to compute radiation doses due to airborne releases. A description of the meteorological program is in Appendix A along with tabulations of data collected during the accident.

2.4 Radiological Environment Monitoring Program (REMP)

For about five years, Metropolitan Edison Company has conducted an operational environmental monitoring program to evaluate the radiological impact of TMI station operations by sampling and analyzing media from the aquatic, terrestrial and atmospheric environments in the vicinity of the station (within 5 to 10 miles). In accordance with emergency response plans, the program was intensified immediately following the accident. A summary of program results for the period from the start of the accident through April 30, 1979 is included in Appendix D, along with a description of the program and a tabulation of all data collected.

2.5 In-Plant Area Radiation Monitors

Strip chart recordings of radiation measurements in many areas in the auxiliary and fuel handling buildings were used. These strip charts are designated HP-UR-1901 and 1902.

2.6 Other References

Many other references were utilized including:

(1) "Mechanical Flow Diagrams, Electrical One Line Diagrams and General Arrangement Drawings, Three Mile Island Nuclear Station - Unit No. 2," by Burns and Roe, Inc., April 1979.

(2) "Population Dose and Health Impact of the Accident at the Three Mile Island Nuclear Station (A Preliminary assessment for the period March 28 through April 7, 1979) by the Ad Hoc Population Dose Assessment Group, May 10, 1979.

WHICH SHOWS 40 pCi/l Cs-137 + 21 pCi/l I-131 [handwritten margin note]

(3) NRC Regulatory Guide 1.111 for dispersion plume models.

(4) NRC Regulatory Guide 1.109 for environmental pathway models.

(5) Three Mile Island Unit 2 Final Safety Analysis Report.

(6) "Preliminary Report on Sources and Pathways of TMI-2 Releases of Radioactive Material", Draft, dated 6/22/79.

(7) "Preliminary Annotated Sequence of Events, March 28, 1979", Draft, dated 6/22/79.

3.0 OFFSITE LIQUID RELEASE AND DOSES

3.1 Releases

3.1.1 Release Quantities

During normal operations, the two nuclear units at Three Mile Island Nuclear Generating Station routinely release small quantities of radioactive isotopes in liquids discharged to the Susquehanna River in accordance with limits specified by the operating license. At the time of the accident at Unit 2, Unit 1 had just been refueled and wastes typical of refueling operations were being treated and released. From March 28, 1979 to April 30, 1979, these releases included 10.7 curies of tritium and about 0.3 curies of other radioisotopes as shown in Table 3-1.

The only significant radionuclide released to the river from Unit 2 as a result of the accident was iodine-131. The best estimate is that .24 curies of iodine-131 were released from March 28 through April 30. Most of this was released from March 31 through April 2 as is shown in Figure 3-1.

Although the release of iodine-131 in liquid effluents exceeded normal levels because of the accident, all liquid releases, including this iodine, were within acceptable release rate limits specified by the operating license. Concentrations in releases were within limits of federal regulations in 10CFR20.106 and 10CFR20.303. They did not exceed values in 10CFR20, Appendix B, Table II, when as the regulation permits, they are averaged over twenty-four hours (10CFR20.303) or one year (10CFR20.106).

3.1.2 Release Paths

The sources of the iodine-131 in liquid discharges were the Industrial Waste Treatment System (IWTS) and the Industrial Waste Filter System (IWFS). These systems which are shown schematically in Figure 3-2 are used to filter and, if necessary, neutralize floor drainage from plant areas having low potential for significant radioactive contamination. Following the accident, small quantities of iodine-131 entered these normally non-radioactive sumps and were pumped to the IWTS and IWFS. A schematic diagram showing details of the streams feeding the IWTS and IWFS is given in Figure 9.3-4 of the Three Mile Island Unit 2 Final Safety Analysis Report.

The secondary neutralization tank (Figure 3-2) was not a source of any radioisotopes in liquid releases. It receives liquid waste from a system in which raw river water is purified for use in the plant. Since the system does not process plant effluents, but only river water, no radioactive iodine would be expected in it. Analyses of tank contents made during the course of the accident has confirmed that no radioactive isotopes from the plant entered this system.

Analyses indicate that the Waste Evaporator Condensate Storage Tanks (WECST) were the source of essentially all of the radionuclides from normal refueling operations which were released to the river including a trace of iodine-131 (about 1% of that discharged from IWTS and IWFS). They were not the source of accident generated radionuclide discharges. These tanks are used for hold-up of radioactive liquid waste in normal operation. They are located in Unit 1, but receive liquid wastes from both units. They are used to control batch releases of radioactive liquid wastes to the Susquehanna River in accordance with plant procedures and Technical Specifications and governmental regulations. Each batch is sampled and analyzed prior to release. After release, contents are diluted in the mechanical draft cooling tower blowdown before discharge to the river. Releases from these tanks are controlled so that calculated concentrations at the point of discharge to the river do not exceed ten percent of maximum permissible concentrations in 10CFR20, Appendix B, Table II.

3.1.3 IWTS and IWFS Release Measurements

Prior to the accident, effluents from the IWTS and IWFS were not routinely sampled and analyzed because the potential for significant contamination of these systems was low. After the accident, a program for regular sampling and analysis was instituted. From March 28, at 0700, through April 30, all but one of 17 releases from the IWTS and four of 12 from the IWFS systems were sampled.

The five discharges that were not sampled are shown below:

Source	Date	Start	Stop
IWTS	3/28	0400	0900
IWFS	3/31	0140	0430
IWFS	4/01	0130	0534
IWFS	4/01	1521	1915
IWFS	4/02	0515	1110

Concentrations and quantities of iodine-131 released in these discharges have been estimated from data for subsequent discharges for which measurements were available. Measurement of iodine-131 in water samples collected from the Susquehanna River downstream of the point of discharge (see Section 3.2 below) indicate these estimates are reasonable. Data from a liquid effluent monitor which operated continuously at the point of discharge to the river have been used to make upper limit estimates of concentrations and quantities released in these discharges. The best estimates and upper limit estimates are described below.

It is unlikely that any iodine-131 was released in the unsampled March 28 discharge from the IWTS. Routine sampling (grab samples about every two hours) and analysis of contents of the IWTS and IWFS began on March 29. Samples from the IWTS on March 29 and 30 indicate no detectable iodine-131 in the IWTS. In addition, the unsampled March 28 IWTS release was terminated at 0900, just a short time after release of radioactive materials to plant areas other than the containment building. Because of hold-up times in feed stream sumps, and in the IWTS sump, and because no iodine-131 was detected in two subsequent samples, it is unlikely that significant quantities of iodine-131 were released during the March 28 IWTS discharge. For purposes of estimation, however, the concentration of iodine-131 in that release is assumed to be the average concentration of IWTS discharges the period March 28 to April 2.

A best estimate of the quantities of iodine-131 in the four unsampled IWFS releases was developed from concentrations measured subsequently in IWFS discharges. A sample from the first post-accident IWFS discharge was collected on March 30 but it was misplaced in the sample storage area for several weeks. When it was analyzed after it was located on April 24 there was no detectable iodine-131 in the sample. After adjustment of the minimum detectable concentration for radioactive decay of iodine-131, it was concluded that the concentration in the IWFS sump on March 30 was at most 5.6×10^{-7} µCi/cc. When the IWFS sump was next sampled on April 7 (for the discharge starting April 6) the concentration was 3.4×10^{-6} µCi/cc. Measured concentrations in the next three discharges from April 10 through April 16 varied over the range from 3.8×10^{-7} µCi/cc to 7.9×10^{-6} µCi/cc. It is assumed that the IWFS sump concentration during the four unsampled discharges from March 31 to April 2 was 2.5×10^{-6} µCi/cc, the average of concentrations measured in the IWFS sump from April 6 to April 6. On this basis the four unsampled releases contained a total of 1377 µCi of iodine-131.

It is worth noting that from April 6 to April 10, measured concentrations in the IWTS sump exceeded concentrations in the IWFS sump by about a factor of 10. If this was also true in the period for which no IWFS samples are available, the estimates of IWFS in this report, based on averages of subsequent IWFS samples, are reasonable.

An upper limit of quantities discharged in the four IWFS releases can be established by considering information from a radiation monitor, RML-7, which measured all liquid releases during the period March 28 through April 30, including the unsampled releases. This monitor did not alarm. Therefore concentrations in water just before release to the river could not have exceeded the alarm point which for iodine-131 is 9×10^{-6} µCi/cc. Thus, if the four unsampled IWFS discharges are assumed to have contained iodine-131 at concentrations just below the alarm point, the total discharged had to be less than 0.5 µCi. If it is assumed to be 0.5 µCi then the total release of iodine-131 to the river from March 28 through April 30 would not have exceeded 0.75 Ci which is three times the best estimate of (25 Ci. A total discharge of .75 Ci is still well within regulatory limits (10CFR20.106).

Detailed data from each liquid release are included in Table I of Appendix C. Daily release quantities are presented in Figure 3-1.

3.2 Environmental Measurements

The radiological environmental monitoring program (REMP) conducted by Metropolitan Edison Company includes analysis of river surface water, finished water from treatment plants, and aquatic biota. A full description of this program and a summary of results is provided in Appendix D. Three samples collected March 31, April 1 and April 2 at Station 7G1, the Columbia Water Plant, showed levels of iodine-131 (0.4, 0.72 and 0.66 pCi/l) slightly above minimum detectable concentrations. One sample, collected April 27 at Station 7G2, the Wrightsville Water Treatment Plant, contained 0.49 pCi/l of iodine-131, also slightly above minimum detectable concentration. Except for the cases noted above, no gamma-emitting isotopes other than low levels of naturally-occurring potassium-40 and radium-226 were detected. Tritium and gross beta concentrations were within normal ranges. The low concentrations measurable at Station 7G1 and 7G2 were consistent with estimated iodine release rates for the same period if it is assumed that liquid effluents were fully mixed in the river prior to sampling downstream.

3.3 Estimated Offsite Exposures

Radiation doses from all releases made from March 28 through April 30 are extremely low; a few hundredths of one millirem for a person drinking water or eating fish from the river or using the river for swimming, boating, or shoreline activities. The dose to the population from these liquid effluent pathways is only a few hundredths of a person-rem. These estimates are based on an evaluation of REMP data and dose calculations performed by Porter-Gertz Consultants, Inc. as reported in Appendix E.

Table 3-1

SUMMARY OF RADIONUCLIDES
RELEASED TO THE SUSQUEHANNA RIVER

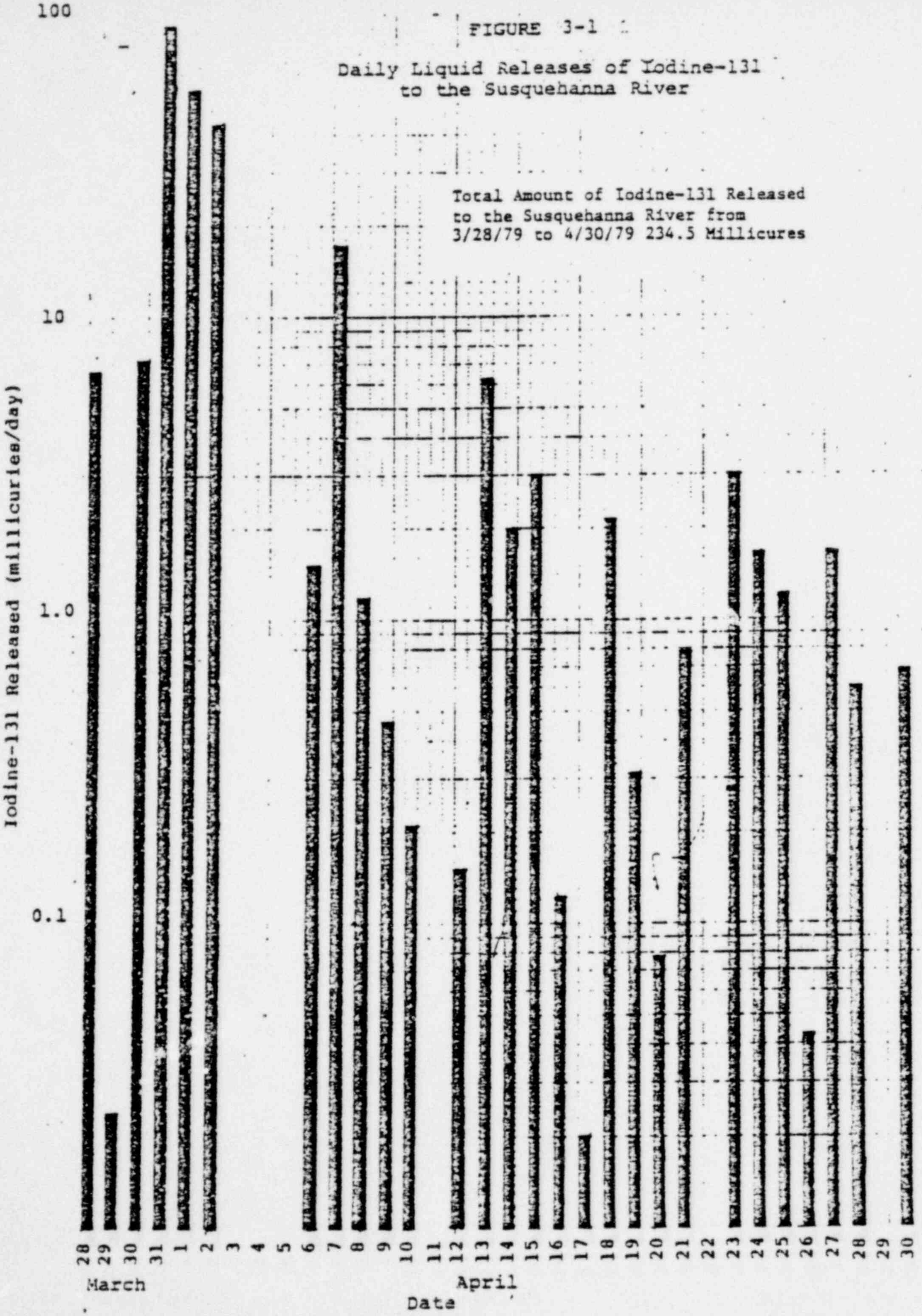
(3/28/79 - 4/30/79)

Radionuclide	Activity (Ci)
^{3}H	10.670
^{51}Cr	3.5E-4
^{54}Mn	4.11E-4
^{58}Co	0.022
^{60}Co	6.9E-3
^{95}Zr	4.83E-5
^{95}Nb	1.82E-4
^{110m}Ag	1.25E-3
^{131}I	0.235*
^{132}I	3.44E-4
^{133}I	1.4E-4
^{133}Xe	0.012
^{134}Cs	2.11E-3
^{136}Cs	2.7E-4
^{137}Cs	5.61E-3
^{140}La	1.29E-3
^{140}Ba	5.99E-4

*^{131}I is the only radionuclide of significance released to the river from the Unit 2 accident of March 28, 1979. Other isotopes came primarily from Unit 1.

