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Rockwell International
Rockwell Hanford Operations

BWIP REVIEW COMMENT RECORD (RCR)

1. Date 8/14/87
2. Page 1 of 7
3. Project No.
4. Review

5. Document Number(s)/Title(s)
Expedited Special Case package; documents for restart of DC-24CX and DC-25CX

6. Project/Building Number

7. Reviewer
CTUIR

8. Organization/Group

9. Location/Phone

10. Agreement with indicated comment disposition(s)
August 14, 1987
Date
Reviewer
M.W. Person. M.W. Person
Project/Cognizant Engineer

11. CLOSED
Date
Reviewer
Project/Cognizant Engineer

12. Item	13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	14. Disposition (provide justification if NOT accepted).
1.	The BWIP has quality graded all components related to drilling and piezometer installations as either level 1 or level 3. Quality level 1 is applied to an item or activity in which failure may allow radioactive materials to reach the uncontrolled environment or involves or affects public safety and health. Quality level 3 generally applies industry-accepted practices and standard, and sound engineering or scientific practices. The quality level assignments appear to be appropriate to the needs of the data requirements. However, DOE/BWIP assigned quality level 3 to logging of drill cuttings, but quality level 1 to geophysical logging. This would seem to be somewhat inconsistent. The implication here is that if data are machined produced (geophysical data) it is level 1 because it can be essentially log drill cuttings the same way. Little bias would be introduced. It seems that the physical description of drilled materials should be weighted equally in the interpretation of lithologic sequences as their geophysical properties. It could be argued that physical lithologic description are more accurate than geophysical logs of the same medium, because lithologic characteristics are inherent in the material, whereas geophysical properties are as influenced by borehole and fluid conditions as they are of the inherent character of the geologic material.	See Nez Perce item 1.

from: Cook, NRC To: Browning

2586

Reviewer	BWIP REVIEW COMMENT RECORD (RCR) CONTINUATION	Review No.	Page
TJIP			2 of 7

Item	Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
2.	Piezometer installations DC-32CX and DC-33CX are proposed by BWIP to provide intermediate information during LHS testing. These would be the closest monitoring wells to pumping of RRL-2B, with the exception of RRL-2A (500 feet south of RRL-2B) and RRL-2C (250 feet east of RRL-2B). DC-32CX and DC-33CX are both several thousand feet from the pumping well. Although they do provide intermediate distances as compared to the other wells within the Controlled Area Study Zone (CASZ), they are not sufficiently close to provide additional monitoring locations close in to the pumping well. Consideration should be given to installing additional close-in monitor wells to provide better coverage for the proposed tracer testing as well as evaluate the directional hydraulic properties of the basalt medium on a local scale.	See Nez Perce item 2.

MADE FROM MICROFICHE

Reviewer

CTUIR

BWIP REVIEW COMMENT RECORD (RCR) CONTINUATION

Review No.

Item	Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
3.	DOE-BWIP is proposing the CX-series piezometers because they feel that drilling a single borehole and completing seven piezometers in that borehole disturbs the system less and that hydrologic baseline can be achieved sooner. It is also argued that some cost savings can be realized because fewer holes have to be drilled. However, there is continuing concern as to whether or not adequate sealing between monitored zones can be assured. The potential for hydraulic interconnection through the borehole remains a continuing problem, especially in hole drilled to the depth these will (are) be. In addition, it would seem that the QA/QC requirements to be followed and associated costs in such a multiple completion would exceed the benefits derived from such complex installations. It would seem to be preferable to ensure high quality piezometer installations with reliable performance and longer time to achieve hydrologic baseline. If the CX piezometers do not work as planned, then redrilling and installation of reliable piezometers would increase even further the time to reach hydrologic baseline.	See Nez Perce item 3.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
4. It would appear that DOE/BWIP has put into place sufficient checks and balances through the NQA-1 QA/QC program to ensure that licensable data will be obtained. However, there is some concern that the field investigation program is so enveloped in procedures and QA inspections that the professional staff responsible for the geohydrology program will not be able to conduct a sound technical program. Procedures are never a substitute for good professional, experienced judgment. This should not be construed to mean we do not want proper QA controls. A delicate balance between QA controls and professional judgment needs to be found. Profesional judgment needs to be included as part of the overall quality assurance plan. If you have further questions, please contact us.	See Nez Perce item 5.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
5. To save time and money, we would ask you to think about the possibility to change the characters of one or two of these boreholes, and to use them by drilling deeper, below the basalts, into the sediments, as an information source for the problem related to the potential natural resources of the repository area.	Umatilla 5 Reject. Drilling one of these holes down to the sediments is inconsistent with the goals of the piezometer installation. The horizons to be monitored would be open to drilling fluid pressure effects and contamination for an extended period of time. This would require extensive clean up work, delay establishing the baseline, and the possible loss of future high quality groundwater samples.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
6. The geotechnical concerns raised should not minimize DOE's responsibility to ensure laws and regulations are followed prior to drilling any of the DC's. Of most interest to the Tribe are the American Religious Freedom Act and archaeological laws. We feel documented proof is required that no adverse impacts will occur to present day, ethnohistorical or archaeological resources. This means that the area receiving clearance as having no adverse impact be of sufficient size to ensure no vehicle traffic, earthmoving equipment, or vegetation removal occur outside the area where clearance is granted. Also, the integrating of the site should remain as near pristine as possible during operation and well monitoring.	Answer to question #6,7 Accept-- We fully agree that geotechnical concerns should not bear upon DOE's environmental regulatory responsibilities, and point in fact, DOE BWIP believes that the program currently in place insures that environmental regulatory issues are addressed prior to undertaking site characterization activities. The program currently in place includes a BWIP Environmental Review prior to any specific site characterization activity. The BER's are an important integral part of the Environmental Regulatory Compliance Plan (ERCP.) The ERCP in turn is a programmatic document describing, generically, the expected site characterization activities that may trigger an environmental law, an analysis of the applicable laws resulting from these activities and the approach to compliance. In this regard, although the working draft ERCP will not be released until the fall of 1987, the BER's assure full environmental regulatory consideration of all specific site characterization activities. All of the BER's, including those completed for DC-24 and DC-25 contain three key sections, addressing environmental impacts, cultural resource impacts, and environmental regulatory considerations, respectively. This format assures that those areas of particular interest to the Tribe such as the Indian Religious Freedom Act and the several laws addressing protection of of cultural resources are adequately addressed. For DC-24 and DC-25, the area area that has been prepared at the DC's is of sufficient size to contain all of the expected site activities. In addition a 20 meter strip of land around the cleared area was examined during the BER review. All BER's including these include both an archival search and an on-site inspection. The BER's for DC 24 and 25 recommend that off-road vehicular travel be restricted to the cleared area.

Comment/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
7. How can you follow through with an expedited special case without a plan to follow regarding all the legal responsibilities that would be identified under the Environmental Regulatory Compliance Plan (ECRP)? We feel you should prepare this plan first.	Answer to question #6.7 Accept-- We fully agree that geotechnical concerns should not bear upon DOE's environmental regulatory responsibilities, and point in fact, DOE BWIP believes that the program currently in place insures that environmental regulatory issues are addressed prior to undertaking site characterization activities. The program currently in place includes a BWIP Environmental Review prior to any specific site characterization activity. The BER's are an important integral part of the Environmental Regulatory Compliance Plan (ERCP.) The ERCP in turn is a programmatic document describing, generically, the expected site characterization activities that may trigger an environmental law, an analysis of the applicable laws resulting from these activities and the approach to compliance. In this regard, although the working draft ERCP will not be released until the fall of 1987, the BER's assure full environmental regulatory consideration of all specific site characterization activities. All of the BER's, including those completed for DC-24 and DC-25 contain three key sections, addressing environmental impacts, cultural resource impacts, and environmental regulatory considerations, respectively. This format assures that those areas of particular interest to the tribe such as the Indian Religious Freedom Act and the several laws addressing protection of of cultural resources are adequately addressed. For DC-24 and DC-25, the area area that has been prepared at the DC's is of sufficient size to contain all of the expected site activities. In addition a 20 meter strip of land around the cleared area was examined during the BER review. All BER's including these include both an archival search and an on-site inspection. The BER's for DC 24 and 25 recommend that off-road vehicular travel be restricted to the cleared area.

Rockwell International
Rockwell Hanford Operations

BWIP REVIEW COMMENT RECORD (RCR)

1. Date	9/11/87
2. Page	1 of 5
3. Project No.	
4. Review No.	
Document Number(s)/Title(s)	Response to: Proposed Restart of Drilling of DC-23, DC-24, DC-25, DC-32 and DC-33 for BWIP Hydrology Program
6. Project/Building Number	N/A
7. Reviewer	Ronald T. Halfmoon
8. Organization/Group	Nez Perce
9. Location/Phone	Idaho (208) 843-2253
10. Agreement with indicated comment disposition(s)	August 14, 1987 (Date); Reviewer; M. W. Parsons M. W. Parsons (Project/Cognizant Engineer)
11. CLOSED	Date; Reviewer; Project/Cognizant Engineer

13. Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	14. Disposition (provide justification if NOT accepted).
Comments and Observations 1. The BWIP has quality graded all components related to drilling and piezometer installations as either level 1 or level 3. Quality level 1 is applied to an item or activity in which failure may allow radioactive materials to reach the uncontrolled environment or involves or affects public safety and health. Quality level 3 generally applies industry accepted practices and standard, and sound engineering or scientific practices. The quality level assignments appear to be appropriate to the needs of the data requirements. However, DOE/BWIP assigned quality level 3 to logging of drill cuttings, but quality level 1 to geophysical logging. This would seem to be somewhat inconsistent. The implication here is that if data is machine produced (geophysical data) it is level 1 because it can be reproduced or replicated. Professionally trained personnel would also essentially log drill cuttings the same way. Little bias would be introduced. It seems that the physical description of drilled materials should be weighted equally in the interpretation of lithologic sequences as their geophysical properties. It could be argued that physical lithologic descriptions are more accurate than geophysical logs of the same medium, because lithologic characteristics are inherent in the material, whereas geophysical properties are as much a reflection of borehole and fluid conditions as they are of the inherent character of the geologic material.	Nez Perce 1 Reject. The determination of QA level is based upon the use of the data, not how the data is produced. Formal stratigraphic interpretations and piezometer placement decisions will be based upon geophysical logging data, and confirmed by drill cutting analyses. QA Level 1 has been designated as applicable to these activities. The geologic logs, consisting of drill-rate and chip descriptive logs for these rotary boreholes, are considered inconclusive by comparison. While they are of value for information purposes during drilling and for initial recognition of stratigraphic contacts, they will not be used for direct interpretations. Therefore QA Level 3 has been applied.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
2. Piezometer installations DC-32CX and DC-33CX are proposed by BWIP to provide intermediate information during LHS testing. These would be the closest monitoring wells to pumping of RRL-2B, with the exception of RRL-2A (500 feet south of RRL-2B) and RRL-2C (250 feet east of RRL-2B). DC-32CX and DC-33CX are both several thousand feet from the pumping well. Although they do provide intermediate distances as compared to the other wells within the Controlled Area Study Zone (CASZ), they are not sufficiently close to provide additional monitoring locations close in to the pumping well. Consideration should be given to installing additional close-in monitor wells to provide better coverage for the proposed tracer testing as well as evaluate the directional hydraulic properties of the basalt medium on a local scale.	Nez Perce 2 Reject. The principal objectives of the Pre-ES LHS tests are to determine the continuity of flow tops and confining layers (flow interiors), and provide an indication of the presence of disqualifying conditions (see DOE memorandum, A. Jelacic et.al. to S. Kale, "Geohydrologic Testing Program for the Hanford Site Before Construction of the First Exploratory Shaft," dated March 16, 1987). Estimation of directional hydraulic properties is not an objective, but may be considered for subsequent tests, depending on 1) the results of the Rocky Coulee Flow Top and Birkett Flow Top LHS tests, and 2) data requirements for issue resolution. The LHS tests in the Pre-ES time are designed to stress large volumes of earth, on the order of kilometers in distance from the pumping well. DC-32 and DC-33 are installed to provide observation points intermediate between the near-field piezometers at RRL-2A and 2C, and those at greater distances such as DC-20 and DC-22. Based on present knowledge, this is deemed to be an adequate configuration.

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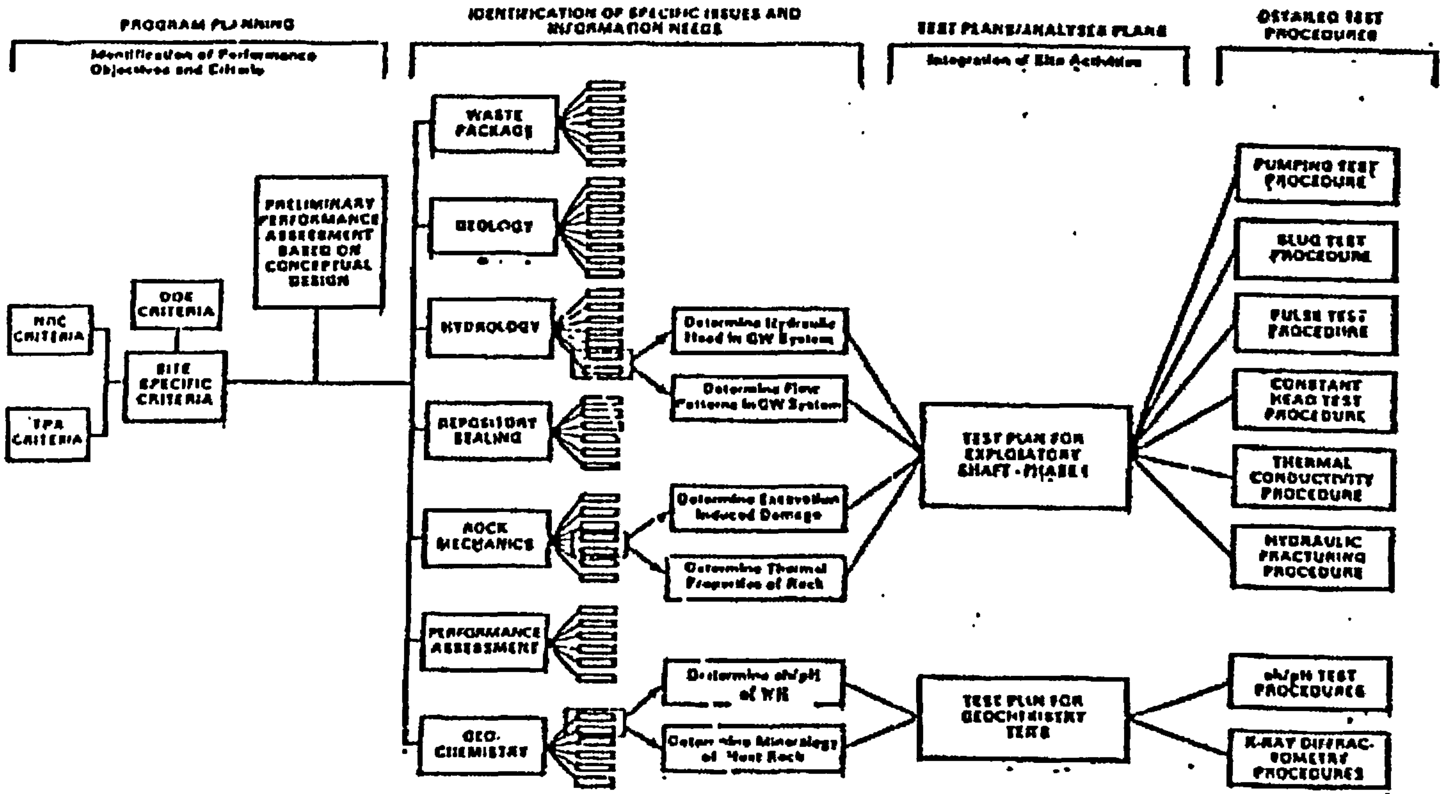
Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
3. DOE/BWIP is proposing the CX-series piezometers because they feel that drilling a single borehole and completing seven piezometers in that borehole disturbs the system less and that hydrologic baseline can be achieved sooner. It is also argued that some cost savings can be realized because fewer holes have to be drilled. However, there is continuing concern as to whether or not adequate sealing between monitored zones can be assured. The potential for hydraulic interconnection through the borehole remains a continuing problem, especially in hole drilled to the depth these will(are) be. In addition, it would seem that the QA/QC requirements to be followed and associated costs in such a multiple completion would exceed the benefits derived from such complex installations. It would seem to be preferable to insure high quality piezometer installations with reliable performance and longer time to achieve hydrologic baseline. If the CX piezometers do not work as planned, then redrilling and installation of reliable piezometers would increase ever further the time to reach hydrologic baseline.	3A. Agree. DOE/BWIP agrees with the concern about adequate sealing between monitored zones. To address this concern about adequate sealing, DOE/BWIP is conducting laboratory hydraulic conductivity tests on prototype cement samples to ascertain whether the proposed grout-mix design meets or exceeds the acceptance criteria given in the Technical Specification Data Report (SD-BWI-TN-010). No piezometer seal will be placed unless the grout meets or exceeds the acceptance criteria. One of the major technical reasons why DOE/BWIP selected a CX-series piezometer design was based on their experience gained from similiar prototype piezometer facilities. The DOE/BWIP believes that the CX-series piezometers will be installed on a timely basis to meet QA requirements and provide reliable performance-based on past installation experience as well as noted in recent design-verification studies.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
5. It would appear that DOE/BWIP has put into place sufficient checks and balances through the NQ-1 QA/QC program to insure that licensable date will be obtained. However, there is some concern that the field investigation program is so enveloped in procedures and QA inspections that the professional staff responsible for the geohydrology program will not be able to conduct a sound technical program. Procedures are never a substitute for good professional, experienced judgment.	The Nuclear Regulatory Commission (NRC) requires implementation of the 18 criteria, delineated in Title 10, Chapter 1, Code of Federal Regulations - Energy, Part 50, Appendix B (10 CFR 50, App. B), in the quality assurance (QA) program to be applied during site characterization. The NRC Review Plan, 1984, identifies how the staff will review these QA program descriptions. The NRC Review Plan emphasizes the requirements for QA programs and the interaction of the QA groups including management meetings, audits, inspections, and performance monitoring. The following excerpt from the NRC Review Plan provides the flavor of the NRC's expectations for documentation of procedures: "The plans outlining the conduct of a data gathering program are of varying levels of detail ranging from identification of general performance objectives and criteria to detailing specific technical procedures (Figure 2, see attached)." While it is agreed that procedures are never a substitute for good professional, experienced judgement, lack of them would render non-compliance to NRC regulations and an undocumented program that would not stand alone in a licensing application. Those individuals possessing good professional, experienced judgement are responsible for authoring and reviewing the procedures. The system provides flexibility in that there are provisions for making real-time changes to the procedures that would not unduly constrain conduct of test activities.



SCOPE OF DIAGRAM:
To show levels of detail involved in developing a technical program.

PURPOSE OF DIAGRAM:
To convey the various levels of detail in planning and controlling a technical program; to define level of detail necessary in executing a technical program properly.

FIGURE 2

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BWIP REVIEW COMMENT RECORD (RCR)

...ument Number(s)/Title(s): edited special case package; uments supporting restart of 24 CX and DC-25 CX

6. Project/Building Number:

7. ...: Yakima Indian Nation

8. ...ization/Group:

9. Location/Phone:

10. Agreement with indicated comment disposition(s): 8/11/82 — Date; Reviewer; Project/Cognizant Engineer

11. CLOSED: Date; Reviewer; Project/Cognizant Engineer

13. Comment(s)/Discrepancy(s) (Provide technical justification for comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	14. Disposition (provide justification if NOT accepted).
Issue #1: The cost savings resulting from an early res... may not be great enough to balance the associated risks Discussion: According to the DOE, one of the main benefits resulting from an early restart is the savings of $40,000 in stand-by rig costs at DC-24. The DOE also asserts that an early restart would save $50 million that would otherwise be incurred due to delays in ES construction and License Application Design (LAD). This assertion assumes that the 19-week schedule reduction applies directly to submittal of the LAD schedule reduction. However, the DOE concedes that "the Exploratory Shaft has other prerequisites that may be more controlling than restart of [the] boreholes..." The link between $50 million in savings and an early restart of test borehole drilling is not well enough estabished to be used as a basis for recommending an early restart, and in the context of the discussion is misleading. Compared to the overall cost of site characterization activities, $40,000 is not an amount that should be used to justify a change in schedule, considering the risk involved.	Accepted Page 9 para 7 The statement "However, the Exploratory Shaft has other prerequisites that may be more controlling than restart of borehole DC-23, DC-24, DC-25, DC-32, DC-33." Will be deleted. Since the issuance of "The Expedited Special Case (ESC) Package for Drilling and Piezometer Installation at Boreholes DC-23GR, 24CX, 25CX, 32CX, 33CX" in May the Basalt Waste Isolation Project has initiated an investigation on impact of drilling the Exploratory Shaft's (ES) two holes to top of Basalt during Large Scale Hydraulic Stress (LHS) Testing. If current study confirm that ES drilling to top of Basalt does not impact LSH Testing then the Hydrology Baseline and the ES Design become the critical work activities involved with the restart of ES drilling. The savings to License Application Design Schedule in this case by starting the borehole drilling under the ESC will be 4 weeks and 10 million dollars. Otherwise the original statement of saving 19 weeks and 50 million dollars is still valid because LHS Testing will stay on the critical path for ES drilling and LAD. No other prerequisites will have control ...

