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NUCLEAR REGULATORY COMMISSION

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ADVISORY COMMITTEE ON NUCLEAR WASTE (ACNW)

173rd MEETING

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MONDAY,

SEPTEMBER 18, 2006

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ROCKVILLE, MARYLAND

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The Advisory Committee met at the Nuclear Regulatory Commission, Two White Flint North, Room T2B3, 11545 Rockville Pike, at 10:00 a.m., Michael T. Ryan, Chairman, presiding.

COMMITTEE MEMBERS:

MICHAEL T. RYAN	Chairman
ALLEN G. CROFF	Vice Chairman
JAMES H. CLARKE	Member
LATIF S. HAMDAN	Member
WILLIAM J. HINZE	Member
RUTH F. WEINER	Member

ACNW STAFF PRESENT:

JOHN T. LARKINS, Executive Director, ACRS/ACNW

ANTONIO DIAS

NEIL M. COLEMAN

DEREK WIDMAYER

ALSO PRESENT:

DR. THEODORE ROCKWELL, Radiation, Science & Health, Inc.

DR. DON COOL, NRC

I-N-D-E-X

P-R-O-C-E-E-D-I-N-G-S

(10:02 a.m.)

CHAIRMAN RYAN: We will come to order, please. This is the first day of the 173rd meeting of the Advisory Committee on Nuclear Waste.

During today's meeting, the committee will consider the following: observations from ACNW members on staff and recent member activities, and discussion of draft ACNW letters. The first item will be this morning's activity, and the draft letter writing will be this afternoon.

The meeting is being conducted in accordance with the provision of the Federal Advisory Committee Act. Antonio Dias is the Designated Federal Official for today's session.

We have received a request by Dr. Theodore Rockwell from Radiation, Science & Health, Incorporated to make an oral statement during today's session. Should anyone else wish to address the committee, please make your wishes known to one of the committee staff.

It is requested that speakers use one of the microphones, identify themselves, and speak with sufficient clarity and volume, so they can be readily heard. It is also requested that if you have cell phones or pages that you kindly turn them off.

I will begin with some items of current interest. Dr. Richard Savio -- is Dr. Savio with us at the moment? Has been with the ACRS for more than 30 years. He will be retiring on September 30, 2006. During his tenure with the ACRS and the ACNW staff he has provided outstanding technical support to the ACRS on numerous matters, including reviews and evaluation of safety research project and programs in support of ACNW safety research reports.

On behalf of the committee, I would like to thank Dr. Savio for his contributions, and I know I speak for all members and staff in wishing him good luck in his future endeavors, and thank him for his more than 30 years of service to this agency and to the country.

Mr. Noble S. Green, Jr., an administrative secretary to the Executive Director for ACRS/ACNW office for the past three years has accepted a position as an administrative support specialist in the Information Management Branch for Nuclear Reactor regulation. He started his new job on September 1st, and he has provided outstanding administrative support to both the ACRS staff and the committee members.

And on behalf of the committee, I again

would like to thank Mr. Noble S. Green, Jr., for his support and wish him much success in his new position in the agency. Thank you very much.

Without further ado, I will turn to our agenda. And the first item is some observations of members, and we will start with the visit to the Crow Butte in situ leach facility in Nebraska. And I think Dr. Weiner will lead the discussion, supported by Latif Hamdan.

MEMBER WEINER: I have some slides. It's a Powerpoint slide. Just take a moment to get our slides up.

On August 15th, Dr. Hinze and Dr. Hamdan and I went to -- visited the Crow Butte facility, and we -- I want to get the slides up. The trip report that we put together -- and I really want to thank Latif Hamdan, who is really the expert on this, much more so than Bill and I are -- he did most of the work on the trip report. The committee members have the trip report. There it is.

And I made a few slides from the trip report and from a background document that we had.

Okay. Can I have the next slide?

These -- and I apologize, I made these fairly quickly and had some other things to do, and I ask that Latif and Bill interrupt and make comments whenever they have a comment to make. This is one in situ leach facility. It has been in operation since 1991. The host rock for the uranium deposit is a sandstone aquifer in Chadron formation, and it goes from several hundred feet to 1,000 feet deep.

The near surface aquifers are the potable aquifers. The Chadron formation is underlain by about 1,500 feet of an impermeable shale, and the groundwater below the shale is not of usable quality.

Can I have the next slide?

We were very interested to see how the in situ leach mining is done, and I want to point out that what is done when they mine in situ is chemically basically the same process that was done on the rock when the uranium was mined as a hard rock and brought to the surface, crushed, and then they did the leaching at the surface.

For the in situ leach, there are three phases -- a mining phase, uranium processing phase, and the last is aquifer restoration. The mining is conducted in aquifers or aquifer units which are exempted by the EPA based on criteria and standards for the underground injection control program in 40 CFR Part 146.

There are repeated -- the mining involves repeated cycles of injecting native groundwater which contains carbonate ion, because the uranium uranyl carbonate is quite soluble, and heavily oxygenated water. What they inject is called the lixiviant, and it is injected into the host formation. The uranium is leached, and the dissolved uranium is then extracted.

The lixiviant which contains the uranyl carbonate is called the pregnant lixiviant, and when they take it out then it's called the barren lixiviant.

(Laughter.)

I think this is -- it's very interesting. And Latif may know the origin of these terms. I don't. The pregnant lixiviant is pumped to above ground facilities for recovery and processing, and we also had a tour not only of the mine -- and I'll show you some pictures of things that we had a tour of -- but also of the surface reprocessing facility.

Next slide, please.

The uranyl carbonate is collected on an ion exchange column, and it is precipitated as U-308. The U-308 is crystallized, washed, and dried, and transported offsite to further processing. From Crow

Butte, the offsite processing is done in Canada, and this is because the Crow Butte uranium contains quite a bit of vanadium contaminant. And the Canadian processor that they send it to can handle that vanadium contaminant better than a number of sites in the United States.

The barren lixiviant from which the uranium has been removed is recycled by reinjection into the ore body. A small amount is sent to an evaporation pond, and this keeps the gradient, the lixiviant gradient, moving toward the production well. There are really three kinds of wells, and you'll see them. There are the production -- there are the injection wells that inject the lixiviant, the production well where the pregnant lixiviant comes out, and then there are monitoring wells that monitor the aquifers.

Can I have the next slide, please?

They mine until it is no longer profitable, and that is usually -- we asked that question, and that is usually when the pregnant lixiviant is down to about 10 parts per million. They do continue to extract uranium from the lixiviant, but that is -- they extract down to three to four parts per million, and that is for restoration. But it doesn't produce an economic product.

There are three options for groundwater reclamation that you can reclaim to baseline or background conditions, or to the class of use -- drinking water or whatever -- or to an alternate concentration limit. And Latif can speak much more knowledgeably than I to the ACL, the alternate concentration limit.

This amounts really to a change in the point of compliance. Instead of requiring compliance with one of the first two standards at the well, the point of compliance is moved to a further point, usually no further than the site boundary.

Latif, do you want to make any further comment on that?

MEMBER HAMDAN: Yes, I think just instead of complying with the standard at a point of compliance, they elected instead that they move the compliance point from the original point of compliance to what they call the point of exposure, which is the point where somebody could be exposed. And by doing that, essentially you are exceeding the standard at the original point of compliance, but meeting it at the point of exposure.

MEMBER WEINER: This is the area that is

to be addressed. It's groundwater reclamation. It's the area that is to be addressed in the draft rule. At the present time, the standard -- there is no rule that gives you a standard for compliance. It is done -- this was from conversations with the project manager, Steve Cohen. It is done either in the license conditions or the -- in some combination with state standards. The state can set standards for offsite concentrations, and so on.

There are other mines other than Crow Butte where there is actually very little water in the monitoring -- they have difficulty monitoring the groundwater because there is so little of it. There is a site -- a mine in Wyoming -- Wyoming mines are basically in deserts, and they frequently have too little water, even to get good measurements for monitoring.

But this is one of the areas where I believe -- or it was our impression that some kind of a baseline regulation is needed. This is really the impetus for having a rule.

Can I have the next slide, please?

This is just further details about how they mine. At Crow Butte, they are completing restoration at one mine section that had a seven-year lifetime. And reclamation -- the reclamation usually takes about two years.

The contaminated water is disposed by discharging into an onsite deep injection well or into onsite evaporation ponds. Both of them have physical limitations. The ponds have a limited area, and injection -- a deep well injection is very deep. It is below the pure shale.

Can I have the next slide, please?

Okay. These are some slides that I took from Steve Cohen's very excellent background document. This is just -- shows you where the Chadron mine is. And I apologize a little bit, I copied these as images, as graphics, not as text. Can I have the next one?

This is a -- the little compass in the lower right is very difficult to see, but the top of the graph is north. And this is a picture --

CHAIRMAN RYAN: Do you mean the top on the screen or the top on the --

MEMBER WEINER: The top on the screen --

CHAIRMAN RYAN: Okay.

MEMBER WEINER: -- is north. I blew that up as much as I could, and I still couldn't tell -- barely tell what the letters are. This is just a map of the ore body itself, and -- oh, wow.

MEMBER HAMDAN: Right here.

MEMBER WEINER: Right here. Okay. North is up here. This is a map of the ore body at Chadron.

Can I have the next slide, please?

CHAIRMAN RYAN: What do the colors mean?

MEMBER WEINER: I can't read what the colors mean.

CHAIRMAN RYAN: Are they different concentration zones?

MEMBER WEINER: Yes, they're different concentration zones.

MEMBER HAMDAN: These are different. I mean, it's --

CHAIRMAN RYAN: Okay. All right.

MEMBER WEINER: Yes.

CHAIRMAN RYAN: Fair enough.

MEMBER WEINER: This is a general picture of all of the wells that are on the site, and on this particular diagram you can't tell which well is which.

CHAIRMAN RYAN: You can't even tell what a well is.

MEMBER WEINER: These little thingies.

CHAIRMAN RYAN: This might get the "bad graphic of the week."

(Laughter.)

MEMBER WEINER: It does, I think. Every one of these little things that look like specks on the picture.

CHAIRMAN RYAN: So there's a thousand wells?

MEMBER WEINER: There are thousands of wells. When you see the -- Latif took some pictures, but they didn't come out.

CHAIRMAN RYAN: Just so I'm clear, every one of these little tick marks all over the place --

MEMBER WEINER: Yes.

CHAIRMAN RYAN: -- are wells.

MEMBER WEINER: Are wells, that's correct.

CHAIRMAN RYAN: Wow. It's Swiss cheese.

MEMBER WEINER: It depends on what kind of well they are. When you see the site, what you see is a relatively undisturbed grassland with all these little white barrels on it. And I'm just sorry Latif's pictures didn't come out, but he had good pictures.

The next slide gives you -- okay. This is a diagram of a single section of -- a single well section. Each production well -- the yellow ones are production wells, and each production well is surrounded by a network of injection wells, so that you have this grid of production and injection wells. And typically 300 feet away from the mining area, if you will, are the monitoring wells, and they surround -- and I think it is 300 or 400 feet maximum between monitoring wells, 400 feet.

There is a central pump house which I have -- there are central pump houses that control the flow in the injection and production wells. The flow of the monitoring wells is done at the well head.

Can I have the next slide, please?

Okay. This is --

MEMBER HINZE: It might be well to point out that those are monitoring wells that go to the upper aquifer.

MEMBER WEINER: Yes, thank you.

MEMBER HINZE: It's the one that has potable water in it.

MEMBER WEINER: Yes. These monitor the potable water wells. This is -- unfortunately, this picture is dark, but this gives you an idea of what the site looks like on the surface.

CHAIRMAN RYAN: All the things that look like tree stumps are actually the well heads?

MEMBER WEINER: Yes. These are the well

heads. Here are the wells. Here is a little -- this little house houses the control of the injection and production wells. And it is an enormous site that -- as you can see. But the thing that --

CHAIRMAN RYAN: Well, just so -- I mean, "enormous" is what, a thousands acres, 1,500 acres, or --

MEMBER WEINER: How big is the site? Do you remember, Latif? It's --

MEMBER HINZE: Square miles.

MEMBER WEINER: Yes, it's square miles. The thing that impressed me is that there is so little surface disturbance, really, in a mine like this.