FIGURE 3-1

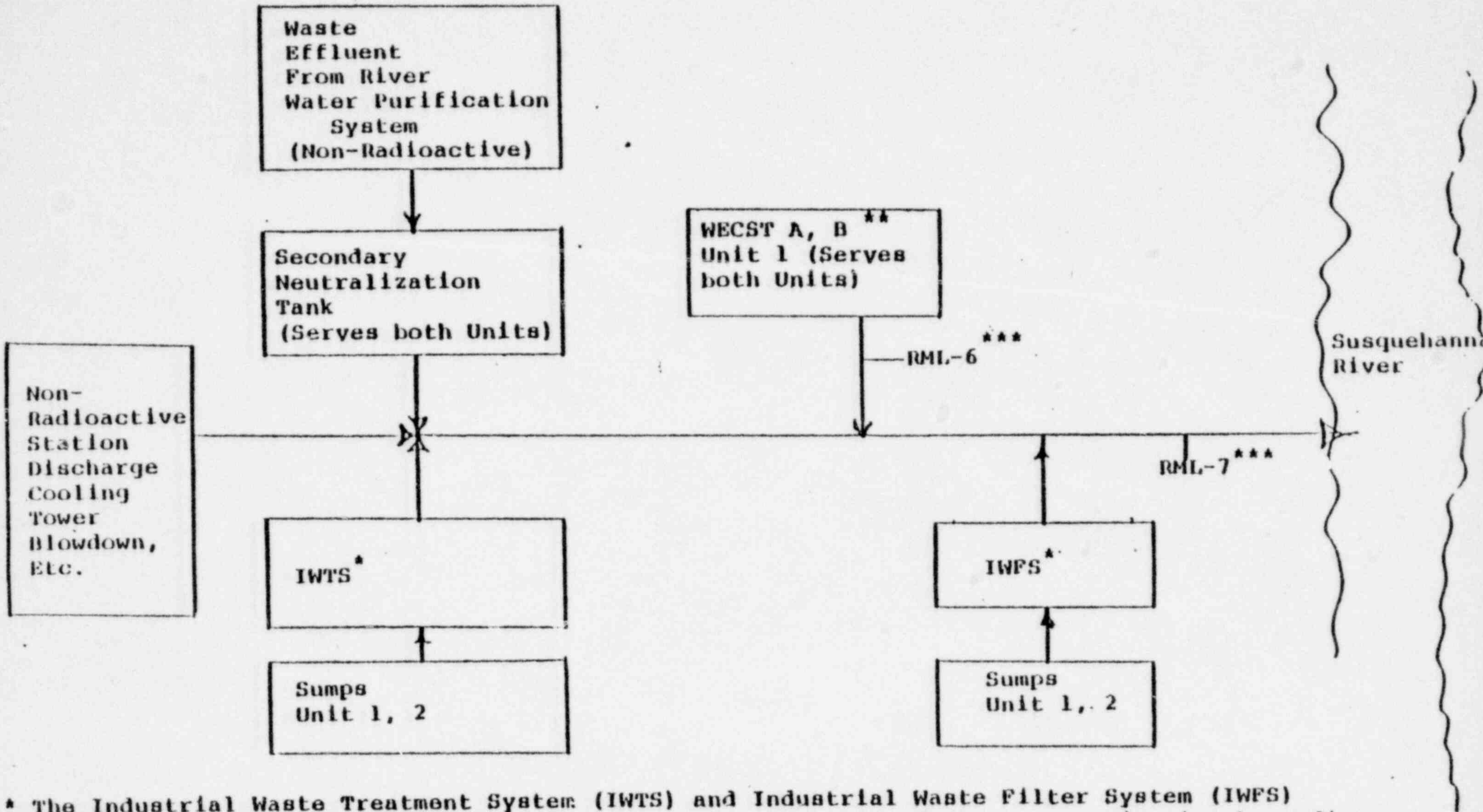
Daily Liquid Releases of Iodine-131 to the Susquehanna River



No releases were made on April 3,4,5,11,22 and 29

FIGURE 3-2

LIQUID RELEASE FLOW PATHS FROM TMI UNITS 1 & 2



* The Industrial Waste Treatment System (IWTS) and Industrial Waste Filter System (IWFS) collect floor drainage form areas having normally low potential for contamination by radioactive materials, but small quantities of Iodine-131 entered these systems after the accident.

** WECST=Waste Evaporator Condensate Storage Tank

These tanks are the only sources of radioactive isotopes in liquid discharges during normal operations.

*** Continuous radiation monitors in liquid discharge lines which record and alarm in both control

4.0 OFFSITE NOBLE GAS RELEASES AND DOSES

The analyses made to estimate offsite doses from radioactive noble gases are discussed below in three sections. Section 4.1 deals with releases of radioactive materials from the plant; Section 4.2 with radiation dose measurements outside the plant and offsite; and Section 4.3 with offsite dose calculations.

4.1 Releases from the Plant

Radioactive noble gases could have been released to the atmosphere in leakage from the reactor building, in steam released from the atmospheric steam dump valves or in ventilation air from the auxiliary and fuel handling buildings which is exhausted through the plant vent. Evaluations of these and other potential sources indicate that the only significant releases occurred from the plant vent. These evaluations are summarized in the "Preliminary Report on Sources and Pathways of TMI Releases of Radioactive Materials", dated July 16, 1979 (Rev. 0).

4.1.1 Plant Vent Monitors

Strip chart records from all noble gas radiation monitors located in the plant ventilation system exhaust have been examined in detail. They show no significant radiation levels during the first three hours following the reactor trip at 0400 on March 28. Since the plant vent was the pathway for release of noble gases, it is concluded that no significant releases occurred from 0400 to 0700 hours. About 0700, however, the plant vent monitors increased rapidly to full scale indicating that releases had started.

The plant vent monitors are designed to measure very low levels of radiation during normal operation, and to give plant operators rapid indication when these levels increase. They are not designed to provide information about releases of the magnitude experienced during the accident. While they did show when significant increases started, they went off-scale at too low a level to be useful in making quantitative measurements. Furthermore, because of their sensitivity, they stayed off-scale for a number of days, being affected not only by radiation in vent gases, but also by radiation from liquids, gases and/or deposited solids in the rooms in which the monitors are located and by radioactive materials deposited in the monitoring systems themselves.

4.1.2 In Plant Area Radiation Monitors

At about 0700, the same time the plant vent monitors went off-scale, the inplant area monitors inside the fuel handling and auxiliary buildings began to record increasing levels from 1 milliroentgen per hour at 0700 to 100 milliroentgen per hour at 0740. At about 0900, the readings began to increase again and by 1000 hours read about 1000 milliroentgen per hour. They continued to fluctuate at high levels for about four days, as is indicated on Figure 4-1. One or more of these area monitors continued to read on-scale during the course of the accident.

Strip chart recordings from these monitors provide information which was used to estimate the relative magnitude of releases from the plant as a function of time. Although these monitors respond to airborne radioactivity, they also could measure radiation from nearby local sources such as liquids and gases in tanks and pipes, as well as radioactive materials on filter banks. However, area monitors in several different locations responded together (but at different magnitudes), periodically rising as much as an order of magnitude to a peak, then returning to an elevated baseline. This suggests that they were responding primarily to fluctuations in airborne radioactivity which affected all of them in about the same way, rather than to local sources which would affect each one differently. After the first day of the accident, upward fluctuations occurred when the makeup tank was vented, further demonstrating that the monitors responded to events which released radioactivity to the building atmosphere. Additionally, grab samples from the plant vent on March 31 shown on Figure 4-3, agree well with the assumed noble gas release rates. Thus, it is inferred that the recorded levels are primarily related to the concentration of radioactivity in the building air.

The assumption that area monitor levels are proportional to release rates also depends on the subsidiary assumption that the ventilation system exhaust was operated at a constant flow rate throughout the course of the accident. This appears to be true with minor exceptions. Review of ventilation system operations indicates that either the auxiliary building fans or the fuel handling building fans were on at all times after 0900 on March 28, when significant releases began. The fuel handling building fans were only off for a one-hour period starting at 0100 on March 29. Therefore, it is judged that area radiation monitor readings, as summarized in Figure 4-1, adequately characterize relative release rates.

The fuel handling and auxiliary building ventilation systems each have charcoal filter beds for iodine removal. Evaluations of iodine inventories on charcoal samples from these filter banks indicate about four times as much iodine was collected on charcoal in the fuel handling building ventilation system as on the auxiliary building charcoal (see the report entitled "Analysis of the Adsorbers and Adsorbents from Three Mile Island Unit #2" by Nuclear Consulting Services, Inc.). Assuming the noble gases were released in proportion to the iodines, and considering that the fuel handling building ventilation system operated almost continuously, it can be inferred that a greater portion of the noble gases were released through the fuel handling building to the plant vent. The principal area monitor (HP-R-3240) used to define the release trend on Figure 4-1 is located near the filter banks which service the fuel handling building and, thus, was in a good location to have responded to the bulk of the releases.

There are openings between the fuel handling and auxiliary building air spaces and the pressure balance is such that flow occurs from the auxiliary building to the fuel handling building. Therefore, measurements indicating that a greater proportion of the releases may have been from the fuel handling building exhaust system while the source of leakage was probably in the auxiliary building are not necessarily contrary to expectations.

The wide fluctuations in area monitor readings suggest that the sources of noble gas releases were intermittent and associated with the paths of liquids and gases following their letdown from the primary system. It does not seem plausible, based on the available data, that a release of liquids from the reactor building sump into the auxiliary building could have caused the observed area monitor responses since changes in area monitor readings continued long after the reactor building sump discharge line was isolated and the reactor building was at subatmospheric pressure.

4.1.3 Noble Gas Mix

It is assumed for purposes of this analysis that the "mix" of noble gas fission products released is, with one exception, the same as that calculated to be in the nuclear fuel by the ORIGEN computer program. This program computes the quantities of fission products as a function of time following reactor trip based on the Unit 2 operating history prior to March 28, 1979.

Comparisons of the ORIGEN results with measurements of isotopic mix in samples of gaseous effluent show good agreement except that measured values of Xe-133m were about a factor of 6 lower than ORIGEN predictions. Following an evaluation of assumptions in the ORIGEN program, it was decided that the measured Xe-133m fraction was more appropriate and ORIGEN results were modified accordingly. The resulting noble gas mix versus time is shown in Figure 4-2. Dose calculations which follow are not sensitive to the relative quantities of Xe-133m which comprises only a small portion of the mix.

* THIS PROVES THAT NOT JUST Xe-133 WAS RELEASED, BUT THE NORMAL MIX OF FISSION PRODUCT AND ACTIVATION GASES

Isotopic analyses of noble gases found in the plume by DOE helicopter monitoring teams have also been made. A preliminary analysis made by DOE of a plume sample taken about 12 hours after the accident showed the presence of Xe-133, Xe-135 and Kr-88 in proportion to ORIGEN predictions. Krypton would not have been expected if the only major source of noble gas releases had been iodine decay in the auxiliary building sump.

The released mix is complicated by the separation of the noble gas and iodine isotopes during the changes in the steam-water-air environment in which the isotopes were transported for days after the accident. Iodines tend to remain with the liquid phase whereas noble gases remain with the gaseous phase. Additionally, iodine isotopes decay to produce many of the noble gas isotopes. Thus, it is not obvious that the mix in released gases would be like that in the fuel had there been no fuel failure. Nonetheless, it is judged that the ORIGEN results represent a best estimate of the mix.

4.1.4 Procedure for Estimating Noble Gas Releases

Assuming the radioactivity levels recorded by the area monitors provide a relative indication of the release rate of noble gases, and are not sufficient to establish the actual quantities released, an iterative procedure was developed as described below to estimate noble gas releases:

Step 1: Define area monitor indications (R) as a function of time as shown in Figure 4-1.

Step 2: Determine the relative quantities of each isotope with respect to the predominant isotope, Xe-133 using results from the ORIGEN computer program with corrected values for Xe-133m (Figure 4-2).

Step 3: Determine the dose equivalence factor using the following procedure, assuming area monitors respond in direct proportion to noble gas energy levels as follows:

$$\sum_i Q_i \bar{E}_i \cong R \quad (1)$$

where:

Q_i = release rate (μCi/sec) of isotope i

$\bar{E}_i$ = gamma energy per disintegration (Mev) of isotope i

R = area radiation monitor indication (roentgen/hr).

This expression can be expanded for any given time as follows:

$$Q_1\bar{E}_1 + Q_2\bar{E}_2 + Q_3\bar{E}_3 \; . \; . \; . \; . \cong R \quad (2)$$

and, using the relationship of each isotope to Xe-133 from Figure 4-2:

$$f_i = \frac{Q_i}{Q_1} \qquad (3)$$

Values of Q_1, the release rate for Xe-133, as a function of time can be written as:

$$Q_1(t) \cong \frac{R(t)}{F(t)} \qquad (4)$$

where the dose equivalence factor F(t) is:

$$F(t) = \bar{E}_1 + f_2(t)\bar{E}_2 + f_3(t)\bar{E}_3 \ldots f_n(t)\bar{E}_n \qquad (5)$$

Release rates $Q_i(t)$ for other isotopes are then obtained using Equation (3).

Step 4: Establish a set of trial release rates for each isotope proportional to $Q_1(t)$ computed above and use them along with the diffusion model to compute gamma doses around the site perimeter based on measured onsite meteorological data. These data include quarter-hourly wind speed, wind direction and vertical temperature difference from which atmospheric dispersion estimates are made as a function of time. A dose calculation is made for each quarter-hour and results are summed over the exposure time for each TLD monitoring station. Input meteorological data are discussed in Appendix A.

The dispersion model utilizes a finite plume model to compute gamma dose to a ground level receptor in accordance with procedures outlined in NRC Regulatory

Guides 1.109 and 1.111. Downwash in the wake of a large plant structure is accounted for by using a "mixed-mode" model which accounts for building wake effects on the plume when the wind speed is above certain levels. Atmospheric dispersion models and input assumptions are described in more detail in Appendix B.

Step 5: Having computed gamma dose at each TLD monitor site using the trial set of release rates, the results are compared with TLD data and the trial release rates are adjusted according to wind direction to provide the best match at each TLD location which had readings substantially higher than background. This was done for each of the first four TLD measurement intervals. Table 4-1 gives the final release rates after adjustment.

The above procedure was used for the period of most significant releases during which plant vent noble gas monitors were unavailable and environmental TLD doses were measurable, starting on March 28, 1979 and continuing through April 6, 1979.

The initial trial release rates for Step 4 arbitrarily assumed releases in units of μCi/sec for each isotope proportional to area monitor readings in roentgens per hour and inversely proportional to the dose equivalence factor in accordance with Equations (3), (4) and (5). This gave good correlation between calculated doses and corresponding TLD measurements except for releases during the afternoon and evening of March 28, during which time winds were blowing toward the NNW (see direction arrows on Figure 4-1). Computed doses at the NNW TLD were a factor of 2 lower than measurements. Consequently, isotope release rates for March 28 from

1600 through 2400 were increased by a factor of two. Doses calculated to the ENE were too high. So Q_i values were reduced by a factor of 1.5 on March 29 at 0300 and by a factor of 2.0 on March 29 at 0600. With these adjustments, the agreement between calculated and meaasured doses was satisfactory for those locations with relatively high measured doses. During portions of the 9-hour period of adjustment in the evening of March 28, some of the area monitors were reading off-scale. This suggests that the upward adjustment in release rate made for this time period might have been supported by the area monitor data had these data been available.

Table 4-2 summarizes results and shows comparisons of calculated and measured gamma doses for each TLD location and measurement interval prior to April 6. The ratio of predicted to measured doses was chosen as a simple indicator for comparing results. In determining release rates, more importance was placed on matching TLDs with high readings. As a result, for the TLDs with highest exposure, the ratios are close to 1.0. Average ratios for each period are greater than 1.0, which would indicate that average estimates of noble gas release rates are high. There is considerable scatter in the ratios for TLDs which measured very low doses.

Table 4-3 summarizes predicted versus measured doses for each TLD location over the total period of exposure through April 6, 1979. The ratios of predicted to measured dose are not as widely scattered for this longer period as they are for the shorter periods in Table 4-2. The accuracy of calculated doses is discussed in Section 4.1.6 below.

4.1.5 Estimated Noble Gas Releases

Using the procedure outlined above for estimating release rates, the total number of curies of each significant noble gas isotope released was calculated for each of the four time periods corresponding to TLD measurement intervals. The results are shown in Table 4-4. They indicate about 10 million curies of noble gases were released through April 30. About 81% of the total was Xe-133. About 66% of the total was released during the first day and a half after the accident started. Another 22% of the total was released in the next two days from March 29 at 1700 to March 31 at 1600. On Friday morning, March 30, a short-term radiation measurement of 1200 millirem per hour was made by a helicopter stationed above the plant vent. Although it received considerable attention, the release rate associated with this measurement did not result in significant ground level doses as compared with those which had already occurred.

Figure 4-3 shows the estimated noble gas release rates through April 30, 1979 versus those derived from laboratory analysis of grab samples and, after April 22, from continuous noble gas effluent monitors.

4.1.6 Accuracy of Calculated Doses (NOTE: EXTERNAL DOSES ONLY)

For the time period when all significant noble gas releases occurred, doses calculated by the procedure described in the previous section are within a factor of 2 of those measured for 13 of the 16 TLD stations which are 600 meters or more from plant buildings (Table 4-3). At the other three of these 16 locations, the calculated doses were 3 to 4 times those measured. For the time period when exposures were highest, calculated doses at 11 of these 16 stations are above one millirem. At 8 of the 11 calculated doses are within a factor of two of those measured. At the other 3, they are a factor of 2 to 6 higher.

The most significant uncertainties in calculated versus actual doses are probably due to the difficulty of accurately accounting for the large influence that turbulent wakes from adjacent structures may have on dispersion of the plume. This is especially true since the TLDs with high readings which were used to calibrate the atmospheric dispersion model are also the ones at locations most influenced by this turbulence. Some uncertainties are due to the difficulty of modeling meteorological conditions conducive to "puddling."

