ENVIRONMENTAL IMPACT STATEMENT

CLEANUP, REHABILITATION, RESETTLEMENT OF ENEWETAK ATOLL — MARSHALL ISLANDS

APRIL 1975

DEFENSE NUCLEAR AGENCY
Washington, D.C. 20305

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"Fight Pollution –
The island you
save may be your own"

ENVIRONMENTAL PROTECTION BOARD
Division of Environmental Health
Department of Health Services
Trust Territory of the Pacific Islands
Saipan, Mariana Islands 96950

Cable Address TTEPB Saipan

October 15, 1974

Warren D. Johnson
Lieutenant General, USAF
Director
Defense Nuclear Agency
Washington, D.C. 20305

Dear Sir:

Enclosed are comments prepared by the Trust Territory Environmental Protection Board's Technical advisors in response to the Draft Environmental Impact Statement - Clean up, Rehabilitation, Resettlement of Enewetak Atoll, Marshall Islands - prepared by Holmes and Narver, Inc. for the Defense Nuclear Agency.

I was pleased to have one of our Board members and a representative of our technical staff in attendance at the hearing on Enewetak Atoll.

I sincerely hope our comments and technical recommendations will assist in the drafting of the Final Environmental Impact Statement and speed the safe return of the dri-Enjebi and dri-Enewetak to their traditional homeland.

Sincerely,

Masao Kumangai, M.O.
Chairman, TTEPB

enclosure

cc: High Commissioner
Special Assistant for District Affairs, TTPI
Micronesian Legal Services Corp., Saipan
Micronesian Legal Services Corp., Majuro
District Director of Health Services, Majuro
Stanley Carpenter, Office of Territorial Affairs,
Dept. of Interior, Wash. D.C.

ENVIRONMENTAL PROTECTION BOARD
Division of Environmental Health
Department of Health Services
Trust Territory of the Pacific Islands
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COMMENTS TO THE
CLEAN-UP, REHABILITATION, RESETTLEMENT OF ENEWETAK ATOLL

MARSHALL ISLANDS

DRAFT ENVIRONMENTAL IMPACT STATEMENT

The Trust Territory Environmental Protection Board has reviewed the Draft Environmental Impact Statement on the "Clean-up, Rehabilitation, Resettlement of Enewetak Atoll--Marshall Islands," prepared by Holmes and Narver, Inc.

The Draft Statement satisfactorily addressed most of the various environmental, social, cultural and political aspects of the return of Enewetak Atoll to the dri-Enjebi and the dri-Enewetak people. The participation and support of the Enewetak Planning Council in preparing the Impact Statement and Master Plan has produced a document which addresses itself to the particular needs and requirements of returning these people to their traditional homeland.

In the opinion of the Board's technical staff, Case III represents the most practical and realistic approach to the proposed clean-up, rehabilitation and resettlement program. Specific technical comments will be addressed in Section 2.

Section 1. The need for an Environmental/Health Education Program.

Two areas that are of primary concern to the Board do not appear to be adequately addressed in the Draft Environmental Impact Statement or the summary, nor does the Board feel they were adequately discussed during the hearing on Enewetak Atoll. They involve the full understanding and education of the dri-Enjebi and dri-Enewetak with respect to the concept of radiation poisoning and the real or potential effects of somatic and genetic injury as a consequence of long-term exposure to excessive radiation levels.

The Board's concern or doubt is based upon the overall concept of radiation and the vocabulary and terminology associated with isotopes, dosages, occurrence in food chains, etc. We question whether or not the Marshallese translation presented at the Hearing (and summarized in the DEIS) provided a complete and thorough enough understanding of the potential hazards involved here, with respect to the various living, food-gathering and agricultural restrictions which will have to be imposed, should Case III be elected.

The Board does not question the competency of the translation during the hearing; rather it addresses itself to the concern over words and phrases not translatable into Marshallese. The delegation from Ujelang indicated it understood the imposed restrictions and the rationale behind those restrictions. However, the subject matters of nuclear physics and radiation biology are extremely complex.