Can I have the next slide? This may be the last. Okay. This is the interior of the -- of one of the pump houses, and I have forgotten which side is injection and which side is production. But one side in injection wells, and the other side is production wells. And also, there is -- one pump house handles a number of wells.

Do you all remember --

MEMBER HINZE: Mine unit.

MEMBER WEINER: A single mine unit.

MEMBER HINZE: That's different colors.

MEMBER WEINER: Yes.

CHAIRMAN RYAN: Okay.

MEMBER WEINER: Okay. Next slide? This is a flow diagram of the process itself, which I described. And it is centrally -- the injection and production wells are centrally controlled from a control room in the processing facility. And basically, this shows the extraction of uranium, the ion exchange columns, and then the recovery, the crystallization and recovery of yellowcake. And the yellowcake is what is shipped offsite.

I don't -- I'm not sure that's -- is there another slide? I'm not sure. Yes.

This is a picture of one of the ion exchange resins. I just thought it was interesting to look at.

CHAIRMAN RYAN: Not much uranium on it.

MEMBER WEINER: Not -- just a little bit.

CHAIRMAN RYAN: Not much.

MEMBER WEINER: Okay. Finally, the Commission voted to promulgate a rule, either Part 41 or a section of Part 40. And the -- if you read the Commission -- and each of the Commissioners put a little bit of text with his vote, and essentially the reason for promulgating a rule is to eliminate overlapping and dual -- where they exist, dual regulatory schemes, EPA regulation, state regulation, what's in the license, and so on.

Now, I might point out at this point that if the state wants to pass a regulation that is more stringent than any rule EPA -- NRC rule, they are free to do so. We talked this over -- Latif and Bill and I talked this over on the way back, and we thought, as I pointed out in the P&P, that the committee needs to hear from a spectrum of stakeholders in addition to NRC staff. And our proposal is that we have one or two state representatives, since the states do regulate this, that we have some representative from industry and we have a hydrologist to talk about the reclamation and the groundwater considerations.

Latif and I attended the National Mining Association conference, and we did not observe that there was a lot of miscommunication among the various stakeholders. In fact, they seemed to community very well.

Do you want to add any more about that conference?

MEMBER HAMDAN: The only thing that was notable about that meeting was that it was -- everybody that was there was industry, and so the stakeholders were not -- I think the reason there was no miscommunication, everybody agreed --

MEMBER WEINER: There weren't many --

MEMBER HAMDAN: -- they were all industry people, you know. And although it was a public meeting, and it was open to the public, but just having that there was --

MEMBER WEINER: There were very few members, if any, members of the public there.

MEMBER HAMDAN: That's correct.

MEMBER WEINER: I went the day before the meeting and attended the meetings that the NRC project manager has with the various states and mining industry people. And part of my question -- part of my own observation was that when you had a small group discussing a single mine, and you always had the state there and the industry there and NRC, the communication seemed to be very good. In other words, there was no withholding of information. They seemed to understand each other's problems quite well.

My last thing is we proposed -- and I have -- not really a working group session, but we would like to propose a session for the committee on in situ leach mining for February or March that includes all of -- representatives of all of the stakeholders, so that we can hear what their problems are, what their views are, of the draft rule. There will be a draft rule at that time.

I believe that's all the slides I had. Thank you.

CHAIRMAN RYAN: Just one friendly amendment to that list of stakeholders. If there are other stakeholders, of course, that wanted to express their views to the committee --

MEMBER WEINER: Oh, yes.

CHAIRMAN RYAN: -- to us, we'd certainly welcome that.

MEMBER WEINER: Yes, we certainly would.

CHAIRMAN RYAN: So that is just the starting point.

VICE CHAIRMAN CROFF: I'm not clear at this point. What are the technical issues that need to be addressed here?

MEMBER WEINER: I believe the issue that is of concern to the Commission is groundwater reclamation, and the only technical hook is to what extent, when you -- when you resolve the problems of overlapping regulations, are you ensuring a better, more consistent reclamation of groundwater?

Bill or Latif, do you want to add anything to that?

MEMBER HAMDAN: Actually, there is the main problem, restoring the aquifer to either the background -- water conditions that existed before mining or to some acceptable standard, you know, like class reviews or even ACL, but at least there is a standard that you agree to restore the aquifer to, because you can't just go to the licensee and then they will just mine and leave. So you need a standard.

And at this time, frankly, there is no consistent or uniform standard in the regulation. So each -- you know, they have it, but it's not codified in any code.

VICE CHAIRMAN CROFF: Is the expectation that the NRC's proposed rule will include groundwater issues within NRC jurisdiction?

MEMBER HAMDAN: The rule is all about groundwater protection.

MEMBER WEINER: Yes.

VICE CHAIRMAN CROFF: Okay.

MEMBER HAMDAN: And it will include that. But by UMTRACA, which by -- the in situ leach is mentioned only briefly, there is no standard there for in situ leach. And by UMTRACA, EPA is supposed to promulgate the standard, NRC is supposed to take the promulgated relations based on the standards, so you can see the role of the EPA in this -- the EPA has to agree to understand that it is going to be, and NRC takes it from there and --

VICE CHAIRMAN CROFF: Okay.

MEMBER HAMDAN: -- that's why the EPA is so -- the role of the EPA is so important to this.

VICE CHAIRMAN CROFF: Okay. Thanks.

MEMBER CLARKE: Latif, I was going to say when you say "the standard," are you talking about the alternate concentration limit, that there would be a federal limit and then the states could revise that downward if they wanted to? Is that --

MEMBER HAMDAN: You see, the guide for this is actually the primary standards which are in Appendix A to 10 CFR Part 40. And these are background MCLs, maximum concentration limits, or alternate concentration limits.

MEMBER CLARKE: Right, I understand.

MEMBER HAMDAN: And yet these are the standards -- the primary standards, you know, and there are -- the thinking has been until recently of the last two, three years, that standards -- background, MCLs, ACLs -- are also applicable to in situ leach.

Two or three years ago the industry complained about that, and they ended up with the standards that are in a NUREG document -- I think it's 1573 -- which indicates the standard for in situ leach is background, class reviews, and ACLs. But this is not codified in, you know, in NRC regulations. Unless we need some consistency, you know, make sure that your regulation, which Ruth mentioned, they need some consistent source so they can know what they are dealing with.

And the idea now is either to add something to Part 40, you know, amend it with something that's applicable to in situ leach, which I think was going to happen, and initially they thought about having a Part 41, which I don't think is going to happen.

MEMBER CLARKE: Thank you.

MEMBER WEINER: I would say that most, if not all, of the mining that is now done, uranium mining that is done in the United States, is in situ leach mining. They have gone pretty much away from hard rock mining. And given the status of the uranium market -- we didn't talk about this too much -- the in situ mining will increase. And I think one of the -- another impetus for a rule is that there really is no rule presently that addresses in situ leach mining. They are using the mill tailings rule.

MEMBER HINZE: We have a rule for oranges that is being applied to apples.

MEMBER WEINER: Thank you.

MEMBER HINZE: And that really is the problem, in addition to the overlap problem. And so what one should try to do is build in some consistency, and that's the word you've heard here ad nauseam. And as far as technical problems, you know, we discussed this quite a bit after visiting, and the technical problems are not severe. They're really doing a very good job with the present regulations in terms of monitoring everything where we're able to scratch at in terms of monitoring, in terms of baselining, it's a great job.

CHAIRMAN RYAN: These regulatory changes, then, in my -- from what I've heard you guys report is that we'll be focused on consistency and clarity more than anything else.

MEMBER WEINER: Yes.

CHAIRMAN RYAN: Okay. John had a question.

MEMBER HAMDAN: And the new regulation issue.

MEMBER WEINER: Yes, right.

MEMBER HAMDAN: Review it.

MR. LARKINS: For Ruth and Latif. Do we have an idea what the correct standard should be? I mean, should it truly be focusing on the EPA groundwater standard, or should we be looking at a more risk-informed approach which allows some flexibility for those sites where you don't -- aren't using -- you know, this is not potable water, and the -- it is somewhat isolated from the groundwater table or any usable aquifer.

MEMBER WEINER: I think you've made a very good point. The usage seems to be that practice is that you set the standard in accordance with the conditions of the mine that you have, which is in fact a risk-informed approach. And the staff has simply said -- I actually asked staff people why you want a regulation. And they said because right now there is simply no consistency. It's in the license -- much of it is in the licensing conditions, and that depends on what you're doing.

CHAIRMAN RYAN: So the idea would be to have this one-day session of meetings from various stakeholders and staff, and then maybe offer a view on what the risk-informed approach is forward. That is kind of our path on this.

MEMBER WEINER: I would say half a day probably, but --

CHAIRMAN RYAN: Half a day.

MEMBER WEINER: Yes.

CHAIRMAN RYAN: I mean, the idea is we're looking to advise on what's the risk-informed approach.

MEMBER WEINER: Yes.

CHAIRMAN RYAN: All right. With that, we probably ought to press on to our next two segments.

VICE CHAIRMAN CROFF: Can I ask one more question?

CHAIRMAN RYAN: Sure.

VICE CHAIRMAN CROFF: Is there anybody during your little session that could come in and address sites, ISL sites that have been previously closed?

MEMBER WEINER: Oh, yes.

VICE CHAIRMAN CROFF: You know, they were remediated and what happened there. Have things gone well? Have things gone bad? And it's gone bad. How did it go bad?

MEMBER WEINER: Yes, there is. Latif will --

MEMBER HAMDAN: I think we can invite DOE. There have been mill tailing sites, and we can give the committee very good insights as to what the reference is, and so forth, and we have a lot of experience with --

CHAIRMAN RYAN: Be careful, though. Mill tailing sites are not the same as in situ leach mining sites, by a long shot.

MEMBER HAMDAN: They're not the same, but they are --

CHAIRMAN RYAN: They're not even close.

MEMBER HAMDAN: I'm not so sure.

VICE CHAIRMAN CROFF: Has DOE reclaimed, or are they watching over any ISL sites?

MEMBER WEINER: Oh, yes. Yes, they are. The ones in Wyoming they --

CHAIRMAN RYAN: If they're doing ISL sites, that's the direct comparative of -- the surface mill tailing site is a whole different ball of wax.

MEMBER WEINER: And, actually, Crow Butte has reclaimed one mine section, and they can give us a --

CHAIRMAN RYAN: Okay.

MEMBER WEINER: Yes. The answer to Allen is yes.

CHAIRMAN RYAN: Okay.

MR. DIAS: But would DOE be willing to say what went wrong with their mining, in situ mining experience?

MEMBER HAMDAN: They will say what DOE will say.

MR. DIAS: Okay.

MEMBER WEINER: We'll ask them.

CHAIRMAN RYAN: Okay. Any other questions? Once? Twice?

I will go ahead and take up the next topic, which is the attendance that we had at the U.S. Department of Energy workshop on low dose radiation research. Neil Coleman from the staff and I attended. There were other NRC staff members present as well.

We will probably write a letter later on this afternoon on this topic, but I will kind of summarize the meeting. It was interesting on a number of points. There is an awful lot of what I will term phenomenological research where people are trying to develop understandings of what happens at "low dose," and I use that term in quotes for the moment, of radiation exposure. And that's acute exposures in the upwards of 100 rad and above kind of range.

While not an absolute observation in terms of, you know, a clear cutoff, a lot of the experiments involve doses that from a regulatory standpoint that is worker protection standards or members of the public standards where high doses -- and they are looking at some interesting biology and radiobiology phenomena. And they talked a lot about things that people are familiar with, like bystander effects and other kinds of effects that -- their phenomenology kinds of things that people were observing and providing reports on.

I think -- you know, so many of these experiments are at doses that are even up to orders of magnitude above what you expect to be exposures from a workplace or public exposure standpoint. And that includes even medical exposure and some of those things.

MEMBER HINZE: Could I interrupt you to ask --

CHAIRMAN RYAN: Yes, sir.

MEMBER HINZE: -- why that is true?

CHAIRMAN RYAN: Well, I think it's because they're working kind of at levels where they can demonstrate some of these phenomenology.

MEMBER HINZE: In a fairly short --

CHAIRMAN RYAN: In a fairly -- and they

are working with the constraints of --

MEMBER HINZE: Right.

CHAIRMAN RYAN: -- you know, the typical experimental design constraints.