A study was made to compare doses computed using the chosen dispersion model with those computed using two other dispersion models which bound it. The resulting comparisons are shown in Figure 4-4. One bounding model assumes the plume released from the plant vent remains elevated, unperturbed by turbulent building wake effects. The other assumes all releases are trapped in turbulent wakes behind plant structures so that the releases are effectively at ground level. The chosen model, on the other hand, is a mixed mode model which combines both elevated and ground level releases depending on wind speed. Winds from each direction travel over a different set of building configurations. These differences are not accounted for in any of the models used. However, the bounding calculations probably encompass these differences. Appendix F illustrates the estimated effect that the building wakes have on plume geometry.

In developing the isotopic release rates following the procedure in Section 4.1.4, emphasis was placed on matching calculated doses with TLD measured doses in the NNW direction sector since TLD measurements were highest and the wind was relatively steady in this direction. Inspection of Figure 4-4 shows that results from the chosen mixed mode model were well matched with measured doses in this direction.

Ideally, all measured doses would be within the values computed by the bounding models. However, as shown in Figure 4-4, some measured values are within the bounds and some are not. For several directions all three models predict higher than measured results. Significant mismatches may be due to low wind speeds and meandering plumes after the first day. However, offsite doses were relatively low when these conditions existed and significant errors during these times have a relatively small effect on total time-integrated doses.

The sensors used in the area monitors are G-M tubes which may under-respond to the predominant isotope, Xe-133. Additionally, the geometry of the source in the room in which the area monitors are located may affect the relative dose readings of these instruments. This response may change with time as the isotopic mix changes. However, these effects are not expected to introduce substantial uncertainties in the estimates of the relative releases.

Uncertainties in TLD dosimetry for relatively high doses compared to expected background are less than dispersion model uncertainties and should be considerably less important by comparison. There is some evidence that the TLDs may have over-responded to Xe-133 (see Section 4.2 and Appendix G), however, for the first few days following the accident, other isotopes for which the TLDs do not over-respond contributed significantly to the total dose making any correction for Xe-133 of less importance.

Additional uncertainties may have been introduced into the analysis by assuming that release rates corresponded to area monitor fluctuations. However, during the period of expected highest release rates, starting on the afternoon of the first day, winds were fairly steady and it would be unlikely that combination of changes in dispersion and release rates that would maximize dose would coincide in such a manner as to cause an unrealistic assessment of dose.

It is conceivable that plume meander during periods of low wind speeds may have caused "puddling" in such a way that a volume of the plume passed over a given TLD more than once. Since the plume model does not account for this behavior, such conditions could cause errors in the calculated dose. However, for most of the time during the period of highest area monitor readings before 0600 on March 29 (see Figure 4-1), a fairly well established plume in the NNW and WNW directions existed. This is illustrated in Figure 4-5 which shows plume centerline trajectories starting every 15 minutes during the periods of highest releases on March 28. These trajectories are developed from weather data measured at the site. They show the existence of a steady (non-meandering) plume in the northwestern sectors and do not show any puddling. Further verification that puddling did not exist during this period has been sought by studying DOE helicopter data. However, no flights were conducted during the evening of March 28 when major releases occurred. Data from ground observation teams are of value only beyond three miles because during this time the plume was tracking up the river in areas which were inaccessible to the ground teams.

4.2 Environmental TLD Measurements

Metropolitan Edison Company conducts a routine environmental radiation monitoring program including use of stationary thermoluminescent dosimeters (TLD's) which measure integrated gamma dose. They are in place at all times at 20 locations as shown on the map in Appendix D. Most are within several miles of the plant, but a few are located up to 15 miles away. These dosimeters were in place in the field at the time the accident occurred. Dosimeters in the field were replaced with fresh dosimeters every one to three days following the accident, and

IMAGE EVALUATION
TEST TARGET (MT-3)

6″

MICROCOPY RESOLUTION TEST CHART

the collected dosimeters were evaluated to determine trends for dose rate as well as the dose accumulated since the beginning of the accident. These data represent a comprehensive measurement of doses due to noble gas releases at the locations monitored. Table 4-5 provides a summary of significant TLD mesurements through April 30, 1979. Background has been subtracted as described in the footnotes. No other adjustments have been made. Additional information concerning the dosimeter monitoring program is contained in Appendix D.

Shortly after the declaration of an emergency, mobile monitoring teams were dispatched by Metropolitan Edison Company. A police helicopter was used during the early hours of the response to assist the monitoring teams since the onsite meteorological tower indicated winds toward the west over the river. These teams were equipped with instruments which measured dose rates from airborne radioactive material (primarily noble gases with Xe-133 dominant) and with air samplers which were capable of collecting airborne radioactive materials other than noble gases for later laboratory analysis.

From the second day on following the accident, release rates varied over a wide range and frequent wind shifts occurred. This combination of events caused radiation levels to fluctuate rapidly with time at any single location. The emergency response survey teams had to move from place to place following the transport of airborne radioactivity. Because of the fluctuations in radiation levels and the short monitoring periods at any one location, data collected by survey teams are not the best available for the determination of cumulative doses and they were not used in this assessment except in attempts to determine when noble gas releases were significantly higher than baseline values.

Thermoluminescent dosimetry measurements used in this report are from dysprosium doped calcium sulfate dosimeters supplied by Teledyne Isotopes. An evaluation of the response of these dosimeters to the low-energy photons from Xe-133 is provided in Appendix G. The conclusion of the evaluation is that the dosimeters did not under-respond to Xenon-133 in field exposure conditions, and that over-response in the field was probably no greater than a factor of 1.5.

Results of a study made for several directions with highest exposures to estimate the fraction of the dose contributed by Xe-133 for the first two TLD exposure periods are shown in Table 4-6. As noted on the table, the total dose contributed by Xe-133 is not the same in each direction. This occurs because the wind direction and relative amount of each isotope change with time. Relative contributions to the dose from each isotope also change with distance due to the height of the plume above terrain as well as changes in plume dimensions. No corrections were made in this assessment for possible TLD over-response to Xe-133.

4.3 Estimated Offsite Doses

Mathematical models for estimating doses to individuals and populations normally use known isotope release rates along with atmospheric dispersion models and meteorological parameters. However, since atmospheric releases of noble gases were not monitored, release rates estimated using the procedure in Section 4.1.4 above were used to estimate doses to individuals at locations not monitored by TLD's and to the population within 50 miles of the plant. For these calculations, the atmospheric dispersion model described in Appendix B which had been previously used only for estimates at TLD locations close to the plant was extended to a distance of 50 miles in each of 16 direction sectors. Figures 4-6 through 4-9 are isopleths showing estimated whole body gamma doses to distances of 1, 2, 5 and 50 miles, respectively. These estimates are based on estimated noble gas release data as well as the atmospheric dispersion and dose models in Appendix B. Figure 4-10 represents an isopleth of the beta portion of the skin dose.

4.3.1 Population Dose Estimates

Population dose estimates were computed using the straight-line dispersion model and site meteorological data to compute the whole body dose each hour at 10 locations downwind out to 50 miles in the sector in which the wind was blowing. These hourly doses were added for all hours in the period after the accident extending to April 30, 1979 and multiplied by the population in each of these 10 distances. The estimated 1980 population given in Appendix B was used. Results of this analysis indicate that the aggregate whole body dose to the population within 50 miles (about two million people) was about 3500 person-rems from noble gases released through April 30, 1979. This estimate does not consider the effect of occupancy and shielding due to housing or other structures which

* BUT THIS LEAVES OUT THE POPULATION BEYOND 50 MILES WHERE MOST OF THE INFANT DEATHS OCCURRED (FOR EXAMPLE PITTSBURGH & UPSTATE N.Y.

could reduce dose estimates. Figure 4-11 shows the estimated population doses as a function of time following the accident.

A similar calculation was made to determine the population skin dose. For this case the beta contribution was computed and summed over the population grid and then added to the whole body population dose. The beta contribution was 3670 person-rems which when added to the gamma dose of 3500 person-rems gives 7170 person-rems to the skin.

Uncertainties in the population dose calculation are estimated as follows. First, the population doses were computed using the bounding dispersion models for ground and elevated releases discussed in Section 4.1.6 along with the estimated noble gas releases to obtain 4197 and 3418 person-rems for the ground and elevated cases, respectively. If the source term had been overestimated by a factor of 2 using the ground level release model as discussed in Section 4.1.6, the population dose would be 4197 ÷ 2 or 2098 person-rems. On the other hand, if the plume had been elevated resulting in a factor of 2 underestimate, the population dose would be 3418 x 2 or 6836 person-rems. Thus, the uncertainty estimated in the 3500 person-rem population dose is considered to be within a factor of ±2 based on the atmospheric dispersion model.

There is some evidence that channeling of the plume within the river and "puddling" due to wind meander at certain locations may have occurred, however, this is not expected to have a significant affect on overall population dose calculations. Restrictions in plume growth in the river valley could result in less dilution than calculated at ground level at certain locations over the river at distances beyond several miles. *

* ∴ GREATER DOSES

However, this effect should not result in significant increases in population dose because there are generally fewer receptors in the river valley. Concentrations in a plume cannot increase, thus if plume reversals or puddling occur within the hour for which the dose increment is computed, the additional dose would be less than that assumed to have been delivered in the hour. If puddling persists for more than one hour, and one population group is being affected by such a "puddle", the radioactive materials in the puddle could not affect any other group at the same time. Thus, no significant increase in population would be expected. Effects of any puddling that occurred near the site would have been measured by the TLD's.

4.3.2 Maximum Measured Offsite Doses

Table 4-5 summarizes net gamma doses based on measurements from the TLD monitoring program. The highest offsite integrated whole body dose measured at any TLD location through April 28 was 75.8 millirems above background at Station 4A1 located about 800m ENE from the plant. For purposes of this discussion "offsite" is assumed to be locations greater than 600 meters from the plant that were known to be occupied following the accident. The accumulated doses measured at the Goldsboro (Station 12B1) and Middletown (Station 1G1) TLD monitoring stations over the same period were 11.9 and 9.1 millirem above background, respectively. There are some uncertainties inherent in measurements of doses of this low magnitude due to normal fluctuations in background dose. This uncertainty does not affect the maximum dose of 76 millirems for which the accident contribution was substantially greater than fluctuations in natural background.

4.3.3 Maximum Calculated Offsite Doses

By contrast, as shown in Table 4-3, whole body dose calculations at these same TLD monitor locations using the estimated noble gas releases resulted in doses of 43.3 mrem 800m ENE; 21.5 mrem near Goldsboro on the west river bank; and 29.9 mrem at Middletown. Inspection of Figures 4-7 and 4-8 shows that the maximum estimated offsite dose was about 75 mrem at several locations in the WNW, NNW and NNE directions. These estimates are about a factor of two higher than doses measured by the TLDs in the same general areas reported in Section 4.3.2 above and are likely to be overestimates.

Since beta radiation from noble gases cannot be reliably measured in the environment, skin dose due to beta radiation was calculated based on the noble gas source term developed using the procedure in Section 4.1.4. The dose mode used is described in Appendix B. Figure 4-10 shows an isopleth of estimated skin dose due to beta radiation in the site vicinity. These values must be added to the gamma dose to obtain total skin dose. The combined beta plus gamma maximum skin dose is estimated to be less than 200 millirem at occupied locations near the site. About 125 millirem of this amount is due to beta radiation. No reduction in beta dose is assumed for the protective effect of clothing or for occupancy factors.

The above calculations of maximum dose were made for locations near the site that were known to be occupied after the accident. Subsequently, the "Ad Hoc Committee for Dose and Health Impact of the Accident at the Three Mile Island

Nuclear Station" reported that an individual had been working on Hill Island to the NNW for about 9-1/2 hours (from 1000 to 1630 on March 28 and from 1100 to 1500 on March 29).

An additional dose calculation specifically for this location was made using methodology described herein and the estimated noble gas releases from Table 4-1 for this period. Meteorological conditions and dose calculations were updated every quarter of an hour during the occupancy period. The total whole body dose was determined to be 23 millirem, which is considerably below the highest offsite exposures of 75 millirem.

4.3.4 Time Distribution of Offsite Dose

Figure 4-12 shows the whole body dose rates estimated to have occurred as a function of time after the accident at the TLD locations near the site. Doses are given for each quarter of an hour as indicated by the vertical lines for the representative TLD location in each direction sector. Each line represents the dose in millirems that occurred during the given quarter-hour period. As shown, the major portion of the release travelled to the NNW between 1600 and 2400 on March 28.

4.3.5 Fraction of 10CFR20.106 Maximum Permissible Concentrations (MPC) for Noble Gas Isotopes

Using the estimated noble gas source term in Table 4-1, a computer run was made using the best-estimate atmospheric dispersion model (see Appendix B) to determine the annualized fraction of MPC limits in offsite areas occupied after the accident. The relationship used for this determination is as follows:

$$\text{Fraction of annual MPC} = \frac{\sum_{t=1}^{R} (X/Q)_t \sum_{i=1}^{n} \frac{Q_{i,t}}{MPC_i}}{8760}$$

where:

X/Q_t = atmospheric dispersion coefficient applicable for hour t (sec/m^3)

$Q_{i,t}$ = release rate of each isotope i for hour t (μCi/sec)

MPC_i = maximum permissible concentration of isotope i ($\mu Ci/m^3$)

t = hour of release

R = total hours of release

n = total number of isotopes

Figure 4-13 shows an isopleth of results for noble gases. The concentrations were averaged over a one-year period as allowed by 10CFR Part 20. Results show that MPC concentrations would have been exceeded in only a few locations offsite for noble gases and most of these would have occurred in areas not occupied after the accident started.

*THIS GREATLY UNDERESTIMATES THE SHORT-TERM DOSES RECEIVED BY A FETUS

Table 4-4

Estimated Quantities (Ci) of Each Noble Gas Isotope for Release Periods Corresponding to TLD Measurements 3/28/79-4/30/79

Isotope	3/28 @ 0700- 3/29 @ 1600	3/29 @ 1700- 3/31 @ 1600	3/31 @ 1700- 4/3 @ 1500	4/3 @ 1600- 4/6 @ 1300	4/6 @ 1400-* 4/30 @ 2400	Total
Xe-133	4.9E6	2.1E6	1.1E6	2.7E5	1.5E4	8.3E6
Xe-133m	1.2E5	3.9E4	1.5E4	1.9E3	0	1.7E5
Xe-135	1.5E6	7.7E4	1.4E3	0	0	1.5E6
Xe-135m	1.4E5	1.3E3	0	0	0	1.4E5
Kr-88	6.1E4	0	0	0	0	6.1E4
	6.6E6	2.2E6	1.1E6	2.7E5	1.5E4	1.0E7

= 6.6 MILLION CURIES

*The last three weeks of the month are combined into one group since the contribution is less than 1% of the total. The estimated quantity released during this period is based on effluent measurements.