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #2: The risks associated with early restart may be greater than indicated by the DOE. Discussion: The DOE maintains that the risks associated with an early restart are minimal, and that there is only a "small possibility" that work will have to be repeated. Even a "small possibility" that work will have to be repeated could have a significant effect, depending on the type of work to be repeated, and when a decision is made to repeat that work. If, for instance, data gathered during the pre-ES phase of the program need to be collected again (because they are not suitable for licencing), repeating the work during the post-ES phase will not help provide the desired information needed regarding the hydrologic system. This is particularily the case for data that are perishable in nature and that are needed to establish baseline hydrologic conditions.	Accepted; DOE acknowledges that repeating work could be difficult and time consuming if the data is perishable or time dependent. The risk of having to repeat work can not be eliminated even with all prerequisite documents in their final released format. Comments have been received and incorporated from interested parties, and therefore the risk has been reduced as low as is reasonable at this time. The hold points that are identified in the Expedited Special Case (ESC) for Restart insure that the documents that control the quality of the data have been reviewed and approved prior to starting the work. The risk of obtaining unlicensable data can never be reduced to zero. Determining the actual degree of risk can not be determined until after the tests are completed. DOE believes that obtaining more information on which to base a decision regarding the suitability of the site at this time is more important than pursuing the elusive target of obtaining the theoretically perfect test. The possibility that new knowledge may require the repetition of work is an unavoidable risk.

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BWIP REVIEW COMMENT RECORD (RCR) CONTINUATION

Review No.

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Issue #3: The importance of favorable public/political perception as a basis for early restart is overemphasized.

Discussion: Another DOE justification for early restart of drilling is the anticipated favorable public/political perception of such an action. The early restart is expected to have strong favorable support from the technical community. The "technical community" being referred to is unclear since the DOE also anticipates strong negative reaction from "those who have established a negative opinion regarding locating a repository at Hanford." Any decision to restart should have a sound technical basis and should not be motivated by anticipated public/political perception.

Disposition (provide justification if NOT accepted).

Rejected: The Nuclear Waste Policy Act of 1982 (NWPA) requires that DOE consider public opinion of the effort to locate a geologic repository for nuclear waste, and therefore public perception is one of the ten factors considered in deciding to expedite the restart of drilling. A sound technical basis for restart is identified by the prerequisite list of documents that control the work and the hold points that were established to insure that controlling procedures that were not in place at the time that the ESC was written are in place prior to the start of work. Thus the start of work is based on a sound technical basis and public confidence in this basis is just one of ten factors considered in assessing the risk of restarting drilling prior to lifting the general stop work order. DOE believes that the public perception is not overemphasized because of the NWPA requirements, and because public perception is only one of ten factors considered in the decision to propose expedited restart. The major emphasis s the ESC for Restart requirement to have the necessary controls in place prior to the restart of work.

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...nt(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- ...the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
...e #4: Prerequisite documents will not be completed before drilling begins. ...ussion: According to DOE, the restart risk is mitigated by the use of approved procedures and the DOE/subcontractors Evaluation of Readiness that will be conducted after all draft documents have been completed and before drilling commences. However, both restart requests state that "prerequisite documents that are not in place at the time the work begins will be integrated with the completed work when the prerequisite documents are released." These statements are contradictory. At this time, at least 10 of the 16 Test and Operations Procedures (TOP's) reviewed for ...his report are still in their draft form. Other documents ...lso currently in draft form include the Study Plans, the ...CDS, the DRD, the Project Plan and Charter, the Records ...anagement Plan, the Document Control Plan, the BWIP ...onfiguration Management Plan. Given the July 1, 1987 ...rilling restart date discussed above, a substantial ...ercentage of the prerequisite documents will not be ...n final form, and therefore will not be approved, when work ...ommences.	Accepted: A few of the prerequisite documents that control the management systems for BWIP may not be issued by DOE when restart of drilling begins, but the documents that directly control the quality of the work will be approved (released by Westinghouse or issued by DOE). These directly controlling documents that were not approved a the time the ESC for Restart was written are listed as requirements to begin work at the four hold points. These hold points insure that the directly controlling documents will be approved before the work begins. Those documents, such as the study plans, that may not be issued by DOE when drilling begins do not directly control the quality of the work and therefore do not affect the acceptability of the data obtained. The Nuclear Regulatory Commission, has had an opportunity to review the prerequisite documents and has not identified technical deficiencies that would preclude restart of drilling. Based on the reviews of the documents received to date, DOE believes that the study plans are sufficiently complete to begin work on the boreholes included in the ESC for Restart.

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nent(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
· example, one of the prerequisite documents which is rrently incomplete is the "Quality Evaluation Board Level signments Expedited Special Case for Restart of Boreholes -24 and DC-25". This document sets the QA levels for the ems and activities for the boreholes and test facilities. irrently, this document is undergoing technical review, and ies not include boreholes DC-23, -32, and -33. Restart equest A states that "the purpose and construction of oreholes DC-23, -32, and -33 are very similar to those of C-24 and -25; therefore, the QA levels are expected to be he same." This document should be fully completed before rilling commences, because it directly affects the ESC scope of work. In addition, an early restart would result in the release of the Design Requirements Document (DRD) prior to the release of reviewed study plans and Test Data Collection ecifications. If the DRD is based on the study plans, the udy plans should be in final form before the DRD is alized.	

...nt(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- ... the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
...ssue #5: The restart requests are not correct in stating that higher quality hydrogeologic data will be obtained because the borehole data collection and test design are now being done under QA level 1 status. ...iscussion: Collection of borehole and test design data under quality level 1 status will hopefully ensure the traceability of this information. However, traceability does not necessarily guarantee that the data will be of high quality. In addition, because the actual analysis and interpretation of these data is independent of QA level 1 status, the final results may not be of higher quality.	Accept: DOE recognizes that your interpretation of this statement is a possibility. However, designating the activity as QA level 1 also increases the surveillance for adhering to procedural requirements and therefore the potential for varying from the procedures without detection is lessened which results in having greater confidence that the data collected will represent what it is supposed to represent. This is what was meant by stating that the data would be of higher quality. The correct interpretation of the data can only be assured by technical and peer review processes which, as you imply, is less precise than operational procedures. The technical and peer review processes are controlled by procedures. In addition, reviews by interested parties and the Nuclear Regulatory Commission will also increase the probability that the most plausible interpretations of the data will be utilized.

nt(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
ue #6: The DOE does not clearly define what constitutes a "completed" or "in place" document. scussion: The DOE states that "all prerequisite documents will be completed and reviewed before drilling begins", and that "documents that are not in place at the time work begins will be integrated..." The DOE should specify if "completed" or "in place" refers to a released draft version, an approved but not final version, or a finalized version.	Accept: The term "completed" means that the document is finished by the author and is in the review cycle. The "completed" document is draft version until it has been released (approved by management) by the designated responsible organization. The responsible organization may be designated as DOE Headquarters, DOE Richland, or Westinghouse Hanford Company. An "in place" document is one that has been released by the designated responsible organization. An in place document is a finalized version. The time required to obtain release of a document can take several months because of the complexity of the program and conflicting priorities. Significant technical changes normally do not occur after the document is considered "complete". Therefore a "complete" document may be approved for use pending finalization.

ent(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- I the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
ue #7: The DOE claims that the earlier availability of data resulting from an early restart will permit earlier determination of site suitability (Request for Restart Document B, p. 11). This may be true if the data were to prove the site to be unsuitable; however, it is anticipated that no such determination will be made by the DOE prior to ES construction and testing.	Accepted: Your analysis is correct. Determining if the site is suitable includes the possibility that the site may be unsuitable and therefore there is a potential that expenditure of funds for site characterization may be stopped prior to constructing the Exploratory Shaft. Current req's & justification do not say this per Dittman
scussion: The DOE position at the April 7-9, 1987 Hydrology Workshop concerning determination of site suitability is reflected in the folowing statement: "USDOE does not believe the preliminary tests will produce enough information to determine whether Hanford may be disqualified as a repository site" (Nuclear Waste Update, May 1987). Therefore, it is not likely that an early restart will have a significant effect on the timing of suitability determination, which is not expected to be made for several years. This is particularly true given the uncertainty associated with the geohydrologic system and the tentative nature of schedules and locations presented in the Site Groundwater Study Plan.	Issue of is that there is no recog. of the critical path concept of DOE by

ment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #8: The Site Groundwater Study Plan does not address the determination of bou lary conditions for CASZ numerical models. Discussion: In the pre-ES phase, hydraulic head data will be collected at new locations within the CASZ that hopefully will define the undisturbed potentiometric baseline in the CASZ. During the post-ES testing phase, new monitoring facilities will help define the post-ES potentiometric surface outside of the CASZ. Numerical models for the CASZ will be used in the site performance assessment required for licensing performance application. For the GWTT criterion evaluation, undisturbed hydraulic head field boundary conditions should be used as input to these models to characterize the hydraulic conditions that prevail before disturbance of the system by LHST and ES activities. In order to characterize these boundary conditions, the DOE should study the groundwater flow within a larger area than the CASZ before ES drilling. Since this approach is not planned, and the present DOE strategy is to characterize the two parts of the groundwater system in two separate phases (pre-ES and post-ES), the DOE will have to link the	Open. While this comment is appropriate to the Site Groundwater Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

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nt(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
nformation resulting from these two phases in order to efine undisturbed flow conditions at the CASZ boundary. he method by which these pre-ES and post-ES generated data ill be combined to properly determine the undisturbed oundary conditions, should be clearly presented in the Site roundwater Study Plan.	

ent(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted)
Issue #9: Water-level measurements in piezometers should be corrected for borehole deviations from true vertical. Discussion: Because of the very low hydraulic gradients in the various confined aquifers, it is crucial that accurate water-level measurements be made frequently in the piezometers. This requires: (1) extremely accurate riser pipe surveys with respect to other riser pipes; (2) precise water-level measuring instruments; and (3) trained technicians. However, several sources of error are possible in the water-level measurements. First, the error tolerance in surveying the elevations of riser pipes will be 0.1 ft. The second source of error is in the water-level measurement, which has an error tolerance of 0.1 ft. The more serious source of error, however, arises from the 5 degree tolerance in the borehole deviation from true vertical. For instance, a deviation of 5 degrees will produce an error of 1.53 ft in the measured water table depth of 400 ft when steel tape is used for measurements. With this type of uncertainty, and with the very small hydraulic gradients expected in the confined aquifers, it	#9. Accept. All measurement errors will be identified and either eliminated or compensated for before interpreting any hydraulic head data. This includes water-level measu[illegible]t errors resulting from borehole deviati[illegible] Past and proposed BWIP drilling programs have included routine borehole deviations surveys in their suite of geophysical logs. Previous survey records, for example, can be found in SD-BWI-TI-226 (Jackson, 1986) for the RRL-2B and -2C boreholes, and in SD-BWI-TI-329 (Jackson, 1986) for DC-19, -20, and -22 cluster sites. These examples compare the actual drilled depth to the corrected corresponding true vertical depth and show them to disagree by only 0.02 feet at a depth of 400 feet for the "C" wells. Errors of this magnitude, though measurable should not, by themselves, constrain a determination of accurate groundwater gradient direction of key hydrogeologic units. Again, all measurement errors, large or small, will be collectively assessed for their impact on gradient determination.

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nt(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
be almost impossible to delineate groundwater flow ions and accurately estimate gradients. Corrections ccount for the borehole alignment must be made to : the present uncertainty.	

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...nt(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
...sue #10: The Study Plan does not clearly explain the procedure by which alternate conceptualizations at the flow systems will be ranked and the "preferred" representation will be identified. ...iscussion: The study plan discusses the method by which integrated information will be used to generate a suite of alternate flow system representations consistent with the available data. Quantitative evaluation will be made by building numerical models based on each conceptualization. The constraints upon the conceptual model are in the form of "hard" data which provide reference points to which the qualitative representation of the conceptual model must adhere as closely as possible. This way of proceeding appears to be direct. However, the actual process is not as direct as is suggested in the study plan. For instance, many parameters are inferred from raw data obtained during testing. The parameter inference generally is already based on a conceptualization of the system (e.g., porous medium versus fractured medium for	Open. While this comment is appropriate to the Site Groundwater Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

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nt(s)/Discrepancy(s) (Provide technical justification for the comm..ts and detailed recommenda- the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
umps and tracer test, density effect negligible for hydraulic head measurement, etc.). In addition, numerical models that are used to analyze test data and ultimately used to rank the preferred conceptual model have non-unique solutions. For the same conceptualization of the system, as it is adequately stated in the study plan, different values of the investigated parameters may be obtained. Additional parameter values are obtained when using alternate conceptualizations of the hydrologic system. Due to the difficulty of answering the questions raised above and the dramatic consequences that a "preferred" conceptualization may have, the DOE should be more explicit and present clearly the selection process that will be used.	

(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommende action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
#11: The study plan contains an incorrect assumption regarding the rates of water extraction during and after construction of the exploratory shaft testing facilities. ssion: It is stated that the rate c. water extraction that will have to be maintained to keep the exploratory shaft facilities at atmospheric pressure will be similar to the rates of the LHS test pump. It is not clear why such an analogy is made. While the rate of water extraction per unit of borehole/test facilities interior surface area can be assumed to be of the same order, this situation cannot be true for the global yield since the yield of water extraction is proportional to the area through which water can flow.	Open. While this comment is appropriate to the Site Groundwater Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- e action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
ssue #12: The only valid justification for an early restart is not considered in the request for restart document. scussion: An early restart would be better justified if plans had been made to gather additional information. DOE could have planned to conduct testing while drilling DC-24, -25, -32, and -33 on a drill and test basis. These tests would provide a way to refine the geostatistical properties of the local hydraulic conductivity/transmissivity field in the CASZ. Such information is needed for an early determination indication of the presence of the groundwater travel time disqualifying condition.	Reject. Conducting the drilling of DC-24, DC-25, DC-32, and DC-33 in a drill and test fashion would cause perturbations to the potentiometric surfaces of the tested horizons and would likely result in a significant delay in the establishment of hydraulic head baselines. Hydraulic conductivity conditions in the vicinity of DC-24, DC-25, DC-32, and DC-33 are not regarded as "perishable" due to any site characterization activity. This information could be obtained later in the post-ES timeframe, if needed. The stochastic estimate of groundwater travel time requires data at many points. Many tens of estimates of hydraulic conductivity are required to lend statistical credibility to the stochastic estimate of groundwater travel time. The additional data, if collected at DC-24, DC-25, DC-32, and DC-33, would not significantly enhance groundwater travel time estimates in the pre-ES timeframe.

t(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- he action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
sue #12: The study plan does not adequately discuss verification of measured pumping rates. scussion: On page 32, paragraph 3, it is stated that: "the accuracy needed for pumping rates will vary according to the magnitude of the rate and is therefore set at +/- 5% of the measured rate." It is not clear how the measured pumping rates can be verified and whether redundant flow measuring devices will be used to verify this variance. Finally, DOE should provide the rationale for selecting this specific variance value (+/- 5%).	Open. While this comment is appropriate to the Site Groundwater Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

...)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- ...action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
...#14: Not enough detail is provided to assess the efficiency of tracer tests. ...ussion: The hydrogeology study plan does not provide the detail necessary to determine whether tracer tests and the data generated from them are useful, or whether such tests can be undertaken. Options are given for when and how the tracers will be introduced, but no information is given regarding data analysis or potential problems that might occur. Because they are an integral part of the overall hydrologic testing program, the tracer test plan should be released in a timely fashion to allow review and input by the affected parties.	Open. While this comment is appropriate to the Site Groundwater Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

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(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommende- ...e action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
...e #15: Drilling the ES through suprabasalt sediments before LHST may result in undue perturbations of the unconfined aquifer and contamination of the ES. ...cussion: The ES is situated to the west of the 200 West Area. Under the 200 West Area is an extensive groundwater mound, formed primarily by radioactive water infiltrating through the unsaturated suprabasalt sediments from the U Pond. Other disposal sites are present in the 200 West Area, as well. The radioactive components are primarily tritium and beta emitters (mostly as Ru-106). Non-radioactive nitrate is also present. The plumes from the U Pond groundwater mound are migrating southeast at present, but a considerable	Open. While this comment is appropriate to the Site Groundwater Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

omment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
amount of contaminated water remains near the 200 West Area because of the relatively low transmissivities in the Ringold Formation in this vicinity. map in Gephart et al. (1979) shows that the groundwater ound under the U Pond has extended west, under the ES site the U pond is only about one mile east of the ES site). he water table under the ES has risen 40 to 60 feet since 944. By drilling the ES down to the top-of-basalt surface, the potential exists for creating a large groundwater sink, if water in the ES is pumped out. Such a sink will likely cause a change in the local hydraulic gradient. This sink is likely to expand the longer the unfinished shaft is kept in place. Contaminated groundwater under the U Pond can begin to migrate west toward the shaft, causing the shaft to become filled with water containing radioactive solutes. There appears to be evidence of westward migration of contaminants already. Well E33-37-82A, less than 0.5 miles from the ES site and about 0.75 miles from the U Pond, was noted in 1981 by Graham to have a tritium concentration in the groundwater of 1.02 pc/ml. Graham (1981) notes that many of the wells in the separations area are screened near the water-table surface and contaminant sinking has been observed to be associated with mounding. Therefore, the contaminant concentration noted here may be a lower bound. The ES site is in the vicinity of Cold Creek, which acts as	

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Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
tended period of time may perturb groundwater flow throughout the aquifer and alter the pattern of contaminant plumes. Because the ES site is in a recharge area, greater than normal inflows might be expected in the shaft, and pumping would be necessary on a frequent or continous basis. The alternative would be to pump the water into settling ponds, creating yet another groundwater mound in the area and altering flow patterns in the unconfined aquifer even further.	

References:

Gephart, R.E., R.C. Arnett, R.G. Baca, L.S. Leonhart, and F.A. Spane, Jr., 1979, Hydrologic Studies within the Columbia Plateau, Washington: An Integration of Current Knowledge, RHO-BWI-ST-5, Rockwell Hanford, Richland, WA.

Graham, M.J., 1981, Hydrology of the Separations Area, RHO-BWI-ST-42, Rockwell Hanford Operations, Richland, WA, 83 p.