MEMBER HINZE: Right.

CHAIRMAN RYAN: So extrapolations of lower doses and further reconciliation with existing epidemiologic studies have so far not really been performed at a level of detail that would be terribly useful in informing policymaking in any new way at this point, or in revising, at least in my own view, and I think from the developing -- you know, for revising current or developing new radiation protection standards at the moment. It just -- there's nothing overpowering.

In fact, one speaker at the end of the last day commented on the fact that the research community in low dose work has not really done a very good job of communicating their results in a way that is relevant to the thought process of policymakers.

Dr. -- Dr. -- I'll call his name out in a little bit, check it out. But that -- it was interesting that there's a lot going on.

The other interesting reports were from folks outside the United States. The European Union has a study that's ongoing between 2006 and 2010 involving a number of EU countries that are interested in this topic. And they are launching a specific project on non-targeted bystander effects of ionizing radiation, and when we do report in a letter we'll have the website information so others can certainly track this process.

Additional work is also being performed by the European integrated project, which is examining the radiosensitivity of individuals and susceptibility to cancer induced by ionizing radiation. And, again, they have a website with more information. We can certainly track that.

I guess the one word --

DR. COLEMAN: Oh, the name you were looking for, Dr. William Morgan of the --

CHAIRMAN RYAN: William Morgan, thank you.

DR. COLEMAN: -- Radiation Oncology Research Lab, University of Maryland. And he offered the challenge to other researchers that the research results of these low dose studies could be much better communicated -- to the public, policymakers, stakeholders, to everyone.

CHAIRMAN RYAN: Right. Thank you.

MR. LARKINS: How large is this European

Union study, do you know?

CHAIRMAN RYAN: It's a five-year study, and it's in -- I don't recall the exact number amount, but it's a substantial effort on the part of the EU. I'm recalling something in the multi-millions of dollars, tens of millions -- you know, $10 million, something in that -- up to that range. I'd have to look in our notes and see specifically, but, yes, it's very much an EU-wide system. There are member countries participating. France was one, Finland was I think the speaker, and there were other participants attending the DOE workshop.

The other point that I didn't say earlier, John, is that they're working hard to coordinate with the DOE effort, so they're not spending the same dollars on the same projects. They're actually looking at things that will be complementary rather than overlapping. So that's a positive effort that they're putting forward.

I think it's -- I believe the work is useful and helpful to the basic science of radiation biology myself. I think it should continue, because I think some of the phenomenology they're exploring needs to continue. Whether it will be helpful or change in any way how we view radiation protection standards at this moment I'm not sure anybody is willing to -- you know, to say that as clearly or not clearly, some may be -- I don't know -- but it seems that at least from the work that was reported that it's interesting. There are clear results that need further study, and they have good plans to do that.

As far as our tracking this work, I think we might think of somewhere in the year and a half, or maybe even two years out, an update where we bring a working group of some of the -- you know, the senior folks in this area to the ACNW and to this forum, so we can hear directly.

And maybe if they take Dr. Morgan's advice from this meeting and start thinking about, well, what does this mean in a policymaking arena, or how do you translate the science into radiation protection standards one way or another, whatever their way might be, that that might be a focus for a working group that we might want to hold.

I think the other part, of course, in November we'll be hearing from the French Academy of Sciences Report Committee on their recent report, where they see a very clear threshold at 10 Gray in their work. So we'll have certainly the benefit of both of those to further advise the Commission.

So that's really a short summary of the meeting. Many of the papers were on very specific projects, some at the molecular level, some at the cellular level, some at the organism level. With zebra fish they had an interesting experiment or two there. And even some with patients where they were doing some specific studies to look at reactions in other tissues related to tissues nearby radiation therapy sites and others.

So there was a whole host of experiments. We even heard from some folks that on the one hand said the epidemiology is not really complete at these very low doses that you'd expect from public exposures, and others that felt that there are very clear thresholds that show up for certain analyses.

One researcher from the Institute for Inhalation Toxicology in New Mexico, for example, spoke about that. So there's a broad range of views, interesting and ongoing research that I think we should follow and integrate in our thinking about how ICRP makes recommendations or how the other national and international bodies make recommendations. But that's a work in progress.

MR. LARKINS: The committee has over the years had several working group meetings, as Bill probably remembers, on the effects of low levels of ionizing radiation and written a couple of reports. And there always seems to be --

MEMBER HINZE: Just beyond the horizon.

MR. LARKINS: -- yes, more work, but it's not clearly -- and you raise it in terms of putting the information out there in a form that the decisionmaker can use. Do you see in two years you'll be able to make a recommendation as to what is -- what's the ultimate experiments that are needed in order to impact the regulations? If it's LNT or other areas, worker exposure limits, or --

CHAIRMAN RYAN: I think some of the researchers who have been in that field for a long time, and particularly those that were involved in summarizing sessions in the rapporteur for the meeting, and so forth, brought together those kinds of questions. And, you know, I think that at least I took away the impression that the folks who are summarizing said we really need to kind of think about how we go from phenomenology to what this means for standard-setting.

And I think -- you know, and as work goes, it might very well be a year or two down the line before that matures a little bit. I would hope so, and I would hope that, you know, if we could invite folks and get them to come that we would have them or ask them to focus on the very question you have raised, John. I think it's time to ask that, you know, what's the impact on phenomenology? I mean, of the phenomenology on standard-setting.

MR. LARKINS: The standards and --

CHAIRMAN RYAN: Right.

MR. LARKINS: -- limits.

CHAIRMAN RYAN: Right.

MEMBER HINZE: Well, perhaps the lack of communication is appropriate, because we don't know how to deal with that lower dose area. And we -- it's difficult to communicate when we don't know how to deal with that down there. I don't understand how we're going to foster communication when we don't have the data to interpret down there.

And the only problem there is that their regulators may make decisions based upon their interpretation of these higher levels, and, therefore, be quite inappropriate as well.

CHAIRMAN RYAN: Well, and that's -- and if we heard that, you know, as the message that, you know, there isn't a clear change in path or direction, that's okay, too. I mean, I'm not trying to offer a view that -- you know, what theory or what approach is right. I'm just -- we're just -- I think we need to continue to stay up to date on what research findings are coming out of this area and react to them accordingly.

MEMBER HINZE: Well, was there any sense that there is hope of making investigations that will help us to get definitive answers with a lower degree of uncertainty down in those lower ranges?

CHAIRMAN RYAN: Well, you know, it's -- yes, I think there's -- there certainly are productive lines of research that many of the researchers spoke of as here's where I am now, and here's where I think we can go forward in a productive way to learn more. It's kind of like geology. I've never met a geologist that doesn't want to drill one more hole.

(Laughter.)

And I don't mean that to belittle in any way the quality of the work that these folks are doing. They were all thinking ahead, but, you know, how it comes together at -- down the line a bit, it wasn't -- that wasn't as crystal clear to me.

DR. COLEMAN: If I may --

CHAIRMAN RYAN: Please.

DR. COLEMAN: -- offer just one example of an interesting research result that they're following up aggressively now is that there appear to be unique gene expression profiles for high dose versus low dose, which then could lead to an understanding of why the different responses at high dose versus low dose and when repair mechanisms kick in. So that was new to me, just one example.

MEMBER WEINER: Could I ask a question? When you say high dose or when they at the meeting said high dose and low dose, are they using low dose as a synonym for chronic as distinct from acute dose?

CHAIRMAN RYAN: That's a really good question, and it's one that I haven't resolved in my own mind. Most of these experiments are what I would characterize as acute doses in the high range. And my measure of that is that they are higher compared to background exposure rates from, you know, typical lifestyle in the United States, say, or the range of lifestyle for radon and all the things that vary.

And they tended to be in the, you know, upwards -- higher than 10 Gray acute over short periods of time. So you're right, that's a caution that's well taken, is it high or low, and acute and chronic, you know, are in the eye of the beholder sometimes. So in order to really develop a keen and detailed understanding, we'd have to sort through all that in some level of detail.

Before we get too far along here, we do have a request for time to speak to the committee from Dr. Rockwell, So I'd like to ask him at this moment to give us his presentation, and then we'll continue with the question and answers. If you wouldn't mind, Dr. Rockwell, if you would come up front, and we can -- that way everybody can see you and hear what you've got to say. Thank you for being with us today.

DR. ROCKWELL: Is this the hot mike?

CHAIRMAN RYAN: Yes.

DR. ROCKWELL: Okay. If you're comfortable, just have a seat there, and that'll be fine.

DR. ROCKWELL: Well, I'm Theodore Rockwell from the Radiation, Science & Health, Incorporated, which is an international nonprofit public interest group that has been concerned for many years now in trying to reconcile some pretty wild discrepancies between radiation practice and radiation science.

And what I've done is to make available two pieces of paper for you here. This is an article in Science, which talks about the worst realistic casualty that could happen to our reactor plant or its fuel, and this is a thing on some history on the review of NCRP-136, which was yet another review of the low dose radiation.

And as Mike just told us, there are a lot of people looking at the low dose radiation problem and at the casualty problem. On September 8th there was a meeting that the NRC internally looked at their program of trying to evaluate the casualty case where they are concerned not only with the low dose health effects question, but the question of the release and attenuation processes of fission products in an actual realistic situation.

If you assume, for example, that there is no water or steam present when these fission products are released in a casualty, you are sure going to get a different answer by several orders of magnitude than if you assume that there is in this colder structure steam condensing out, and so forth. There's about a factor of 10^5 difference in iodine that gets out of the containment under that situation.

So what I did -- the purpose of putting these out at this time is to say that there are a lot of people again reviewing the LNT and the casualty case both. And the reason for this is that it has been so poorly done every time.

And the main fault of the reviews in the past have been that they have just failed to look at all of the data that have been accumulated, literally thousands of technical reports, hundreds of which are quite good. We've been collecting them on our website. I've referred to that.

So this one here about NCRP, which is the one that was to look at NRC, that was the one that was done because BEIR-V was such a bad report. Everybody said you didn't look at the data. So they went through the whole thing again, and they didn't look at the data.

And this is a little bit of that history, and my urging to you is -- you, not only ACNW, but NRC in general -- that we don't leave another one of these reports as our legacy. This is really a disgrace, that the data that exists were not looked at. We've been told that epidemiologically you can't get sufficient data. You'd have to have a population of millions. That's true only if the LNT is true.

So what you're saying is if the LNT is true, you can't prove that the LNT is true, and, therefore, we should assume the LNT is true. I don't think that's a very good way to set policy.

So the other thing is that there has

always been some discussion of what the public would buy. That is not our problem here as scientists and technologists. Our problem is to tell them what the science is. The policy people are going to have to decide how to deal with that, but we don't -- we don't help them by biasing our science in terms of what we think the public will buy. That's a circular process that never gets to the truth.

So these two things I have that I think will help you look at where we've been. The question that the DOE program doesn't seem to be giving information that effects the policy much is a deliberate result -- Greta Dicus made it very clear when that program was first started that she did not want to see -- she wanted to see fundamental research. She did not want to see anything that would necessarily affect policy, and that's been in effect for the 10 years of the program.

But I think the point that several people have made that the time has come now to look at this information, and when you say, "Oh, we've got a program that shows bystander effects," bystander effects don't necessarily have anything to do with health effects themselves. This is part of the process by which cells communicate to the immune system and protective mechanisms.

So I was not intending to give a speech here, but I did want to say that I've put these two things in the record. I think you'll find them useful. At the bottom of the one on NCRP you'll see our website, and you'll see the vast amount of data that exists there that shows over and over and over again that low dose radiation has a stimulatory effect.

The thing that's sort of ironic to me is that every one of these reports that recommends that we use the LNT as our basic tool, every one of those reports starts right out at the beginning and says that's not what we find. It says it is important to note -- this is quoting from NCRP-136 now.

It is important to note that most populations exposed to low dose radiation are not harmed, and most populations are in fact benefitted. It says that right in the report. And they say over and over again that there is no data that shows that low dose radiation is harmful. And yet they say -- the ICRP's famous statement, since there is no harm in assuming that it -- it's harmful, let's assume that it's harmful.

And I think we've seen the kinds of

problems that result from over -- from exaggerating a hazard. We do just as much disservice by claiming a hazard is worse than it is. That's not conservative, it's not prudent to say that one gamma ray can kill you.