Poisons of various types are not unknown in the Trust Territory. In early times poisons were used during inter-island warfare. Even today, poison is occasionally used to "settle" disputes in cases of land ownership, jealousy, sibling rivalry and inter-clan disagreements. The use of traditional poisons in the taking of fish and other marine resources is still common in many districts of the Trust Territory. It would be logical for a given cultural group to associate radiation poisoning with their traditional poisons; however, the effects of low level radiation doses spanning a period of many years are far less obvious or understandable than the overt (and traditionally known) systemic responses to traditional poisons.

The Board strongly recommends that a comprehensive training program be administered to the dri-Enjebi and the dri-Enewetak, their Marshallese legal council, Health Services and other governmental officials. Movies, slides and educational booklets should be developed (in the vernacular) to adeqautely explain the concept of radiation and radiation poisoning, radiation induced genetic mutation, "normal" background radiation,etc. Documentation of the radiation exposures or injuries suffered in Rongelap, Uritik and other atolls in the Marshall Islands during the nuclear weapons testing period should also be depicted as factually as possible. The objective should not be to frighten, but to inform.

The Board strongly feels that only through a comprehensive educational program could the dri-Enjebi and the dri-Enewetak <u>safely</u> return to Enewetak Atoll. Fuller and more complete understanding of these concepts should engender in the people voluntary cooperation regarding restrictions on their life-style which the Board feels would be far more successful than enforcement by outside agencies such as the Atomic Energy Commission or the military.

<u>Section 2:</u>

1. Disposal of non-radioactive scrap and debris (Section 5.5, page 5-46.)

    a. Combustible materials

    The Board does not forsee environmental problems resulting in the burning of non-radioactive combustible scrap and debris. The Board takes the position that the ash represents a substantial mineral resource and recommends that the ashes be utilized as a soil conditioner in areas lacking adequate soil and/or used as a soil conditioner in areas that have been covered with concrete or asphalt for many years and may lack certain minerals or trace elements that would normally be present in the "undisturbed" state. The proportionally small cost of this extra effort could conceivably be balanced by increased soil fertility and faster recovery of of natural flora and/or agricultural crops.

b. Non-Combustible materials (Section 5.5, page 5-46.)

The Board suggests that the non-radioactive scrap and debris (concrete, steel etc.) represents another potential resource to the Enewetak people, if utilized properly. In this regard the Board suggests that with proper research and planning the scrap and debris could be effectively utilized to create artificial reefs within the lagoon. These materials might be used most effectively if introduced in areas deficient of natural "reef" environments, in expanses of unconsolidated sand or in areas where entire reef ecosystems were destroyed as a result of nuclear testing. The creation of artificial reefs from materials that might otherwise be indiscriminately dumped into the lagoon could provide a stable substrate for the development of new reef environments and the flora and fauna associated with such environments. Thus, if properly marked and located, these areas at some point in the future could potentially yield commercially valuable marine resources. To this end, we recommend that appropriate agencies be contacted and studies performed to explore the feasibility of establishing of artificial reefs within the Enewetak Lagoon. These investigations should include measurements of current flow. in the lagoon, productivity determinations, ecological succession patterns, potential for ciguatera poisoning, and habitat requirements for reef fish and invertebrates and commercially valuable marine resources.

2. Disposal of radioactive soil, scrap and debris - discussion of alternatives (Section 5.5.2, subsections 1-4.)

   1. The packaging of radioactive soil, scrap and debris for shipment to the United States for disposal would reflect the expressed interests of the dri-Enjebi and the dri-Enewetak. However, aside from the cost (and assuming the required Congressional appropriation) the legal ramifications would preclude this alternative from being practical. The time involved in lengthly legal proceeding would not to be in the best interests of the Enewetak people.

   2. Deep ocean dumping might be practical from a cost standpoint, but could potentially result in unpredictable ecological consequences of untold magnitude.

   3. Utilizing one or both craters on the north side of Runit Island for disposal of radioactive materials is the favored means for disposal, as presented in the Draft E.I.S. However, the D.E.I.S. does not discuss any supportive data which would describe the feasibility of the proposal from an engineering or geological

standpoint. The Board expresses concern on the justification of this alternative on the basis of no reported feasibility studies having first been conducted. Can these craters actually be "Pumped out" and "lined" with concrete? In the final E.I.S., attention should be directed toward engineering design as a function of the geological history of Enewetak Atoll, impact of typhoon or tsunami, structural integrity of concrete versus other lining materials, porosity of ancient corals, and environmental consequences and remedial or clean-up procedures in the event of a crack or leak in the craters or their linings.

DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20201

NOV 15 1974

Lt. Gen. Warren D. Johnson, USAF
Defense Nuclear Agency
Washington, D. C. 20305

Dear Sir:

We appreciate the opportunity to review the draft Environmental Impact Statement for the proposed Cleanup, Rehabilitation, and Resettlement of the Enewetak Atoll - Marshall Islands. On the basis of our review, we offer the following comments:

5.3.3.1 Control of Food Sources

The results of a radiological survey show high levels of contamination on the northern islands and low levels of contamination on the soutern islands. This high level of contamination is of significance both from the standpoint of external exposure and from the uptake of the radionuclides by plants as well as by indigenous fauna which if eaten would result in internal dose and deposition of radionuclides. Radiological surveys on Enewetak have found evidence of uptake of cesium-137 and strontium-90, among other radionuclides, in indigenous plants used for food including coconuts, pandanus, breadfruit, and tacca (arrowroot). The surveys also report radionuclies in flesh and organs of indigenous fauna such as terns, rats, and land crabs. Presumably domestic animals such as poultry and swine would, if they foraged on indigenous radioactive plants, also show uptake of these radionuclides. If the driEnjebi faction of the Atoll population are to live on the northern islands and particularly the island of Enjebi, care would need to be taken that the pandanus and breadfruit are grown in non-radioactive soil, either on the southern islands or imported from elsewhere. The alternative would be to provide farm plots for pandanus and breadfruit by removing existing soil and replacing it with non-radioactive soil in sufficient volume to contain the roots of these plants. The removal and replacement of soil to create these farm plots is of questionable and unproven value, since sustained land removal and replacement operations could result in serious ecological damage of unknown proportions. Also, there is no guarantee that sufficient soil could be removed and replaced to assure radiological safety of residents who would be eating plants grown on these plots.

5.6.1 Dose Estimates

It is unclear as to whether the dosage estimates include contribution of potential ground water supplies such as brackish or fresh water wells. While it is clear that the use of grossly contaminated supplies would be precluded, estimates of potential added dosage from these sources in the southern quadrant should be made.

As noted in the statement, the implications of concentrations of cesium and strontium in bone marrow by ingestion routes is an item of considerable concern. However, it is unclear from the draft statement if the mortality rate shown in Table 5.14 (page 5-60) includes the effect of doses to the bone marrow.

6.1 Selection of Cleanup Case 3

As stated, the selection of Case 3 is preferred as the most favorable mode of resettlement. Inherent in this choice is the restriction of the inhabitants to residence in the lower half of the Atoll, with limited use of the islands in the northern quadrant. This implies as a minimum self-discipline on the part of the inhabitants with respect to public health and safety, i.e., exposure to the on-site hazards in the northern islands. The proposed plan should delineate control or quarantine measures to be implemented and enforced over a specified period of years.

7.2.4 Community Center Development

We found very little information contained in the statement addressing the long-term, on-going, health services following the initial phases of the resettlement. Continuing health services should be included in the preliminary planning in order to receive maximum benefit from the facilities and to establish, insofar as possible, some patterns of health service delivery early in the process. There is no indication as to whether the TTPI will have a medical officer on the Atoll. If so, would he have the responsibility for health education, particularly radiology? We note that the TTPI currently has a significant health manpower shortage: MD's, nurses, medics, etc.

Remote communities in other districts of the Trust Territory are generally served by a sub-professional health aide with training similar to that of a U.S. Navy Hospital Corpsman serving a small ship or outpost. Ideally, this aide should have at his disposal a supply of drugs with a very simple numbering system. Reliable radio contact with the District Hospital is essential so that the aide can communicate with physicians in case of an emergency. Periodic visits by a physician and other health professionals are important in order to update the aide's training and to replenish his supplies.

Prior to relocation, all persons should receive physical examinations, necessary immunizations, and have their individual health records prepared or updated.

Should radiation sickness cases develop, is the Majoro Hospital (or Kwaplain Base) prepared to treat them?