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...ment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda... of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
...ue #16: No cores will be taken from the planned hydrologic test boreholes. ...cussion: A high degree of uncertainty has been associated with much of the intraflow structure data determined by downhole geophysical techniques. While improved geophysical logging techniques will be developed as part of site characterization, these techniques will probably not be available for use in the boreholes to be drilled for pre-ES hydrologic testing. Cores would provide additional intraflow structure information to supplement that gained from geophysical methods. Even more important, cores would provide much needed fracture and cooling joint data which cannot be obtained from geophysical methods at this time. By not taking cores in these boreholes, the DOE is losing the opportunity to gain important information necessary for site characterization.	Reject. The objective of these boreholes is hydrologic data collection, not geologic data collection. Multiple use holes were considered. There are incompatibilities in the practical aspects of drilling between meeting geologic data collection objectives and meeting hydrologic testing objectives (e.g., drilling fluid control is much more difficult in coring). These incompatibilities resulted in the decision against multiple use holes at this time. Specific geologic characterization will be accomplished with other boreholes, where the need for hydrologic data is not as important. For these holes it is important to identify major intraflow structures (flow top, flow bottom, flow interior, vessicular zones) in support of piezometer placement decisions. While this information is easier to obtain from core, geophysical logs provide an appropriate level of detail for this purpose.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #17: The Stratigraphy Study Plan does not address sub-basalt strata. Discussion: The omission of sub-basalt strata from the scope of the Stratigraphy Study Plan is a reflection of the seemingly disinterested attitude towards these rocks. Knowledge of sub-basalt strata is very important for structural geology/tectonic studies and natural resource assessment. In addition, the deep groundwaters within the sub-basalt sedimentary rocks could be a recharge source for the groundwater flows in the basalts. Therefore, to be complete, the Stratigraphy Study Plan should include a discussion of plans to characterize the sub-basalt strata. This would allow the study plan to more clearly meet the objectives of site characterization.	Open. While this comment is appropriate to the Stratigraphy Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

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Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #18: The Stratigraphy Study Plan implies that all basalt layers are to be imaged. Discussion: The study plan states, "Utilizing the proper acquisition and processing techniques, the problems can be solved and the basalt layers in the CASZ can be imaged" (p. 40). While it may be true that some of the basalt layers can be imaged, the study plan does not provide sufficient detail of the procedures for data acquisition and processing to support the idea that all basalt layers can be imaged. In order to successfully image the basalt layers, two subsurface requirements must be met. The first is that each individual flow top must be sufficiently thick to be distinguishable from the layers above and below. The second requirement is that velocity and density contrasts be great enough between adjacent layers to generate a reflection that is detectable on the record section. Some of the thicker flows may be detectable.	Open. While this comment is appropriate to the Stratigraphy Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

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Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #19: The Stratigraphy Study Plan is overly optimistic with respect to the expected quality of seismic survey results. Discussion: In Section 3.2.2.4, the study plan describes seismic resolutions expected relative to the quality of the survey results. "It is expected that the survey results will not be of excellent quality unless the BWIP makes a significant breakthrough in the quality of seismic acquisition and processing." For excellent quality results, features with seismic expressions on the order of 5 to 25 meters should be resolvable. The definitions of quality provided in the study plan are - Survey Results of Average Quality (i.e., slightly better than now available). Features with seismic expressions on the order of 30 to 100 m should be resolvable. - Survey Results of Good Quality. Features with seismic expressions on the order of 15 to 40 m should be resolvable. - Survey Results of Excellent Quality. Features with seismic expressions on the order of 5 to 25 m should be resolvable.	Open. While this comment is appropriate to the Stratigraphy Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

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...ment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda... of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Unless the following problems can be solved the results may not even be of good quality: (1) A high velocity layer within the suprabasalt sediments causes channeling of low velocity energy near the surface. (2) The above mentioned layer has large features causing statics problems. (3) Velocity variations in the sediment cause scattering of seismic energy. (4) Problems of source and receiver coupling exist. (5) Alternating high and low velocity layers of the basalts and interbeds cause a high attenuation of seismic energy (Stratigraphy Study Plan, p. 39-40).	

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ment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #20: It is questioned whether software of the sophistication used in seismic processing can be developed in the time frame given. Discussion: roject requirement 2 on page 43 states that processing tools such as surface-consistent statics and ray-trace statics must be developed or acquired to adequately process the data. The BWIP plans to begin the three-dimensional seismic testing in summer of 1987. If the necessary processing software cannot be acquired, then it must be developed. In this event, it is doubtful that the software would be developed before the scheduled seismic testing.	Open. While this comment is appropriate to the Stratigraphy Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

(Discrepancy(s)) (Provide technical justification for the comment and detailed recommendation action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
sue #21: The study plan has an overly optimistic view that strata and structure can be mapped to a depth of 1500 meters. scussion: The expected results of the 3-D seismic project are that the "acquisition of seismic reflection data will image the sediments and basalt to a depth of 500 meters or greater. In addition, data will be acquired that will allow the BWIP to determine how to use seismic reflection data to map the strata and structure to a depth of over 1500 meters" (p. 44). These statements are not substantiated by any technical references. In order to map the CASZ subsurface at depth, the problem of energy loss within the basalts and the sedimentary interbeds must be solved. If the BWIP intends to make use of a previous similar survey to arrive at the 1500 meter depth, the study plan should make reference to it.	Open. While this comment is appropriate to the Stratigraphy Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

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Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #22: It is recommended that the parameters for the actual three-dimensional seismic reflection survey be readjusted using FY 88 final parameters. Discussion: In section 3.2.3.3 (p. 45), the study plan describes the data acquisition for the three-dimensional seismic reflection survey. Acquisition parameters are to be determined during the processing of the preliminary three-dimensional test data. The study plan states that these parameters are to be chosen during the processing of the preliminary three-dimensional test data collected in FY 87. Since the BWIP will perform additional testing in FY 88, it is recommended that the parameters for the actual survey be readjusted using the data of the FY 87 data.	Open. While this comment is appropriate to the Stratigraphy Study Plan, it is not related to the work scope of the Expedited Special Case package. It is recommended that this comment be addressed and resolved in the context of a more general study plan review.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #23: Many of the prerequisite TOP documents are unavailable for review. Discussion: Of the eighteen TOP's made available for critical review, ten were draft reports. All draft reports should be finalized prior to commencement of restart activities. This is important because performance of restart activities based on draft reports may result in invalidation of collected data, unsafe practices, and lost time due to backtracking and implementation of changes. Furthermore, it is difficult to review the overall program based only on the eighteen TOP reports made available. A total of fourty-six additional TOP documents exist and have not been provided; hence, a comprehensive assessment of the overall restart program cannot be performed.	All documents in the hierarchy (TDCs, Test Plan, and Test and Operations Procedures (TOPs) necessary to control drilling are or will be issued prior to restart. This is assured by the conduct of an Open Item Review per internal BWIP procedures as well as approval by DOE and the Westinghouse manager at hold point one in the Expedited Special Case package.

;)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- : action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
24: The TOP's do not provide adequate QA/QC procedures to sure the integrity and quality of the cement seals. ion: The cement seals are essential to prevent the itercommunication of unique groundwater systems in the rehole. When computing the amount of cement necessary to .ll a given interval with cement, anomalous porosities ;.g., fractures) are not considered. If such anomalies are ot incorporated into the calculation, the distribution of ie cement cannot be assured. Furthermore, although the OP's do discuss geophysical testing of the integrity of the ment seals, corrective actions are not discussed should ie seals prove to be inadequate.	Reject. The transmittal of TOPs in your review package contained TOPs required for drilling DC-24 CX under hold point 1 of the expediated special case (ESC). Test and Operating Procedures and other documents that covered piezometer installation, including QA/QC on the placement of the isolation seal, will be transmitted for review at a later time. This review corresponds to hold point 3 of the ESC. If suspected problems, i.e., integrity of the cement seal, are noted while implementing the test activity, a iterim problem report (IPR) is initiated in accordance with PMPM 7-119, "Data Collection Test Control." The IPR initiates dianostic activities to determine the effect of the problem and the appropriate corrective activities.

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ment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda- of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
ssue #25: The TOP documents lack sufficient QA/QC criteria with regards to development and sampling of the boreholes. iscussion: It is specified in the Requests for Restart A and B that higher quality hydrogeologic data will be obtained as a direct result of the higher level of QA requirements; however, the TOP's do not reflect this higher level of QA/QC requirements. The TOP's do not provide sufficient information regarding sampling frequencies or procedures to ensure adequate decontamination and cleaning of sampling equipment. In addition, the relevant TOP's do not describe calibration methods for important geophysical and geochemical equipment (i.e., neutron probe and pH meter), but rather rely on the manufacturer or the contractor calibration methods. This may pose serious problems of (1) standardization, (2) applicability of the calibration results (i.e., see comment #36), and (3) traceability.	Reject. Borehole development and development sampling activities follow hold point 2. Procedures covering these activities will be provided prior to release of hold point 2.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #26: The QEB document does not discuss plans to monitor and measure methane in the boreholes to be drilled. Discussion: The QEB report states, "Drilling history at Hanford has not shown natural gas (methane) to be a problem... Monitoring for natural gas production is a common way to mitigate unforeseen adverse situations" (p. 18). Measurements of methane in groundwaters at Hanford have shown relatively high concentrations in some boreholes. Some concentrations may be as high as 90% or more (Early, 1986). Consequently, the potential exists for problems in the drilling of future boreholes. This document does not contain any further reference to monitoring for natural gas, and the other restart documents reviewed also do not indicate plans to monitor and measure methane. A BWIP document (Early, 1986) has recommended that new methane sampling and analytical procedures be adopted for future borehole drilling. According to Early (1986), "The BWIP recently procured several downhole sampling devices capable of collecting dissolved gases in situ. Addition of a more reliable gas extraction process and analysis both by gas	Reject. The QEB Report does not discuss plans to monitor and measure methane because there currently are no plans to monitor and measure methane in these boreholes. These boreholes do not currently have such hydrochemistry objectives in the interest of minimizing the impact on the hydrologic baseline and attaining the hydrologic objectives. Site hydrochemistry investigations will be addressed separately in the Hydrochemistry Study Plan. To discuss further.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
chromatograph and mass spectrometric techniques should greatly improve future measurements." It is important that all boreholes be tested for methane, both for safety reasons and also to provide information regarding the hydrocarbon potential of the area.	

Reference:

Early, T.O., 1986, Concentrations of Dissolved Methane (CH4) and Nitrogen (N2) in Groundwaters from the Hanford Site, Washington: SD-BWI-TI-296, Rockwell Hanford Operations, Richland, Washington, 30 p.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #27: The OEB report fails to recognize the adverse consequences of borehole deviation relative to water-level measurement accuracy. Discussion: The OEB assessment identifies borehole deviation as a possible failure during rotary drilling. According to this document, the possible consequences of a nonvertical hole are difficulty in completing the borehole to a predetermined depth and problems in setting and cementing casing. A more important and likely consequence of borehole deviation is the uncertainty that a nonvertical hole introduces to water-level measurements. Uncertainty could have serious implication for groundwater flow studies. Therefore, correction for borehole plumbness should be made to reduce this uncertainty (i.e., see comment #9).	Reject. The consequences of borehole deviation on water-level measurement uncertainty are recognized. As-built deviations will be determined by borehole directional survey, which has been designated as QA Level 1. This information will provide a basis for correcting water-level measurements as needed. Requirement in TDCS Survey is level 1.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted)
Issue #28: The CEB considers the presence of voids in the casing cement to be of minor importance even though such voids could allow undesirable communication of groundwater in the Saddle Mountain Basalt and the suprabasalt sediments (p. 72). Subsequently, this item was given a quality level rating of 3. Discussion: Aquifer intercommunication in the upper part of the section may not have a great effect on borehole objectives or on waste isolation. However, such an occurrence could result in problems relative to environmental monitoring of site characterization activities and the Hanford Reservation, in general. Much of the unconfined aquifer system in this area is highly contaminated from previous Hanford waste management practices.	Reject. It is correct that voids in the casing cement could result in undesirable communication through the Saddle Mountain Basalts and above. and consequent problems. The designation of QA Level 3 is appropriate in that formations above the Wanapum basalts are not being relied upon for repository waste isolation. QA Level 3 does not, however, imply inadequate design or contruction. Procedures controlling the placement of casing and cement include provisions to ensure technically acceptable completion.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #23: The OEB assessment of drill cuttings is unclear and inconsistent. Discussion: The geologic information from drill cuttings will be used as input to stratigraphic and structural models and for creating borehole geologic logs (p. 86). Drill cutting sampling is given a quality level rating of 1, but borehole geologic logs are rated as a level 3. The lower rating assigned to the geologic logs is apparently due to the fact that these logs are to be used for informational purposes only, not for site characterization. In the Request for Restart B, one of the activities listed for interpreting stratigraphy and intraflow structures in order to select piezometer installation depths is review of geologic logs. If, as the Request for Restart indicates, the geologic logs will be used to help select piezometer depths, then these logs should have a quality rating of 1. The OEB does not recognize the use of drill cuttings as a method to help determine piezometer installation depths. However, it does state the following: "Cuttings will be used to verify test horizons by chemical analysis. Verification takes place after piezometers are installed" (p. 86).	Reject. Borehole geologic logs are designated under QA Level 3 because they are used only for informational purposes during drilling, and for initial recognition of stratigraphic contacts. They are not used for formal interpretations. Drill chip sampling is designated QA Level 1 because drill chip chemical analysis is used to confirm formal stratigraphic interpretations based on geophysical logs.

Yakima Nation

BWIP REVIEW COMMENT RECORD (RCR) CONTINUATION

Review No.

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #30: Stratigraphic, intraflow structure, and geologic structure data needs were not taken into consideration when determining borehole locations. Discussion: The hydrologic test borehole sites were chosen solely on the basis of hydrologic data needs. While it is crucial that the borehole location meet the objectives of the hydrologic characterization programs, other data needs should also be considered. Such considerations should be possible without endangering the primary goals of the hydrology characterization. It is important that all boreholes drilled for site characterization be located so as to provide the optimum amount of data, regardless of their primary purpose.	Reject. These borehole locations were chosen not on the basis of optimum data collection, but on the basis of hydrologic data needs. Hydrologic and geologic information are not completely independent, and stratigraphy and structure were considered to the extent that their influence on hydrologic measurements were anticipated. However, geologic data needs were not integrated into the location determinations. There are practical difficulties in drilling multiple use boreholes to support diverse data collection, and the project has chosen to proceed with the collection of critical hydrologic data before resolving those difficulties. Geologic data will be collected to the extent that it will not interfere with attaining hydrologic objectives. See also the response to issue 16.

omment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #31: The TDCS document consistently refers to the TOP's in a general fashion rather than providing specific references in order to qualify and quantify procedures. Discussion: The failure to indicate specific TOP's makes assessment of the overall restart program difficult and does not allow verification of the TDCS/TOP references.	Reject. It is not within the scope of the TDCS to identify specific TOPs. In the hierarchy of controlling documentation for BWIP site characterization, the Test Plan responds to the TDCS requirements with specific procedure references. For specific TOP references in support of test requirements, see SD-BWI-TP-045, "Test Plan for Completion of Multi-Level Piezometers."

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).

Issue #22: The TDCS document indicates that all TOP's must be in place prior to the commencement of drilling operation; however, the TDCS document does not indicate that all TOP's should be in finalized form.

Discussion: It is highly recommended that all TOP's be finalized prior to commencement of drilling operations. Furthermore, it is recommended that the level of QA/QC presented in the TDCS document be upgraded to a degree that will ensure the integrity of the data. For example, it is stated in the TDCS that "Efforts to exercise control of drilling fluids losses and gains shall, however, at all times be balanced against the objective of successfully completing the borehole." This statement indicates that fluid losses and gains are of minor concern relative to the continuing operation and timely completion of the boreholes. Since the quality of hydrologic and geochemical data can be adversely affected by the presence of drilling fluids, actions should be taken to minimize drilling fluid losses and gains. In fact, mitigative actions should be proposed and documented for all cases in which operations may not meet specified requirements.

Disposition (provide justification if NOT accepted).

Reject. The TDCS is not the only control governing the use of TOPs. General test control procedures require that all testing, data collection, and associated activities shall be conducted in accordance with written procedures or instructions (TOPs) appropriate to the circumstances. General procedures for TOP processing prescribe their review and approval before distribution. Therefore, the TOPs will be in finalized form, in that they will be reviewed and approved, prior to their use.

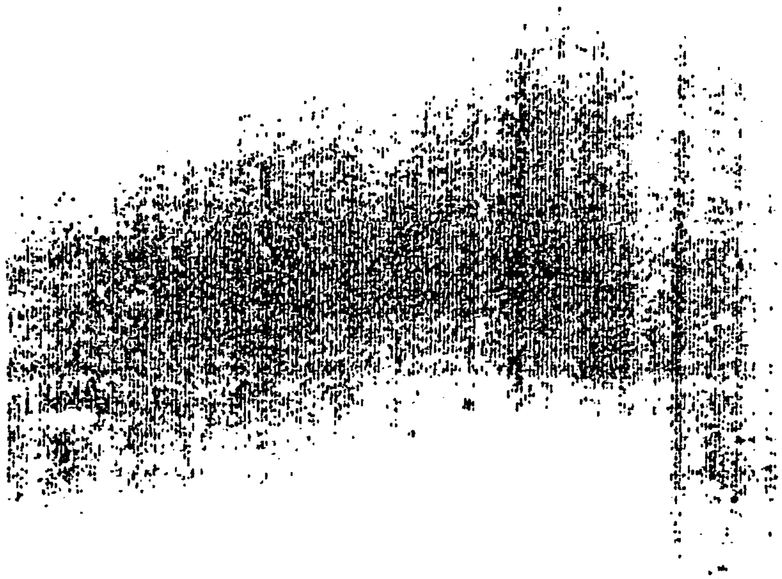
Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #33: Poor packer and sealing integrity may affect the quality of hydrochemistry and piezometer data. Discussion: The TDCS document states that there are three alternative designs for multi-piezometer installation. For each of these designs, the integrity of the packer and sealing quality is in question (TDCS, p.14). Faulty packer seals could result in aquifer cross-contamination which would have adverse effects upon the representativeness of the hydrochemistry data. Furthermore, an interconnection between tested units due to a lack of packer integrity would render the piezometer data highly questionable.	Reject. The chosen design for these boreholes does not depend upon packers, but upon cement seals for zone isolation. See the response to issue 24 regarding the integrity and quality of the cement seals.

Reviewer Yakima Indian Nation	BWIP REVIEW COMMENT RECORD (RCR) CONTINUATION	Review No.	Page 42 of 44

Comment(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation of the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
Issue #34: The TDCS states that standardization, calibration, acquisition, and display of neutron logging data must conform to API standards as defined in API RP 33-74, Recommended Practice for Standard Calibration and Format for Nuclear Logs. In the neutron logging TOP's, no reference is made of this document. Discussion: It is not known whether API RP 33-74 was used in formulating the standards for calibration, acquisition, and display in the TOP's pertaining to neutron logging. The standards used must be consistent in both sources.	Accept. The Test and Operating Procedures (TOPs) concerning nuclear logging have been prepared to conform with the standardization, calibration, acquisition, and display requirements specified in the publication API RP 33-74, "Recommended Practice for Standard Calibration and Format for Nuclear Logs." A statement to this effect will be incorporated in all of the TOPs which are involved with nuclear tool logging.

...(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommenda... ...e action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
...sue #35: The TDCS includes a calibration technique for the three-and four-arm caliper that is not included in TOP GT-ES-310, Field Set-Up, Calibration and Operation of the Four-Arm Caliper and Gamma Ray Tool String. ...iscussion: The TDCS notes that a check on calibration of the caliper may be performed in cased intervals with known casing diameters and that borehole diameters measured shall be within 5% of the known casing size. The TOP does not mention this calibration check at all and hence does not use the + 5% tolerances. This additional check on calibration should be described in the TOP.	Reject. This particular calibration check was determined to be ineffective, and the requirement has been deleted from the TDCS. The remaining calibration requirements are adequate, and are implemented in the TOPs.

nt(s)/Discrepancy(s) (Provide technical justification for the comment and detailed recommendation the action required to correct/resolve the discrepancy/problem indicated).	Disposition (provide justification if NOT accepted).
...ment: The porosity measured by the thermal neutron tool is highly questionable because calibration curves may be inadequate. ...ussion: The TDCS states that BWIP has established a maximum total core porosity of 26%. Through compensated thermal neutron porosity logging, Gearhart Industries has measured total porosities as large as 37%. The TDCS states that the discrepancy between core-measured porosities and porosities derived from thermal neutron logging may be due to high iron content and that a plan for quantifying iron effect on neutron porosity will be provided in the appropriate TOP's. An important factor that may be the cause of such discrepancy and which has not been stated in the TDCS is the presence of methane in water. Hydrogene atoms from the methane molecule (as well as the ones from the water molecule) are likely to interact with neutrons. Since calibration of the neutron tool is done with a limestone saturated with water, correction for the presence of methane is not accounted for. This could be a plausible explanation to the higher porosity inferred from neutron measurements. The presence of methane could even jeopardise the use of the thermal neutron tool to provide reliable estimate of porosity since the concentration of methane is not uniform throughout the Basalt layers.	Reject. At this time, the principal use of compensated thermal neutron logging data is in support of stratigraphic interpretations from relative porosity changes along the borehole. Absolute accuracy of porosity measurements do not affect this use. It is recognized that absolute porosities indicated from thermal neutron logs appear high, and this effect will be investigated. For these boreholes, epithermal sidewalled porosity (SNL) log data will be collected for comparison. The effect of dissolved methane on thermal neutron logs is expected to be negligible, based on investigations to date, which include consultation with petroleum industry log analysts.