Figure 4-2

Activity of Principal Noble Gas Fission Products as a Function of Time After Trip (Average Gamma Energy is Given in Parentheses)

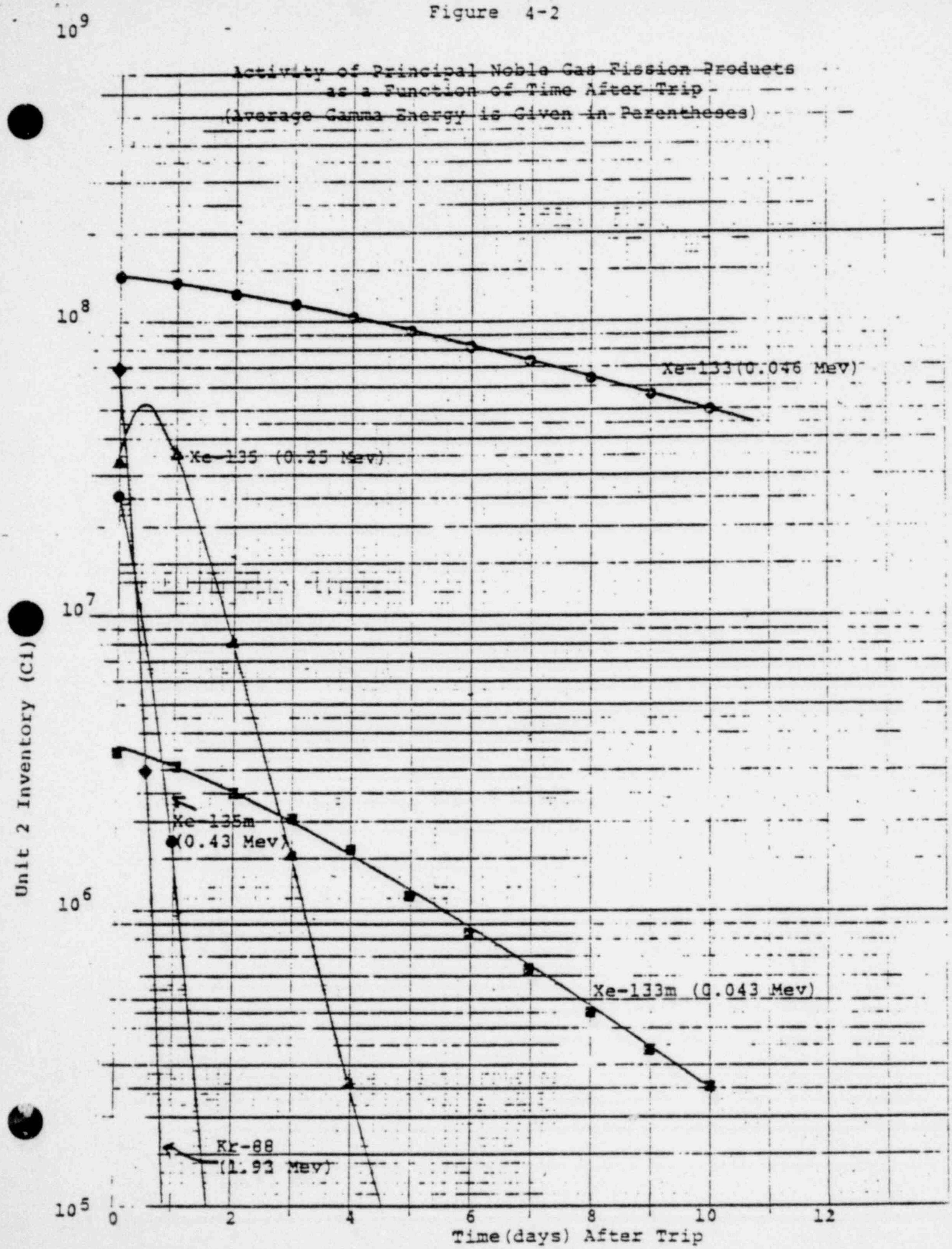


Figure 4-1

Trend of Auxiliary and Fuel Handling Building Area Radiation Monitors (Primarily from HPR-3240 at the 328ft Level in the Auxiliary Building)

Arrows indicate hourly wind direction, each bar on arrow indicates 3mph wind speed

↑Indicates wind toward north

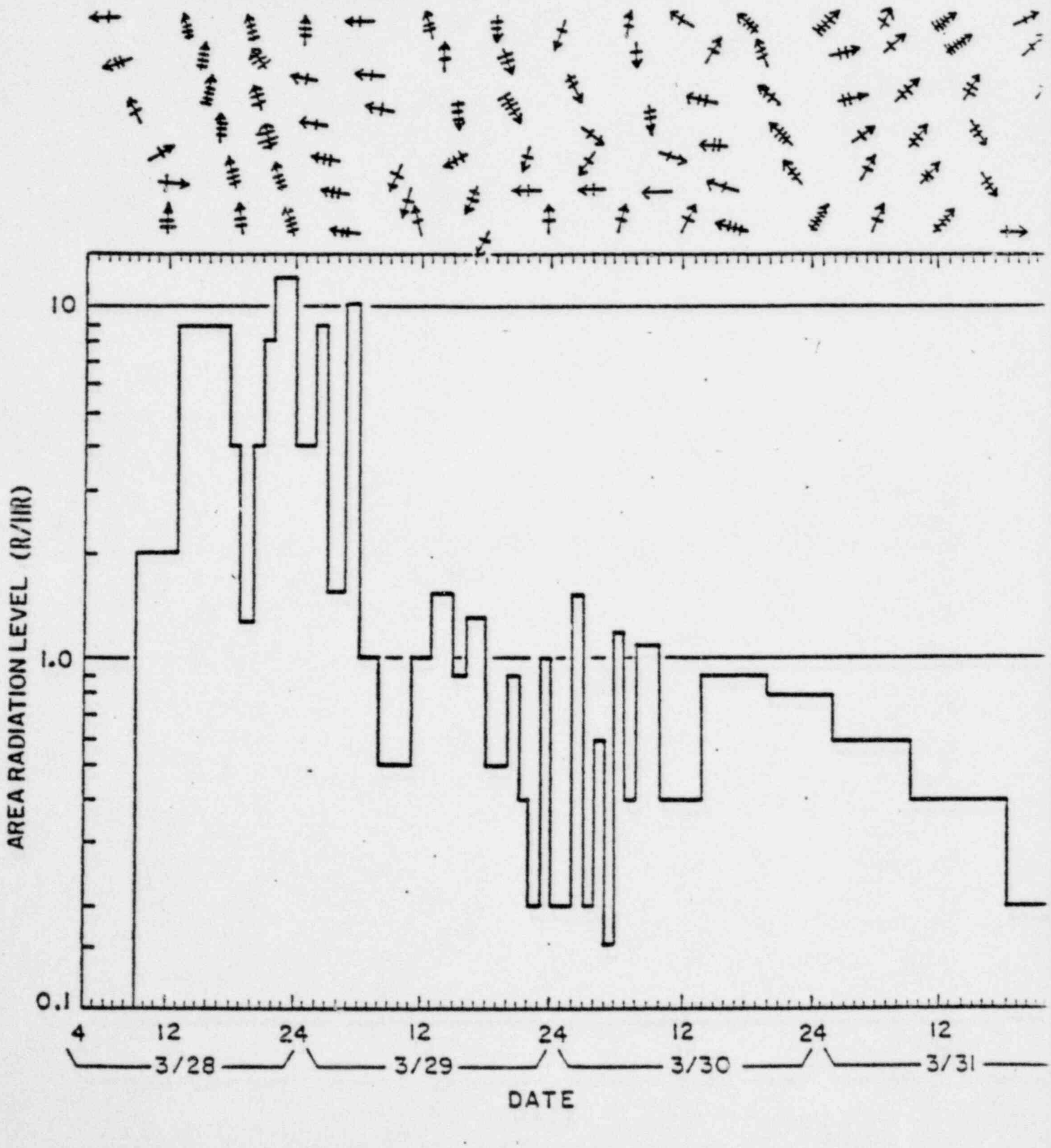


Figure 4-3

Estimated Noble Gas Release Rate
3/28/79-4/30/79

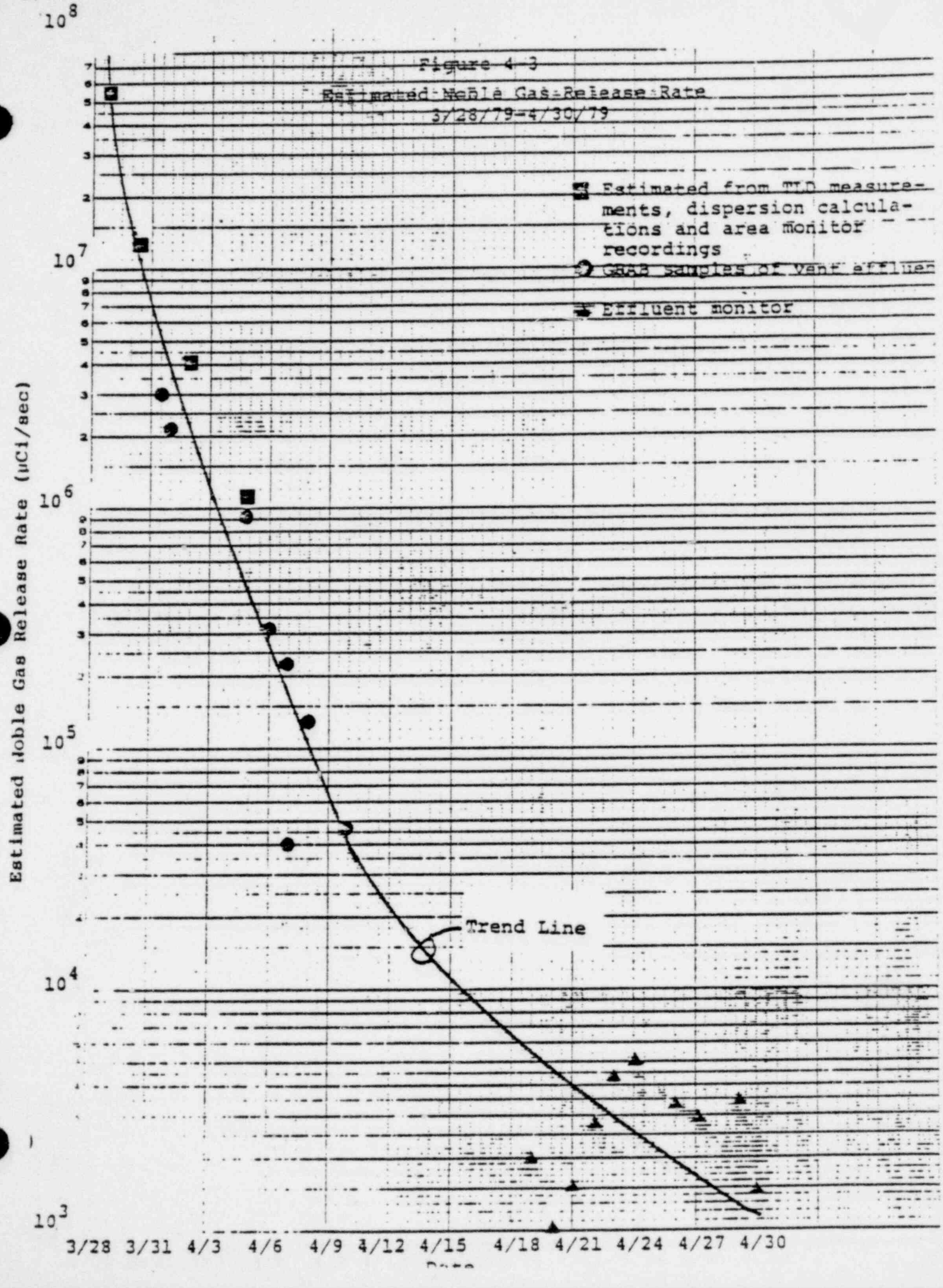
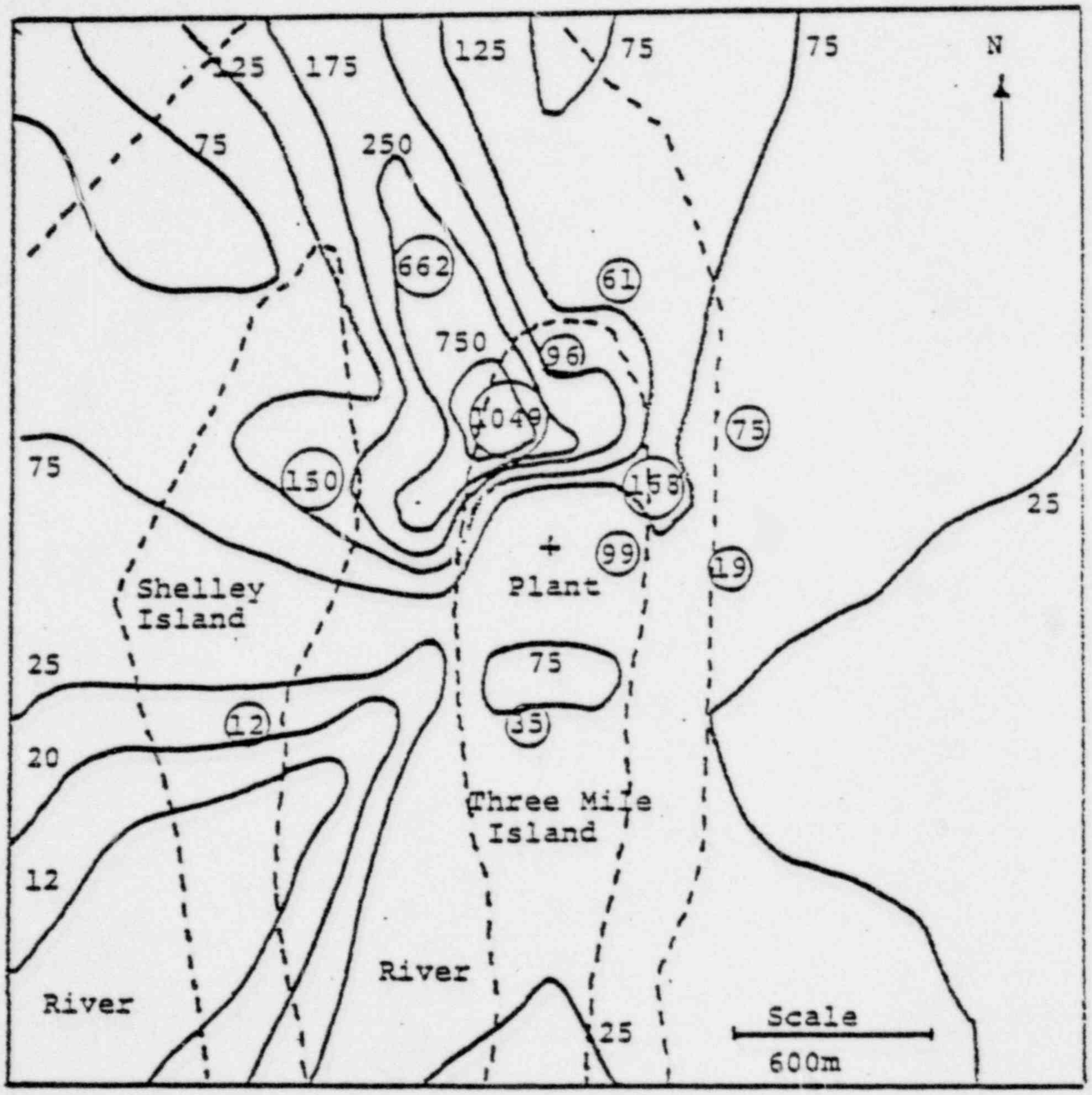


Figure 4-6

Estimated Whole Body Dose (millirem)
Within a One Mile Radius*

(Period of Record 3/28-4/6)



*Measured TLD doses over the same time period given in circles for comparison

Figure 4-7

Estimated Whole Body Dose (millirem)
Within a Two Mile Radius

(Period of Record 3/28-4/6)

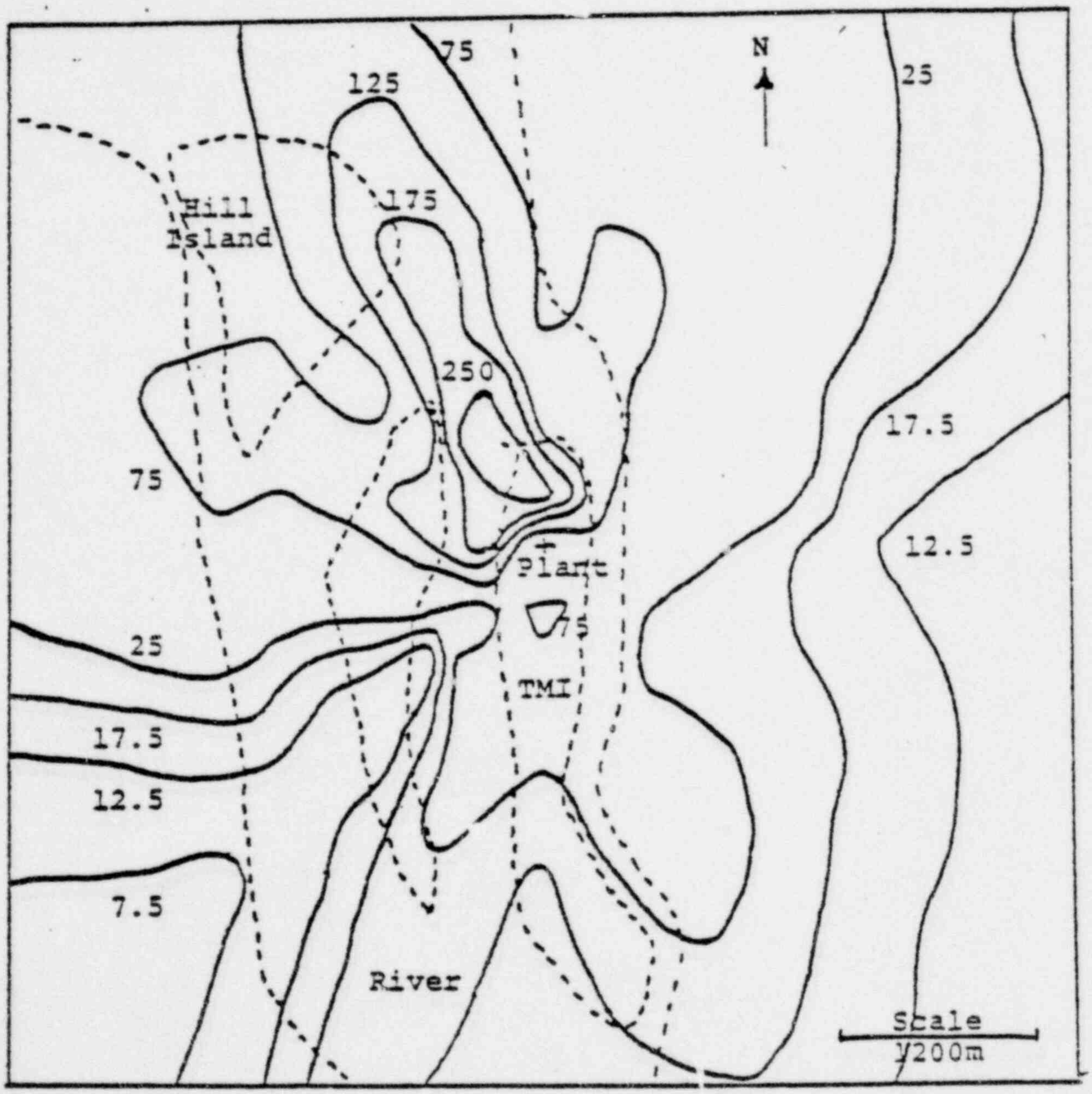


Figure 4-8

Estimated Whole Body Dose (millirem) Within a Five Mile Radius

(Period of Record 3/28-4/6)