We have situations in which brave firemen, policemen, and other emergency guys that are trained and ready to run into a burning building, a collapsing building, into a hail of gunfire, and those people we are told should never cross a radiation line because one gamma ray can kill you. And that's nonsense. It's just scientifically false, and it's time we repudiated that.

That's my message.

CHAIRMAN RYAN: Dr. Rockwell, thank you for your message. I want to make sure that staff has available the two handouts on the back --

DR. ROCKWELL: Yes. There were 50 copies that we were supposed to supply.

CHAIRMAN RYAN: Okay, great. Just --

DR. ROCKWELL: And it's on your --

CHAIRMAN RYAN: Right. We've got that, but I just want to make sure everybody knows that those items are available.

Any other questions or comments? Yes,

Latif.

MEMBER HAMDAN: Yes. Mike, I understand that we are talking about very low dose radiation. So I understand that. But in this workshop or in the database that was mentioned here, do we have any data from, say, rays at Chernobyl for example? If you go 50 miles or 20 miles or 10 miles, there must be a point at Chernobyl where the doses are low and -- or even very low.

So in the database that was mentioned or the workshop, do you tap into this data source, or everybody is doing the --

CHAIRMAN RYAN: My view of that is that Dr. Shirley Frye from Oak Ridge talked about the epidemiologic studies to date. I can't recall if she specifically mentioned Chernobyl, but she sure mentioned a number of them. And to me she highlighted the fact that the current experimental work that's ongoing is really distant from the resolution with the epidemiology.

They haven't brought those together yet, and I think that might be in part what Dr. Rockwell is addressing, is that there really is a separation from the epidemiology. I mean, the biggest cohort, of course, is Hiroshima and Nagasaki, and that is where

BEIR-VII has hung its hat for a long time.

DR. ROCKWELL: Well, it's really -- you talked about dose rate. I think it's really an embarrassment to the scientific community that we hold up today as our gold standard for looking at chronic low level radiation, we hold up the Hiroshima data.

CHAIRMAN RYAN: It's clearly a different situation. You know, and I sat through the presentations, as I think you did, and, you know, I mean, in my own mind I'm doing calculations of what is a low dose, what is a low dose rate. And these terms need a lot more clarity than the way different researchers use them, because they -- low dose and low dose rate mean different things to different folks. You know, to an interventional radiologist, 1 R per hour is a low dose rate.

DR. ROCKWELL: But the data that we have -- one of the things that's referred to here is the shipyard study, the nuclear shipyard studies, a population of 700,000, years of excellent dosimetry, or this is under the naval reactors program. Every worker had a film badge.

The comparisons were made not between the healthy worker and the average citizen, but were made between welders and welders in radiation and not the steamfitters and steamfitters. And they were done all with the same demographics, age, and sex, and so forth.

And then, after 10 years of that where we had a very clear showing that the cancer rate is lower, that the death from all causes is lower, they try to brush it off as if it were healthy worker effect. But the whole purpose of this multi-million dollar 10-year study was to eliminate that. And they have the technical advisory panel on that study with Arthur Upton, the author of NCRP-136, and that data is not used when they come in and Ethel Gilbert gives her study of workers, and this one isn't used. It's just varied.

MEMBER WEINER: Could I ask a question?

DR. ROCKWELL: Yes.

MEMBER WEINER: Is there such a thing as a healthy worker effect?

DR. ROCKWELL: Oh, of course. Yes. I mean, if you take a guy in a factory and get the data from the factory and then compare that with the population as a whole, the population as a whole has old people and sick people and lazy people and all kinds of people that wouldn't be at a workshop.

(Laughter.)

CHAIRMAN RYAN: Thank you. We'll have to move to our next topic, but, again, Dr. Rockwell, thank you for your time and your comments.

DR. ROCKWELL: Mike, I appreciate it.

CHAIRMAN RYAN: Sure. The final item on this morning's discussion points that were -- was attendance at the International Commission on Radiological Protections Workshop held right across the street in the Marriott. And it was one of several meetings around the world actually where the ICRP was soliciting comments on its draft 2006 guidance document.

And if you recall, and of course in our record there's the letters that we provided to the Commission on the 2005 draft, we prior to the meeting provided the Commission with a draft -- or with a letter on the 2006 draft. And then, this was an opportunity to hear other stakeholders raise questions and issues on the 2006 draft.

Many of the points that we covered in our letter were brought up by various speakers and participants on panels and from the audience in the sessions that were held during the day.

I think just to summarize briefly what the comments were about, a lot were about terminology.

The ICRP tends to use terminology in a way that doesn't cross the borders well from one country to another. They use the word "constraint" in the way we use the word "limit." They use the word "limit" in the way we use the word "guidance" or "goal." And so there's a lot of confusion in terminology, and much of the discussion centered on those kinds of things.

I participated on a panel with several folks, and, you know, offered comments on the implications for, you know, waste management questions, and so forth, and, you know, just enjoyed the presentation. I think it was -- Commissioner Lyons, of course, gave the keynote address, and, you know, I think what will happen from that meeting is the ICRP will certainly take the comments it received here in Washington. They had a meeting in Canada. They had a meeting in Tokyo. And I think they were going to have a meeting in Prague or Brussels, one or the other, I forget which.

I'm sorry? It was Prague, thank you. Oh, there's Dr. Cool. Thank you. Dr. Jones, we appreciate it.

And there were going to be, you know, additional meetings, and I think the summation of all of that information gathering is that hopefully they will take that into consideration as they further revise the 2006 draft. And maybe we'll get a 2007 draft to look at. Dr. Cool?

DR. COOL: Quick synopsis having just been in ICRP Committee 4's meeting last week. In fact, even as the comments have been coming in, the ICRP has been looking at and starting to revise the draft based on all the comments they have been receiving thus far. What they were saying was that the meeting in Prague, which will be the last week of October, will in fact be an opportunity to discuss some of the things that they are doing in terms of reorganizing and structuring the draft and responding to some of the comments.

So that third conference they are actually being sponsored by the Nuclear Energy Agency of the OECD. That conference will be different in character than the conference that was here in Washington or that in Tokyo in that it will be representing an evolution based on the first two conferences and all the input and additional discussion.

I understand from Lars-Erik Holm, who is the Chairman of ICRP, that that material will be considered by the ICRP's Maine Commission in their meeting in Morocco the first week of November. And that there will likely be another draft for a short -- emphasis on short at least at this time -- public consultation towards the end of the year or very early in 2007 before the ICRP would actually complete its work and send the draft recommendations to the printer for publication.

CHAIRMAN RYAN: Okay.

DR. COOL: We shall see.

CHAIRMAN RYAN: I might also note that, again, the committee had written a letter on the 2006 draft, and the staff also offered its comments to the Commission on the 2006 draft and also, in turn, to the ICRP. So that is the summary of where that activity is.

I guess I think the next step for the ACNW will be to take Dr. Cool's schedule and react to it as we have comment time available, but we'll have to be ready because with the short comment time everybody has to act quickly if any additional comments will be made and delivered in a way that they can be accepted and considered. So --

DR. COOL: I would note at this point there is no formal schedule in terms of specifically when something would come out. What Dr. Holm was talking about was something that might be available for a month.

So we will have a very short window of opportunity if, in fact, that kind of scheduling continues to take place. But there may be further reactions and schedules, so I -- I don't want to try and pin any particular timeframe on this yet.

If you look at the ICRP's website, you can actually see all of the comments that are being posted by organizations. There is a huge amount of comment that has been put on in the past week. The NRC comments were officially put on last week, a number of other countries, so they have a lot of material to be posted and looked at.

I would also note that the things that the committee said, and the things which the NRC staff said, were echoed, repeated in various ways by many other commenters from a variety of countries and positions.

CHAIRMAN RYAN: Thank you, Don. Appreciate that update.

And with that, unless there are any other questions, that really is the substance of that meeting. So questions, comments? Any other questions or comments?

Hearing none, that will take care of our morning session. And to say on schedule we'll adjourn until 12:30, and then reconvene to consider letter writing activities this afternoon, and those are listed on the agenda.

I do not believe we will need the recorder for the rest of the day on letter writing, so we'll finish the record for today here. And we'll start the record tomorrow promptly at 8:30.

(Whereupon, at 11:08 a.m., the proceedings in the foregoing matter were adjourned.)

CERTIFICATE

This is to certify that the attached proceedings before the United States Nuclear Regulatory Commission in the matter of:

Name of Proceeding: Advisory Committee on Nuclear Waste 173rd Meeting

Docket Number: n/a

Location: Rockville, MD

were held as herein appears, and that this is the original transcript thereof for the file of the United States Nuclear Regulatory Commission taken by me and, thereafter reduced to typewriting by me or under the direction of the court reporting company, and that the transcript is a true and accurate record of the foregoing proceedings.

Charles Morrison
Official Reporter
Neal R. Gross & Co., Inc.

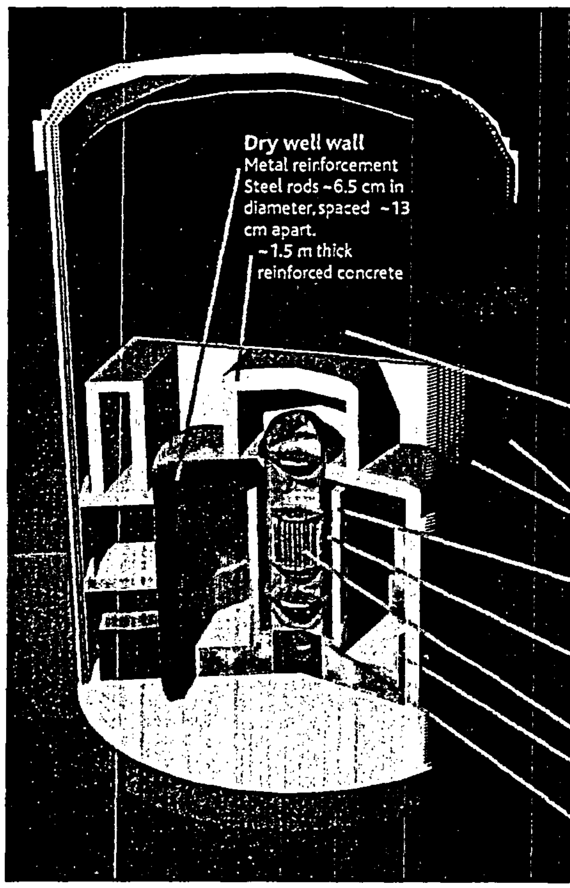
POLICY FORUM: NUCLEAR SAFETY

Nuclear Power Plants and Their Fuel as Terrorist Targets

Douglas M. Chapin, Karl P. Cohen, W. Kenneth Davis, Edwin E. Kintner, Leonard J. Koch, John W. Landis, Milton Levenson, I. Harry Mandil, Zack T. Pate, Theodore Rockwell,* Alan Schriesheim, John W. Simpson, Alexander Squire, Chauncey Starr, Henry E. Stone, John J. Taylor, Neil E. Todreas, Bertram Wolfe, Edwin L. Zebroski

If you watch television or read repeated public statements of concern about nuclear power plants as terrorist targets, you would be justified in believing that spent nuclear fuel casks being shipped to Nevada for storage are each a nuclear catastrophe just waiting to be triggered. These casks have been called "mobile Chernobyls," and we are told they are capable of causing "tens of thousands of deaths" (*1*). What are the facts about the safety of nuclear shipments and power plants?

Since 11 September 2001, the U.S. nuclear industry and its regulators have been reevaluating plant and fuel shipment safety. These studies are being kept secret. But it is no secret that basic engineering facts and laws of nature limit the damage that can result. Extensive analysis, backed by full-scale field tests, show that there is virtually nothing one could do to these shipping casks that would cause a significant public hazard (*2, 3*). Before shipment, the fuel elements have been cooled for several years, so the decay heat and the short-lived radioactivity have died down. They cannot explode, and there is no liquid radioactivity to leak out. They are nearly indestructible, having been tested against collisions, explosives, fire, and water. Only the latest antitank artillery could breach them, and then, the result was to scatter a few chunks of spent fuel onto the ground. There seems to be no reason to expect harmful effects of the radiation any significant distance from the cask.