IODINE-129: EVALUATION OF RELEASES FROM NUCLEAR POWER GENERATION

National Council on Radiation Protection and Measurem

NCRP REPORT No. 75

IODINE-129: EVALUATION OF RELEASES FROM NUCLEAR POWER GENERATION

Recommendations of the
NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS

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Preface

Iodine-129, the longest-lived radioisotope of iodine, has a half-life of 1.57×10^7 years and is produced during fission. Natural occurring ^{129}I is estimated to be ~40 Ci and man-made ^{129}I could increase this by a factor of approximately 100 by present estimates. Because of its very long half-life, any ^{129}I released to the environment is, for all practical purposes, a permanent addition to the total inventory of global iodine. This report considers and evaluates the available information on ^{129}I in terms of its physical properties, production sources, physical transport, biological behavior, projected future production, waste management, and the short- and long-term dose implications of ^{129}I in the environment.

The biological significance of ^{129}I is limited by its low specific activity. The largest potential source of ^{129}I is from spent nuclear fuels. If this irradiated fuel is reprocessed, then ^{129}I emissions will have to be controlled. If spent nuclear fuels are not reprocessed, the short-term exposure is insignificant and the potential long-term exposure is of principal interest. The potential long-term global dose to people in the environment is considered not to be manageable on the assumption that eventual release to the environment through the hydrological cycle is inevitable. The ultimate reservoir for the ^{129}I is the oceans with the resulting aquatic food chains which have man at the top. Emissions from operating light-water reactors are, and will continue to be, insignificant compared to potential short-term releases from proposed fuel reprocessing or ultimate releases to the global environment from reprocessing nuclear waste or the inevitable release resulting from long-term storage of unreprocessed spent fuel.

Although the uncertainties of future development of nuclear energy are great, the inventories of ^{129}I are certain to increase. However, we can make a scientific judgement as to the biological significance of present inventories and potential future production and management of ^{129}I and this report is aimed at that goal.

The Council has noted the adoption by the 15th General Conference of Weights and Measures of special names for some units of the

· the SI unit of *absorbed dose, absorbed dose index, kerma,* and *:cific energy imparted.* The becquerel (symbol Bq) has been adopted the special name for the SI unit of *activity* (of a radionuclide). One ıy equals one joule per kilogram; and one becquerel is equal to one :ond to the power of minus one. Since the transition from the special its currently employed—rad and curie—to the new special names :xpected to take some time, the Council has determined to continue, the time being, the use of rad and curie. To convert from one set units to the other, the following relationships pertain:

$$1 \text{ rad} = 0.01 \text{ J kg}^{-1} = 0.01 \text{ Gy}$$

$$1 \text{ curie} = 3.7 \times 10^{10} \text{ s}^{-1} = 3.7 \times 10^{10} \text{ Bq (exactly).}$$

The present report was prepared by the Council's Task Group on of Scientific Committee 38. Serving as Chairman of Scientific mmittee 38 on Waste Disposal was:

Merril Eisenbud
Institute of Environmental Medicine
New York University Medical Center
Tuxedo, New York

·ving on the Task Group were:

Leo K. Bustad, *Chairman* (1973–1981)
Washington State University
Pullman, Washington

Members

ven A. Book
versity of California
is, California

Joseph K. Soldat
Battelle, Pacific Northwest Laboratories
Richland, Washington

ohn Garner
Environmental Protection Agency
·arch Triangle Park, North Carolina

Consultants

I P. Brauer
elle, Pacific Northwest Laboratories
land, Washington

Lee L. Burger
Battelle, Pacific Northwest Laboratories
Richland, Washington

NCRP Secretariat—**Thomas Fearon** (1975–1980)
E. Ivan White (1981–1983)

he Council wishes to express its appreciation to the members and ultants for the time and effort devoted to the preparation of this rt.

Warren K. Sinclair

CONTENTS

1. Introduction

Iodine-129, the longest-lived radioisotope of iodine, has a half-life of 1.57×10^7 years. Because of its very slow rate of decay, any ^{129}I released to the environment (from either natural or man-made sources) is, for all practical purposes, a permanent addition to the total inventory of biospheric iodine.

Since ^{129}I emits only very low energy beta (maximum energy = 0.15 MeV) and gamma (0.04 MeV) radiation, accurate detection and measurement are both difficult and tedious. It is detected most readily in animal and human thyroid glands, since these endocrine organs exhibit the highest concentrations of iodine. However, the amount of ^{129}I that can be accumulated in the thyroid is limited by the ^{129}I low specific activity (0.17 mCi g^{-1}).

Considerable attention has been given to ^{129}I because of the potential for long-term accumulation in the environment from prolonged low-level releases from the nuclear industry, principally from facilities concerned with the separation and processing of irradiated fuels and storage of wastes. Currently, the reprocessing of spent nuclear fuels is very limited, but is likely to increase in the future. If retrievable storage is the means chosen for handling spent fuel elements, ^{129}I will remain potentially available for release to the environment whenever reprocessing occurs, because of its slow rate of physical decay. If, on the other hand, spent nuclear fuels remain unprocessed in a permanent disposal site, then releases of ^{129}I to the environment from U.S. facilities described herein will be insignificant compared to the estimates given in this report. The extent to which ^{129}I could be released to the accessible environment from a permanent disposal site will be determined by the design of the repository, and by conditions in the environs. The details of potential long term releases of ^{129}I from such repositories is beyond the scope of this report. However, the U.S. Environmental Protection Agency, in proposing standards for the disposal of spent fuel, high level and transuranic radioactive wastes, indicated that the total ^{129}I in their model repository would be a fraction of their calculated allowable release limit (U.S. Environmental Protection Agency, 1982), i.e., the ^{129}I is not controlling on the design

Geographical Sources and Distribution of Stable Iodine and ^{129}I

2.1 Introduction

ıe has only one stable isotope, ^{127}I, which is widely distributed seas, rocks, and in all organisms. It usually occurs in the iodide ate form. The marine environment and biota usually have erably higher iodine concentrations than do terrestrial plants il, as shown in Table 2.1. Marine organisms concentrate iodine rprising degree; certain tropical sponges may contain up to 14 t iodine by weight (Mellor, 1946). Some land masses contain urces of iodine, such as the Chilean nitrate beds; other areas low in stable iodine that their inhabitants suffer from iodine ıcy. Large areas in the northern and western United States ɘen labeled as "goitrogenic" because of their low iodine content and Snedden, 1960; Bruner, 1963).

wide variation in soil iodine content has been the subject of speculation and argument (Schaklette and Cuthbert, 1967). ɘr, Goldschmidt's view (Goldschmidt, 1954) that the major of iodine in soils is material released from the ocean surfaces ı to be well substantiated (Schaklette and Cuthbert, 1967). A theory has been developed that the Chilean deposits resulted ·ecipitation scavenging of the atmosphere, together with the ı of weathering and biological activity (Claridge and Campbell,

e concentration in the atmosphere generally diminishes with ng distance from the oceans. This reduction consequently the amount of iodine transferred to inland soils by precipita- venging and dry deposition. The period of exposure of the soil processes also affects the iodine deposit. Hence, the concen- ɪf iodine ıs generally lower in young postglacial soils, particu- their deeper horizons (Goldschmidt, 1954).

TABLE 2.1—*Iodine in terrestrial and marine environs*[a]

Component	Percent by Weight	
	Terrestrial	Marine
Thyroid gland (mammals and fish)	10^{-1}	10^{-1}
Mammals and fish (other than thyroid)	10^{-4}	10^{-4}
Plants (algae)	10^{-4}	10^{-3}
Soils (silts)	10^{-4}	10^{-3}
Rock	10^{-4}	—
Water	10^{-7}	10^{-6}
Salt (non-iodized)[b]	10^{-7}	10^{-6}
Air	10^{-8}	10^{-8}
Rain and snow	10^{-7}	—

[a] From Goldschmidt (1954); Chilean Iodine Educational Bureau (1950a, 1950b, 1956); Vinogradov (1953); Hanson (1963).

[b] Iodized salt contains 10^{-3} to 10^{-2} percent iodine.

up to 10 $\mu g\ m^{3}$, were found in the atmosphere of coastal regions. Rain and melted snow ranged from 0.2 to 5 $\mu g\ L^{-1}$, and the water of European rivers was reported to contain about 1 $\mu g\ L^{-1}$. Mineral spring waters contain concentrations up to 300 $\mu g\ L^{-1}$ (Goldschmidt, 1954).

Several processes are believed to release iodine from the ocean surface to the marine atmosphere. The release of gaseous iodine (I_2) by photochemical oxidation of iodine has been demonstrated experimentally, and release of iodine-bearing particulates from an experimental sea water surface has also been reported (Miyake and Tsunogai, 1963; Martens and Harris, 1970). It has also been suggested that organically-bound iodine may be released to the marine atmosphere (Dean, 1963; Blanchard, 1968). Understanding of relationships between the various sources of airborne iodine and elucidation of the mechanisms that produce the observed concentrations and relative iodine enrichment (Duce *et al.*, 1963, 1965, 1967) await further detailed measurements, particularly of iodine species. Some of the common inorganic chemical species in which iodine can be found are listed in Table 2.2.

The human body contains 10 to 20 mg of iodine, of which more than 90 percent is contained in the thyroid gland. The ICRP Reference Man (ICRP, 1975) contains 13 mg of iodine, 12 of which are in the thyroid gland. The thyroidal iodine concentration of 600 $\mu g\ g^{-1}$ presented in the 1975 ICRP report is substantially higher than the 350

TABLE 2.2—*Common inorganic chemical species of iodine*[a]

Valence	Common Species
−1 (Iodides)	I^-, HI, NaI, $HI \cdot nH_2O$
0	I_2
+1	ICl, IBr, HOI
+5 (Iodates)	I_2O_5, IO_3^-, HIO_3, $NaIO_3$
+7 (Periodates)	IO_4^-, HIO_4, $NaIO_4$

[a] From Holland, 1963.

9; central nervous system, 0.12; muscle, 0.01; milk, 0.07; and 14 (ICRP, 1975).

2.2 Natural Sources

-three radioactive isotopes of iodine have been identified. naturally-occurring radioisotope, ^{129}I, has a half-life of 1.57 ars (Walker *et al.*, 1977). It is produced in nature by the on of high-energy particles with xenon in the upper atmos- d, to a lesser extent, by neutron-initiated reactions $^{128}Te(n,$ $^{130}Te(n, 2n)$ and spontaneous fission (Kohman and Edwards, dwards (1962) estimated that these natural reactions would a global steady state atom ratio of ^{129}I: ^{127}I of $\geq 10^{-14}$, which and Edwards (1966) estimated should result in a ratio of $\times 10^{-11}$ in the oceans. More recently, analyses of samples of a ilver iodide deposit in Australia (Srinivasan *et al.*, 1971) have estimate that the equilibrium terrestrial ratio was bounded s:

$$2.2 \times 10^{-15} \leq {}^{129}I : {}^{127}I \leq 3.3 \times 10^{-15}$$

and Edwards (1966) also estimated that natural production in a steady state inventory of 8.7×10^{26} atoms of ^{129}I in the ere[1] (primarily oceans), equivalent to 31 Ci($\approx 1.8 \times 10^5$g) and transfer rate from oceans to sediments of ^{127}I is 2.2×10^8 g

antity of ^{129}I in the lithosphere is more difficult to estimate. ly on the spontaneous fission of ^{238}U widely dispersed at 3 μg ntent of ~0.01 Ci can be obtained. However, from the atom

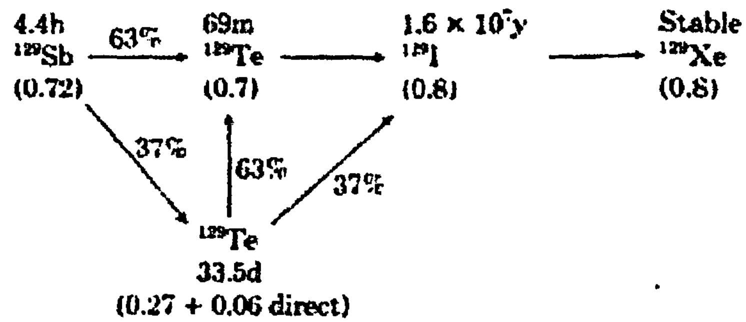
[1] they used a reservoir consisting of the hydrosphere, atmosphere and

ratio of $\sim 3 \times 10^{-15}$ listed above (Srinivasan *et al.*, 1971), a quantity of ~10 Ci of ^{129}I can be estimated.

The ~30 Ci of ^{129}I in the hydrosphere plus the ~10 Ci of ^{129}I in the lithosphere suggest an upper global total of about 40 Ci of naturally occurring ^{129}I.

2.3 Man-Made Sources

Iodine-129 is produced in nuclear fission as a decay product of ^{129m}Te. The fission yields of several radioiodine isotopes from thermal neutron fission of ^{235}U were tabulated by Holland (1963). The ^{129}I mass chain is partly reproduced below, with more recent values of radioactive half-lives and fission yields from Lederer and Shirley (1978) and Walker *et al.* (1977).



The values in parentheses are cumulative yields in atoms per 100 fissions. The quantity of ^{129}I present in a fission product mixture will increase slowly with time after irradiation has ceased as the ^{129}I precursors decay. The peak activity is not reached for several months.

Iodine-129 is produced in nuclear explosions of ^{235}U or ^{239}Pu at approximate rates of 30 and 50 μCi per kiloton (KT) TNT equivalent, respectively. The atmospheric transport and diffusion of radioiodine depend upon the initial height of the cloud and upon meteorological processes. A review of these factors was made by the United Nations Scientific Commitee on the Effects of Atomic Radiation (UNSCEAR, 1982). Fission products injected into the lower stratosphere have mean residence times of ≤ 0.5 y; while those from medium altitude explosions may have residence times of 2 years. The fission products that diffuse to the lower atmosphere (troposphere) are deposited (mainly by precipitation) in a matter of weeks. Dry deposition is a significant fraction ie net production of ^{129}I from ^{235}U fission in a thermal reactor is it 1 μCi per megawatt-day (MWd), depending upon the neutron and irradiation time, which affect the transmutation of ^{129}I by ron absorption. An additional source of ^{129}I is fission of ^{239}Pu uced in uranium fuel by neutron absorption in ^{238}U. The atomic l of ^{129}I in ^{239}Pu fission is 1.5 percent, compared to 0.8 percent in fission (Walker *et al.*, 1977). If, for example, 40 percent of the tor energy comes from ^{239}Pu fission (Russell and Hahn, 1971), the production will increase by about 30 percent. For the purposes of report, total production of ^{129}I in light-water reactors containing tly enriched fuel is taken as 1.3 μCi per MWd.

nce nearly all of the fission products generated in nuclear fuels retained within the fuel cladding until the fuel is chemically ocessed, the principal potential environmental sources of ^{129}I are effluents from nuclear fuel reprocessing plants rather than those n nuclear reactors.

2.4 Atom Ratios $^{129}I:^{127}I$ in Nuclear Fission

able ^{127}I is also produced in nuclear fission, but with a smaller ic yield (0.12 percent from ^{235}U and 0.5 percent from ^{239}Pu) lker *et al.*, 1977). It would appear, based upon these values of on yield for ^{127}I and ^{129}I, that the atom ratio $^{129}I:^{127}I$ in irradiated should be about 4 when irradiation is followed by cooling times of ral months to allow the ^{129}I to grow in. Since ^{127}I should burn up ture neutrons) at a faster rate in the reactor (resonance integral[2] than will ^{129}I (resonance integral 30) (Walker *et al.*, 1977), the ^{127}I ratio should be even greater than 4 for irradiation times of t 1 year.

om about 1945, the atom ratio of ^{129}I to stable ^{127}I in the environ-t has been increasing because of the ^{129}I added to the environment uclear weapons testing and nuclear facilities. Based on a small ber of samples of animal thyroids from locations *remote* from ear facilities, the ratio of $^{129}I:^{127}I$ was 10^{-8} to 10^{-7} in the 1960's 1970's (Brauer *et al.*, 1974b; Smith, 1977). However, values as as 10^{-4} to 10^{-3} for thyroids and vegetation have been measured

esonance integral is the integral of the product of an isotope's neutron cross n multiplied by the neutron flux (both of which are a function of neutron energy)

near some nuclear facilities (Russell and Hahn, 1971; Soldat *et al.*, 1973; Brauer *et al.*, 1974b). Currently, a wide range of values for this ratio can be found, depending upon the geographic location, the time of the year, and type of material sampled.

Releases of Man-Made ^{129}I to the Environment

3.1 Nuclear Weapons Testing

total yield of about 540 megatons (MT) of nuclear weapons was ed in the atmosphere or at ground level during the period from 5 to 1975 (FRC, 1963; Carter and Moghissi, 1977). The majority of total was accounted for by tests of thermonuclear devices in the osphere. The total fission yield from the atmospheric tests conted by all nations through 1962 was calculated to be 193 MT from in FRC Report No. 4 (FRC, 1963). For the period 1963 through 5 the total fission yield was estimated to be about 14 MT from given by Carter and Moghissi (1977) under the assumptions that monuclear devices were 50 percent fusion and 50 percent Pu fission that the others were Pu fission devices. Atmospheric testing since lication of the Carter and Moghissi report has not added significtly to the total. Thus, a total of about 207 MT equivalent of Pu on devices can be assumed to have been detonated above ground he period 1945 through 1975.

he rate of release of ^{129}I to the atmosphere from these weapons s, as estimated from the detailed data in the two references and n a yield of 50 μCi ^{129}I per KT Pu fission, are tabulated in Table

uclear weapons tests since 1976 have added very little to the ^{129}I ntory; hence, the total is still close to 10 Ci. This amount of ^{129}I ss than the inventory of natural ^{129}I (~40 Ci) existing prior to 5 (see Section 2.2).

3.2 The Nuclear Fuel Cycle

redictions of future ^{129}I releases to the environment obviously end on assumptions of future growth of the nuclear energy industry. ... difficult to make and in the past have proven to

TABLE 3.1—*Approximate releases of ^{129}I from atmospheric and high altitude nuclear weapons tests*[a]

Year	Cumulative ^{129}I released (Ci)
1945–1951	0.04
1952–1954	2
1955–1956	3
1957–1958	5
1959–1961	6
1962–1963	10
1963–1975	10

[a] Based on data in the FRC Report No. 4 (FRC, 1963) for the period 1945–1962, and on data of Carter and Moghissi (1977) for the period 1963 to 1975.

production between nuclear and non-nuclear sources. Accurate estimates are complicated further by the variability of national and international governmental policies, and economic factors, that affect fuel reprocessing.

Recently, each years published projections of nuclear power growth have indicated a lower expectation of installed generating capacity (Laue, 1982). A 1982 projection for the United States (U.S. Department of Energy, 1982) reports that spent fuel discharged from U.S. power reactors as of December 1981 totalled 8100 metric tons of uranium equivalent (MTU), only 230 MTU of which had been reprocessed. The installed nuclear power capacity was predicted to increase gradually from 61 GWe in 1982 to 170 GWe by the year 2000. Because of uncertainties in these estimates, it is considered unwise to project the world-wide inventories of ^{129}I beyond 2000. There is sufficient time before the year 2000 to develop reasonable estimates of environmental impacts of plants now built or to be constructed by the end of the century.

An estimated 4 Ci of ^{129}I could have been in the 230 MTU of spent fuel processed at the Nuclear Fuel Services plant at West Valley, NY, depending upon the reactor exposure of the fuels. Most of this ^{129}I probably was sent to the high level waste storage tanks on site.

About 170 Ci of ^{129}I were contained in the 7870 MTU of unreprocessed fuel as of December 1981 (U. S. Department of Energy, 1982).