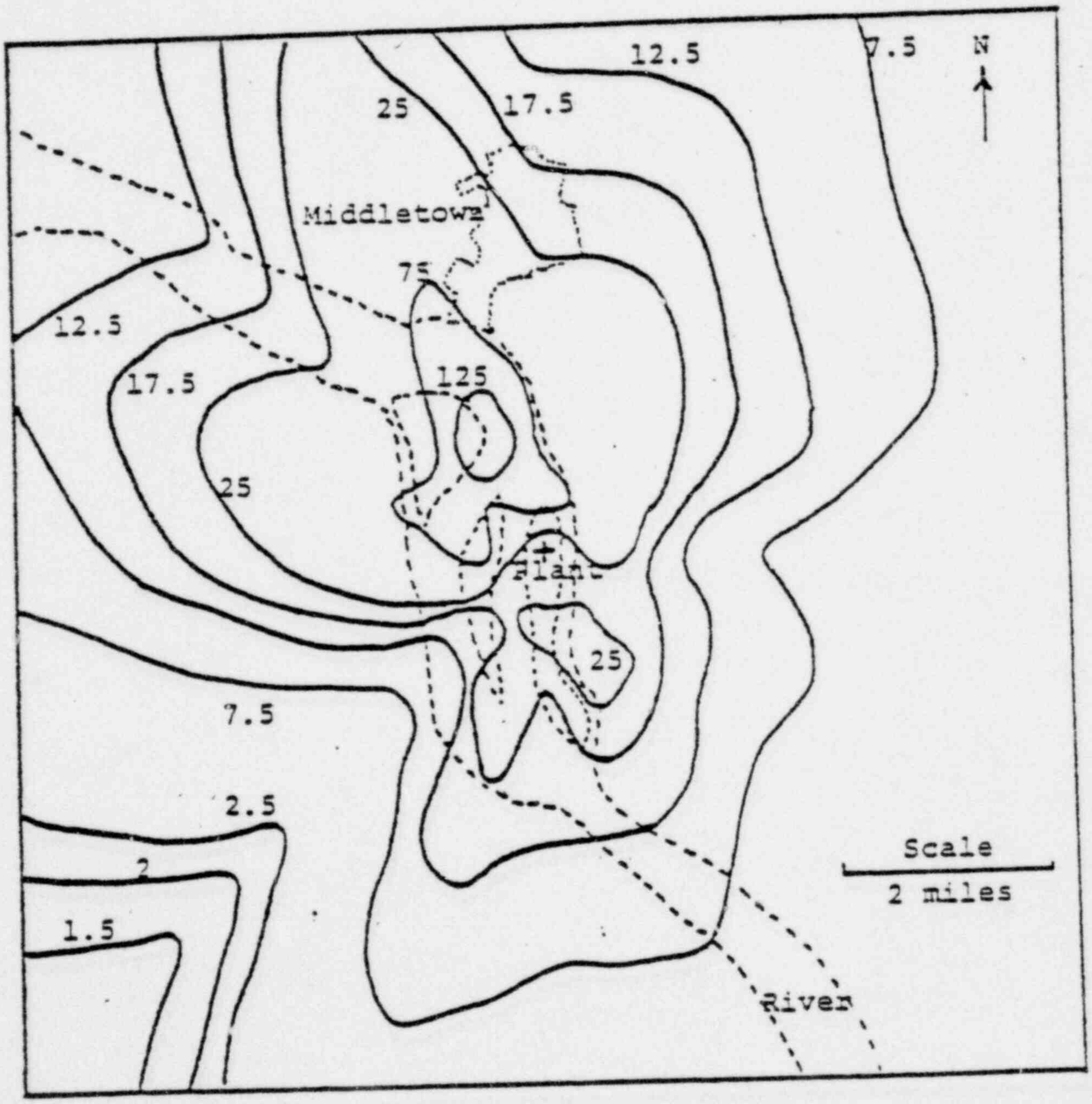


Figure 4-9

Estimated Whole Body Dose (millirem)
Within a 50 Mile Radius
(Period of Record 3/28-4/6)

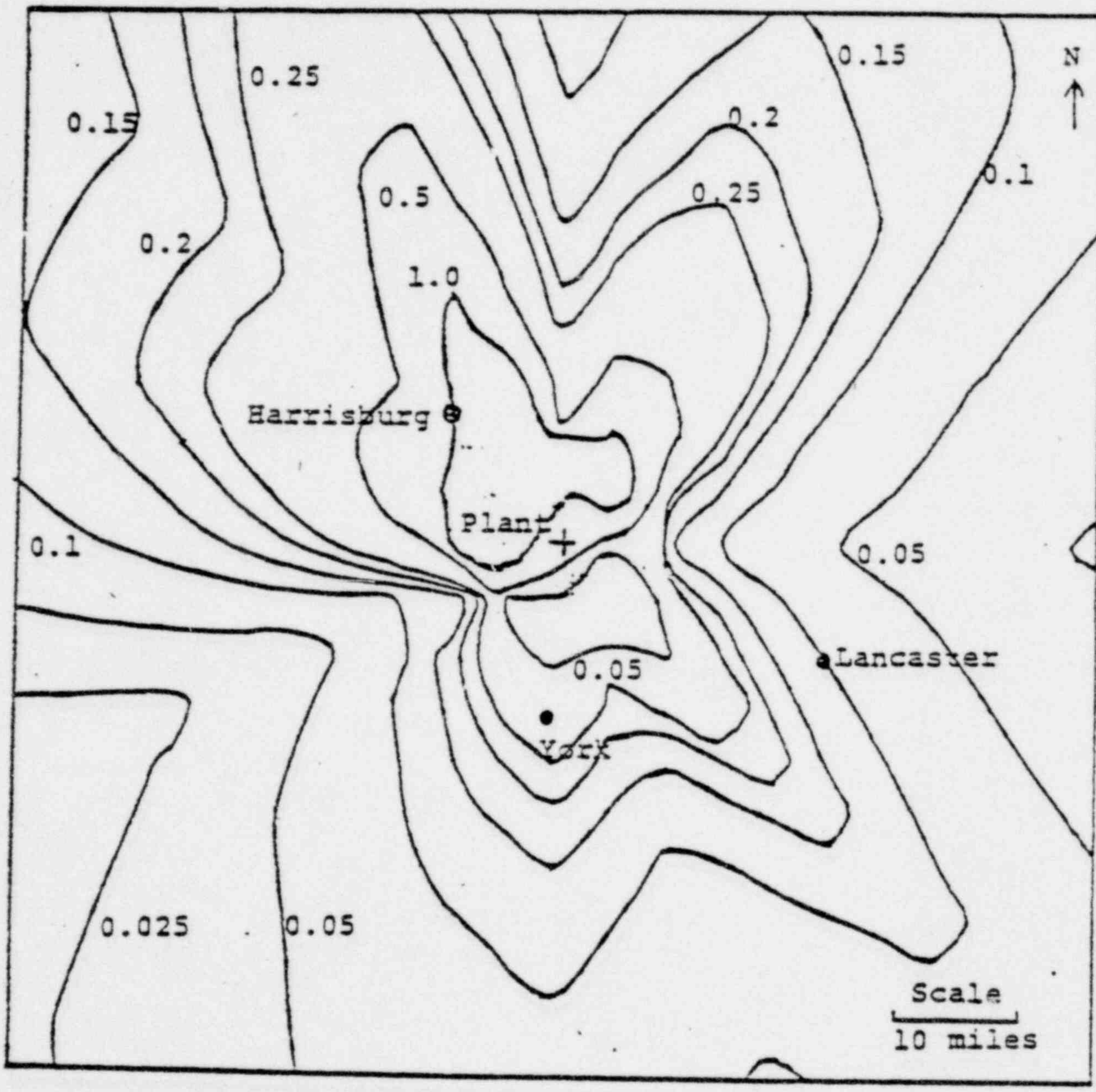


Figure 4-10

Estimated Beta Dose to Skin (millirem)
Within a Two Mile Radius

(Period of Record 3/28-4/6)

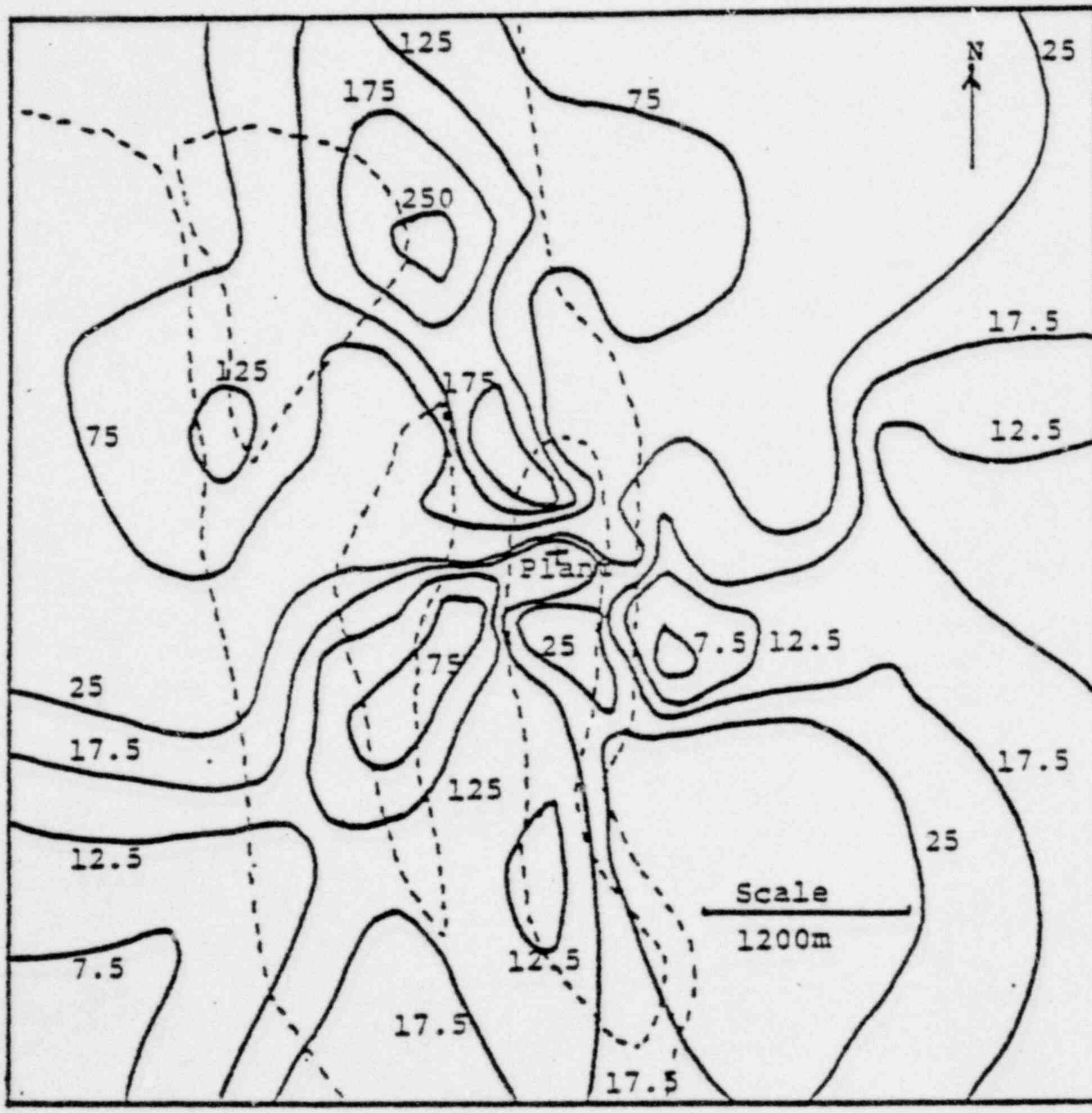
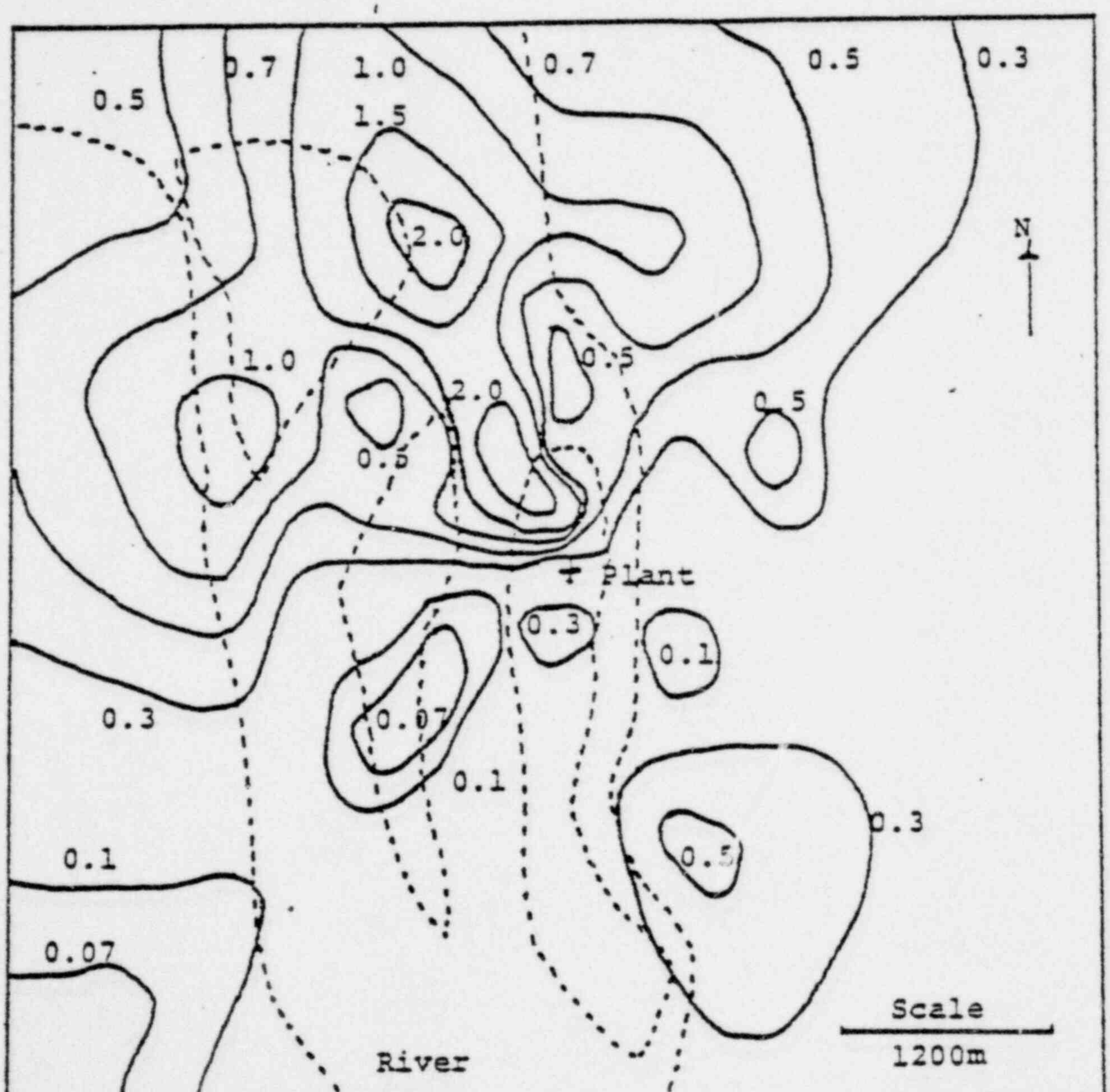


Figure 4-13

Estimated Fraction of Annual MPC for Noble Gases Released After the Accident

(Period of Record 3/28-4/6)



AVERAGED OVER WHOLE YEAR

5.0 OFFSITE IODINE AND PARTICULATE RELEASES AND DOSES

5.1 Releases

During the period March 28, 1979 through April 30, 1979, about 14.1 curies of iodine-131 and 2.6 curies of iodine-133 were released to the atmosphere from the ventilation systems of Units 1 and 2. The small fraction of the iodine discharged from Unit 1 came from Unit 2, probably through the Fuel Handling Building shared by the two units. Preliminary evaluations of particulate radioisotopes in airborne effluents indicate that these isotopes are not a significant contributor to offsite doses.