Multiple layers of safety at nuclear power plants. Boiling water reactor

Similarly, we read that airplanes can fly through the reinforced, steel-lined 1.5-m-thick concrete walls surrounding a nuclear reactor and inevitably cause a meltdown resulting in "tens of thousands of deaths" and "make a huge area of the U.S. uninhabitable for centuries," to quote some recent stories (*4*). However, there seems to be no credible way to achieve that result (*5, 6*). No airplane, regardless of size, can fly through such a wall. This has been calculated in detail and tested in 1988 by flying an unmanned plane at 215 m/s (about 480 mph) into a test wall 3.6 m thick. The plane, including its fuel tanks, collapsed against the outside of the wall, penetrating a few centimeters. The engines were a better penetrator, but still dug in only 5 cm. Analyses show that larger planes fully offset their greater impact by absorbing more energy during their collapse. Higher speed increases the impact, but not enough to matter. And inside the containment wall are additional walls of concrete and steel protecting the reactor.

Is it possible to cause a nuclear reactor to melt down some other way? Yes, it happened at Three Mile Island (TMI) in 1979. Reactors are much improved since then, and the probability of such an accident is now much less. But suppose it happens, through terrorist action or other; what then? Well, the TMI meltdown caused no significant environmental degradation or increased injury to any person (*7–10*), not even to the plant operators who stayed on duty. It has been said that this lack of public impact was due primarily to the containment structure. But studies after the accident showed that nearly all of the harmful fission products dissolved in the water and condensed out on the inside containment surfaces. Even if containment had been severely breached, little radioactivity would have escaped. Few, if any, persons would have been harmed.

To test how far the 10 to 20 metric tons of molten reactor penetrated the 13-cm-thick bottom of the reactor vessel on which it rested, samples were machined out of the vessel and examined. The molten mass did

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CREDIT: NUCLEAR ENERGY INSTITUTE

not even fully penetrate the 0.5-cm cladding, confirming tests in Karlsruhe, Germany, and in Idaho, that the "China syndrome" is not a credible possibility (*8–10*).

The accident at Chernobyl in 1986 is simply not applicable to American reactors. The burning graphite dispersed most of the fission products directly into the atmosphere. Even in that situation, with no evacuation for several days, the United Nations' carefully documented investigation UN-

Image not available for online use.

Three Mile Island nuclear power plant.

SCEAR-2000 (*11*) reported that there were 30 deaths to plant operators and firefighters, but no significant increase in mortality or cancer due to irradiation of the public have been observed (*12, 13*). A possible link between exposure and thyroid cancer is still under study (*14*). The terrible and widespread consequences of that accident—increased suicide, alcoholism, depression, and unemployment (*15*), plus 100,000 unnecessary abortions (*16*)—were caused primarily by fear of radiation and by poor planning based on that fear. The evacuated lands are generally now no more radioactive than the natural background levels where many people have lived healthily for generations.

It's not surprising that some people overstate the concern about radiation, for whatever reason. But it is surprising that most nuclear advocates are reluctant to challenge such claims. They say they just want to be cautious. But striving for maximum caution leads to the assertion that we should act as if even the tiniest amount of radiation might be harmful, despite the large body of good scientific evidence that it is not (*17–22*). This policy has scared people away from mammograms and other life-saving treatments and has caused many Americans to die each year from pathogens that could have been killed by food irradiation (*23*). It has piled regulations on nuclear medicine facilities that caused many of them to shut down. And now, "permissible doses" have been pushed below those found in natural radiation backgrounds (*24–26*).

Such cautiousness has drawbacks when applied to design and operation of nuclear facilities. But it is particularly dangerous when applied to terrorism. To tell people that they and the Earth are in mortal danger from events that cannot cause significant public harm is to play into the hands of terrorists by making a minor event a cause for life-endangering panic. Now is the time to clear the air and speak a few simple scientific and engineering truths.

CREDIT: DOE

References and Notes

1. "[A] major fire is possible which could release 25 times more radioactive material than Chernobyl... such a fire could render 29,000 square miles uninhabitable...cause 28,000 cancer deaths and $59 billion in damage." B. C. Smith, *The Tech*, 1 May 2002. Available at: www-tech.mit.edu/V122/N22/col22brice.22c.html.
2. The shipping casks and the spent fuel are described in the 207-page Appendix J of the *Yucca Mountain Environmental Impact Statement* (DOE/EIS-0250, Government Printing Office, Washington, DC, 2002); available at: www.ymp.gov/documents/feis_a/vol_2/eis_j_bm.pdf
3. For an independent analysis, see J. L. Sprung *et al.*, *Re-examination of Spent Fuel Shipment Risk Estimates* (NUREG/CR-6672, Sandia National Laboratory, Albuquerque, NM, 2000); available at http://ttd.sandia.gov/nrc/nuregcr6672/chap1.pdf
4. "You could have tens of thousands to hundreds of thousands of fatalities from cancer ... the downwind path from these types of casualties could extend for hundreds of miles." P. Leventhal, Director of Nuclear Control Institute, on the Cable News Network, 1 February 2002; "Nuclear specialist Mark Gaffney said that an attack on a plant could make a huge area of the US uninhabitable for centuries." D. Nelson, in OneWorld UK, 2 November 2001 (www.oneworld.net/uk). To which the Government reportedly responded, "Of course it would be a big mess. Would it lead to multiple tens of thousands of deaths? That's much less certain." B. Henderson, Nuclear Regulatory Commission (NRC) representative, in K. Davidson, *San Francisco Chronicle*, 5 October 2001, p. A6. NRC Commissioner Nils Diaz recognized the need to correct this situation in his plenary talk at the American Nuclear Society Conference, Hollywood, FL, 10 June 2002: "I do not believe nuclear power is being portrayed in a balanced manner.... This is probably the fault of all of us who know better ... public health and safety consequences might very well be nuclear power and radiation technology's strongest and most favorable arguments when comparing risks and benefits." But on 5 August 2002, the Associated Press reported that NRC declared that "the best available way" to prevent a public health hazard is "controlling the airspace over atomic power plants."
5. "A hijacked commercial airliner loaded with explosive jet fuel like the one that hit the Pentagon on September 11 could not penetrate a U.S. nuclear power reactor and release deadly radiation," from a Reuters report, 17 June 2002, of a National Press Foundation Seminar. The report, commissioned by the Nuclear Energy Institute of independent contractors, is being reviewed by industry experts and will be completed this fall. The study reports detailed computer modeling, confirmed by large-scale tests.
6. Videotapes of tests of an unmanned airplane impacting a mockup of a section of containment wall can be seen at www.sandia.gov/media/NRgallery00-03.htm.
7. J. G. Kemeny, Chairman, *The Need for Change: The Legacy of TMI*, Report of the President's Commission on the accident at Three Mile Island, October 1979 (Government Printing Office, Washington, DC, 1979), 179 pp.
8. Organization for Economic Cooperation and Development (OECD), *Three Mile Island Reactor Pressure Vessel Investigation Project: Achievements and Significant Results*, Proceedings of an open forum sponsored by the OECD Nuclear Energy Agency and the U.S. Nuclear Regulatory Commission, Boston, MA, 20 to 23 October 1993.
9. See especially N. Cole, T. Friderichs, B. Lipford, pp. 81–91 of (*8*), "Specimens Removed from the Damaged TMI Reactor Vessel."
10. N. Cole, "TMI-2, A learning experience: Assessing the damage" (MPR-889, MPR Associates, Alexandria, VA, 1985).
11. *Sources and Effects of Ionizing Radiation: UNSCEAR 2000 Report to the General Assembly, with Scientific Annexes* (U.N. Scientific Committee on the Effects of Atomic Radiation, U.N. Publications, New York, 2000); available at www.unscear.org/reports.htm. See especially "The Chernobyl accident," vol. 1, p. 13 and the extensive scientific annexes, specifically vol. 2, Annex J, "Exposures and effects of the Chernobyl accident."
12. This report (*11*) was reviewed and the conclusions on Chernobyl reaffirmed in the 3rd International Conference, Health Effects of the Chernobyl Accident: Results of 15 Years of Follow-Up Studies, Kiev, Ukraine, 4 to 8 June 2001, sponsored by UNSCEAR; the World Health Organization; other U.N. agencies; and Ukraine, Belarus, and Russia; available at www.unscear.org/chernobyl.htm. Z. Jaworowski, member and former chairman of UNSCEAR, discusses the significance of these findings in *Phys. Today* **52**, 24 (1999).
13. Z. Jaworowski, *Science* **293**, 605 (2002).
14. See D. Williams, *Nature Rev. Cancer* **2**, 543 (2002) and recent news coverage [R. Service, *Science* **292**, 420 (20 April 2001)].
15. *The Human Consequences of the Chernobyl Nuclear Accident: A Strategy for Recovery, A Report Commissioned by UNDP and UNICEF, with the support of UN-OCHA and WHO* (25 January 2002). The report (356KB) is summarized in a U.N. news release at www.undp.org/dpa/frontpagearchive/2002/february/7feb02/ and is available for download at that URL.
16. G. Walinder, "Has radiation protection become a health hazard?" (Swedish Nuclear Training and Safety Center, Nykoping, 1995).
17. H. F. Henry, *JAMA* **176**, 671 (1961).
18. A.M. Brues, *Science* **128**, 693 (1958).
19. L. Gerber *et al.*, *Q. Rev. Biol.* **74** (no. 3), 273 (1999).
20. R. S. Yalow, *The Scientist* **2** (13 June), 11 (1988).
21. L. E. Feinendegen, M. Pollycove, *J. Nucl. Med.* **42** (no. 7), 17N (2001).
22. M. Pollycove, L. E. Feinendegen, *J. Nucl. Med.* **42** (no. 9), 26N (2001).
23. The FDA site on Food Irradiation, www.fda.gov/fdac/features/1998/398_rad.html states, "A May 1997 presidential report, 'Food Safety from Farm to Table,' estimates that 'millions' of Americans are stricken by food-borne illness each year and some 9,000, mostly the very young and elderly, die as a result." There is general agreement that this number could be reduced markedly by food irradiation, but reliable estimates will not be available until irradiation is in widespread use.
24. The U.S. Environmental Protection Agency set an annual limit on radioactivity in primary drinking water, based on a permissible annual dose of 0.04 mSv/year [65 Fed. Reg. 76708 (7 December 2000), with technical justification in the Notice of Data Availability, 65 Fed. Reg. 21576 (21 April 2000) and its Technical Support Document]. Natural radiation background typically varies from less than 1 mSv/year to about 10 mSv/year. The U.S. average is about 3 mSv/year. (NCRP Report no. 94, available from the National Council on Radiation Protection and Measurements, 7910 Woodmont Avenue, Bethesda, MD 20814, USA.) In high-background regions, doses to populations range up to several hundred mSv/year, with no indications of adverse health effects. [UNSCEAR 2000, cited in (*11*), vol. 1, Annex B.]
25. *Low Level Radiation Health Effects: Compiling the Data*, J. Muckerheide, Ed. [Radiation, Science, and Health (RSH), Needham, MA, ed. 2, 1998]; with revisions and preliminary contents for the 3rd ed.; available at http://cnts.wpi.edu/rsh/docs, with access to UN reports on the Chernobyl accident health effects provided by the Center for Nuclear Technology and Society (CNTS) at Worcester Polytechnic Institute. James Muckerheide, Director of CNTS and Massachusetts State Nuclear Engineer, contributed to authoring this statement. RSH, along with the Nuclear Energy Institute, the National Mining Association, and several municipal water districts are currently suing the U.S. Environmental Protection Agency, charging that by basing its rules on the premise that low-dose radiation is harmful at any level, EPA is arbitrarily and capriciously failing to follow the best peer-reviewed science as required by law.
26. The most comprehensive compilation and evaluations of the biology and health effects of low-dose ionizing radiation from 1898 to 1988 are T. D. Luckey, *Hormesis with Ionizing Radiation* (CRC Press, Boca Raton, FL, 1980) and *Radiation Hormesis* (CRC Press, Boca Raton, FL, 1991).
27. The authors are all members of the National Academy of Engineering, but this statement does not constitute an official statement of the academy.