In addition, the statement indicates that two small dispensaries (2 room-2 bed) with health aid quarters will be located on Enjebi and Enewetak. However, it is also stated on page 7-10 that "Since development of the Master Plan, it has been shown that it is impractical to...develop Enjebi until such time as it can be shown to be safe." Will the dispensary serving Enewetak be enlarged to adequately care for the people, and/or will an additional dispensary be located in the southern quadrant? In general, much more attention needs to be given to addressing the provision of health services, particularly long-term requirements of the population of the Atoll.

7.2.5 Utilities

With regard to water supply, the statement indicates rain catchment-cistern utilization as the primary potable water source. The statement also projects potential curtailed water availability at the end of the "dry season". The inventory of Atoll resources includes a 43,000 gal/day distillation plant which may be put to limited use. Could this resource be made available for use to augment the Atoll's potable water supply? Further, the use of brackish wells as a limited water source is suggested in the statement.

The feasibility of using ion-exchange, reverse osmosis or other presently available techniques should be investigated for water supply augmentation.

The housing and community development plans project the use of privie-septic tank-drain field installation for disposal of domestic wastes. While placement of such installations will be carefully considered, the possibility exists that effluents may enter the usable water table, posing potential for contamination of the existing water lens. Therefore, we suggest that a definitive sanitation program be implemented for continued monitoring of the usable water supplies and maintenance of disposal installations. A recently developed small scale aerobic digestion unit may be a possible alternative to the septic-drain field concept. We recommend that the feasibility of utilizing this concept be studied.

With regard to 7.2.4 and 7.2.5 mentioned above, the Health, Sanitation, Education, and Social Service section of the 1973 HEW/Interior Task Force Report on the Trust Territory of the Pacific Islands should prove a useful reference item.

8.6 Impact of Base Camp Sewage Disposal on Human Health

Sewage outfall lines would best be located to flow into ocean waters rather than the lagoon, because of the possibility of disease transmission through consumption of raw or partially cooked shellfish or other marine organisms contained by partially treated raw sewage. The assumption that raw sewage will be flushed out of the lagoon by ocean currents is apparently based on speculation and observations of the dispelling of solid wastes from the lagoon by this method. Isolations of pathogenic organisms from similar lagoons in the Trust Territory suggest that these waters may become contaiminated even under low volume dumping.

8.11 Impact of Pesticides in Base Camp on Human Health

It is stated that chlorinated hydrocarbons will not be used for pesticide control, but organic phosphates would be used only in the required quantities. The concerns seem to be focused on the environmental residuals. However, some concern should also be focused on the toxic effects to the workers applying the pesticides and to people in the general area. EPA, NIOSH, and USDA are establishing some feasible standards and/or work practices for persons using pesticides.

8.16 Impact of Blasting During Cleanup - Human Health

The draft statement indicates that all kinds of shellfish may be consumed by the people populating the islands. It appears the best shellfish growing site in the lagoon is the blast area. Because shellfish tend to concentrate pollutants, including radionuclides, we believe extensive sampling and testing (for fission and activation products) should be undertaken before any shellfish growing areas are harvested.

8.22 Impact of Toxic Materials Encountered During Cleanup

We note that beryllium contaminated materials will be disposed of along with the radioactive material. However, no mention is made concerning the safeguards needed for the workers conducting the cleanup. Occupational health experience dictates that some degree of expertise is needed in controlling the exposure of workers to beryllium. NIOSH has put out a criteria document which deals in part with control of worker exposure to beryllium and the USAF has had extensive experience with decontamination of buildings where beryllium was being machined.

8.26 Impact of Noise During Rehabilitation and Resettlement

We found no mention in the draft statement concerning the impact of noise levels effecting workers and people on the Atoll during the rehabilitation and resettlement activities.

Summary

Based on information contained in the draft statement, Ujeland has a total land area of 429 acres and Enewetak 1760 acres. Enjebi has a land area of 290 acres. The islands of Enewetak, Medren, and Japtan have areas of 322, 220, and 79 acres respectively for a total 611 acres. This latter area would appear to be ample and certainly an improvement over the current conditions on Ujeland for the resident areas for all of the Enewetakese. The southern islands which have very low residual radioactivity have a total area of 804.68 acres. This makes an additional 193 acres available over and above the resident islands acreage which could be devoted to unrestricted agriculture use. In addition, there are 524.31 acres in the northern islands which have intermediate levels of residual radioactivity that are judged to be suitable for raising coconuts.