These estimates are based on analyses of air samples from the ventilation systems. Air leaving the plant through the ventilation system is continously sampled for radioactive particles and iodine by drawing a small side stream through a filter which traps particulate isotopes and a treated charcoal cartridge which traps iodine. The filters and cartridges are changed periodically and are analyzed in the laboratory to determine radioactive isotope concentrations in the effluent air. After the accident started, iodine samples from Unit 2 vent samples (HPR-219) were collected and analyzed every other day. For the few short periods when continuous samples are not available from HPR-219, release rates have been estimated by interpolation from data taken before and after. These interpolations are supported by analyses of continuous air samples drawn from the several air streams which flow into the Unit 2 vent during these periods.

Table 5-1 shows the estimated average release of iodine versus time from the plant vent through April 30, 1979. For purposes of the dose calculations release rates given in detail in Appendix C, Tables 3 and 4, have been grouped in periods during which release rates were reasonably constant. The selected periods and release rates are shown in Table 5-1. These periods are typically about three days long. Shorter time periods are used during periods of rapidly changing release rates.

5.2 Environmental Measurements

In addition to sampling air in the plant ventilation exhausts, Metropolitan Edison routinely and continuously samples air for radioactive iodine and particulates at specified locations both on and offsite as a part of the Radiological Environmental Monitoring Program (REMP) described in Appendix D. This environmental monitoring program also includes sampling of vegetation and milk. The program was in effect at the time of the accident and has continued with a higher than normal sampling frequency since the accident. Appendix D is a tabulation of measured data and a brief discussion of the program. Results from this program indicate that iodine-131 was the only radioactive isotope or particulate isotope released in significant quantities. Iodine-131 was detected in air and milk samples, as discussed below, and was also detected in some grass samples.

5.3 Thyroid Dose Estimates

Of the particulate and iodine isotopes released, iodine-131 accounts for essentially all the offsite dose. This dose results from concentration of iodine in the thyroid gland if air containing iodine-131 is inhaled or if milk from cows which have eaten grass containing iodine-131 is ingested. Two methods were used to estimate doses. In cases where sufficiently sensitive measurements of iodine-131 concentrations in air or milk were available, they were used to calculate doses. Otherwise, measured release rates and meteorological data were used in the dispersion model described in Appendix B to calculate concentrations of iodine-131 in air and milk. The first method was used primarily for assessing maximum doses to individuals and the second method was used primarily for assessing aggregate doses to the population within fifty miles.

Where possible, both methods were used and results were compared to aid in determining that the limited number of sampling points reasonably reflected the maximum dose to an individual and to aid in assessing the accuracy of the results obtained using the mathematical model.

5.3.1 Thyroid Doses Based on Effluent Data and Dispersion Model

5.3.1.1 Inhalation Pathway

As a part of the calculation of offsite inhalation doses from iodine-131, estimates were made of the average iodine-131 concentration in air, at all offsite locations near the plant. Results on Figure 5-1 show the highest average concentration from March 28 through April 30 to be 6.6 pCi/m^3 about 2400 meters west of the plant. If an adult had occupied this location throughout the accident, the inhalation dose would have been about 7.3 mrem as shown in Figure 5-2. Because of differences in thyroid size and breathing rates, the dose to a child would have been slightly higher, about 9.8 mrem.

MAY ... 73 FROM ALONE

The population dose due to inhalation of iodine was estimated using the release rates and the hourly dispersion model to compute inhalation doses at each population grid location (see Figure B-1 and B-2 of Appendix B). These were then multiplied by the population in each sector and summed. The total population dose was estimated to be 180 person-rems to the population within fifty miles of the plant (about two million people). [BUT ~ 30 MILLION PEOPLE WERE EXPOSED IN N.E. U.S (N.Y.; PA.; MD., N-ENGLAND)

Measurements of airborne iodine-131 concentrations near Three Mile Island are useful in assessing the uncertainties involved in estimating concentrations (and doses) using release rate and meteorological data with the dispersion model. An illustration of the magnitude of these uncertainties is given in Figure 5-3, which compares airborne iodine-131 measured concentrations versus calculated. Data in this figure are presented in Table 5-2.

Data in Figure 5-3 suggest that the calculated airborne iodine-131 concentration is likely to be within a factor of 4 of that measured. As shown in Figure 5-3, 14 of 23 comparisons were within this range and calculated values are more likely to be higher that those measured. The data in Figure 5-3 include all data collected in the REMP from March 28, 1979 through April 21, 1979, except for Station 8C1 during the period April 3 through April 12 when data were questionable.

Some caution should be used in interpreting the four points on Figure 5-3 with measured concentrations less than 0.05 pCi/m^3. These points represent stations at least 20,000 meters from the plant, and one or more of the three individual samples comprising the set used to determine a single point contained iodine-131 at levels lower than the lower limit of detection. In such cases, the concentration was assumed to be zero. Except for the four points under discussion, this assumption does not affect results. For these four points, however, actual concentrations may have been somewhat higher than this treatment of measurement results would indicate. A more accurate treatment would move these points horizontally somewhat closer to the line of agreement.

It should be expected that (the performance of) the atmospheric dispersion model is less accurate for calculating ground-level iodine-131 concentration than for calculating gamma doses (Section 4). The calculated gamma dose is a function of airborne radioactivity concentration integrated for significant spatial volumes around the receptor point whereas the ground level iodine concentration is calculated for a single point. Furthermore, calculated gamma dose does not depend as heavily on plume height as ground level concentration does. Thus, for any particular location, the gamma dose calculation is relatively less sensitive to uncertainties in the determination of plume height and the spatial distribution of concentration about the plume centerline.

*- THEREFORE, I-131 INHALATION DOSES MAY HAVE BEEN 4 TIMES LARGER.

5.3.1.2 Milk Pathway

Population doses from ingestion of milk produced within fifty miles were also estimated. These estimates were developed using detailed cow inventories out to 5 miles. Beyond 5 miles, county milk production rates were used to estimate cow populations assuming each cow produces 34 pounds of milk per day. Milk produciton rates within a 50-mile radius suggest a population of about 300,000 dairy cows. The population density in sectors to the ENE, E, ESE, and SE is about 75 cows per square mile which is approximately 2.5 times that in other sectors. There is evidence from cow population surveys within five miles that stored feed is an important fraction of the dairy cattle diet. Supporting evidence was found on page 2.1-4 of the TMI-2 FSAR which shows that in three counties near the plant only 5 to 10 percent of the land is used for pasture. At the grass yield (0.7 kg wet/m^2) specified for dose calculations in Regulatory Guide 1.109 (Rev. 1), pasture grass from 7.5 percent of the land within fifty miles of the plant could provide only twenty percent of the diet for 300,000 cows each consuming 50 kg per day. For these reasons and since warnings had been issued to keep cows in barns during the period following the accident, it has been assumed in making estimates of doses due to consumption of milk that pasture grass accounted for ten percent of the average cow's diet. All milk produced was assumed to be consumed in the form of fresh milk. Conversion to cheese and other processed forms would lead to reduction in doses due to decay of the iodine-131 during processing and storage.

The portion of iodine that was released in organic form does not deposit on grass. It was measured periodically in the exhaust vent and found to be at least 50 percent of the total on the average. This has been taken into account in making the thyroid dose estimates.

* BUT THE PLUME DID NOT STOP AT 50 MILES!

THIS NEGLECTS I-131 THAT PASSED THROUGH OPEN BARNS AND WAS FILTERED-OUT IN THE STORED HAY

Iodine concentrations in milk were estimated using the atmospheric dispersion model previously described and iodine uptake models which are the basis for Regulatory Guide 1.109. Details of this calculation are shown in Table 5-3. The population dose was estimated by calculating the average iodine concentration in milk produced in each sector within 50 miles. The sectors and cow populations in each sector are shown in Figure B-1 and B-2 of Appendix B. Results were then multiplied by the amount of milk produced in the sector and added to determine the total population dose. Results of these calculations indicated the potential for population thyroid doses to be 1100 person-rems due to consumption of milk produced within fifty miles of the plant.

This estimate is likely to be higher than the true population dose. In a test of the model for three locations at which suitably sensitive analyses of iodine-131 in cow milk were available, doses calculated using the model with assumptions noted above were ten to fifty times those estimated from measured concentrations in milk. The estimates based on reliable measured concentrations are certainly more accurate because the model must simulate the process of dispersion in air, deposition on grass, and transport from grass to milk, each of which is subject to some analytical uncertainty.

As shown in Figure 5-4, the points at which milk samples were collected in the REMP are representative of those locations where highest concentrations of iodine-131 in milk would be expected, based on calculated iodine-131 concentrations in air. Because of this fact and because conservative results were obtained in the test described above, the model was deemed unsuitable for accurate assessment of maximum doses to individuals consuming milk.

However, this model is considered suitable for assessment o population doses even though it leads to substantial overestimates. ||*
Measured concentration of iodine-131 in the many milk samples collected within fifty miles of the plant are not useful for making

NO: IT NEGLECTS ALL COWS BEYOND 50 MILES!

a population dose assessment. Measurements of iodine-131 in milk collected by organizations other than Metropolitan Edison at distances beyond a few miles indicated no detectable concentrations for the most part. However, the sensitivities of these measurements are not sufficient to provide an accurate population dose estimate.

5.3.2 Thyroid Doses Based on Environmental Samples

The above dose estimates have been made independently of measured iodine concentrations in air and milk. Measurement results in Appendix D indicate peak iodine levels in goat milk to be less than 110 pCi/l, with an average from March 28 through April 30 at any one sample location of about 29 pCi/l. These figures apply to goat milk collected at location 1B1 (see Appendix D), about one mile north of the plant. The comparable values for cow milk are 21 pCi/l peak and 2.4 pCi/l average at location 7B3, 1.4 miles SE. If an infant had been consuming milk produced at these locations from March 28 through April 30, 1979, his dose is estimated to be 1.1 millirems from cow milk or 13 millirems from goat milk. However, as noted in Appendix E, the goat milk is not now being used for human consumption. Airborne sample results (Appendix D) indicate that the highest average airborne iodine concentration at any location from March 28 through April 30, 1979 was 3.3 pCi/m^3 which would result in an adult inhalation dose of 3.7 millirems and a child inhalation dose of 5.0 millirems. These values are slightly lower than the estimated adult inhalation thyroid dose of 7.3 millirems and child inhalation dose of 9.8 millirems based on effluent releases and weather data as discussed in section 5.3.1 above.

* COMPARES WITH N.Y. CITY AV. I-131 IN MILK AT HEIGHT OF 1961-66 NUCLEAR TESTS.

Table 5-1

Smoothed Iodine Release Rate Data
Used in Dose Assessments

Start Date (yr. mo. da. hr.)	I-131 Release Rate µCi/sec
79032804	4.2
79032819	22.7
79033022	2.7
79040106	9.7
79040303	2.3
79040319	7.0
79040519	0.43
79040615	3.7
79040706	6.9
79040803	12.7
79040909	0.46
79041016	1.3
79041119	2.2
79041323	4.1
79041410	6.6
79041505	8.6
79041508	14.0
79041518	6.0
79041616	11.0
79041624	3.0
79041716	5.5
79041804	7.5
79041808	2.0
79041914	5.5
79042022	1.5
79042213	2.5
79042304	1.0
79042312	3.8
79042316	1.5
79042406	0.80
79042516	0.50

Table 5-2

Calculated Versus Measured Concentrations of Iodine-131 in Air (pCi/m^3) (3/28/79-4/21/79)

ation	Distance	Direction	3/28-4/3 Calculated	3/28-4/3 Measured	4/3-4/12 Calculated	4/3-4/12 Measured	4/12-4/21 Calculated	4/12-4/21 Measure
9G1	21000	S	.98	.22	.09	.02	.12	.02
2B1	2600	WSW (close to W)	16.733	8.26	7.35	.58	3.66	.21
5G1	24000	NW	.42	.61	.12	0	.26	.02
S2	640	N	2.43	8.00	1.29	.36	.22	.32
C1	4200	N	3.42	3.81	.61	.16	1.23	.16
A1	640	E	1.73	6.9	1.29	1.72	.83	2.89
F1	14500	SE	.85	.17	.30	.11	.22	.21
C1	3400	SSE	4.30	7.39	1.06	*	1.12	.23

Measurements for each period are based on time-weighted averages of concentration measured as follows:

Data for 3/28-4/3 are based on samples 3/22-3/29, 3/29-3/31, 3/31-4/3 with 3/22-3/29 results adjusted to the period 3/28-3/29.

Data for 4/3-4/12 are based on samples 4/3-4/6, 4/6-4/9, and 4/9-4/12.

Data for 4/12-4/21 are absed on samples 4/12-4/15, 4/15-4/18, and 4/18-4/21.