Authors' response to letters

Our Policy Forum paper documents that engineering tests and analyses of radioactivity from molten nuclear fuels, with failed containment, under realistic worst-case assumptions, would produce few, if any, casualties. Commenters have made no attempt to answer the referenced reports that support this conclusion and refute their position.

Commenters have questioned the use of Sandia tests that rocketed an aircraft into a concrete block. These tests were not intended to prove containment invulnerability, but to confirm calculations that impact energy disintegrates large aircraft, with little penetration. Containment damage itself cannot lead to reactor damage. But we examined worse accidents or terrorist events that destroy redundant plant systems inside or outside containment, rupturing containment penetrations, producing ground-level, unfiltered releases. Even in this extreme situation, the radioactivity remains largely bound in the fuel. Condensing water and the physical-chemical properties of fuel retains most radioactivity in water and structures (as at Three Mile Island). Condensing water limits releases, which are not in readily dispersible forms, nor do they remain in respirable forms. This minimizes inhalation hazards (*1*).

Spent fuel pool radioactivity has lost the short-lived and most volatile products and has insufficient energy to disperse in hazardous forms. Even hypothesized zirconium fires would only burn cladding and structures, external to the fuel, adding little to the radioactivity release.

In the worst case scenario, near-plant contamination would warrant evacuation, but not urgently; there would be time for evacuation without significant public health risk. Radioactivity dispersed widely has lower concentrations, in low-hazard forms. Our Policy Forum documented [in notes (*11–15*)] that even ejecting Chernobyl radioactivity directly to the environment, burning for 10 days, without evacuation or interdicting contaminated food, caused few, if any, deaths or injuries among the public. (Most evacuated area dose rates remained below those of high natural radiation areas.) The average effective dose (8.2 mSv in 5 million people) is small compared with doses from hundreds of millions of relevant medical exposures showing no adverse effects at much higher doses (*2, 3*).

Brenner and von Hipple correctly note increased thyroid cancer rates from the Chernobyl accident (about 2000 cases) but do not acknowledge that the references we cited document that these cases are readily treated, producing few if any (none confirmed) fatalities, with expected normal health and life-span, with patients taking thyroid hormones. No other cancer increases have been identified.

Analyses that predict many deaths use invalid release quantities, materials characteristics, dispersion, dose estimates, and dose consequences. For example, the Department of Energy spent fuel cask missile damage study assumes no cleanup and exposes "victims" for 1 year. Even so, the highest dose is tolerable, and if the "victims" walked away, it would be negligible. Similarly, a Nuclear Regulatory Commission report falsely "predicts" radiation deaths 500 miles from spent fuel fires (*4*).

Brenner concedes that the issues of nuclear terrorism relate to a very small individual lifetime risk, but he claims that multiplied by a very large number of people, it presents a significant public health concern using linear no-threshold (LNT) assumptions. Lyman similarly "predicts" thousands of deaths. But there is no scientific basis for such predictions.

NCRP-121 states, "Few experimental studies, and essentially no human data, can be said to prove, or even provide direct support for the concept... It is conceptually possible, but with a vanishingly small probability, that any of these effects could result from the passage of a single charged particle... It is a result of this type of reasoning that a linear non-threshold dose response relationship cannot be excluded." (*5*, p. 45).

NCRP-136, cited by Brenner, states "It is important to note that the rates of cancer in most populations exposed to low-level radiation have not been found to be detectably increased, and that in most cases the rates have appeared to be decreased." (*6*, p. 6) The LNT fails at every level—molecular, cellular, microorganism, animal, and human. Organisms' responses produce beneficial, nonlinear health effects (*7*). Natural radiation varies from below 1 mSv/year to 10 mSv/year, with local areas exceeding 100 mSv/year. Inhabitants of high radiation areas show average or better health and cancer rates (*8*).

Following Roentgen's 1895 x-ray discovery, low-dose radiation (LDR) was found to produce immunological stimulation, curing infections and inflammatory diseases and enhancing physiological conditions (*9*); by the 1920s, it was found to prevent and cure some cancers (*10*). We referenced [notes (*21–22*) in our Policy Forum] information that relevant mechanisms are being elucidated: Radiation produces consistent biphasic responses in vivo: on immune cells and molecules; transcription factors; and enzymes, genes, and intercellular communications; etc. LDR responses are consistent with medical and health benefits (*7*). Antibiotics have largely replaced LDR therapies (*11*), but positive LDR effects on biology and health remain. Oak Ridge hospital facilities successfully exposed patients at moderate dose rates for hours and low dose rates for days (*12*). LDR, including radon therapies, is applied worldwide, with physicians' prescriptions, and is covered by medical insurance.

Commenters objected to our asserting that LDR is essential to life. But relevant, confirmed, uncontroverted data show detrimental health effects and biological functions when organisms are "protected" from background radiation (*13*) and in experiments using potassium with potassium-40 removed, e.g., in the Oak Ridge calutrons (*14*). [Signed]

References

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2. E.g., R. S. Yalow, *Mayo Clinic Proc.* 69, 436 (1994).
3. For example, A. Berrington, S. C. Darby, H. A. Weiss, R. Doll, *Br. J. Radiol.* 74, 507 (2001).
4. U.S. Nuclear Regulatory Commission (NRC), NUREG/CR-6672 (NRC, Washington, DC, 2000).
5. Principles and Application of Collective Dose in Radiation Protection (Report 121, NCRP, Bethesda, MD, 1995).
6. Evaluation of the Linear-Nonthreshold Dose-Response Model for Ionizing Radiation (Report 136, National Council on Radiation Protection and Measurements, Bethesda, MD, 2001).
7. S. Kojima, H. Ishida, M. Takahashi, K. Yamaoka, *Radiat. Res.* 157, 275 (2002). This and other supporting research is available at http://cnts.wpi.edu:9000/rsh/dd3/_database.jsp. J. Muckerheide, Ed., *Low Level Radiation Health Effects: Compiling the Data* (Radiation, Science, & Health, Inc., Needham, MA, ed. 2, 1998) (searchable by author and by topic, with annual update supplements).)
8. See M. Tubiana, *Radiat Environ. Biophys.* 39, 3 (2000), and other reports on variations in natural background radiation available at http://cnts.wpi.edu/rsh/docs/background.html.
9. See A. Richards, *Science* 42, 287 (1915), and other early 20th century low-dose studies on physiological responses described at http://cnts.wpi.edu/rsh/docs/earlystudies.html.
10. S. Russ, H. Chambers, G. M. Scott, *Proc. R. Soc. London* 92, 125 (1921), and other early LDR therapeutic data available at http://cnts.wpi.edu/rsh/docs/earlyimmune.html.
11. LDR is still sometimes used when antibiotics and antiinflammatories fail, e.g., in some arthritic conditions, and radon therapies are used extensively and successfully by medical direction in Europe, Russia, and elsewhere. LDR had 95% success treating gas gangrene, largely eliminating any amputation, whereas current practice is to amputate and use antibiotics, with 30-70% mortality (*15*).
12. Human radiation studies: Remembering the early years, Oral history of pathologist Clarence Lushbaugh, M.D., conducted 5 October 1994 (Report DOE/EH-0453; DE96-009839, Department of Energy, Washington, DC, 1995) (available at http://tis.eh.doe.gov/ohre/roadmap/histories/0453/0453d.html).
13. H. Planel *et al.*, *Health Phys.* 52, 571 (1987).
14. T. D. Luckey, *Radiat. Res.* 108, 215 (1986).
15. J. F. Kelly, D. A. Dowell, *Radiology* 37, 421 (1941).

16. The authors are all members of the National Academy of Engineering, but this statement does not constitute an official statement of the academy. James Muckerheide, Director of the Center for Nuclear Technology and Society at Worcester Polytechnic Institute, and Massachusetts State Nuclear Engineer, contributed to authoring this response.

von Hippel letter excerpts:

Chapin *et al.* assert that "no airplane, regardless of size, can fly through such a wall" ["the reinforced, steel-lined 1.5-m-thick concrete walls surrounding a nuclear reactor"]. Sandia National Laboratory, whose report Chapin *et al.* cite as evidence of this assertion, has already disputed the relevance of its report to this conclusion (*1*). Also relevant to the overall question of the risks from aircraft crashing into nuclear power plants is the conclusion of a recent Nuclear Regulatory Commission (NRC) report on the potential risks to the spent fuel pools that adjoin U.S. nuclear power reactors: "1 of 2 [large] aircrafts are large enough to penetrate a 5-foot-thick reinforced concrete wall" of a pressurized water reactor spent fuel storage pool, potentially causing it to be "so damaged that it rapidly drains and cannot be refilled from either onsite or offsite resources." (*2*.

The authors cite the UN's review of the consequences of the Chernobyl accident as the basis for their assertion that "no increase in mortality or cancer due to irradiation of the public have been observed." However, that report shows an up to a 25-fold increase in the incidence of childhood thyroid cancers in cities in the most contaminated regions of Belarus and concludes that "there can be no doubt about the relationship between the radioactive materials released from the Chernobyl accident and the unusually high numbers of thyroid cancers observed in the contaminated areas during the past 14 years" (*3*, Table 57, p. 504).

The public fear of the risks from ionizing radiation may be disproportionate. However, this fear is reinforced by a learned distrust of reassurances from the nuclear industry. This article by 19 mostly retired nuclear-industry leaders does nothing to remedy that situation. Contrary to the implied conclusion of their Policy Forum piece, the U.S. government should require strengthened protections against and preparations for emergency response to terrorist attacks on U.S. nuclear power reactors.

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Brenner letter excerpts:

With regard to potential terrorist scenarios involving a nuclear power plant, the authors are correct to point out that the very thick walls of the containment vessel make the nuclear core an unlikely target. They do not, however, address the more pertinent issue of the spent fuel-rod storage pools, which are located adjacent to most commercial reactors (*1*). These spent fuel storage facilities typically contain amounts of radioactivity comparable to that in the reactor core itself. Typically, the fuel rods are stored under water and in nonhardened buildings; often they are on upper floors. The issues relating to the possibility of a plane- or missile-based attack on a spent-fuel pool or the possible theft of a spent fuel rod for use in a "dirty bomb" seem much more relevant than the unlikely scenario of an attack on a nuclear reactor core.

In terms of the radiological risks from the low levels of radiation that might be produced in a radiological terrorism incident, the authors present a one-sided perspective. Indeed, the biological effect of low levels of radiation are hard to quantify because the individual risks are small, but there is little evidence that low doses of radiation are actually beneficial, as the authors suggest....the risk probably goes down proportionately, but is unlikely to actually reach zero.

Chapin *et al.* suggest that no significant increase in mortality or cancer has been observed from the radiation from the 1986 Chernobyl accident...It is only 16 years since the Chernobyl accident, which, based on the A-bomb survivor experience (*4*), is still too early to expect significant radiation-related increases in solid cancers. Most of any potential increase in cancer rates in individuals exposed in 1986 would not be expected to appear until 25 to 50 years after the accident (*4*).

Yes, the cancer risks from very low doses of radiation are probably very small. But nuclear terrorism could result in large numbers of people being subject to these very small risks. That's why it may represent a significant public health concern.

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Lyman letter excerpts:

As president of an organization criticized for exaggerating the danger of a terrorist attack on a nuclear power plant ("Nucle[ar] power plants and their fuel as terroris[t] targets," D. M. Chapin *et al.*, Policy Forum, 20 Sept., p. 1997), I would like to outline the technical basis for our concern. Chapin *et al.* selectively invoke "a few simple scientific and engineering truths" to assert that nuclear plants are essentially invulnerable to attack. In fact, the issues they raise are far from simple and cannot be so neatly resolved.

Today's nuclear plants are vulnerable to common-mode failures, such as station blackout events, that could result in core damage in as little as 2 hours (*1*). Terrorists could exploit these weaknesses to maximize the severity of an attack.

The 1979 Three Mile Island (TMI) accident has little bearing on this scenario because operators were able to restore core cooling before the core became fully molten. With time, a molten core will indeed cause rupture of the reactor vessel, an event that was observed in a dramatic test at Sandia National Laboratories in 2000 (*3*). In contrast to the sequence of events at TMI, if terrorists were able to seize the control room and remote shutdown panels during an attack, they could prevent operators fro[m] taking timely corrective action.