Based on all of these considerations, it appears that from a cost-benefit standpoint the use of Case 3 would be the optimum solution to the question of resettling the Enewetakese. On the other hand, if the driEnjebi would be extremely dissatisfied under these conditions, political and social indications may be such that they should be allowed to resettle on Enjebi, thus necessitating the use of Case 4. In this instance, the annual dose to individuals would exceed the AEC limits, but would be below those set by the FRC (whole body 0.35 rem/year vs. 0.5; bone 0.975 rem/year vs. 1.5; and bone marrow 0.3 rem/year vs. 0.5). It would leave a residual of approximately 140,000 cubic yards of contaminated soil and/or soil and radioactive debris to be disposed of other than that which could be achieved through crater dumping or crater containment. It would very likely require indefinite storage of soil on the island of Runit until suitable methods of disposal could be developed and agreed upon.

If the technique of crater containment is finally judged to be feasible, it should provide a reasonable degree of protection from the stored radioactive materials. One then might consider utilizing an additional crater to contain the residue of radioactive scrap and soil as mentioned above. This would require a cube approximately 73 feet on a side and 73 feet deep. With the apparent relative insolubility of the residual plutonium and fission products in this material, relatively small leaks into and out of a structure of this sort as well as that from sealed craters would appear to present a minimal hazard.

Thank you for the opportunity to review this draft statement.

Sincerely,

Charles Custard

Charles Custard
Director
Office of Environmental Affairs

DEPARTMENT OF TRANSPORTATION
UNITED STATES COAST GUARD

MAILING ADDRESS: (G-WS/73)
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1 9 DEC 1974

Director
Defense Nuclear Agency
Washington, D. C. 20305

Dear Sir:

This is in response to your letter dated 3 September 1974 addressed to Office of Marine Environment and Systems U. S. Coast Guard.

The concerned operating administrations and staff of the Department of Transportation have reviewed the material submitted. The Coast Guard commented as follows:

"The U. S. Coast Guard will be required to maintain a LORAN Station on Eniwetok Island until at least 31 December 1977. The DNA contractor is currently providing the Coast Guard with sleeping quarters, all meals medical services, electrical power, communications services, fuel and vehicles. Should any or all of these services be terminated, it will be necessary for the Coast Guard to replace them with some probable adverse impacts on the environment. Among these impacts will be:

(1) An increase in personnel assigned from 10 to approximately 16 to 20.

(2) Construction of sleeping quarters with cooking and dining facilities.

(3) Installation of diesel powered generators and fuel tanks with 180,000 gallon capacity. Enlargement of the present power building will also be required.

(4) Installation of additional communication equipment and associated antennas.

While these are contingency items and their environmental effect would be small in comparison with the overall project, they should be addressed in the final EIS. Mention of the LORAN Station should be made in the 'Enewetak' (Eniwetok) section, page 15 of the summary, and appropriately in the text of the EIS.

"The basis for calling the atoll and the island 'Enewetak' vice 'Eniwetok' should be reviewed.

"In the summary, the third sentence of 'Phase 3 - Resettlement' on page 3 contains a phrase 'that the living patterns of the people conform to the limitations recommended....' Out of context this phrase could be offensive, i.e., natives are being asked to change their culture to adapt to recommendations of the American Government. It is recommended that the phrase be reworded to avoid any 'Ugly American' connotation.

"The elements of sewage disposal and ocean/lagoon water quality should appropriately be commented on by the EPA. (NPDES)

"Section 8-23, DEIS text, states 'standard radiological safety procedures will be practiced during the cleanup operation.' Undoubtedly AEC will govern this aspect. It should be mentioned in this section, however, that the transportation of radioactive material by vessel, such as to a remote disposal site, will be so accomplished in compliance with current regulations (46 CFR 146.19).

"In a telephone conversation on 12 December 1974 between Mr. M. E. Stevens of your office and Commander L. Y. Wald of my office, the impact of the termination of the contract was further discussed. The point of the discussion was that it should be emphasized that a possible two year lead time would be required to obtain the equipment necessary to duplicate the services now being supplied by contract. It is the Coast Guard's grave concern that should the services to the Loran Station on Eniwetok Island be terminated, the outage of this station would affect the entire Pacific Ocean Loran net."