The projections made by the U.S. Department of Energy (1982) of installed nuclear capacity and the associated masses of spent fuel

LE 3.2 *Estimated nuclear power growth and ^{129}I inventories to the year 2000*

Year	Installed Nuclear Capacity[a] (GWe)	Spent Fuel Discharged[b] (MTU)	^{129}I in Spent Fuel (Ci)	
			Annual[c]	Cumulative
ir to 1982	—	8100[d]	—	180[de]
1982	61	1200	50	230
1983	74	1600	60	290
1984	86	1700	70	360
1985	95	2200	90	450
1986	110	2600	110	560
1987	120	2600	110	670
1988	120	2900	120	790
1989	120	3200	130	920
1990	130	3100	125	1045
1991	130	3100	125	1170
1992	130	3500	140	1310
1993	130	3400	140	1450
1994	140	3500	140	1590
1995	140	3600	140	1730
1996	140	3500	140	1870
1997	150	3600	140	2010
1998	150	3900	160	2170
1999	160	3900	160	2330
2000	170	4000	160	~2500

m U.S. Department of Energy (1982), Table 1.1, page 27 in units of gigawatts of al energy.
m U.S. Department of Energy (1982) Table 1.7, page 37.
ntory as discharged, calculated at 0.04 Ci per MTU.
udes 230 MTU reprocessed at NFS.
n U.S. Department of Energy (1982) Table 1.13, page 49.

a fuel exposure of 33,000 megawatt-days (MWd) per MTU and
i ^{129}I per MWd. (This is equivalent to 0.04 Ci ^{129}I per MTU of
ischarged.) On this basis, the accumulated total of ^{129}I in the
fuel discharged by U.S. reactors through the year 2000 would be
) Curies. This 2500 Ci of ^{129}I would be available for release at a
eprocessing plant whenever reprocessing was accomplished, sub-
n treatment by gaseous effluent decontamination equipment.
a decontamination factor of 500 for ^{129}I at reprocessing plants,
l of about 5 Ci of ^{129}I would be released to the environment
g whatever period is required to dissolve all of the spent fuel
ulated by the year 2000.

vever, even under the assumption that reprocessing were to
e in the near future in the United States, not all previously
ated spent fuel could be processed by the year 2000 because of
... would be required to design and construct the necessary

aged less than 10 years would need to be dissolved prior to the year 2000. Fuels accumulated up to 1990 would contain about 1000 Ci of ^{129}I. Thus no more than 2 Ci of ^{129}I would likely be released to the atmosphere from reprocessing of commercial fuels prior to the year 2000.

Projections made in 1982 of worldwide nuclear generating capacity in place by 1990 and 2000 (Laue, 1982) were one-third to one-fifth of those estimated in 1973 and 1974. As of 1981, the installed nuclear generating capacity of International Atomic Energy Agency member states was 154 GWe with a projected linear growth to 430 GWe by 1990.

Estimates for 2000 range from 740 to 1075 GWe. For purposes of this report, nuclear generating capacity for the year 2000 will be assumed to be 900 GWe.

Estimates of quantities of spent fuel discharged per year and its ^{129}I content were made from the IAEA projections in a manner similar to the estimates for United States spent fuel discharge. A plant factor of 60% was assumed for the first decade and 70% for the second, in accordance with the IAEA practice (Laue, 1982). With a 30% thermal efficiency, the projected total fuel exposure in the decade 1981-1990 would be 2500 GWth-y (9×10^8 MWd). At 1.3 μCi ^{129}I per MWd, this fuel would contain 1200 Ci ^{129}I at the time of discharge. Similarly, the fuel discharged in the decade between 1990 and 2000 would have received a total exposure of 5500 GWth-y (2×10^9 MWd) and would contain a total of 2500 Ci ^{129}I. If, eventually, all of this fuel (88,000 MTU) were to be reprocessed at a fuels reprocessing plant having a decontamination factor of 500 for ^{129}I in gaseous effluents, then 7.4 Ci of ^{129}I would be released to the world's atmosphere. About 3700 Ci would be collected for disposal (presumably with the high level waste). No account is taken here of ^{129}I in the spent fuel discharged world-wide prior to 1981. In the previous discussion of the United States projections, spent fuel discharged prior to 1982 accounted for only about 12% of the projected ^{129}I estimated to be contained in all of the spent fuel generated to the year 2000. (The radiological significance of releases of ^{129}I to the atmosphere will be addressed in Section 4.8.)

Human Thyroid ^{129}I Exposures from Dietary Sources

4.1 Intr 'uction

the following subsections, we first summarize what is known it the transport of ^{129}I from the environment to the human thyroid. dosimetric implications are then discussed. A model atmosphere contains 1 pCi m^{-3} is assumed for this purpose. Then, experience he vicinity of the West Valley reprocessing facility and other ces of ^{129}I is reviewed, followed by estimates of the dose from ^{129}I opulations in the vicinity of future reprocessing plants that may uilt. Finally, the collective dose to the world population resulting i global transport of ^{129}I is discussed.

he near future releases of ^{129}I to the environment are likely to inate from nuclear facilities. Most of the ^{129}I will be discharged in ous effluents, with somewhat less present in liquid effluents. ne-129 deposited on land may eventually percolate through soil to indwater and, together with ^{129}I in liquid effluent discharged di- ly to water, ultimately reach ocean waters. Most of the earth's le iodine (^{127}I) is in the oceans (Kocher, 1979); therefore the marine ronment will evenually constitute the primary reservoir of ^{129}I.

irborne ^{129}I can enter human foods by depositing directly on tation, either from the atmosphere or by irrigation with contam- ed water. To a lesser extent, crops can be contaminated by root ike. Ingestion of contaminated vegetation and of dairy products meat from animals feeding on contaminated forage are the most ortant pathways for ^{129}I exposures of human populations. The sfer of ^{129}I from atmosphere to man has been described by Soldat . (1973), Soldat (1976) and Kocher (1979). Dietary sources of ^{129}I been described by Book *et al.* (1977), and reviewed by Poston 8) and Kocher (1979).

lthough radioiodine released into the biosphere in North America Europe reaches people chiefly through cow's milk, the stable

stage of lactation, the dietary intake of stable iodine, and, possibly, intake of other materials.

Marine fish and invertebrates contain more stable iodine than other human foods. However, because average seafood consumption in the U.S is small, the impact of these foods in the U.S. on iodine metabolism is generally insignificant. Concentrations of iodine in fresh-water biota are about 1% of those in marine biota. The main sources of dietary stable iodine in the U.S. are bread made with iodate dough conditioners, milk, and iodized salt (Kidd *et al.*, 1974).

4.2 Deposition and Accumulation of ^{129}I in the Food Chain

Because of insufficient experimental data, many of the physical and biologic characteristics of ^{129}I must be based on observations of other iodine isotopes. For example, studies of short-term iodine behavior have utilized fallout radioiodine from nuclear explosions, principally ^{131}I in particulate form, and releases of elemental vapor forms of ^{131}I in field experiments or associated with nuclear power generation. However, little information is available concerning the changes in bioenvironmental concentration processes that might result from alterations in form and availability of ^{129}I in the long term. Analyses of behavior and potential accumulation of ^{129}I released to the environment must therefore be based on studies of ^{131}I as a model for short-term behavior, and stable iodine for long-term ^{129}I behavior.

The transfer of iodine among the various portions of the environment depends on its chemical and physical form (Holland, 1963; Perkins, 1963). Inorganic vapor is the most chemically reactive form of iodine, but iodine associated with particles and organic compounds, such as methyl iodide (CH_3I), is readily metabolized (Morgan *et al.*, 1967).

A study of ^{129}I in Missouri indicated the following order for successively lower values of ^{129}I:^{127}I ratios in the local environment: rain, wild deer, commercial milk, beef cattle and humans (Oliver *et al.*, 1982). These progressively lower values apparently reflect increasing dilution with stable iodine, especially as added to the diets of man and domesticated animals. Radioecological studies at the Karlsruhe reprocessing plant in West Germany showed a wide range of concentration in air, the soil, thyroids and milk (Schuttelkopf and Pimpl, 1982). The concentration ratio of milk/air (Ci L^{-1} milk to Ci m^{-3} air) varied from studies have verified that the ^{129}I accumulates in the top soil layer (Brauer and Strebin, 1982).

'ollowing discussion, factors used for the transfer of ^{129}I from ants and from animal feeds to animal products are those d by Soldat for the study of the potential doses to people iclear power complex in the year 2000 (Fletcher and Dotson, though a number of models for the environmental transport dine exist in the scientific and technical literature (many of the atmosphere → vegetation → cow → milk → person for ^{131}I), the concepts and values from the many other models are similar to those presented in the Fletcher and eport.

'ontamination of Food by Direct Deposition

ng-term accumulation of atmospheric ^{129}I by vegetation via position from the atmosphere onto plant surfaces is approxi- the normalized equation (Soldat, 1976):

$$C'_p = \frac{RDT_c(1 - e^{-\lambda_E t})}{Y\lambda_E} \qquad (4\text{-}1)$$

Concentration in edible portion of plant in pCi kg^{-1} per pCi ^{129}I m^{-3} of air via direct deposition onto plant surface,
Deposition velocity in pCi m^{-2} d^{-1} per pCi ^{129}I m^{-3} of air,
Fraction of aerial deposition retained on plant,
Plant yield in kg m^{-2},
Time of exposure of crop to airborne contamination in d,
Effective removal constant in d^{-1}, and
Fraction of deposited nuclide translocated to edible parts of plant.

tive removal constant (λ_E) is given by:

$$\lambda_E = \lambda_R + \lambda_w = \frac{0.6932}{T_R} + \frac{0.6932}{T_w} \simeq \frac{0.6932}{T_w} = 0.05\ \text{d}^{-1} \qquad (4\text{-}2)$$

Radiological half-life of ^{129}I in days, and
The plant surface half-time, 14 days (Garner, 1971).

ted values for the various components of Eq. (4-1) are pre- Table 4.1 (Fletcher and Dotson, 1971; Soldat *et al.*, 1973; 976). The effect of variability in food chain parameters is

TABLE 4.1—*Estimated environmental parameters for iodine*[a,b]

Deposition velocity from air to ground, D (pCi m^{-2} d^{-1} per pCi m^{-3})	864
Fraction of aerial deposition retained on plant, R	0.25
Fraction of deposited ^{129}I translocated to edible portion of plant, T_c	
Leafy vegetables (pasture grass)	1.0
Other vegetables and grains	0.1
Plant uptake from soil (concentration ratio), B [pCi kg^{-1} plant (wet) per pCi kg^{-1} soil (dry)],	0.02
Plant yield, Y (kg m^{-2})	
Leafy vegetables	1.5
Fresh forage (pasture)	1.8
Stored forage (alfalfa, silage)	2.0
Grain	0.8
Time of exposure to airborne contamination, t (d)	
Fresh forage	30
Leafy vegetables	90
Grain	120
Ecological half-time on plant, T_w (d)	14
Transfer from feed to cow milk, S_D (pCi L^{-1} milk per pCi d^{-1} intake)	0.01
Transfer from feed to meat (beef), S_B (pCi kg^{-1} meat per pCi d^{-1} intake)	0.02

[a] From Fletcher and Dotson, 1971; Soldat *et al.*, 1973; Soldat, 1976.
[b] Symbols refer to Eq. (4-1) and (4-3).

m^{-3} of air. The concentration in crops other than leafy vegetables would be reduced by the fractional transfer from the leaves to the edible portions, estimated to be about 10 percent. The ^{129}I concentration in these foods would then be about 290 pCi kg^{-1}. The ^{129}I concentration in cereals, for an assumed yield of 0.8 kg m^{-2}, an exposure time of 120 days, and a fractional transfer of 10 percent, would be 540 pCi kg^{-1}, based upon an assumed air concentration of 1 pCi m^{-3}.

These values for ^{129}I in vegetation were used to estimate concentrations of ^{129}I in dairy and meat products by Book *et al.* (1977). Table 4.2 lists the daily intake of vegetation and the resulting ^{129}I intake for dairy cows and beef cattle as the result of an assumed ^{129}I air concentration of 1 pCi m^{-3}. Iodine-129 concentrations of 1200 pCi L^{-1} (1250 pCi kg^{-1}) for milk, and 1600 pCi kg^{-1} for meat were calculated from the transfer coefficients in Table 4.1 (and the ^{129}I intake listed in Table 4.2). As before, these concentrations were derived for the assumed air concentration of 1 pCi m^{-3} ^{129}I.

4.2.2 *Contamination of Food from Root Uptake*

Contamination of Food by Uptake from Water

accumulation of ¹²⁹I in fish and invertebrates such as mollusks ustacea, over the short-term, can result from the release of ¹²⁹I d effluents. Fish and invertebrates in equilibrium with fresh ontaining 1 pCi ¹²⁹I L⁻¹ would be expected to contain approxi- 15 and 5 pCi kg⁻¹, respectively, based on calculated bioaccu- n factors for iodine (Thompson *et al.*, 1972). Fish taken from ter of the same ¹²⁹I concentration would be expected to contain pCi kg⁻¹ and invertebrates 50-100 pCi kg⁻¹ (Frecke, 1967; son *et al.*, 1972). The intake of ¹²⁹I with fresh water fish having alized concentration of 15 pCi kg⁻¹ per pCi L⁻¹ water were ted from the data in Table 4.3 on fish consumption by the four ups. The results indicate that such fish would contribute 0.05, 15, and 0.21 pCi ¹²⁹I to the daily diets of the 1-, 4-, and 14-year d adults, respectively. These intakes are insignificant compared esponding intakes with drinking water obtained from the same as the fish.

normalized ¹²⁹I concentration in fish assumed here is completely ident of that assumed in the previous section for the air ys. Therefore, it is not possible to make a direct comparison of tive importance of the two media (air and water) in terms of ke with foods.

4.3 Accumulation of ¹²⁹I in the Thyroid

iodine uptake and retention by the thyroid gland are altered mber of factors, including age, amounts of dietary ¹²⁷I and gic state.

burden of ¹²⁹I in the thyroid, Q, resulting from a constant, al intake of the radionuclide may be calculated from:

$$Q = \frac{Pf(1 - e^{-\lambda t})}{\lambda} \quad \text{(pCi)} \qquad (4\text{-}5)$$

: Intake of ¹²⁹I in pCi d⁻¹,
: Fraction of iodine reaching the thyroid,
: Effective decay constant in d⁻¹,
: Exposure time in days.
∞, Equation (4-5) reduces to:

Values for the various age-dependent parameters of Eq. (4-6) are presented in Table 4.5.

Daily ¹²⁹I intake from major dietary items exposed to 1 pCi m⁻³ ¹²⁹I would result in steady state thyroid ¹²⁹I burdens of 11, 11, 37, and 66 nCi in 1-, 4-, and 14-year olds, and adults, respectively (Table 4.6).

TABLE 4.5—*Parameters used in calculating thyroid burden and radiation dose equivalent from ¹²⁹I*

Parameter	1y	4y	14y	Adult	Reference
Fractional uptake via ingestion f_w	0.3	0.3	0.3	0.3	Wellman *et al.*, 1970; ICRP, 1959.
Fractional uptake via inhalation f_a	0.23	0.23	0.23	0.23	ICRP, 1959.
Biological half-time in thyroid (d)	20	20	50	100	Wellman *et al.*, 1970; Bryant 1969, 1970; Rohwer and Kay, 1968.
Thyroid mass (g)	2	5	15	20	Fletcher and Dotson, 1971; ICRP, 1959.
Concentration of ¹²⁷I in thyroid (μg g⁻¹)	90	180	280	600	ICRP, 1959; ICRP, 1975; Cowser *et al.*, 1967.
Weight of ¹²⁷I in thyroid (mg)	0.18	0.90	4.2	12	ICRP, 1975.
Inhalation rate (m³ d⁻¹)	5.6	7.0	16	23	Rohwer and Kaye, 1968; ICRP, 1966; ICRP, 1975.
Effective MeV absorbed per disintegration of ¹²⁹I, (ε)	0.061	0.063	0.064	0.065	Modified from Soldat *et al.*, 1973.

TABLE 4.6—*Expected thyroid ¹²⁹I burdens resulting from continual ingestion of food exposed to an air concentration of 1 pCi ¹²⁹I m⁻³ (Inhalation for comparison)*

Dietary source	¹²⁹I burden (nCi)			
	1y	4y	14y	Adult
Milk products	7.0	6.1	19	22
Meat	1.4	1.8	8.4	23
Leafy vegetables	2.0	2.0	6.3	14
Cereals	0.3	0.3	1.5	3.0
Other vegetables and fruits	0.4	0.5	1.9	4.3
Total from diet	11.	11.	37.	66.
From inhalation	0.04	0.05	0.3	0.8

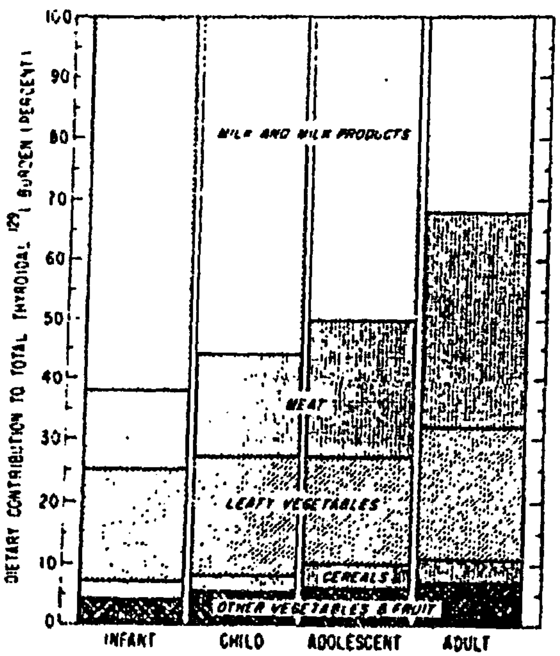
ative contribution of ^{129}I in milk products to the total dietary ıke decreases steadily with increasing age; the increase in ^{129}I from meat offsets the decreasing importance of ^{129}I from dairy ts. The contribution from leafy vegetables, cereals, and other ıles and fruit, remains fairly constant throughout the four age (Fig. 4.1).

comparatively insignificant contribution of inhaled ^{129}I to total al burden is presented for comparison (Table 4.6).

4.4 Radiation Dose

dose rate (*DR*) per unit ^{129}I activity (*Q*) maintained within the l is given by Soldat *et al.* (1973):

$$\frac{DR}{Q} = 18.7\,\frac{\epsilon}{m} \qquad (\text{mrem y}^{-1}\ \text{pCi}^{-1}) \qquad (4\text{-}7)$$



18.7 = Conversion constant,
ϵ = Effective energy absorbed per disintegration, MeV,
m = Mass of the thyroid, g.

The average equilibrium radiation dose equivalent rate per pCi ^{129}I contained within the thyroid is calculated to be 0.57, 0.24, 0.08, and 0.061 mrem y^{-1} for 1-, 4-, and 14-year olds, and adults, respectively. As the effective energy absorbed per disintegration (ϵ) remains fairly constant with age (0.061 – 0.065 MeV per disintegration) (Soldat, 1976), the substantial decrease in dose equivalent per pCi with increasing age results almost entirely from the rapid increase in thyroid gland size.

A steady dietary intake of one pCi ^{129}I ingested daily would lead to an equilibrium burden of 8.7 pCi in the thyroids of 1 to 4 year old children and 22 and 43 pCi in those of 14-year olds and adults, respectively, resulting in dose equivalent rates of 4.9, 2.1, 1.7 and 2.6 mrem y^{-1} for the 1-, 4-, and 14-year olds, and adults, respectively.

Thyroid dose equivalents resulting from ^{129}I burdens detailed in Table 4.5 were determined from the above factors. The radiation dose equivalent rate for the adult thyroid resulting from food items exposed to air concentrations of 1 pCi ^{129}I m^{-3} would be about 4 rem y^{-1} (Table 4.7). Dose equivalent rates to the thyroid glands of 14-year olds and 4-year olds would be about 2.9 and 2.5 rem y^{-1}, respectively, or about 73 and 63 percent of the adult dose. The 1-year-old infant thyroid receives a dose equivalent rate of 6.3 rem y^{-1}, or about 1.6 times the dose to the adult thyroid. The higher dose equivalent rate for the infant results from a burden of one-sixth that of the adult gland contained in a mass 1/10 that of the adult gland.