The security around nuclear power plants is not commensurate with the consequences of a terrorist attack. The cost of additional protective measures is small compared with the benefits of risk reduction. To ignore the dangerous potential of such events, as Chapin *et al.* would do, can only lead to uninformed and irresponsible policy decisions.

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Radiation, Science, & Health INC.

NCRP-136 Misrepresents the Scientific Evidence

Summary

NCRP-136 (Draft) by NCRP Scientific Committee SC-1 misrepresented the scientific data, apparently to support its premise that low-dose radiation (LDR) ***might*** be harmful. The Committee:

1. Produced voluminous irrelevant and misleading data to support the linear no threshold (LNT) premise.
2. Selectively misrepresented data that ***do*** provide highly statistically significant and consistent evidence of LDR benefits, and null dose-response effects, that contradict the LNT.
3. Failed to consider the voluminous scientific literature, submitted to it by the scientific community, including RSH, that consistently contradicts the unsupported LNT premise.

The Committee's position leads to extreme radiation protection policies requiring enormous public expenditures for no public health benefit.

Overview

1. The Committee has compiled material that is mostly irrelevant to health effects dose-response:
   - Data from isolated irradiated cells in tissue, falsely imply effects to living organisms
   - Other high dose, high-dose-rate, data from conditions that overwhelm the body's natural defenses
   - Japanese bomb survivors ('instantaneous' doses; neutrons; poor dosimetry; major confounders)
   - Uranium miners and other extreme conditions (diesel fumes; silica dust; poor dosimetry; smoking)
2. The Committee virtually ignores the vast body of relevant low-dose radiation research data:
   - Human and animal data that show beneficial effects, with no harmful effects where LNT 'predicts' harm
   - Laboratory data and analysis that reveal the many molecular and cellular stimulatory mechanisms
   - Successful use of LDR to treat cancer and other diseases in humans and animals
3. Misrepresents data from credible studies that show statistically-significant benefits from LDR:
   - Nuclear Shipyard Workers Study (24% lower overall mortality; 99.9+% confidence level)
   - Canadian fluoroscopy study (statistically-significant reduced breast cancer, called an "anomaly")
   - The many population radon studies (consistent decreases in lung cancer with increasing radon)
4. Inappropriately applies the fact that initial damage to DNA is linearly proportional to dose:
   - *Initial* damage from radiation is trivial compared to that from normal metabolism
   - LDR stimulates anti-mutagenic systems, so *persistent* mutations are reduced overall
5. Misleads about a higher percent of double-strand breaks (DSBs) from radiation, that are harder to repair:
   - There are still 1000 times more DSBs produced by metabolism than by 100mr/yr background radiation
   - LDR enhances low-error enzymatic repair of ***all*** DSBs, which are mostly produced by metabolism
6. Misleads about the fact that radiation can linearly increase chromosomal damage
   - Chromosome aberrations do not cause adverse health effects

Relevant data and concerns about such flaws were provided to the Committee RSH and others. As a result, in 1996 NRC Chairman Jackson formally required the NRC staff to inform the NCRP that such deficiencies must be avoided – and specifically to consider all relevant data. These admonitions were ignored by the NCRP. In the March 1999 NRC review of the October 1998 draft, the Committee again committed to the NRC to consider all of the relevant data. Despite this official warning, the NRC effectively rescinded

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the NRC to consider all of the relevant data. Despite this official warning, the NRC effectively rescinded Chairman Jackson's direction, by indicating that NRC, and its Advisory Committees, would ***not*** hold the Committee accountable.

SOME INITIAL COMMENTS

Following doggedly in the path of its predecessors, NCRP Committee 1-6 reported on its six-year evaluation of low-dose radiation health effects as predicted by the linear non-threshold (LNT) premise. The Report asserts (p.6) **"it is important to note that the rates of cancer in most populations exposed to low-level radiation have not been found to be detectably increased, and that in most cases the rates have appeared to be decreased."** Despite this proven fact, the Committee concludes that radiation protection policy and regulations should continue on the "biophysical" premise (NCRP 121, p.45) that any amount of radiation, no matter how small, is hazardous and should therefore be reduced to "as low as reasonably achievable." The Committee does not claim that this premise is shown to be valid. It merely states that the possibility **"cannot be excluded."** But this possibility falls if the overwhelming contrary scientific evidence is considered.

Less than two pages, plus a few scattered phrases, of this 287-page report discuss **hormesis,** the basic biological principle cited by Paracelsus in 1540: **"Nothing is poison, but the dose makes it so."** This hormetic principle has been demonstrated in hundreds of studies at the level of cells, tissues, and organisms. LDR has been shown to prevent and cure some cancers other diseases and adverse health conditions. Biological response mechanisms are stimulated by LDR: Immune cells and functions; genes and adaptive responses that enhance system-wide DNA damage control; and hormones and other physiological responses.

By this principle, radiation, like selenium and other toxic metals and minerals that are nutritional supplements, is harmful at high doses but beneficial, and probably essential, at low doses. The Committee concedes (p.8) that the data they use **"come primarily from observations at moderate-to-high levels of exposure."** But there is ***no*** important dispute over moderate-to-high level dose-response data. Far better had the Committee devoted most of the other 285 pages to the abundant LDR human and biological data, showing that populations exposed to LDR show undetectable or beneficial, not detrimental, health effects.

The Committee's mutagenesis review (pp.36-49) omits hundreds of significant biological studies of molecular **anti-mutagenic cell functions** and their responses. Also **unmentioned** are **oxidative free radicals and associated reactive oxygen species (ROS),** the principal cause of DNA damage produced by both ionizing radiation and oxygen metabolism. DNA damage from metabolism exceeds that from 1 mGy per year background radiation by a factor of more than 100 million. The anti-mutagenic system of DNA damage control evolved to cope with this relentless onslaught of **metabolic** damage. There are three effective components of cellular DNA damage control: **prevention** by anti-oxidant scavenging of ROS; enzymatic **repair** of damaged DNA; and **removal** of persistent damage by apoptosis and the immune system.

Double-strand breaks in DNA (DSBs) are a thousand times more likely to have errors in repair than simple single-strand breaks; and they occur in up to 2% of radiation-induced DNA damage, but only in 0.00001% of metabolism-induced DNA damage. However, DSBs from metabolic damage still exceed those from background radiation by a factor of 1000. But, **LDR stimulates all these components of the anti-mutagenic system.** (High-dose radiation, on the other hand, suppresses them.) High dose, high dose-rate, radiation mutagenesis is linearly proportional to doses that are sublethal to cells. In contrast, hormetic **LDR decreases mutagenesis.** This effect has been shown to slow aging, and to decrease mortality from cancer and other causes. This generally results in longer mean lifetimes of LDR-exposed populations.

The Committee's primary flaw, like its predecessors, is that it **ignored most of the vast body of data** that show no harm from low-level radiation, and show stimulatory responses that produce health benefits. E.g., it cites RSH's "Data Document" (but only 1998, though it received the 1999 and 2000 updates), but it does not assess the several hundred science literature data sources there that contradict the LNT. The Committee disingenuously refers to a magazine article that has no references (Muckerheide 1995), while ignoring the actual data sources provided. It cites a one-page editorial comment by Pollycove, but not his comprehensive, data-filled papers; and cites Cohen's 1995 radon health effects paper, but not his many papers that refute the unsubstantiated disparaging comments that were used to simply dismiss, rather than assess, his many studies. *Especially egregious is its failure to assess Cohen's joint paper with the renowned* Harvard epidemiologist, Colditz (1994), that finds Cohen's data and analyses epidemiologically valid. Nor does it mention independent confirmatory studies by Bogen (1998) and others.

Instead of scientific scrutiny, the Committee **dismisses such studies, using generic comments** with *no assessment of their application to the study. The Committee did not show that results were invalidated by* such generic concerns. It only states (p.136) **"Given the intrinsic problems with analyses of ecological data described above, such data cannot be regarded as trustworthy,"** and concludes (p.49): **"Under some experimental conditions the adaptive response can protect cells against the mutagenic effect of ionizing radiation; however... the response seems unlikely to have a significant impact on radiation effects in human populations."** This statement is not compatible with its assertion (p.6 quoted above) that **"cancer in most populations... have not been found to be detectably increased, and that in most cases the rates have appeared to be decreased."**.

After dismissing studies on large populations irradiated by radon in homes, or Co-60 at work, or living in high natural radiation areas, or receiving medical treatment with low-to-moderate radiation doses, the Committee states **"*in vitro* studies have yielded the most reliable dose-response data."** This is true for irradiating cells in a Petri dish, but it has no direct relevance to radiation health effects in whole organisms.

Since *in vitro* tissues and cells do not have capable immune systems, nor enzymatic and hormonal responses, nor apoptotic removal capabilities, etc., they do not indicate how whole organisms respond. Biologists know that cells in culture are laboratory artifacts; that cell experiments may help elucidate mechanisms, but they can ***not*** indicate how an organism will respond. Renato Baserga states in "The Molecular Basis of Cell Cycle and Growth Control," (Ed. Stein, Baserga, et al., Wiley-Liss, 1999): **"If you wish to study the cell cycle of the lining epithelium of the small intestine in mice, there is only one way to study it, and that is in a mouse. But if your concern is about mechanisms, gene expression, growth factors and so on, then yeasts and other cells in culture are the best choice. One only has to be very careful in avoiding extrapolations... the environment of cells in culture resembles the environment of cells in vivo no more than a zoo resembles an African habitat. The Petri dish is a hostile environment, and when cells are asked to grow in that environment, they pull out all the stops and start expressing all kinds of genes they do not express in the adult animal."**

On the page-and-half that "cover" hormesis (pp. 196-197), only two of the studies that clearly show beneficial responses to LDR were "addressed." First: a study by **Miller et al. (1989) of Canadian women TB patients** *who were periodically examined by fluoroscopy. Breast cancer incidence vs. radiation dose shows a* clear, statistically highly significant, cancer deficit in the 100 to 300 mGy range vs. the lowest-dose controls. Contradicting NCRP member E.W. Webster's analysis of this study in his 1992 Lauriston S. Taylor Lecture at the Annual NCRP meeting, published by NCRP September 1, 1992, the Committee claims that the deficit is not statistically significant, and falsely states that **"a simple linear dose-response curve provided an adequate fit to the data."** A 1996 "update" by Howe and McLaughlin is used instead. But it is known that this study grouped the 10 to 490 mGy data into a single dose group. This effectively hides this hormetic effect by burying the 53 deaths in the hormetic range (of about 79 "expected") with deaths above and below this range. They then state that **"the most recent report by Howe (2001-to be published)... found that a simple linear model fit the data better than a pure quadratic model... Thus the alleged deficit... should be regarded as a statistical anomaly that has now disappeared."**

Adding to the apparent effort to suppress the actual data, this manipulation raises other questions: Does the Committee intend that failure to fit a quadratic model automatically proves a linear model? In fact, *since entirely different biological processes take place during low-dose irradiation from those occurring at high* doses, a simple linear fit to both ends of the data is precluded. And is "Howe (2001-to be published)" on which the Committee relies, the same as "Howe (1998-in press)" used in this same context in the October 1998 draft SC 1-6 report (then claimed to be "in press"?) still not accepted for publication? The Committee does not even summarize the methods and results of this "new study," unlike its expositions on other much less significant unpublished studies. This effort to transform a study from one demonstrating statistically significant beneficial effects of LDR, into one "consistent with" linearity, should be re-examined.

Secondly: the Committee discusses the **Nuclear Shipyard Worker Study**, generally considered the best and strongest epidemiological study of nuclear workers ever conducted. This 10 million dollar, 10-year study (1978-1987) was directed by Congress in response to allegations of adverse health effects in shipyard workers. It was done for the US Department of Energy and the U.S. Navy by the Johns Hopkins Department of Epidemiology. Its Technical Advisory Panel was headed by Dr. Arthur Upton, who was concurrently BEIR-V Committee Chairman, and also Chairman of this NCRP Committee. This study population (about 70,000 workers) was taken from more than 700,000 workers that include 108,000 radiation-exposed workers. Thus, the study was able to match unirradiated-worker control groups to exposed-worker groups, by age, under the same health plan, doing the same work under identical working conditions, except for exposure to Co-60 irradiation. In this way, the study, under the guidance of its Technical Advisory Panel, was able to eliminate the "healthy worker effect." All irradiated workers wore film badges, under a rigorous program compared to other early nuclear workers; and since the significant radiation source was external Co-60, they had the most accurate radiation dose data.