[illegible]

TABLE 5-3

Calculation of Population Dose From Milk Ingestion

$$D = f_p * f * \frac{1}{\lambda_{eff}} * \frac{1}{Y_v} * Q_f * F_m * Y_m * \frac{1}{U} * F_d * \exp(-\lambda_i t_f) * \sum_{k}^{time} \sum_{j}^{space} N_j * Q_k * (D/Q)_{kj}$$

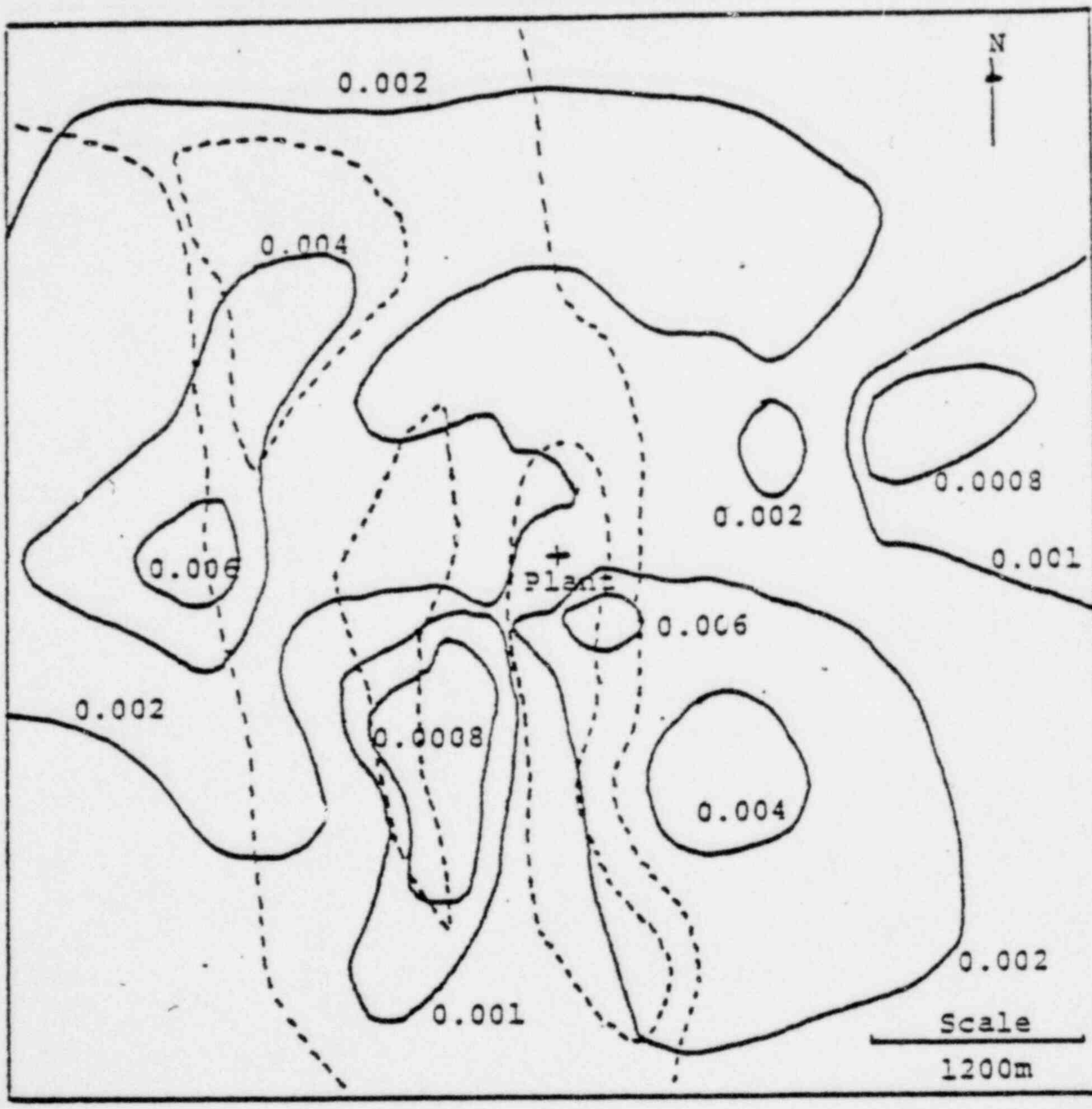
where

D	=	population dose (person-rem)
f_p	=	fraction of feed from pasture, 0.1 (see text)
f	=	fraction of organic iodine in iodine release, 0.5 (see text)
λ_{eff}	=	effective removal constant from vegetation, 49.5 yr^{-1}
Y_v	=	areal vegetation density, 0.7 kg (wet)/m^2
Q_f	=	rate of consumption of feed by cow, 50 kg (wet)/day
F_m	=	transfer factor from cow feed to cow milk, 0.006 day/liter
Y_m	=	milk yield for one cow, 5640 liters/year or 34 lb/day (from local agricultural statistics)
U	=	age weighted milk consumption rate, 137 liters/year-person
F_d	=	age and consumption weighted ingestion dose factor for iodine-131, 3.8 E+08 rem-liter/year-curie
λ_i	=	iodine-131 radioactive decay constant, 0.0861 day^{-1}
t_f	=	delay time between milk production and consumption, 2 days
N_j	=	number of cows in sector segment j (see Appendix B)
Q_k	=	iodine-131 release in time period k (see Section 5)
D/Q	=	deposition parameter (m^{-2}), (see Appendix B)

Unless specified otherwise above, values for all parameters are based on values in USNRC Regulatory Guide 1.109 (Rev. 1), October, 1977.

FIGURE 5-1

Estimated Fraction of Annual MPC (F_{MPC})
for Iodine-131 from 3/28/79-4/30/79
Within Two Miles of Three Mile Island[1]



(1) Concentrations are based on measured release rates and site meteorological data used with a straight-line dispersion model. M... 10CFR20, App. B, Table II, maximum permissible concentration ... iodine-131 in air 1×10^{-10} uCi/cc. Concentration averaged over ... period 3/28 - 4/30 is calculated as follows:

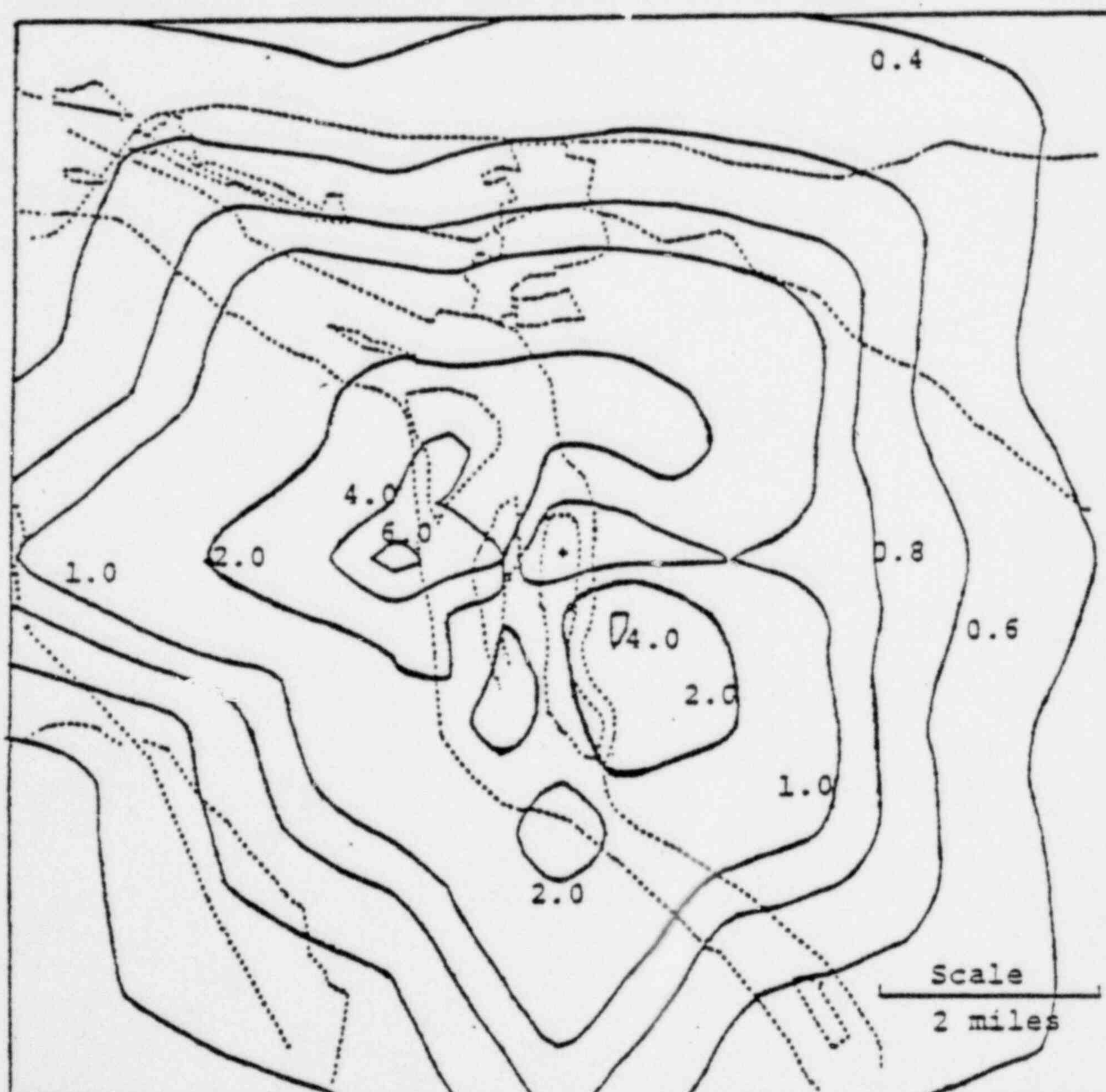
C = FMPC * 1E-10 * 1E12 * 8760 * 1/808

pCi/m³ — uCi/cc — pCi-cc/uCi-m³ — hr/yr — period/hr

[MPC is 0.1 pCi]

Figure 5-2

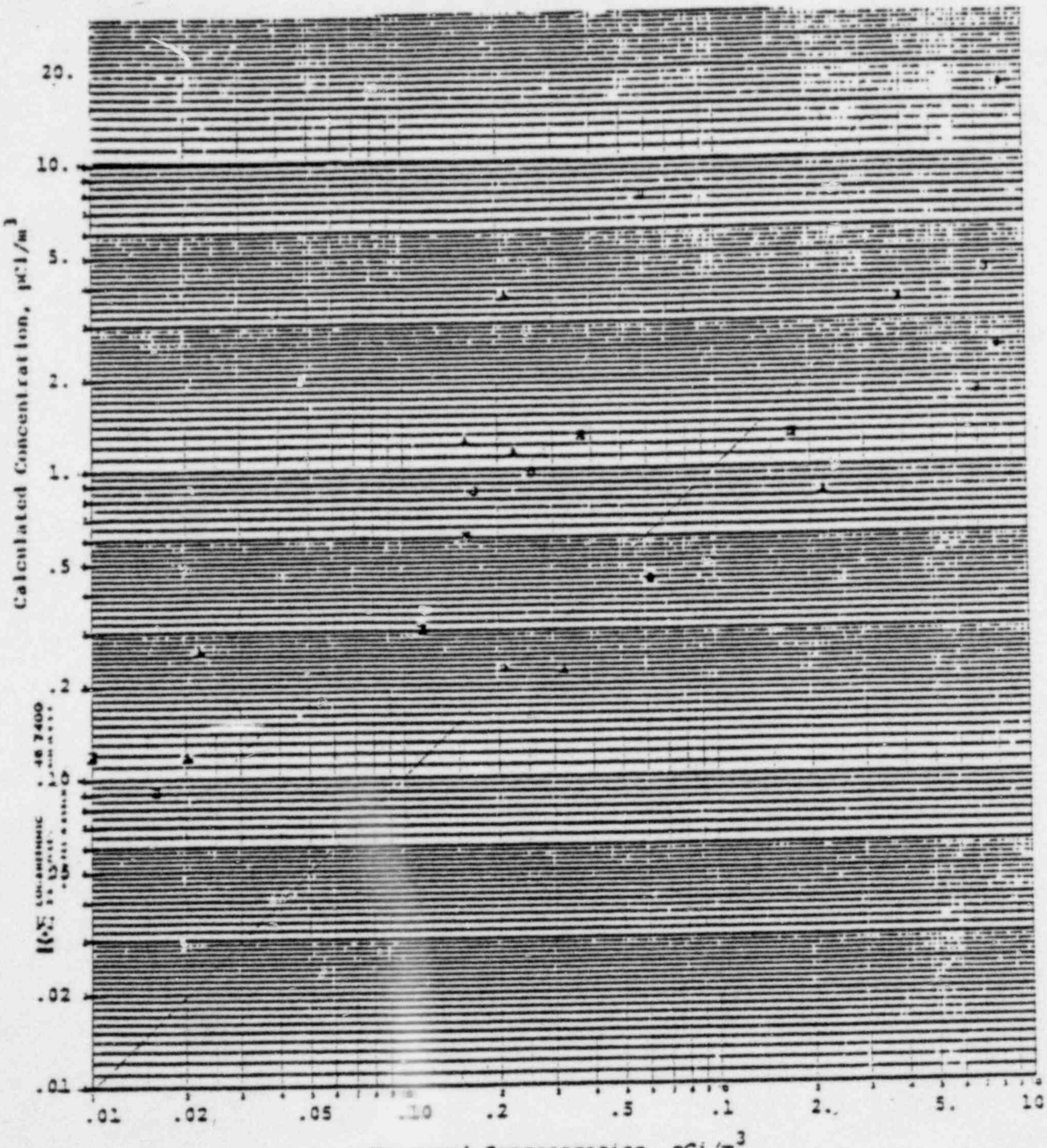
Estimated Adult Inhalation Thyroid Dose
Within Five Miles of Three Mile Island[1]
From Iodine-131 Released From 3/28/79 - 4/30/79 Millirem



[1] Multiply by 1.5 to obtain dose to child thyroid
Multiply by 1.3 to obtain dose to infant and teen-age thyroid

FIGURE 5.3

Calculated Versus Measured Concentrations of Iodine-131 in Air at Three Mile Island Environmental Monitoring Stations



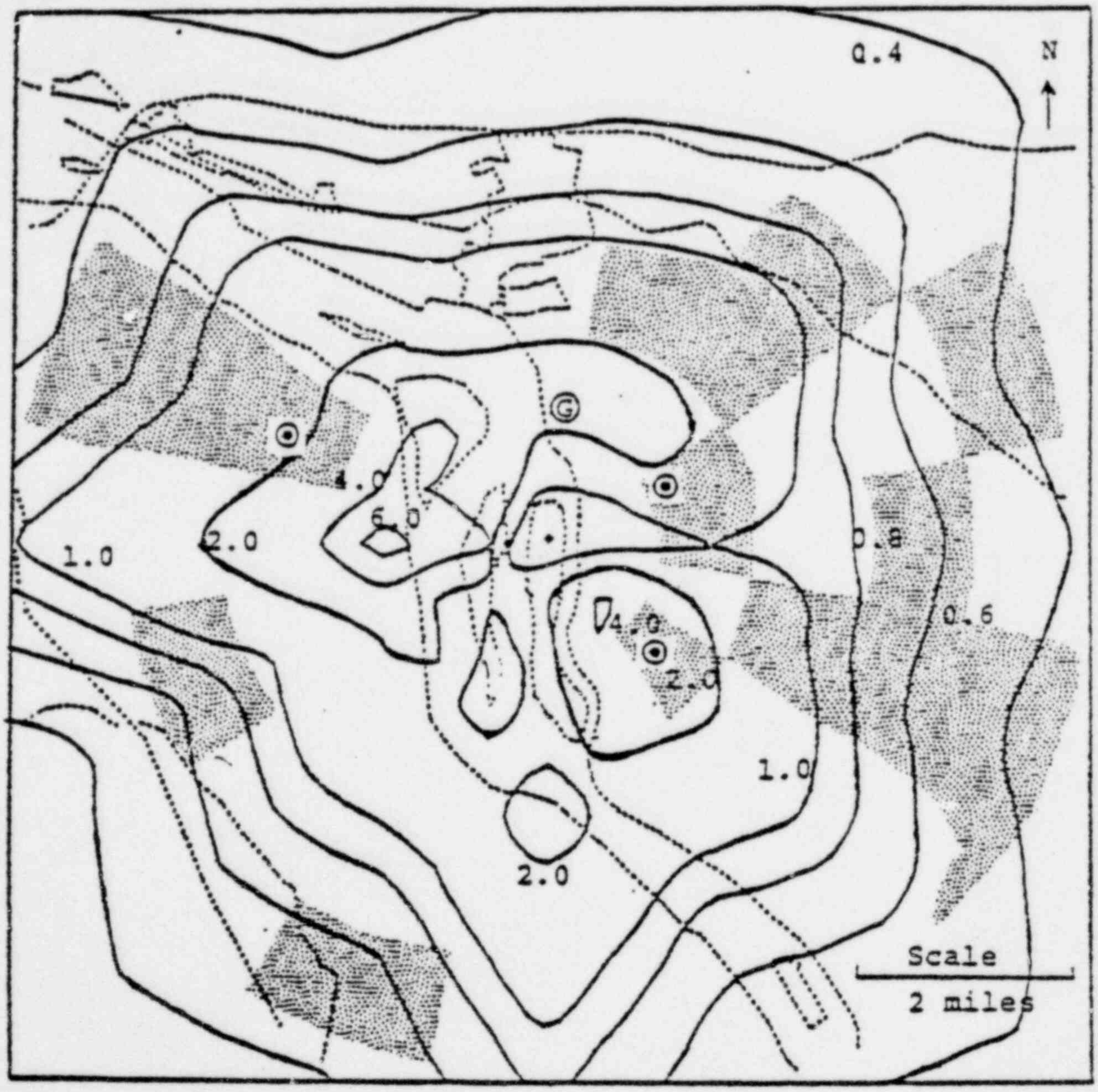
● 3/28-4/3
■ 4/3-4/12
▲ 4/12-4/21

Points within dashed lines agree within a factor of four.

POOR ORIGINAL

Figure 5-4

Cow Locations and REMP Milk Sample Points
Within a Five Mile Radius
With Isopleth of Concentration
of Iodine-131 in Air (pCi/m^3)
Averaged Over the Period 3/28/79-4/30/79



Indicates area within five miles with cows

Ⓖ Indicates goat milk sample point

⊙ Indicates cow milk sample point

7.0 RECOMMENDATIONS

The quality and large quantity of data available for this report make it unlikely that new information will turn-up which substantially changes the dose assessments reported herein. But, if such information exists it is important to find it and assess the effect.