TABLE 4.7—*Thyroid radiation dose equivalent rate resulting from continual ingestion of foods produced where the air concentration of ^{129}I was assumed to be 1 pCi m^{-3}*

Dietary source	Average Thyroid dose equivalent rate (mrem y^{-1} per pCi m^{-3})			
	1 y	4 y	14 y	Adult
Milk products	4000	1400	1500	1300
Meat	800	400	700	1400
Leafy vegetables	1100	500	500	800
Cereals	200	100	100	200
Other vegetables and fruit	200	100	100	300
Total from diet	6300	2500	2900	4000
From inhalation	20	10	20	46

... intake as presented in Table 4.4 and inhalation rates

4.5 The Fetal Thyroid

oiodine is easily transported across the placenta resulting in xposure from maternal radioiodine. The fetal thyroid gland is nal prior to parturition, so it must be considered an important for environmental radioiodine.

uman beings, the fetal thyroid is capable of concentrating dine near the end of the first trimester of gestation (Shepard, The concentration of radioiodine per gram of fetal thyroid s that of the maternal gland toward the middle of gestation in s and large animals exposed to continual low-level radioiodine on (as reviewed by Book and Goldman, 1975). The concentra- radioiodine from chronic exposure increases to values 2 to 3 the maternal thyroid concentration at term. Fetal/maternal of thyroid ^{131}I concentration are higher following acute maternal res; values up to about 9 times the maternal concentration can nd near term (Book and Goldman, 1975). However, the proba- of acute exposures to large doses of ^{129}I is extremely small.

potential dose equivalent rate to the fetal thyroid from foods ed in air containing 1 pCi ^{129}I m^{-3} can be estimated. As deter- above, an assumed 30 percent thyroid uptake, a 100-day biologic ne and a 17-g thyroid in the mother (ICRP, 1975) would result eady-state maternal thyroidal burden of 43 pCi, or 2.5 pCi g^{-1} l for each pCi ^{129}I ingested daily. Such a burden would lead to a quivalent rate of 3 mrem y^{-1} (7×10^{-3} mrem d^{-1}). If a 3-fold se in ^{129}I concentration in the fetal thyroid relative to that of aternal gland is assumed, based upon chronic ^{131}I exposures and Goldman, 1975), then the near-term fetus would contain ^{129}I g^{-1} thyroid. From Eq. (4-7) and an assumed effective energy MeV, the dose equivalent rate to the fetus would be 0.02 mrem en the maternal intake is 1 pCi ^{129}I d^{-1}. Therefore, a pregnant ingesting 1.5 nCi ^{129}I d^{-1} (Table 4.4) would receive a dose lent rate of 10 mrem d^{-1} to her thyroid, while the subsequent tal dose equivalent rate could be as much as 30 mrem d^{-1}.

Doses from Measured Environmental Concentrations

survey of the ^{129}I content in human dietary items in the Pacific vest, Brauer *et al.* (1974b) reported the maximum ^{129}I:^{127}I ratios

is insignificant compared to that obtained via ingestion, the ratio that would govern the thyroidal steady state can be taken to be 1×10^{-6} (Soldat, 1976). Such a ratio implies doses of about 0.02, 0.04, 0.05, and 0.14 mrem y^{-1} to the 1-, 4-, 14-year-old child, and adult, respectively, based on the ^{127}I thyroid contents listed in Table 4.5.

Milk samples from the vicinity of the Nuclear Fuel Services plant in New York contained a peak ^{129}I concentration of about 2 pCi L^{-1}, in March 1972, but generally contained less than 0.3 to 0.5 pCi L^{-1} (Kelleher and Michael, 1973). These concentrations resulted from plant operations in which the iodine removal system consisted of essentially only a chemical scrubber (Magno *et al.*, 1972). For the peak ^{129}I concentration of 2 pCi L^{-1}, the daily ingestion of one liter of such milk for an entire year would yield 9.6, 4.0, 3.4, and 5.2 mrem y^{-1} to the respective age groups.

Kantelo *et al.* (1982) studied the distribution of ^{129}I in the terrestrial environment surrounding the Savannah River reprocessing plant after 25 years of operation. A conservative (worst case basis) calculation yielded an annual dose from ^{129}I of 1.6 mrem to an adult thyroid.

Dose estimates from other measured environmental samples are many orders of magnitude *lower* than the estimates calculated in the previous sections for a concentration of 1 pCi m^{-3} ^{129}I in air. The peak concentration of 2 pCi ^{129}I L^{-1}, as determined in milk samples near the Nuclear Fuel Services plant, would require maintenance of an air concentration of 1.7×10^{-3} pCi m^{-3}, according to the model used above. Concentrations of ^{129}I in air around nuclear power plants are so much lower than those calculated for air around fuel processing facilities that they are essentially undetectable.

4.7 Maximal Radiation Doses

The levels of ^{129}I intake that will result in the maximum permissible dose to the thyroid of 1500 mrem y^{-1} (NCRP, 1971) would be 310, 750, 880, and 580 pCi day^{-1} (from Eq. 4-5 and 4-6) for the 1-, 4-, 14-year-old, and adult, respectively. These intakes would correspond to thyroidal burdens of 2.7 nCi (0.015 mg), 6.5 nCi (0.038 mg), 19 nCi (0.11 mg), and 25 nCi (0.15 mg) in the respective age groups, or approximately 1.4 nCi g^{-1} for 1-year-olds and 1.3 nCi g^{-1} for the other 3 age groups. The isotopic ratios (^{129}I:^{127}I) corresponding to these levels of ^{129}I concentration in the thyroid, based on parameters of stable iodine content and concentration presented in Table 4.4, are 0.093, 0.043, 0.027, and 0.012.

al concentration of radioiodine when radioiodine ingestion is (Book and Goldman, 1975). Therefore, when the maternal ^{129}I concentration is 1.3 nCi g^{-1} and the maternal dose rate is rem y^{-1}, the fetal thyroidal ^{129}I concentration may reach about g^{-1} and its dose rate, about 4400 mrem y^{-1}, or about 12 mrem

4.8 Predicted Population Thyroid Doses

Regional Population Doses Near a Reprocessing Plant

oid doses to a "maximally"[1] exposed 1-year-old infant and to pulation living in the vicinity of a 1500 metric tons per year y^{-1}) fuel reprocessing plant (FRP) were calculated by Soldat U.S. Nuclear Regulatory Commission (NRC) study of nuclear centers (Battelle Pacific Northwest Laboratories, 1976). The ntent of the fuel was taken to be 0.04 Ci per MTU or 60 Ci in l processed annually. With a decontamination factor of 100, nual release rate of ^{129}I would be 0.06 Ci. The maximum heric dispersion factor ($\bar{x}/Q'$)[4] was assumed to be 2×10^{-6} sec the site boundary 2.4 km (1.5 miles) from the stack, where the average air concentration would be 3.8×10^{-4} pCi m^{-3}. The thyroid dose equivalent rate per unit concentration developed e 4.7 was 6300 mrem y^{-1} per pCi ^{129}I m^{-3} of air for an assumed th growing and grazing season. Hence, the air concentration 10^{-4} pci m^{-3} estimated above would correspond to an annual dose equivalent rate of 2.4 mrem to the 1-year-old infant. 60 percent of this dose results from milk consumption. The ally exposed adult would receive a thyroid dose of approximately m y^{-1}. In a more typical environment where the cows might e contaminated forage for 8 months and only half of the fresh les might be home grown, the annual thyroid dose equivalent e 1.5 mrem to the infant.

annual collective thyroid dose equivalent to a population of 3.5 persons living within 80 km (50 miles) of this same fuel

ed as a person with average living and dietary habits residing at the location um environmental concentrations.

processing plant was also calculated. If the population is assumed to be all adults the calculated annual collective dose equivalent was 240 person-thyroid-rem. For a population consisting of 60 percent adults, 20 percent teenagers, 15 percent children, and 5 percent infants, the annual collective thyroid dose would be 220 person-thyroid-rem. (An additional contribution to the thyroid dose from ^{131}I, which would also be released, would be about equal in magnitude to the annual dose from ^{129}I. Of course, there would be no long-term accumulation of ^{131}I in soil.)

The accumulated population thyroid dose over the period 1982 to 2000 could be estimated from the total quantity of ^{129}I released to the environment during that time, plus the contribution each year from accumulated ^{129}I in the soil. The actual rate of release of the ^{129}I would depend upon when reprocessing is resumed and the rate at which reprocessing capacity would become available.

One possible scenario includes the start of reprocessing about the year 1990 at about 1500 MTU y^{-1} over a 2 to 3 year period. Capacity would probably remain at 1500 MTU y^{-1} until new fuel reprocessing plants were constructed at the end of the century. About 15,000 MTU of spent fuel could be processed by the year 2000 in such a scenario. This amount of fuel would contain 600 Ci of ^{129}I. At a decontamination factor of 500, 1.2 Ci of ^{129}I would have been released to the atmosphere by the year 2000 at an average rate of about 0.12 Ci per year between the year 1990 and 2000. For a population distribution around U.S. nuclear fuel reprocessing plants similar to that presented above, the total dose equivalent commitment to the population within 80 km (50 miles) of the plant would be about 43 person-thyroid-rem in the year 2000. Since the ^{129}I in the soil adds about 1 percent per year to the dose, the 1.2 curies accumulated to the year 2000 would add about another 4.3 person-thyroid-rem. The total collective dose commitment then would be 47 person-thyroid-rem during the year 2000.

Time integration of the curies of ^{129}I discharged to the atmosphere during the period 1990 to 2000 yields 6 curie-years. The contribution of the soil/root pathway to the accumulated thyroid dose is proportional to this value. The resulting accumulated population thyroid dose equivalent commitments are 430 person-thyroid-rem from direct contamination during the 10 year period, plus 20 person-thyroid-rem from residual soil contamination, or a total of 450 person-thyroid-rem. The contribution from the soil/root pathway ignores any processes that remove radioiodine from the plant root zone or that make it the 1500 person-thyroid-rem including 60 person-thyroid-rem the ^{129}I gradually accumulated in the soil over the entire period 10 to 2010. Thus the total collective thyroid dose for a population ng within 80 km (50 miles) of plants reprocessing spent nuclear ischarged up to the year 2010 in the U.S. would be 1950 person-id-rem through the year reprocessing is completed.

nilar calculations can be performed to estimate the "first-pass"[5] tive dose resulting from the release of ^{129}I during reprocessing of fuel associated with the world-wide nuclear generating capacity ssed in Section 3.2. The same reprocessing scenario as used before ie United States nuclear fuels will be used for the world-wide estimates (10-year old fuel is reprocessed in plants with a decon-ation factor of 500 and 3.5 million persons residing within 80 the plant). On this basis, the collective dose equivalent commit-from the 7.4 Ci of ^{129}I released as a result of world-wide nuclear r generation through the year 2000 would be about 3000 person-id-rem.

2 Global Dose Commitment

e long-term committed dose equivalent to the world's population releases of ^{129}I is also of interest. A multi-compartment model of l distribution of ^{129}I and naturally occurring stable iodine has developed by Kocher (1979). This linear compartment model of obal iodine cycle has been used to predict the average long-term rior of ^{129}I in the terrestrial environment, e.g., from nuclear fuel cessing and atmospheric weapons testing (Kocher, 1982). Fig. 4.2 iagram of the steady state global iodine cycle, showing environ-al compartments, their inventories in grams, transport pathways, luxes in g y^{-1}. The dynamic behavior of ^{129}I in the terrestrial onment is predicted on the basis of the compartment model for obal circulation of naturally occurring stable iodine. The dynamic rior of ^{129}I in each of these regions is described quantitatively by ean residence time, i.e., the average time an atom of circulating sides in a given compartment before being transported to another artment in the system.[6] The parts of the terrestrial environment

e "first-pass" dose is the dose received from the radionuclides during release and adionuclides initially deposited during passage of the plume downwind of the It does not include subsequent exposure to the radionuclide after world-wide and recirculation occurs.

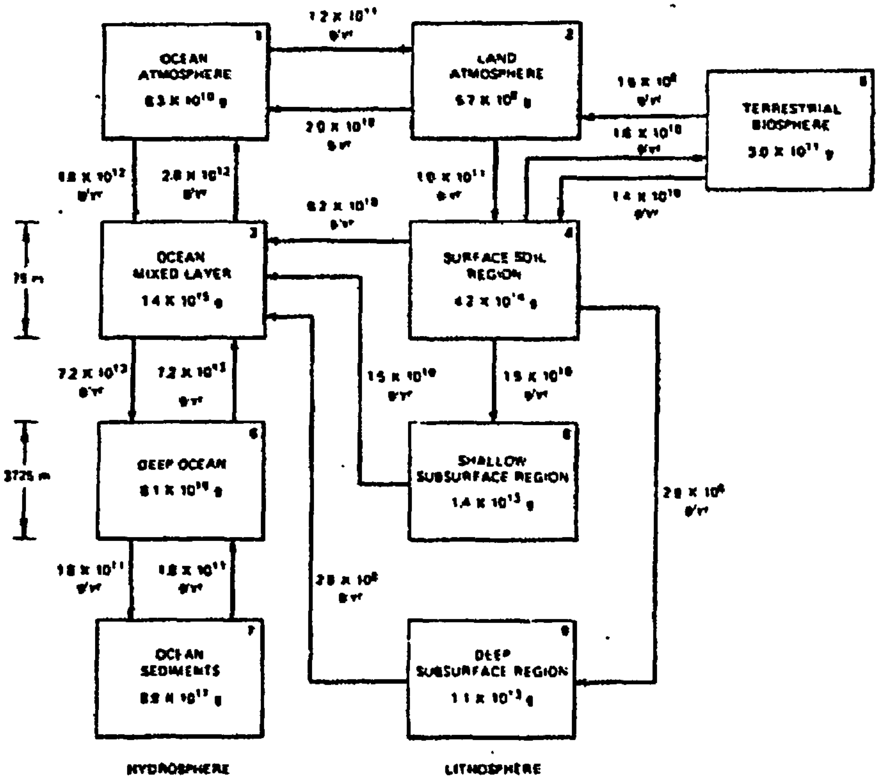


Fig. 4.2 Diagram of the global iodine cycle at steady state, showing environmental compartments, compartment inventories in grams, transport pathways, and fluxes in g y^{-1} (from Kocher, 1982).

considered by Kocher include the surface soil region, with an assumed depth of 1 m, and shallow and deep subsurface regions of the lithosphere in which ^{129}I is transported via groundwater flow. The mean residence time of ^{129}I in the surface soil region with respect to removal to ocean surface waters or the subsurface regions of the lithosphere is predicted to be 4×10^3 y. This value is surprisingly large considering the corresponding mean residence time for water in the surface soil region of 0.7 y and measured distribution coefficients for iodine in soils. The predicted mean residence time for ^{129}I in surface soil leads to the conclusion that ingestion of foodstuffs contaminated via root uptake of ^{129}I by plants is the only significant exposure pathway for man for thousands of years following a release to the atmosphere and deposition onto the earth's surface. The predicted mean residence f ^{129}I in the shallow and deep subsurface compartments of the iere are 1×10^3 and 4×10^4 y, respectively. These values are out a factor of five greater than the corresponding mean ce times for groundwater in these compartments. This result well with the expectation that ^{129}I transport via groundwater not greatly retarded, and leads to the conclusion that the ace lithosphere is not a significant sink for isolating globally ing ^{129}I from man.

multi-compartment model was used by Kocher to calculate ve committed dose equivalent versus time following the release of ^{129}I to each of several compartments. Of interest here is the ion that the long term (> 10^5 year) collective doses are essen- ie same whether the ^{129}I is released to the atmosphere (over water), to the surface soil compartments, or the mixed ocean

collective committed dose equivalent per Ci ^{129}I released to the mosphere compartment are reproduced below:

Years since release of 1 Ci	Committed Dose Equivalent (person-thyroid-rem)
10	530
100	790
1,000	3,800
10,000	23,000
100,000	43,000

short term collective dose is due primarily to the exposure of onal population around the plant to ^{129}I in the air and terrestrial ys as discussed in Section 4.8.1. In the long term the collective controlled by the consumption of food derived from the mixed iyer.

radiation doses beyond even 1000 years, and their significance ct to great uncertainty, and the values are presented here to e the fact that the majority of the committed dose from ^{129}I is received at extremely long times after the release. As calcu- Section 3.2, 3700 Ci of ^{129}I will be generated by the year 2000 pent fuel discharged from the world's nuclear power generation s. Even if this ^{129}I is disposed of in deep geologic storage, one ssume that it would eventually migrate from the disposal site ticipate in the iodine cycle in a manner simulated by Kocher's If this were to occur and if the model were valid out to 10^5 ien the world-wide collective committed dose equivalent would ' person-thyroid-rem. This seemingly large number must be perspective by remembering that it is the summation of $\sim 10^{15}$ ... 10^{10} personal person-years of exposures and probably has

Estimates have been made of the maximum individual thyroid dose equivalent rate and the collective thyroid dose equivalent, out to infinite time, from the ^{129}I produced in a hypothetical nuclear power program orders of magnitude greater than any currently envisioned (CEC, 1982a). As an extreme upper limit case, fissioning of all of the recoverable terrestrial uranium was postulated. The calculated thyroid doses were not high enough to preclude a power program as large as the hypothetical case. However, the significance of the collective dose was considered to be uncertain because of the many unresolved issues involved.

4.9 Dosimetric Considerations

The magnitude of predicted radiation doses to the thyroid gland are dependent on the model used in making the necessary calculations. The values presented previously were derived, as were those of Soldat *et al.* (1973), by utilizing an ICRP model that assumes that the radionuclide is concentrated at the center of a spherical organ and that all particulate radiation and a fraction of the gamma radiation, depending on the effective radius of the organ, is absorbed within that organ. In contrast, a model developed for ^{125}I by Gavron and Feige (1972) assumes that all radioiodine is concentrated within the colloid of follicles and that the critical cells are the thyroid follicle cells. Using that model and metabolic parameters for ^{129}I of Colard *et al.* (1965), daily ingestion of 1 pCi ^{129}I was estimated to result in a dose equivalent rate at the colloid-follicular cell interface in an infant thyroid of at least 400 mrem y^{-1}(Daly *et al.*, (1974).

However, such calculations grossly overestimated the thyroidal burden following continuous exposure (Book *et al.*, 1977) so that 1 pCi day^{-1} resulted in an infant thyroidal burden of 150 pCi g^{-1}. Calculations presented in this report yielded an estimated thyroidal burden in a year-old infant of 4.9 pCi g^{-1} per pCi ingested daily, a value about 3 percent of that of Daly *et al.* (1974). Substitution of this lower and more realistic value into the Gavron-Feige model gives an estimated dose rate at the colloid-cell interface of about 12 mrem y^{-1} per pCi ingested daily. The dose equivalent rate to the colloid-cell interface per pCi ^{129}I concentrated in the infant thyroid gland can be deduced from the computations of Daly *et al.* (1974) to be about 1.2 mrem y^{-1}. However, their calculations indicate an average thyroidal dose equivalent rate of half that of the colloid-follicular cell interface, or 0.65 mrem y^{-1}, about the same as the 0.56 mrem y^{-1} calculated by Soldat of ^{129}I in the shallow and deep subsurface compartments of the here are 1×10^3 and 4×10^4 y, respectively. These values are bout a factor of five greater than the corresponding mean ce times for groundwater in these compartments. This result well with the expectation that ^{129}I transport via groundwater not greatly retarded, and leads to the conclusion that the face lithosphere is not a significant sink for isolating globally ting ^{129}I from man.

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ẓ *et al.* (1970) considered the 2-fold dose increase to the hor-
enic parts (i.e., the colloid-cell interface) from therapeutic ^{125}I
ne basis for the decrease in subsequent myxedema, without loss
ılar reproductive capabilities. Gavron and Feige (1972) ques-
whether the cell-colloid interface rather than the follicular cell
can be regarded as the critical site of radiation damage; they,
nsidered the dose to nuclei from ^{125}I to be about half that at the
lloid interface.

ınt (1970) derived working limits associated with continuous
ıheric release rates of ^{129}I. Her calculations indicate that dose
lent rates to the infant thyroid gland would be about 0.6 mrem
i^{-1} maintained in the gland. For the adult, the dose equivalent
ould be about 0.05 mrem y^{-1} pCi^{-1}. Soldat *et al.* (1973) deter-
similar adult values, 0.06 mrem y^{-1} for each pCi maintained in
roid. Colard *et al.* (1965) estimated the average thyroidal dose
lent from an initial thyroidal burden of 1 pCi to be 0.013 mrem.
fference between the infant and adult dose equivalent rates is
ily due to the difference in thyroid gland size. Colard's calcu-
is based on an initial 1 pCi ^{129}I burden while the others are
ın maintaining a 1 pCi burden of ^{129}I.

5. Limits to the Biological Significance of ^{129}I

Most estimates of the thyroidal radiation dose consequent to ^{129}I exposure are based upon metabolic parameters determined for other radioiodines. For example, Colard *et al.* (1965) calculated thyroidal burdens from chronic (1 μCi h^{-1}) absorption for a number of radioiodines, assuming a stable iodine intake of 100 μg d^{-1}. In the case of ^{129}I, such an exposure was estimated to lead to the deposition of 5700 μCi in the thyroid. Because of its low specific activity, however, one μCi of ^{129}I represents 5.9 mg of iodine. Hence, the data of Colard *et al.* (1965) would require the deposition of 34 g of iodine (all as ^{129}I) in the thyroid. This quantity corresponds to several thousand times the average value of 0.012 g iodine in the thyroid (ICRP, 1975). The ^{129}I intake per day for the maximum permissible dose is discussed in Section 4.7.