As shown in the Figure to the right, there is a highly significant decrease in mortality from "All Causes," by 16 standard deviations (SDs). Deaths from "All Malignant Neoplasms," that is, *All* Cancers, not "just for radiosensitive cancers" (p. 196) were more than 4 SDs below controls (p<0.001). This was apparently not the result expected or desired. These dramatic effects are explained by the Committee as, **"This interpretation ignores the likelihood of occupational selection factors that led some to qualify for radiation work while others did not."**

However, that issue had already been addressed by the study authors. It was determined that this selection affected only a handful of nuclear workers out of nearly 30,000, and could not significantly affect the results.

Nuclear Worker Cumulative Dose: 0.5 – >40 cSv (rem)
SUMMARY OF FINDINGS: SMR Ratios Table 4.1.A
***OTHER CAUSES OF DEATH: SMR Ratios Tables 3.6.B (NW), 3.6.D (NNW)**

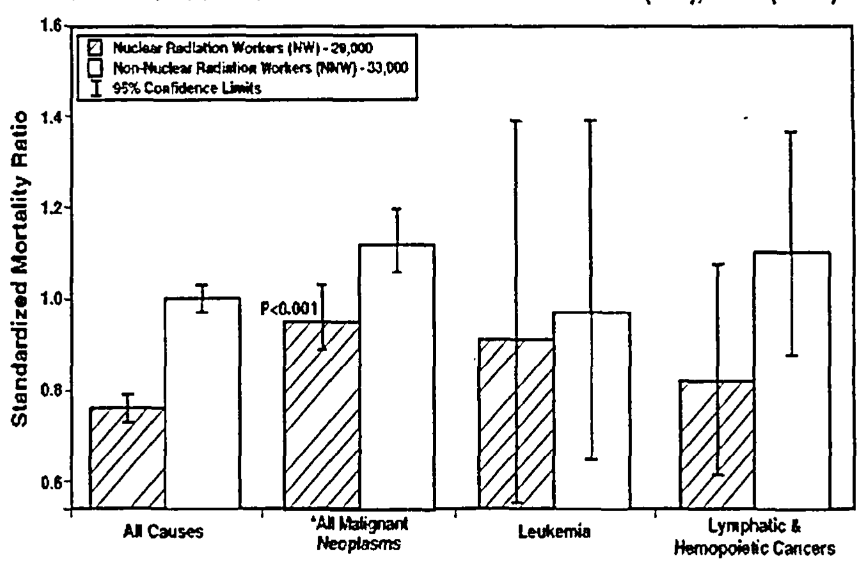


Figure 5. Standardized mortality ratios for selected causes of death among shipyard workers in the U.S. Matanoski GM. (1991)

DOE published an abstract in 1993, but neither DOE nor the Principal Investigator has submitted a paper for publication, even though a contract with the Principal Investigator to support this study was continued in 1994. Most egregiously, DOE's Summary of Findings reported only a few statistically insignificant "radiosensitive cancers", not the most important result - the "All Malignant Neoplasms" category. When DOE finally made the report available with a brief news release in 1991, the large, highly significant decrease in mortality from "All Causes" was explained away as a "healthy worker effect". This duplicitous explanation was recently repeated in DOE's comments on the June 30, 2000 GAO Report on this subject, even though this has been documented and acknowledged many times as a misrepresentation, including by UNSCEAR 1994.

This study was excluded by the BEIR V Committee, by the DOE-funded IARC "study of nuclear workers in three countries" (Cardis 1995), and today in the then on-going IARC "study of 600,000 nuclear workers."

The Committee makes a few fleeting references to **genetic effects of radiation.** It would have been forthright to confirm, at least, the long-standing conclusion that no heritable genetic effects are observed in several generations of irradiated humans; nor in massive animal studies at doses below 250 mGy. In view of the public fear of the possibility of creating mutant off-spring, exemplified by an estimated 100,000 "preventive" abortions after Chernobyl, the Committee inappropriately leaves such answered questions unanswered.

The Committee misrepresents volumes of data, especially by using high-dose data to project effects to zero dose, and using figures that substantially conceal low dose data. The Committee has figures and tables with multiple data sources that exclude highly significant studies. E.g., for lung cancer, Section 9.3.5 (p.166) does not include the well-known analysis of studies by Harald Rossi and Marco Zaider in their 1997 comprehensive assessment of lung cancer caused by external radiation. (Their "Figure 1" is to the right.)

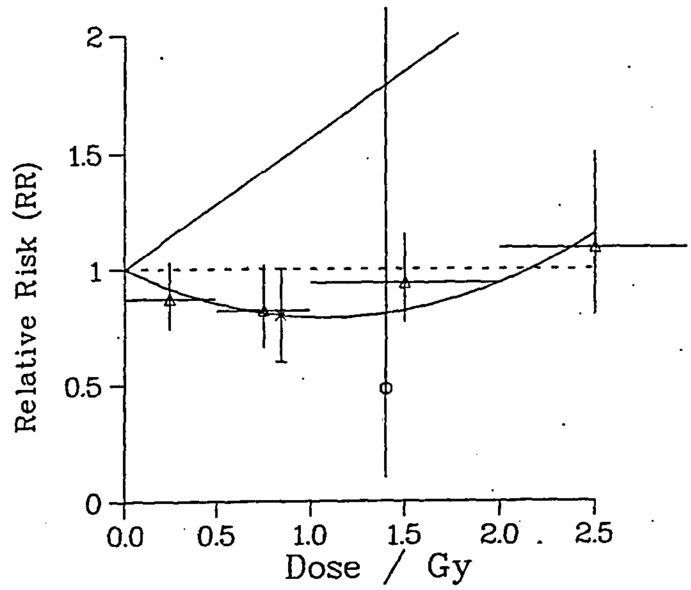


Fig.1 The relative risk of lung cancer following exposure to low-linear energy transfer (LET) radiation: Δ (Howe 1995); × (Davis et al 1989); o (Neuguit et al. 1993). Howe data horizontal bars indicate the dose bins he used. Neugut et al data are the relative risk in the contralateral lung 10 years or more after diagnosis of breast cancer; it is shown at the average of the two doses reported for this tissue. The 95% confidence intervals, indicated by vertical bars, were taken from the original publications; for the data point from Neugut et al., the confidence interval was estimated by us. The straight line of positive slope is: RR=1+0.56D/Gy recommended by ICRP [1991]. The curve represents the expression, Eq(1). [Not shown. From Rossi and Zaider 1997.]

Rossi and Zaider state: **"A critical review of the literature leads to the conclusion that at the radiation doses generally of concern in radiation protection (< 2 Gy), protracted exposure to low linear energy transfer (LET) radiation (x- or gamma-rays) does not appear to cause lung cancer. There is, in fact, indication of a reduction of the natural incidence."**

In addition to selective exclusion of data, and misrepresentation of data, the Committee also suppresses voluminous LDR dose-response data from biology and medicine. Animal and human studies consistently show bio-positive responses to LDR, with lower cancer and disease rates, and successful treatment of some established cancers and other diseases. LDR effectiveness in clinical medicine has shown significant results in combating inflammations and infection. The Committee acknowledges these in its statement (p.124-125): **"...where the mean survival time of lightly irradiated animals has significantly exceeded that of the controls, the differences have generally been attributable to radiation-induced reduction in the rate of mortality from intercurrent infectious diseases..."**

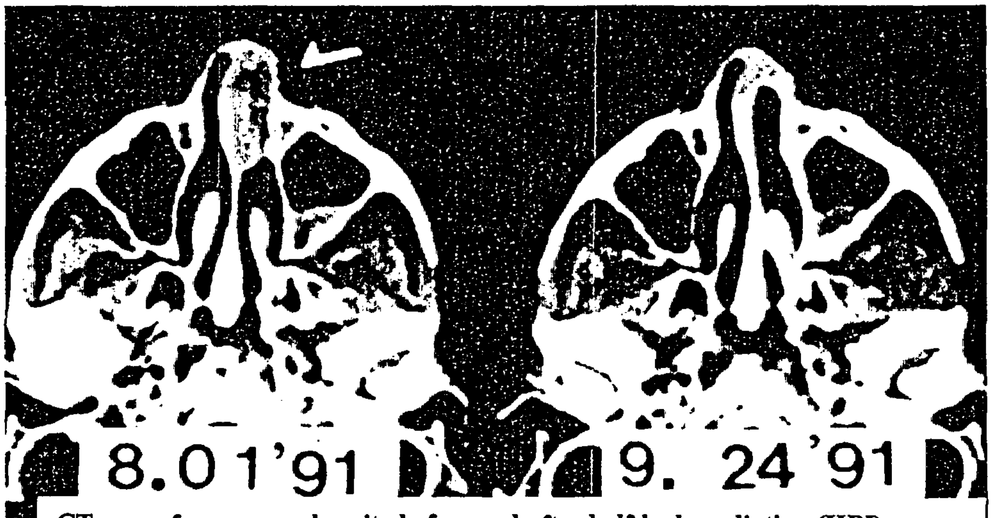
This same immune system also controls cancer.

The Committee stated the significance of its conclusions as follows (p.205): **"Although it is widely acknowledged that adaptive responses may underlie some of the observed [data]...there is no firm evidence thus far that such responses can be expected to operate effectively enough to protect completely against the mutagenic and carcinogenic effects of low-level radiation. Thus, in spite of some suggestions to the contrary... the data are generally interpreted not to exclude the linear non-threshold model and thus to provide insufficient grounds for rejecting the linear non-threshold dose-response model as a basis for assessing the risks of low-level ionizing radiation in radiation protection (ACRP, 1996; NRPB, 1995; UNSCEAR, 1994)."**

To achieve even this weak conclusion, the Committee had to select biased data, and cite for support their kindred policy bodies whose reports are similarly biased, rather than substantial scientific sources

This is shown by hundreds of studies, and current anti-cancer research.

One example, from a study of 24 patients with non-Hodgkin's lymphoma, is shown in the Figure to the right (from Takai, 1992). LDR stimulation of the immune system by "half-body" X-ray (by 2 or 3 exposures / week, of 150 or 100 mGy, for 5 weeks, for 1.5 Gy total exposure) was sufficient to eliminate this nasal tumor at the base of the skull. These CT images were obtained one week before and one week after the LDR series. Blood tests and tumor tissue examinations confirmed the role of the enhanced immune system in destroying the tumor. These studies, and much more data on immune system stimulation by LDR, were provided to the Committee. It chose to ignore, and thereby misrepresent, the data.



CT scan of upper nasal cavity before and after half-body radiation (HBI). Nasal tumor, though completely outside the HBI field, disappeared after HBI

Many knowledgeable scientists have expressed similar frustration with having their carefully documented data never incorporated, evaluated or even acknowledged. For example, former UNSCEAR Chair, Zbigniew Jaworowski, MD, PhD, wrote of how his organization's input was treated:

"We never received an answer to this criticism, and in the final version of NCRP Report No. 136, almost all of these comments were ignored...**The Report is not an objective evaluation** of the validity of the linear-nonthreshold dose response hypothesis (LNT); **but rather is a propagation of LNT.** It does not demonstrate that LNT is scientifically valid, but rather that NCRP holds LNT dear. Because of the longstanding involvement of NCRP in applying LNT as the basis of radiation protection and radiation risk evaluation, with all of its far reaching economic, health and social consequences, **NCRP is probably not a proper body to conduct an objective estimate of the validity of the LNT,** because of the group vested interests that are the case here. In the face of a mounting scientific evidence of invalidity of this hypothesis, and the increasing number of its opponents, the Committee's Report can be seen as an attempt to defend the LNT, and an attempt for an exculpation for its past use...

"The Committee has presented an unbalanced presentation of the pros and contras to the LNT. **The Report demonstrates a biased selection of published results, offering lengthy and often misleading pro-LNT interpretations and data, but curtailing and deforming the information to the contrary, and most often ignoring it. The Report concentrates almost exclusively on detrimental effects of radiation, and ignores totally the beneficial effects,** and even does not mention an existence of the studies of Planel and his group (e.g. Planel et al. 1987) that **suggest that ionizing radiation may be essential for life.**"