Consequently it is recommended that:

1. The systematic review of new information related to dose assessments should be continued to identify and evaluate any important effects it might have on the dose assessments in this report. This recommendation applies particularly to a large body of environmental data collected by governmental agencies in the early days following the accident. Only a part of this data was available for the preparation of this report. The recommendation also applies to any plant data which might enable better definition of isotope releases, particularly noble gas isotope releases.

An important part of the uncertainty in the calculation of doses from noble gases stems from the limited information available for characterizing noble gas releases from the accident. || *

The second recommendation is aimed at improving capabilities for obtaining that kind of information in the future.

Consequently, it is recommended that:

2. An integrated review should be conducted of all radiation monitoring programs (including in-plant area monitoring, effluent measurements, and environmental measurements to evaluate the capability

* THEREFORE TRUE INTERNAL DOSES ARE NOT CALCULATED FOR CRITICAL ORGANS EXCEPT I-131 TO THYROID

2. (cont'd)

for determining the nature, the pathways, the fates, and the impacts of radioactive isotopes which might be released through plant pathways into the environment in normal and accident conditions. To be comprehensive, the review should also consider predictive capability. The report resulting from this review should identify modifications which would improve these capabilities and should include an assessment of limitations in these capabilities.

If, in the future, it becomes desirable to improve the accuracy and reduce the uncertainties in the dose assessments, the atmospheric dispersion models used could be improved. Experience in doing the dose assessments shows that the focus of such improvements would be better definition of the effects of wind direction change, better estimation of the effects of dilution in the wake of plant structures and better estimation of plume height. It is unlikely that work in this area would lead to substantial increases in the dose assessments provided in the body of this report. However, some decreases might result.

Reprinted From The Journal of The American Medical Association
August 27, 1960, Vol. 173, pp. 1895-1902

see p. 1897 Fig. 3 Re: Dr. Sternglass testimony OES hearing State of Calif.

Radioactive Iodine Concentration in the Fetal Human Thyroid Gland from Fall-out

William H. Beierwaltes, M.D., Horace R. Crane, Ph.D., Audrey Wegst, M.S., Norma R. Spafford, A.B., and Edward A. Carr Jr., M.D., Ann Arbor, Mich.

A study was made of the occurrence of I^{131} in human fetal thyroid glands apparently resulting from I^{131} received by the mother from nuclear weapons testing or other types of population contamination. Radioactivity compatible with I^{131} was found in the human fetal thyroid gland. The maximum concentration of I^{131} was 265 μμc per gram of fetal thyroid tissue, 29.1 μμc per gram of adult hog thyroid tissue and 22.9 μμc per gram of adult thyroid tissue. The highest activity found on a reagent blank was 10.0 μμc. The calculated maximum total radiation delivered to any human fetal thyroid gland was 0.47 rads. The average total dose was 0.05 rads. Extrapolations from data on animals suggest that it is unlikely that this quantity of radiation would produce hypothyroidism or carcinoma of the thyroid gland.

Radioactive iodine, I^{131}, from nuclear weapons testing has been reported to be present in the thyroid glands of adult cattle, swine and sheep, in the fetuses of these sheep, and in adult human beings.[1] Since I^{131} passing from the human maternal to the fetal circulation will be concentrated by the fetal thyroid gland as early as the third month of gestation,[2] we should expect the presence of I^{131} in human fetal thyroid glands. This activity results from I^{131} received by the mother from nuclear weapons testing or other types of population contamination. We wish to report on an investigation we have made of the concentration of I^{131} found in human fetal thyroid glands. The concentration of I^{131} was apparently insufficient to cause hypothyroidism or thyroid carcinoma.

Method

Sources of Specimens.—Twenty-seven human fetal thyroid glands from 25 pregnancies were obtained at the time of abortion, caesarean section, premature labor, stillbirth, or neonatal death during the period Nov. 12, 1958, to Aug. 1, 1959, from four hospitals within a radius of 10 miles of Ann Arbor, Mich.

Only fetuses aged 5 months through term stillbirth (except for one newborn infant, 3 weeks of age) were used in this study. Twelve human adult thyroid glands, not from mothers of these fetuses, were also collected from autopsies at University Hospital Nov. 19, 1958, through March 31, 1959, and analyzed. In addition, 25 adult and fetal hog thyroid glands were collected during the period Jan. 6, 1959, to July 8, 1959, from a local abattoir and used as controls. These hogs were all from Washtenaw County (around Ann Arbor, Mich.).

Data on age of fetuses, causes of death, condition of fetus, history of maternal systemic disease, maternal thyroid or iodide medication, or maternal thyroid disease were obtained at autopsy on the fetus, by examination of the medical records of the mother, and by interview of the mother. These data are presented in the table.

Preliminary Treatment of Thyroid Glands.—Most thyroid glands used in this study were dissected free of the fetus by the pathologist within one hour after delivery of the fetus. Histologic sections were obtained on many thyroid gland specimens to identify the tissue as thyroid gland. None of the sections showed a significant degree of autolysis. If chemical extraction of iodine from the thyroid tissue had to be delayed, the tissue was immediately frozen and stored at approximately —40° C until the time of analysis. The chemical extraction was always begun within a period of one hour to three days after delivery of the fetus.

From the departments of internal medicine, physics, radiology, and pharmacology and the Thyroid Research Laboratory, Kresge Medical Research Building, University of Michigan Medical Center.

Presented at the 32nd annual meeting of the Central Society for Clinical Research, Chicago, Nov. 7, 1959.

663-1531

Care of Apparatus.—All apparatus and instruments used for analyses of human and hog thyroids in these experiments were stored and used separately from all other equipment in our laboratory. A second complete set of apparatus was used for recovery experiments. It was never used for unknowns. At the beginning of this study, pipettes were not isolated as described above, but in the latter part of the study separate sets of pipettes were also maintained for each type of experiment.

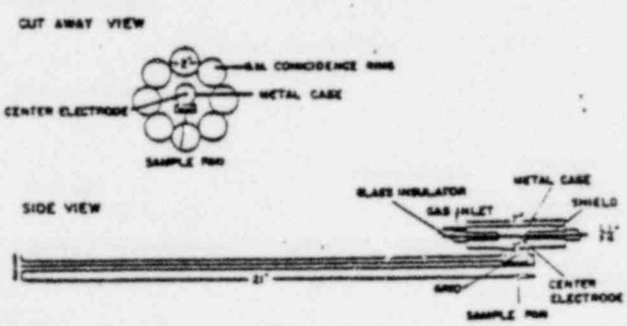


Fig. 1.—Diagram showing assembly of low-background G-M counter in which filter papers were counted.

Chemical Extraction of I^{131} from Thyroid Tissue.—Chemical extraction of I^{131} from thyroid tissue consisted basically of four steps: mechanical preparation of the tissue, digestion with oxidizing agents, distillation of the I^{131} out of the digest, and drying of the collected distillates. Fresh thyroid tissue was dissected free of fat and weighed. If the thyroid tissue weighed less than 1 Gm., normal rabbit serum was added to supplement the protein content to a total weight of 200 mg. (the estimated amount of protein in 1 Gm. of thyroid tissue). The tissue was minced and transferred to a digestion flask containing, in analyses of hog thyroids, 3.5 ml. and in all other experiments 2.5 ml. of chromic acid reagent, 40.0 ml. of sulfuric digestion reagents and glass beads.[3] Parts two and three of the Hycel Hormone Chemical Company's modification of the original Barker method[4] were followed, as described in their procedure manual[3] with the following two modifications. At the suggestion of Dr. Barker,[5] the distillate was collected in a trap solution containing 0.1 N sodium arsenite in 20% sodium hydroxide rather than into a solution of sodium hydroxide alone. No arsenious acid reagent was added to the centrifuge tube into which the distillate was drained.

The distillate was poured into a micro-buret and dripped slowly onto filter paper disks measuring 22 mm. in diameter. The disks were supported between slits in two waxed paper cups and a stream of warm air was used to facilitate drying.

Reagent Blanks.—Eleven reagent blanks were prepared and counted during the period from Nov. 30, 1958, through July 28, 1959. Three milliliters of stored normal rabbit serum, 2.5 ml. of chromic acid reagent, and 40.0 ml. of sulfuric digestion mixture made up the reagent blank. Digestion and distillation were carried out as described above.

Recoveries.—In order to test recovery, six additional experiments using 0.03 to 0.2 μc of I^{131} in the form of added carrier-free NaI^{131} or in the form of I^{131} already incorporated into thyroid tissue were carried out. The mean over-all recovery was 73.6% ± 6.2 (standard deviation). Counts made at various stages of the procedure showed that most of the loss occurred during drying on the filter paper.

Counting of Samples.—The filter papers containing the dried distillate were counted side by side in a windowless gas-flow Geiger counter surrounded by an anticoincidence ring of G-M (Geiger-Müller) counters 61 cm. in length and 5.7 cm. in diameter. The counting assembly was housed in a cave of old iron bricks with a minimum thickness of 8 in. A diagram of this assembly is seen in figure 1.

The background count in the counting chamber not canceled by coincidence counts from the ring of Geiger counters was approximately 1.6 counts per minute.

Each sample was counted for four hours or more and background counts were run overnight. Since the counts occurring in the counting chamber not canceled by a simultaneous pulse from the coincidence ring increased proportionally with an increase in the counts canceled by the coincidence ring, all uncanceled counts were standardized to a canceled count of 25 counts per minute, an average value. Samples showing activity greater than twice the background count were recounted weekly until the fall in count rate showed a plateau.

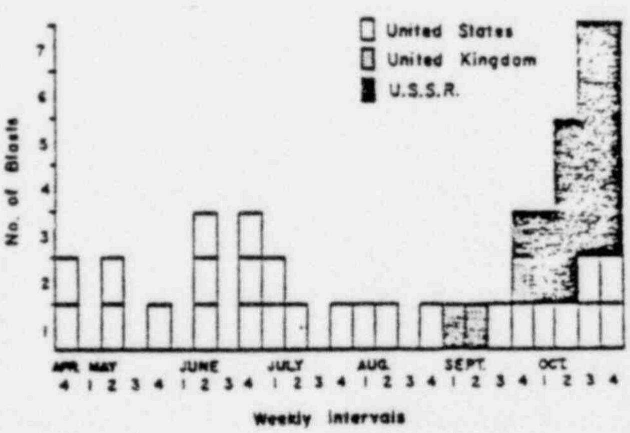


Fig. 2.—Frequency of atomic blasts in 1958.

A line of best fit was calculated from the data, assuming a single isotope decay rate. From this line the half-life of the radioisotope counted was determined. Because the half-lives thus determined agreed closely with the half-life of I^{131}, the activity of each sample was calculated back to the day of fetal delivery, using the decay rate of I^{131}.

The over-all efficiency of the counting system was found by drying a known volume of a solution of I^{131} containing a known number of disintegrations per second on filter paper, as described above. This standard was then counted in the usual manner. The over-all efficiency of the counting system was thus found to be 14%. This value included the loss of activity during the drying process, about 28%. With this knowledge the number of micromicrocuries of I^{131} per gram of fetal thyroid tissue and per total thyroid gland was calculated.

Results

Nuclear Weapons Testing.—Figure 2 is a bar graph presenting the frequency of nuclear blasts during 1958 by the United States, Great Britain, and Russia.*

A maximum atmospheric concentration of I^{131} would be expected to occur during the last week of October. Our sampling began less than two physical half-lives after the last blasts. We have not been informed of the occurrence of any further nuclear weapons testing during the period of November, 1958, to August, 1959.

Data on Human Fetuses and Their Mothers.—The table presents data on human fetuses and their mothers. Repeated counting of extracted material from seven fetal thyroid glands collected over the period Nov. 24, 1958, through May 12, 1959, gave values of radioactive half-life ranging from 7.5 to 9.8 days and averaging 8.4 days, roughly the half-life of radioactive iodine, I^{131} (8.1 days).

Although the median I^{131} content of the reagent blanks was equivalent to only 2.1 $\mu\mu c$, the maximum I^{131} content was equivalent to 10.0 $\mu\mu c$. This maximum is higher than the fetal thyroid gland I^{131} concentration of all but eight fetuses. Excluding the dates Nov. 30, 1958, to Dec. 23, 1958, however, the activity of reagent blanks never exceeded 3.5 $\mu\mu c$ per gram. Only two human fetal thyroid glands were obtained during the above interval. Excluding these two fetal thyroid glands, only eight fetal thyroid glands failed to exceed the maximum reagent blank activity of 3.5 $\mu\mu c$. These eight glands are scattered fairly uniformly throughout the period Feb. 27, 1959, to July 24, 1959.

Figure 3 presents a comparison of the concentration of I^{131} in the human fetal thyroid gland to the concentration in human adult and hog thyroid glands, and in reagent blanks during the same period of sampling.

It is important to note that the plot in figure 3 on a semilog scale minimizes the apparent fetal thyroid gland peak concentrations of I^{131} and tends to emphasize small variations in activity in samples containing little activity. The following observations from figure 3 are noteworthy.

1. These four groups of samples may be listed in order of average decreasing concentration of radioactivity as follows: fetal thyroid gland, hog thyroid gland, human adult thyroid gland, and reagent blanks. Generally, the fetal thyroid I^{131} concentration is 2 to 10 times greater than the human adult thyroid I^{131} concentration and shows greater variation. One group of pooled hog fetal thyroids showed a 58% greater concentration of I^{131} than was found in the mother's thyroid.

It is of interest that the twin human fetuses 13 and 14 showed only a 9% difference and twin fetuses 25 and 26 showed only a 39% difference in concentration of I^{131}. The total thyroid gland I^{131} content of the twins in each instance was roughly the same, even though the concentration of I^{131} differed.

2. Fetal thyroid gland I^{131} concentration decreased during the period December, 1958, through March, 1959, with an apparent half-life of about 20 days.

3. The variation in concentration of I^{131} from one fetal thyroid gland to the next is roughly tenfold to twentyfold during the period from November to February. The variation in concentration then appears to become less as the concentration in all specimens falls between February and May.

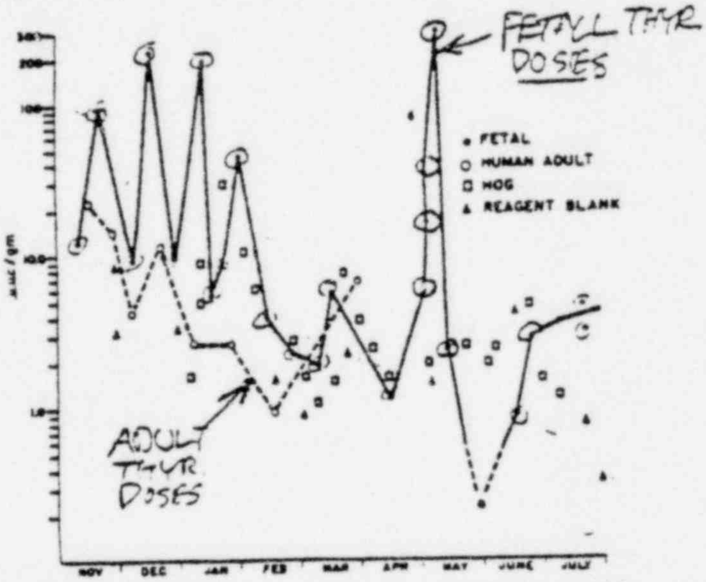


Fig. 3.—Comparison, by month, of concentration of I^{131} in thyroid gland specimens and in reagent blanks.

4. The concentration in fetal thyroid gland specimens in May builds up progressively through four successive specimens to a peak hundredfold increase, with no similar rise in hog thyroid gland or reagent blank I^{131} concentration.

I^{131} Content and Fetal Age.—Histological study of human fetal thyroid tissues demonstrated that colloid-containing follicles were clearly evident in all specimens past 4 months of fetal age. Our data suggest that the fetal thyroid gland weight increases until 7 months of age and then reaches a plateau. No correlation is apparent between I^{131} concentration in the human fetal thyroid and age of the fetus or weight of the thyroid gland after the fourth month of gestation.

Correlation of I^{131} Content of Fetal Thyroid with Condition of Fetus and Thyroid Status of Mother.—No relation was observed between the cause of death in the fetus and the I^{131} concentration of the thyroid gland. Fetus 4, with the second highest concentration of I^{131} in his thyroid gland, died at