The Department of Transportation has no other comments to offer. The final environmental impact statement, however, should address the concern of the Coast Guard.

The opportunity to review this draft statement is appreciated.

Sincerely,

W. E. Caldwell

W. E. CALDWELL
Captain, U. S. Coast Guard
Acting Chief, Office of Marine
Environment and Systems

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

DEC 9 1974

Warren D. Johnson
Lieutenant General, USAF
Director
Defense Nuclear Agency
Washington, D. C. 20305

Dear General Johnson:

This is in response to your letter of September 3, 1974, transmitting to the U. S. Atomic Energy Commission (AEC) the Draft Environmental Impact Statement (DEIS) prepared under supervision of the Defense Nuclear Agency (DNA) for the proposed cleanup, rehabilitation, and resettlement of Enewetak Atoll.

We have reviewed the Statement and are providing the following comments, and the enclosure of supporting comments for your consideration in preparing the Final Statement for this proposed action:

In general, the DEIS reflects a careful and thorough study of the possible cleanup of Enewetak Atoll and the future return of the people. We agree that the Case 3 approach, as presented in the DEIS, should be the preferred option for the cleanup project. This approach is based on successful past experience, appears to be feasible, and ensures the health and safety of the people insofar as practicable. Further, the quantity of material requiring disposal is more manageable than in Cases 4 and 5, and the residual levels of contamination would not appear to be hazardous judging from present knowledge of contaminated levels in soils.

The presentation of the AEC radiation exposure criteria is satisfactory; however, the term "standards," as used throughout the DEIS is inaccurate to describe the AEC criteria and should be replaced by the word "guidelines." While these radiological criteria are based upon current national and international standards (see AEC Task Group Report, Volume II, Appendix B) we view them only as guides for the Enewetak cleanup project. The AEC Task Group report clearly indicates that _ad hoc_ guidelines, derived from the existing recognized standards, were required and formulated for the particular conditions existing at Enewetak Atoll and because future human habitation was planned for there. We further note that the plutonium guideline numbers, while having no particular scientific basis for establishing a standard, appear to be reasonable for the particular conditions existing at Enewetak Atoll.

Dose estimates for use in the Section 5 matrix presentation (Volume I) should be those provided in the AEC Task Group report, not the estimates in NV-140 or estimates derived from equations presented in NV-140. The Task Group report presents estimates of maximum annual exposures for individuals considering the most sensitive members of the population, and estimates of 30-year exposures for population groups living in various parts of the Atoll. The NV-140 survey report does not contain all of these estimates. It is recommended that Tables 5-11, 5-12, and 5-13 be deleted, that Sections 5.6.1.1, 5.6.1.2 and 5.6.1.3 and Tables 5-8, 5-9 and 5-10 be revised using information from the Task Group report (Appendix IV, Section B, Volume II). It is also recommended that doses for bone marrow, not bone, be used in all tables presenting maximum annual marrow criteria, and that AEC estimates of 30 year and maximum annual doses for Belle, the island having the highest predicted doses, be used for Case 1 wherever this appears instead of exposure estimates for an average individual for the entire Atoll. Estimates of exposures averaged over the entire Atoll are not meaningful and should be deleted. Further detailed discussions on these points are presented in the enclosure.

With regard to Section 5.3.1 on biological risk, the BEIR report estimates represent upper limits of risk. The risk at low dose rates may be zero. (See paragraph IV, page 88, of the BEIR report.) It is recommended that estimates of risk in Table 5-14 be presented as upper limits and a footnote added indicating that at low dose rates the risk may be zero. The risk estimates should be recalculated to account for revisions needed for estimates presented in Table 5-8 in calculation of 30-year dose. Further, based upon the suggested revisions for the 30-year and maximum annual dose estimates, a revision of Table 5-16 is in order to reflect these changes.