In a similar fashion, a single administration of one microcurie of ^{129}I would be expected to reduce the uptake of iodine by the thryoid. Several investigators have examined the effect of large doses of stable iodine (^{127}I) on ^{131}I uptake (Hamilton, 1942; Adams and Bonnel, 1962; Saxena *et al.*, 1962; Cuddihy, 1964; Blum and Eisenbud, 1967; Sternthal *et al.*, 1980). Since the uptake of radioiodine by the thyroid is inversely related to the intake of ^{127}I, the fraction of ingested ^{129}I taken up by the thyroid would be expected to decrease as the amount of ^{129}I ingested increases.

The impact of ^{129}I dosage on thyroid iodine metabolism was recently investigated in young beagles (Book, 1977). Dosages of 0–0.8 μCi ^{129}I (0–5 mg I) were given along with tracer doses of ^{131}I for external thyroidal and total-body monitoring. Total-body retention was described as the sum of 2 or 3 exponentials; the rate of release from the total animal during the first week of radioiodine was greater in those receiving ^{129}I than in controls, and the release increased with increased dosage.

Over the range of ^{129}I dosages, there was a 5-fold decrease in peak thyroidal uptake, from about 27 percent of the administered dose in l only slightly, with half-times of 10–13 days. Peak uptakes ·ed at about 2.5 days in the control animals, and slightly later, ıys, in those receiving ^{129}I. The depression in thyroidal radioio- ıptake was found to be related to the total iodine intake by the .on:

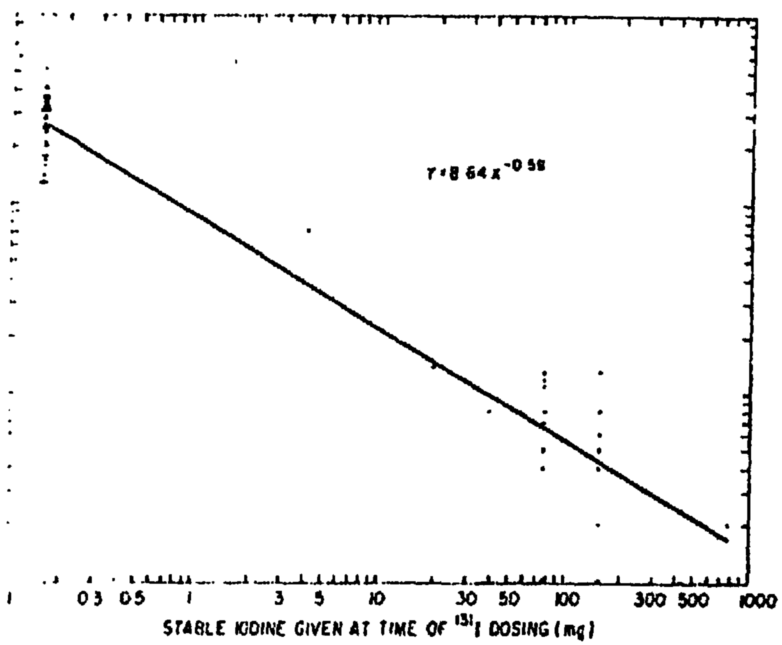
$$Y = 13\ X^{-0.47} \tag{5-1}$$

Y is the peak uptake in percent, and X, the sum of daily dietary ı (0.2 mg) and the ^{129}I administered, in mg. Based upon this ion, young beagles receiving 0.2 mg ^{127}I in their diet would be ·ted to show peak uptakes of 15 percent when given 0.1 μCi ^{129}I, rcent when given 1 μCi ^{129}I, and 1.9 percent from 10 μCi ^{129}I.

humans, the effect of ^{129}I on thyroidal iodine metabolism can ıilarly estimated. From the data of Blum and Eisenbud (1967), in ^{127}I was administered to suppress ^{131}I intake, and for a dietary take of 150 mg d^{-1}, the relationship of the 24-h uptake (Y) in ıt, to the total iodine intake (X) in mg was computed to be

$$Y = 8.64\ X^{-0.59} \tag{5-2}$$

wn in Fig. 5.1 (Book, 1976).



5.1 Thyroid uptake of ^{131}I 24 h after oral administration vs. amount of ^{127}I ·ered simultaneously (calculated and drawn from data of Blum and Eisenbud,

Eq. (5-2) may be utilized in estimating thyroidal ^{129}I uptake. If a daily intake of 0.15 mg ^{127}I is assumed, then thyroidal uptakes at 24 hours would remain at about 27 percent for ^{129}I dosages of less than 1 nCi (5.9 μg iodine). However, at higher dosages of ^{129}I, there would be a considerable reduction in thyroidal uptake, to about 10 percent from 0.1 μCi ^{129}I (0.59 mg + 0.15 mg), to about 3 percent from 1 μCi ^{129}I (5.9 mg + 0.15 mg). Since the radiologic dose to the thyroid is determined by the ^{129}I concentration in the gland, a similar decrease in dose per unit intake would be predicted.

In a study on the effects of lifetime feeding of ^{129}I in rats, the only observed "effect" was a decreased ^{131}I uptake by thyroid glands of ^{129}I-fed rats (Book, 1983). That decrease reflected the "blocking" of the thyroid by the large quantities of iodine required because of the low specific activity of ^{129}I. Lifetime ingestion of ^{129}I in that study resulted in dose rates to the rodent thyroids of about 1 rad per day. There was no significant increase in thyroid tumors of ^{129}I-exposed rats compared to controls, nor in other thyroid effects, nor was there any difference in longevity between ^{129}I-irradiated and control rats.

The metabolic constraints that control the quantity of iodine in the thyroid gland and the low specific activity of ^{129}I restrict the amount of ^{129}I that can be concentrated in the thyroid gland. Considering these factors, and given the lack of effects in the thyroid glands of rats fed ^{129}I for life, the potential for a radiologic hazard from exposure to ^{129}I appears to be limited.

Control Measures

·ar reactors are the prime producers of ^{129}I, but fuel reprocessing are the prime potential sources of environmental releases. s, however, can be minimized by careful design, operating res, and installation of efficient treatment systems.

e control technology has been reviewed in many comprehensive (For example, IAEA, 1973, 1978, 1980; Yarbo *et al.*, 1972; NEA, 1980; Dames and Moore 1977; ERDA, 1976; CEC, 1982a; *t al.*, 1983a, 1983b). There have been several symposia dealing vith radioactive iodine. The most recent of these was the ssion of the European Communities meeting held in Mol in EC, 1982b). The present report can only attempt to consider trol technology in very brief form.

6.1 Control Technology

·elease of radioiodine has generally been controlled by means nethods: (1) holdup for decay and (2) collection by scrubbing , and solid sorbents. Both holdup and collection have been ·d. But the former is not suitable for ^{129}I. When only small s of radioiodine are involved, as with reactor effluents, the method may be adequate and charcoal filters or charcoal delay n be utilized. In fuel reprocessing plants, both holdup and on have been used with more recent effort concentrating on on and disposal.

Scrubbing Systems

al wet scrubbing systems have been used and proposed for use ary systems.

·ic scrubbing is one of the earlier methods used for primary (CEC, 1982a). NaOH or KOH in solution is used in a packed or bubble plate column. Decontamination factors (DF) of 10^2 · have been achieved. I_2 is effectively trapped but organic

compounds of iodine are not, and, as a result, DF's may vary considerably depending on the type and concentration of the iodine compound present. If the gas stream contains large amounts of acidic compounds, then large quantities of caustic will be required and large waste volumes will be generated.

The Iodox process employs high concentration (20 to 23 *M*) nitric acid to scrub iodine from the gas stream (Holladay, 1979). Iodine is removed as anhydroiodic acid (HI_3O_8). All iodine species are converted to I^{5+} and, as a result, DF's greater than 10^4 are possible. However, the equipment is expected to be expensive because of corrosion problems with the concentrated nitric acid. The product of this process is very soluble in water and would have to be converted to a more insoluble form before final storage.

The Mercurex process employs mercuric nitrate-nitric acid in a packed column (Holladay, 1979). While dilute nitric acid has been investigated, improved organic iodine remove is obtained with concentrated acid (> 10 *M*). Mercuric iodine complexes are formed. One treatment method involves oxidation to the iodate, followed by filtration of the iodate. The mercuric iodate can be filtered off. DF's for the mercurex process are affected by aromatic vapors and may be 100 or less. The toxicity and cost of mercury are disadvantages as well as the lack of demonstrated conversion technology for the mercurex solution.

6.1.2 *Solid Sorbents*

Solid sorbents offer the advantages of simpler design, and high collection efficiency and lower maintenance costs. They produce a dry waste product that is easy to handle and comparatively noncorrosive. Solid sorbents proposed for both secondary and final iodine removal systems include charcoal, zeolites, amorphorus silicic acid impregnated alumina, mordenites, and macroreticular resins (Holladay, 1979).

Activated carbon has been widely studied for iodine removal and widely used in nuclear power plants. The carbon is usually impregnated with I^-, KI, $I_2 - KI_2$, or triethylenediamine to improve removal of CH_3I from high humidity gas streams. Removal efficiency is highly variable depending on the particular charcoal, its age and weathering, iodine concentration, flow rate, humidity, temperature and any impregnant used. The DF can vary from 10 to greater than 10^3 depending on the above factors. There are several disadvantages of charcoal absorbers that rule out their use for removal of iodine from gaseous effluents at fuel reprocessing plants. These include low ignition point, ıition in the presence of NO_2, low capacity, desorption of iodine ated temperatures, and adverse ageing effects (Holladay, 1979; 1979).

search for inorganic absorbers in which a stable iodine com- is formed has resulted in the selection of a synthetic zeolite, molecular sieve 13X, converted to the silver form, AgX. AgX advantages of nonflammability, no explosive hazard, resistance soning, good operation at elevated temperatures, and a high y for iodine. In addition, it forms an insoluble iodine product. ıay range from 10^2 to 10^5 (Jubin, 1979). Disadvantages are: cost silver, the deleterious effects of acid and prolonged exposure to on the DF. Collection of CH_3I can be affected by SO_2, H_2S, nd NO_x.

r exchanged mordenites were developed as the result of a search inexpensive substrate with a higher acid resistance than the zeolites, and a capacity for multiple cycles (Holladay, 1979; 1979). Silver mordenite, AgZ, is made by exchanging the sodium synthetic zeolite with silver. The DF depends on particle size, ıte, temperature, gas composition and loading. A DF of 10^3 can ained at a moderate loading of iodine. Advantages are: high ty for iodine loading (but not as high as AgX), good retention ınic iodides, high recycle capability, and more acid resistance ype X zeolites. Disadvantages include a lack of knowledge ning the reactions, uncertainty about poisoning by organic , and the fact that other halogens and sulfur can destroy the ty for iodine sorption.

ic acid/silver nitrate and aluminum oxide/silver nitrate repre- nother class of inorganic sorbents for removal of elemental and methyl iodide. A commercially available sorbent (trade AC-6120) developed around a once-through process using $AgNO_3$;nated amorphous silicic acid is available in Europe. Develop- l work in the United States has been initiated to examine the ial for iodine removal for various nitrates on aluminum (Jubin, Disadvantages are: the cost is high, the presence of certain es, high NO_2 concentrations, and the facts that high relative ity can affect performance and AC-6120 should not be used 250°C for extended periods of time. As with silver zeolites, other ns and probably sulfur and phosphates, will destroy the capacity line sorption. Advantages include good long-term disposal po- , high removal efficiency in a superheated steam environment, ınd performance below 200°C. A DF of 10^3 can be achieved at

Ion-exchange resins have been investigated in the search to find iodine sorbents less expensive than silver impregnated ones or more stable than carbons (Holladay, 1979). The macroreticular structure permits easy diffusion through the resins. Advantages are acid resistance, high capacity, good radiation resistance, and cost. Disadvantages include adverse effects of humidity and elevated temperatures, and limited experience on iodine removal from gas streams. DF's greater than 10^3 have been obtained under experimental conditions.

6.2 Management of Iodine in Fuel Reprocessing Plants

Systems for removal of iodine from gaseous effluents at fuel reprocessing plants have generally been classed into primary, secondary, and final cleanup systems. Primary iodine removal systems are de-

TABLE 6.1—*Management of iodine at fuel reprocessing plants*[a]

Plant	Iodine Removal System	Overall DF
A. *Metal Fuel Plants*		
1. Hanford		
B-Plant, T-Plant (≤1952)	Caustic Scrubber	≈10^{b}
T-Plant, Redox, Purex (≥1952)	Silver Reactor	100–500[c]
2. TBP, Windscale (1964)	Caustic Scrubber	1000 (now 20–30)
3. UP2, La Hague	Caustic Scrubber	20
4. DFR, Dounreay	Mercurex	150
B. *Oxide Fuel Plants*		
1. NFS, West Valley	None	4
2. WAK, Karlsruhe	AC 6120	200
3. HAO, La Hague	Caustic Scrubber	50
4. PNC, Tokai Mura	a. Caustic Scrubber b. AgX	100
5. Eurex, Saluggia (metal and oxide plant)	a. Nitric Acid b. AgX	200
C. *Proposed Designs*		
1. NFS, West Valley	a. Mercurex b. Caustic Scrubber c. Silver Mordenite	3500
2. AGNS	a. Mercurex b. AgX	1000
3. THORP, Windscale	a. Caustic Scrubber b. Possibly AC 6120	NA

[a] Adapted from CEC, 1982a.
[b] Estimated by J. K. Soldat.
[c] Blasewitz and Schwidt, 1958.

d to remove the iodine volatilized in the dissolver. The secondary n gives additional removal from the dissolver off-gas and other ss equipment. Final cleanup is provided by an additional off-gas n before the gas is released from the stack.
merous fuel reprocessing plants have been operated (or planned) ncluded iodine removal systems on the gaseous effluent streams ', 1982a). Table 6.1 lists several reprocessing plants along with of iodine removal system used at each and the overall stack itamination factor. Overall stack DF's can vary considerably ared to the theoretical efficiency of the individual systems be- of routing in the plant of streams that may contain iodine.

6.3 Management of Iodine at Nuclear Reactors

the several radioisotopes of iodine created in nuclear reactors two, ^{131}I and ^{133}I, are present in sufficient quantities in gaseous nts to warrant installation of effluent control systems.
stems used at reactors include delay lines, decay tanks, charcoal bers, and charcoal delay beds (U.S. Atomic Energy Commission, . Decay tanks are used at pressurized water reactors. They are urized tanks which hold up the gaseous effluents for up to 2 hs allowing for radioactive decay of the short lived isotopes, ling all of the radioiodines present except ^{129}I. Charcoal absorbers ally are used at boiling water reactors and provide a DF of about radioiodine. Deep charcoal beds not only absorb radioiodine but its passage long enough to provide nearly complete removal of topes except ^{129}I. The small amounts of ^{129}I present in effluents nuclear reactors are nearly unmeasurable and are of no signifi- from a control standpoint.

7. Methods of ^{129}I Analysis

7.1 Introduction

Levels of ^{129}I in environmental samples have been determined by a number of investigators (Studier *et al.*, 1962; Edwards and Rey, 1969; Keisch *et al.*, 1963, 1964, 1965; Cochran *et al.*, 1970; Matuszek *et al.*, 1974; Markham, 1974; Magno *et al.*, 1972; Boulos *et al.*, 1973; Kelleher and Michael, 1973; Brauer, 1974; Brauer *et al.*, 1974b; Brauer and Ballou, 1975). The high analytic sensitivity for ^{129}I by activation analysis permits measurements at concentrations much below those required for radiation protection.

Field concentration methods can be used to increase the quantity of ^{129}I in certain materials that are collected. Thus, particle filters and activated charcoal filters have been used to collect atmospheric iodine (Brauer *et al.*, 1974a). Ion-exchange methods, usually using anion exchange resins, have been used to sample water-borne iodine and ionic iodine in milk (Daly *et al.*, 1974; Brauer and Rieck, 1973; Brauer *et al.*, 1974b; Keisch *et al.*, 1965). Natural iodine collectors, such as thyroid tissue and seaweed, have been used for collection of environmental ^{129}I samples (Brauer *et al.*, 1974b; Keisch *et al.*, 1964; NSEC, 1963; Boulos *et al.*, 1973; Kelleher and Michael, 1973; Smith, 1977; Oliver *et al.*, 1982; Schuttelkopf and Pimpl, 1982).

The content of ^{129}I in environmental materials has been determined in both fresh and dry samples. Drying methods utilized include air drying, low-temperature oven drying, and freeze drying.

Analysis of ^{129}I in environmental samples generally requires separation of the iodine from the materials of concern. The need for separation results from the low specific activity of ^{129}I, its low-energy emissions, and its low environmental levels. Separation of iodine from environmental samples has been accomplished by both chemistry and combustion methods (Studier *et al.*, 1962; Keisch *et al.*, 1965; Magno *et al.*, 1972; Boulos *et al.*, 1973; Gabay *et al.*, 1974; McFarland *et al.*, 1974; Brauer and Tenny, 1975).

Spike recovery methods are generally used to measure the iodine-separation yield. Spikes used include stable iodine (^{127}I), and the g iodine in the sample. The use of stable iodine, however, also es the capability for determining the $^{129}I:^{127}I$ ratio, which may ıcern in environmental and dosimetric studies.

se of a radioactive spike interferes with some measurement ı involving gross counting of ^{129}I. Generally, a ^{125}I spike is d to ^{131}I because of its longer (60-day) half-life; also, it is absent ıst environmental samples. Methods for measurement of low ^{131}I and ^{125}I are well developed. If amounts of ^{129}I and ^{127}I are termined, care must be taken so that the spike material is free ıd ^{127}I contamination.

7.2 Measurement Methods

Liquid Scintillation Counting

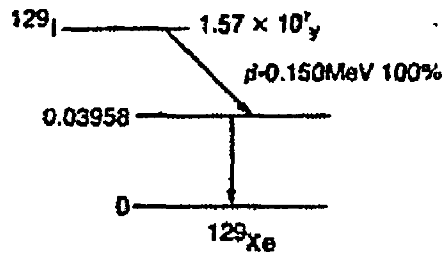
d scintillation counting methods for ^{129}I have been described no *et al.* (1972); Bogen (1973); Gabay *et al* (1974); Rhodes Horrocks (1974); and Ross (1970). The methods require the l separation of iodine from the sample material, with the ncorporated into a suitable liquid scintillation cocktail for ment of the beta and conversion electron activity associated

eported detection limits for ^{129}I by liquid scintillation range to 1.2 pCi.

Low-Level Beta Counting

counting of solid samples of iodine as AgI or other forms has nsidered by several investigators but has not been generally to environmental ^{129}I analyses (Bogen, 1973; Gabay *et al.*, oth gas-flow counters and low-level beta-scintillation counters en considered. The detection limits are about the same as for intillation counting, but larger uncertainties result from self-on in the sample to be counted.

Gamma-Ray and X-Ray Spectrometry



RADIATION	ENERGY (MeV)	INTENSITY (%)	INTENSITY RELATIVE TO $K\alpha_1$	CONVERSION COEFFICIENTS
γ	0.03958 ± 0.0003	7.52		α_K 10.5 α_{LM} 1.8 α_T 12.3
$x(K_{\alpha1})$	0.02978	37.0	1	
$x(K_{\alpha2})$	0.029458	19.9	0.537	
$x(K_{\beta1})$	0.03360	10.8	0.292	
$x(K_{\beta2})$	0.03442	2.4	0.064	
β^-	0.150 ± 0.005			

Fig. 7.1 Decay information for ^{129}I.

Crowther, 1964; Taylor, 1967; Brauer *et al.*, 1970; Matuszek *et al.*, 1974; Horrocks, 1974; Brauer and Kaye, 1974; Thomas, 1973; Thomas *et al.*, 1975; Daly *et al.*, 1975). In some cases, measurements can be made on original sample material (e.g., thyroid tissue), but iodine separations are generally required for maximum sensitivity and selectivity.

The decay scheme of ^{129}I is presented in Fig. 7.1. The ^{129}I gamma ray is significantly converted so that only a relatively low intensity remains. Higher sensitivities have been achieved by measuring the x rays. Since xenon x-rays are emitted during the decay of other radioiodines, x-ray measurements are only useful for total activity or pure isotope determinations. Gamma- and x-ray radiation measurements are usually done with solid state detectors such as Si(Li), Ge(Li), or high-purity Ge detectors When maximum sensitivity has been required for the total gamma-plus x-ray activity in the 25-56 keV region, *Coincidence Counting*

-gamma coincidence counting has been used for standardization sources, but has not been applied to analysis of environmental s (Russell, 1957; Cali, 1973).

Neutron Activation Analysis

analysis of ^{129}I by neutron activation was first reported by vastha and Martin (1956). The first environmental ^{129}I and ^{127}I es by this method were performed by Studier *et al.* (1962). A r of activation analysis procedures have been described (Studier 1962; Buzzelli, 1964; Keisch *et al.*, 1965; Watson *et al.*, 1965; tte *et al.*, 1966; Edwards and Rey, 1969; Heydorn, 1969; Brauer aye, 1974; McFarland *et al.*, 1974; Rook *et al.*, 1975; Brauer and , 1975).

high sensitivity of the neutron activation analysis method (10^{-6} ts freedom from interferences, and the capability for simulta- analyses for ^{129}I and ^{127}I, make the procedure a preferred method asurements of environmental ^{129}I.

Mass Spectrometric Analysis

s spectrometry has been used in the determination of $^{129}I:^{127}I$ (Russell, 1957; McHugh and Sheffield, 1965). When ^{129}I concen- is are needed, independent analysis of ^{127}I is required or isotope n methods must be used. These measurements, however, have en applied routinely to environmental samples.

ique application of mass spectrometry to $^{129}I:^{127}I$ measurements

TABLE 7.1 – *Comparison of ^{129}I measurement methods*

Measurement Method	^{129}I Detection Limit (pCi)
cintillation Counting	0.4
v Proportional Counting	0.5
el Beta Counting	0.05
Ray and X-Ray Spectrometry	
Detector	0.5
(Tl) Detector	0.04
ectrometry	
^{129}I	0.00002
e:^{130}Xe Ratio	0.1
	[illegible]

has been reported (Boulos *et al.*, 1973; Srinivasan *et al.*, 1971) wherein separated iodine samples are irradiated with neutrons to produce ^{126}I, ^{128}Xe, and ^{130}Xe. The xenon isotopic ratios are then measured by mass spectrometry.

The isotope separator has been applied to iodine isotopic analysis (Rook *et al.*, 1975). In this method, neutron activation is used to produce radioactive iodine activities. The isotope separator serves to mass-separate the radioiodine and also to decontaminate the irradiated sample from other interfering radionuclides such as ^{82}Br.

7.2.7 *Laser Extinction*

Detection of iodine isotopes by selective extinction, when traces of iodine are inserted into the cavity of a broad-band dye laser, has been reported (Hänsch *et al.*, 1974).

7.3 Discussion and Conclusions

Selection of a method for ^{129}I analysis is dependent on available facilities, required response time, required sensitivity, and whether a concentration measurement or an isotopic ratio ($^{129}I:^{127}I$) is required. The detection limits for the measurement methods are compared in Table 7.1. Except for cases where the ^{129}I activity is sufficiently high and can be measured without a chemical separation, the relative man-hours required for an analysis are more dependent on the experience of the analyst than the method selected.

When rapid response is desired and only an ^{129}I concentration estimate is required, counting of the ^{129}I by low-level, solid-state gamma-ray and x-ray spectrometric techniques should yield the most reliable results if the amount of ^{129}I is about 1 pCi or more. For smaller amounts of ^{129}I and when simultaneous measurement of the concentration and isotopic ratio $^{129}I:^{127}I$ is desired, neutron activation analysis is the only method in routine use. The errors associated with the activation analysis procedure range from 10 percent to 25 percent, although they can be as high as 100 percent at levels close to the detection limit (10^{-6} pCi).

Recent research has included the areas of laser fluorescence spectrometry, mass spectrometry, tandem accelerator mass spectrometry and improvements in neutron activation analysis (Brauer and Strebin, 1979; Elmore *et al.*, 1980; Goles *et al.*, 1981; Bate and Stokely, 1982;

Summary and Conclusions

dine-129, with a half-life of 1.57 × 10^7 years, is the longest-lived ne radionuclide. It originates from both artificial and natural ces. Natural production is estimated to have led to a steady state a ratio of ^{129}I to stable ^{127}I of approximately 10^{-12} in the oceans r to the introduction of man-made sources. As a result of nuclear nology the ratio of ^{129}I:^{127}I in the environment has increased since mid-1940's. The ratio for the general biosphere was 10^{-8} to 10^{-7} ne 1960's and 1970's.

dine-129 produced in nuclear power reactors and released during reprocessing represents an essentially permanent contaminant of biosphere where it will appear as a fraction of the total environtal iodine.

ne net production of ^{129}I from fission of ^{235}U in a thermal reactor out 1 μCi per megawatt-day, dependent on the irradiation time neutron flux. Fission of ^{239}Pu, which adds about 40% to the power, rates another 0.3 μCi of ^{129}I per megawatt-day. Some small quans of ^{129}I are undoubtedly present in gaseous and liquid effluents power reactors, but its measurement is difficult because of high entrations of other fission and activation products. It is released ly in gaseous form from fuel reprocessing plants.

ne selection of an analytical method is dependent on required nse time, sensitivity, and whether a concentration measurement isotopic ratio of ^{129}I:^{127}I is required. When rapid determination lving only ^{129}I concentration estimates is needed, the use of low-, solid-state gamma-ray and x-ray spectrometric techniques will reliable results if the amount of ^{129}I is about 1 pCi. If smaller nts of ^{129}I must be measured or if ^{129}I:^{127}I ratios are needed, ron activation is the appropriate analytical method.

ng-term accumulation of ^{129}I in soils is not expected to lead to ficant contamination of plant materials. Uptake of iodine from y plants is low and migration below the root zone limits the entrations expected in plants. The ^{129}I will be diluted with stable e already present in soil and should eventually assume the same

A significant part of the ^{129}I that is in the soil will eventually percolate to groundwater and, together with ^{129}I discharged directly to water in liquid effluents, will ultimately reach the ocean. Since most of the earth's stable iodine is in the ocean, the marine environment will probably constitute the primary reservoir for ^{129}I.

Iodine-129 can enter the human food chain via direct deposition on produce, as well as via milk and meat from animals feeding on contaminated forage. Plant uptake of iodine from soil is small and adds only ~1 percent per year to the concentration in food crops present as a result of direct deposition to plant surfaces. After it is ingested, ^{129}I is concentrated in the thyroid gland. Even though the effective half-time of ^{129}I in the human thyroid is much longer than that of other radioiodines, the radiation dose (7 mrem per nCi ingested) is limited by the low energy of its emitted radiations.

The thyroid dose is further limited by the low specific activity of ^{129}I (0.17 μCi mg^{-1}) since ingestion of milligram quantities of iodine can significantly reduce the thyroidal iodine uptake.

The estimated total accumulated amount of ^{129}I that will be produced in U.S. nuclear power reactor fuels through the year 2000 is about 2500 curies. If reprocessing resumes and decontamination factors of 500 exist for gaseous effluent treatment systems, only about 5 Ci of this total will have been released to the environment fr[illegible] fuel reprocessing plants. The remainder will be incorporated into solid wastes appropriately isolated from the biosphere.

The collective dose equivalent from the release of this 5 Ci of ^{129}I over the entire period required for reprocessing is estimated to be 1950 person-thyroid-rem. This is based on a generic reprocessing plant site with 3.5 × 10^6 persons residing within 80 km (50 mi) of the plant.

Similarly, an estimated 3700 Ci ^{129}I would be present in the spent fuel discharged from the world's nuclear power reactors through the year 2000. The estimated collective dose equivalent from the release of 7.4 Ci of this ^{129}I is about 3000 person-thyroid-rem, during the period of reprocessing.

It can be assumed that the majority of the ^{129}I is disposed of with high level waste and is isolated from the biosphere for relatively long periods of time. Nevertheless, it should eventually reach the biosphere and gradually become distributed in a manner similar to that described in the model developed by Kocher. On this basis, the 3700 Ci of ^{129}I generated by the world's nuclear power reactors through the year 2000 could possibly lead to a collective committed dose equivalent to the world's population (10^{10} persons) of 10^8 person-thyroid-rem, integrated has been concluded that the maximum individual thyroid dose valent rate from global circulation of ^{129}I produced from the ılated fissioning of all the recoverable reserves of terrestrial ium would not be significant. Such hypothetical uranium usage is rs of magnitude greater than the usage envisioned under any ently planned power program.

APPENDIX A

Glossary

absorbed dose: The energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The special unit of absorbed dose is the rad. One rad equals 0.01 joules per kilogram.

biological half-time: The time required for the body to eliminate one-half of an administered dosage of any substance by regular processes of elimination.

biosphere: The life zone of the earth, including the lower part of the atmosphere, the hydrosphere, soil, and the lithosphere to a depth of about 2 kilometers.

boiling water reactor (BWR): A nuclear reactor in which water used for coolant is allowed to boil.

$\bar{\chi}$: Average concentration of radionuclide in the atmosphere at a downwind point (Ci m^{-3}).

$\bar{\chi}/Q'$: Ratio of average air concentration to release rate at the source (s m^{-3}).

computer model: The simulation of a physical system by use of a computer program (code) and a set of real world data.

collective dose equivalent: (often referred to as collective dose or population dose) The summation of the radiation dose equivalent (in rem) received by all individuals in a population group. Collective dose is principally used for whole-body dose where it has units of person-rem. When the collective dose is calculated for the thyroid the result is given in units of person-thyroid-rem.

dose commitment: The dose commitment, as used in this report, refers to the radiation dose received during some period of immediate exposure plus the dose over the time period of interest while the material persists in the environment.

dose equivalent (H): The product of the absorbed dose in rads, the *quality factor*, and any other modifying factors. Dose equivalent is expressed in rems and is considered to be related to the radiation risk.

effective half-time: Time required for a radioactive element in an the combined action of radioactive decay and biological elimination.

$$\text{effective half-time} = \frac{\text{biological half-time} \times \text{radioactive half-life}}{\text{biological half-time} + \text{radioactive half-life}}$$

ssion product: Any radionuclide or stable nuclide resulting from nuclear fission, including both primary fission fragments and their radioactive decay products.

We: Gigawatts electric.

Wth: Gigawatts thermal.

loton (KT): A unit of explosive energy equivalent to that released upon detonation of 10^3 tons of TNT.

aximum exposed individual (Maximum Individual): The individual whose locations and habits tend to maximize his radiation dose, resulting in a dose higher than that received by other individuals in the general population.

aximum permissible concentration (MPC): An accepted upper limit for the concentration of a specific radionuclide in air or water, such that occupational exposure for the working life time of an individual to the MPC values would not result in radiation doses exceeding the standards recommended by competent authorities.

egaton (MT): A unit of explosive energy equivalent to that released upon detonation of 10^6 tons of TNT.

TU: Metric tons of uranium equivalent, as applied to mass of reactor fuel.

We: Megawatts electrical.

Wt: Megawatts thermal.

wer: The time rate of doing work; the unit of power is the watt.

essurized water reactor (PWR): A nuclear reactor in which water is circulated under enough pressure to prevent it from boiling, while serving as moderator and coolant for the uranium fuel; the heated water is then used to produce steam for a power plant.

ality factor (Q): A multiplying factor used with absorbed dose to express its effectiveness in causing detrimental biological effects.

dioactive half-life: Time required for a radioactive nuclide to decrease to one-half its initial activity by radioactive decay.

urce strength (Q'): The number of curies of a radionuclide released per unit time to the atmosphere (Ci s^{-1}) (see $\bar{\chi}/Q'$).

ecific activity: Total activity of a given nuclide per gram of a compound, element, or radioactive nuclide.

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The NCRP

The National Council on Radiation Protection and Measurements is a nonprofit corporation chartered by Congress in 1964 to:

1. Collect, analyze, develop, and disseminate in the public interest information and recommendations about (a) protection against radiation and (b) radiation measurements, quantities, and units, particularly those concerned with radiation protection;
2. Provide a means by which organizations concerned with the scientific and related aspects of radiation protection and of radiation quantities, units, and measurements may cooperate for effective utilization of their combined resources, and to stimulate the work of such organizations;
3. Develop basic concepts about radiation quantities, units, and measurements, about the application of those concepts, and about radiation protection;
4. Cooperate with the International Commission on Radiological Protection, the International Commission on Radiation Units and Measurements, and other national and international organizations, governmental and private, concerned with radiation quantities, units, and measurements and with radiation protection.

The Council is the successor to the unincorporated assocation of scientists known as the National Committee on Radiation Protection and Measurements and was formed to carry on the work begun by the Committee.

The Council is made up of the members and the participants who serve on the eighty-one Scientific Committees of the Council. The Scientific Committees, composed of experts having detailed knowledge and competence in the particular area of the Committee's interest, draft proposed recommendations. These are then submitted to the full membership of the Council for careful review and approval before being published.

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SC-16: X-Ray Protection in Dental Offices
SC-18: Standards and Measurements of Radioactivity for Radiological Use
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- Task Group on Carbon-14
- Task Group on Iodine-129
- Task Group on Disposal of Accident Generated Waste Water
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SC-40: Biological Aspects of Radiation Protection Criteria
- Task Group on Atomic Bomb Survivor Dosimetry
- Subgroup on Biological Aspects of Dosimetry of Atomic Bomb Survivors

SC-42: Industrial Applications of X Rays and Sealed Sources
SC-44: Radiation Associated with Medical Examinations
SC-45: Radiation Received by Radiation Employees
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SC-60: Dosimetry of Neutrons from Medical Accelerators
SC-61: Radon Measurements
SC-62: Priorities for Dose Reduction Efforts

C-63: Control of Exposure to Ionizing Radiation from Accident or Attack
C-64: Radionuclides in the Environment
Task Group 5 on Public Exposure to Nuclear Power
Task Group 6 on Screening Models
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C-67: Biological Effects of Magnetic Fields
C-68: Microprocessors in Dosimetry
C-69: Efficacy Studies
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recognition of its responsibility to facilitate and stimulate coop-on among organizations concerned with the scientific and related cts of radiation protection and measurement, the Council has ted a category of NCRP Collaborating Organizations. Organiza- or groups of organizations that are national or international in e and are concerned with scientific problems involving radiation ntities, units, measurements and effects, or radiation protection be admitted to collaborating status by the Council. The present aborating Organizations with which the NCRP maintains liaison s follows:

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American Society of Therapeutic Radiologists
Bioelectromagnetics Society
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Genetics Society of America
Health Physics Society
National Bureau of Standards
National Electrical Manufacturers Association
Radiation Research Society
Radiological Society of North America
Society of Nuclear Medicine
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United States Army
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United States Department of Labor
United States Environmental Protection Agency
United States Navy
United States Nuclear Regulatory Commission
United States Public Health Service

The NCRP has found its relationships with these organizations to be extremely valuable to continued progress in its program.

Another aspect of the cooperative efforts of the NCRP relates to the special liaison relationships established with various governmental organizations that have an interest in radiation protection and measurements. This liaison relationship provides: (1) an opportunity for participating organizations to designate an individual to provide liaison between the organization and the NCRP; (2) that the individual designated will receive copies of draft NCRP reports (at the time that these are submitted to the members of the Council) with an invitation to comment, but not vote; and (3) that new NCRP efforts might be discussed with liaison individuals as appropriate, so that they might have an opportunity to make suggestions on new studies and related matters. The following organizations participate in the special liaison program:

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United States Coast Guard
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The NCRP values highly the participation of these organizations in the liaison program.

The Council's activities are made possible by the voluntary contribution of time and effort by its members and participants and the generous support of the following organizations:

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The NCRP seeks to promulgate information and recommendations based on leading scientific judgement on matters of radiation protection and measurement and to foster cooperation among organizations concerned with these matters. These efforts are intended to serve the public interest and the Council welcomes comments and suggestions on its reports or activities from those interested in its work.

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16	*Radioactive Waste Disposal in the Ocean* (1954)
22	*Maximum Permissible Body Burdens and Maximum Permissible Concentrations of Radionuclides in Air and in Water for Occupational Exposure* (1959) [Includes Addendum 1 issued in August 1963]
23	*Measurement of Neutron Flux and Spectra for Physical and Biological Applications* (1960)
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58 *A Handbook of Radioactivity Measurements Procedures* (1978)
59 *Operational Radiation Safety Program* (1978)
60 *Physical, Chemical, and Biological Properties of Radiocerium Relevant to Radiation Protection Guidelines* [illegible]

62 *Tritium in the Environment* (1979)
63 *Tritium and Other Radionuclide Labeled Organic Compounds Incorporated in Genetic Material* (1979)
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The following NCRP Reports are now superseded and/or out of int:

No.	Title
1	*X-Ray Protection* (1931). [Superseded by NCRP Report No. 3]
2	*Radium Protection* (1934). [Superseded by NCRP Report No. 4]
3	*X-Ray Protection* (1936). [Superseded by NCRP Report No. 6]
4	*Radium Protection* (1938). [Superseded by NCRP Report No. 13]
5	*Safe Handling of Radioactive Luminous Compounds* (1941). [Out of Print]
6	*Medical X-Ray Protection Up to Two Million Volts* (1949). [Superseded by NCRP Report No. 18]
7	*Safe Handling of Radioactive Isotopes* (1949). [Superseded by NCRP Report No. 30]
10	*Radiological Monitoring Methods and Instruments* (1952). [Superseded by NCRP Report No. 57]
11	*Maximum Permissible Amounts of Radioisotopes in the Human Body and Maximum Permissible Concentrations in Air and Water* (1953). [Superseded by NCRP Report No. 22]
13	*Protection Against Radiations from Radium, Cobalt-60 and Cesium-137* (1954). [Superseded by NCRP Report No. 24]
14	*Protection Against Betatron—Synchrotron Radiations Up to 100 Million Electron Volts* (1954). [Superseded by NCRP Report No. 51]
15	*Safe Handling of Cadavers Containing Radioactive Isotopes* (1953). [Superseded by NCRP Report No. 21]
17	*Permissible Dose from External Sources of Ionizing Radiation, Addendum to National Bureau of Standards Handbook 59* (1958). [Superseded by NCRP Report No. 39]
18	*X-Ray Protection* (1955). [Superseded by NCRP Report No. 26
19	*Regulation of Radiation Exposure by Legislative Means* (1955). [Out of print]
20	*Protection Against Neutron Radiation Up to 30 Million Electron Volts* (1957). [Superseded by NCRP Report No. 38]
21	*Safe Handling of Bodies Containing Radioactive Isotopes* (1958). [Superseded by NCRP Report No. 37]
24	*Protection Against Radiations from Sealed Gamma Sources* (1960). [Superseded by NCRP Report Nos. 33, 34, and 40]
26	*Medical X-Ray Protection Up to Three Million Volts* (1961). [Superseded by NCRP Report Nos. 33, 34, 35, and 36]
28	*A Manual of Radioactivity Procedures* (1961). [Superseded by NCRP Report No. 58]
29	*Exposure to Radiation in an Emergency* (1962). [Superseded by NCRP Report No. 42]
31	*Shielding for High Energy Electron Accelerator Installations* (1964). [Superseded by NCRP Report No. 51]
34	*Medical X-Ray and Gamma-Ray Protection for Energies Up to 10 MeV—Structural Shielding Design and Evaluation* (1970). [Superseded by NCRP Report No. 49]

Other Documents

The following documents of the NCRP were published outside of the NCRP Reports series:

"Blood Counts, Statement of the National Committee on Radiation Protection," Radiology 63, 428 (1954)

"Statements on Maximum Permissible Dose from Television Receivers and Maximum Permissible Dose to the Skin of the Whole Body," Am. J. Roentgenol., Radium Ther. and Nucl. Med. 84, 152 (1960) and Radiology 75, 122 (1960)

X-Ray Protection Standards for Home Television Receivers, Interim Statement of the National Council on Radiation Protection and Measurements (National Council on Radiation Protection and Measurements, Washing-

ıfication of Units of Natural Uranium and Natural Thorium (National ouncil on Radiation Protection and Measurements, Washington, 1973)
RP Statement on Dose Limit for Neutrons (National Council on Radiaon Protection and Measurements, Washington, 1980)
pton-85 in the Atmosphere—With Specific Reference to the Public Health nificance of the Proposed Controlled Release at Three Mile Island (National Council on Radiation Protection and Measurements, Washington, 980)
iminary Evaluation of Criteria For the Disposal of Transuranic Contamiated Waste (National Council on Radiation Protection and Measureents, Bethesda, Md, 1982)

opies of the statements published in journals may be consulted in aries. A limited number of copies of the remaining documents d above are available for distribution by NCRP Publications.

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