The arguments presented in the statement opposing ocean dumping of contaminated wastes are in our opinion weak and unconvincing. The "difficulty of obtaining a permit and certainty of international complications," whether true or not, are insufficient grounds for rejecting ocean dumping as a viable waste disposal option. We note that the International Atomic Energy Agency (IAEA) Board of Governors' document, GOV/1688, of August 7, 1974, discusses in draft form the provisional definitions and recommendations concerning radioactive wastes ocean dumping. This document is in relationship to the responsibilities entrusted to IAEA under the Convention on the Prevention of Marine Pollution by Dumping of Waste and Other Matter. For Case 3 in the

DEIS, even if one assumed that 79,000 cubic yards of Atoll soil containing an average of 1 nCi/gm of Pu^{239} were dumped into the ocean, it would represent only about 75 Ci for this one time action. This is far below the upper disposal limit of 10^{10} Ci/year for alpha wastes (based on Pu^{239}) in GOV/1688.

Without necessarily advocating ocean dumping, we note that it is considered by some to be the best solution to this problem and one of the least costly. Indeed, the ocean water already has a certain access to the plutonium in Enewetak Atoll and disposal in the deep ocean would only represent removal of the plutonium to a safer marine location which, because of its remoteness, would minimize the chance of human exposure. We therefore recommend that the pertinent sections on the DEIS be rewritten to leave the ocean dumping option open. Furthermore, we believe that return of this debris to the United States for burial would be unacceptable and that burial on an island in a concrete-capped crater would require periodic followup that for practical purposes would last forever. Specific comments related to ocean dumping and encryptment are included in the enclosed Staff Comments.

In the discussion of the "Impact of Blasting During Cleanup" (Section 8.16) it is not clear whether these blasting operations will open new channels that would pass completely through the reef from lagoon to ocean. If this is in fact planned, we would object in principle and would need to see much more information on the expected impact of new openings in the reef on the ecology of the Atoll.

As a matter of policy beyond the scope of this Statement, we recommend that the last sentence (lines 18-20) on page 5-35 of the fourth recommended study be deleted, since it is not germane for any environmental statement to address detailed responsibilities of other agencies which have not been formally agreed upon.

There appears to be some misunderstanding regarding Storage on Runit (Sections 5.5.2.5, page 5-48). As presented in the DEIS, it is indicated that as an intermediate step, contaminated soil will be stored on Runit pending a study and recommendation by AEC as to its ultimate disposal. AEC is not committed to provide any additional recommendation on the ultimate disposal of the contaminated soil. The disposal of debris is a DNA responsibility. The only open question is whether or not it may be feasible to reduce to some degree the amount of contaminated material to be disposed by removing some of the plutonium from the soil. Whether such reduction is economically sound would depend on the final disposal method and its associated cost. Should deep ocean burial be the chosen method, the removal of plutonium from the soil would not be a cost effective action. In recognition of the above points, DNA should plan its cleanup and disposal actions as if no additional guidance from AEC may be forthcoming. Any results of a further AEC study to determine the possibility of reducing the volume of plutonium-contaminated material should be viewed as an added benefit.

Our discussions with staff of the Department of the Interior during the September 1974 visit to Enewetak Atoll indicated that a group of people from Ujelang Atoll will be allowed to return to Japtan Island before cleanup operations begin. In a July 18, 1974 letter to the Department of the Interior, AEC presented its views on the safety aspects of any proposed early return of people to Japtan. We view an early return as a significant step that should be treated in the DEIS.

Sincerely,

James L. Liverman

James L. Liverman
Assistant General Manager for
Biomedical and Environmental
Research and Safety Programs

Enclosure:
Staff Report

cc: Council on Environmental Quality, w/encl. (5)

Supporting AEC Comments on the Defense Nuclear Agency
Draft Environmental Impact Statement on the
Clean-up, Rehabilitation, Resettlement of
Enewetak Atoll - Marshall Islands

1. Dose Estimates

A severe deficiency in the DEIS concerns the dose estimates presented in matrix form in Tables 5-8, 5-9, 5-10, 5-12, 5-13, and 5-16 and the associated material in Sections 5.6.1.1, 5.6.1.2 and 5.6.1.3. The following estimates of radiation dose and an evaluation of these estimates using the recommended radiation criteria were provided in the AEC Task Group report:

30-year whole body dose (for a population living in various parts of the Atoll).

30-year bone dose (mineral bone).

Maximum annual whole body dose (considering the most sensitive individual).

Maximum annual bone marrow dose (considering the most sensitive individual).

These estimates appear in Section B, Volume II of the DEIS. We have anticipated that the dose most likely to be exceeded at Enewetak is the annual dose to bone marrow. Thus, bone marrow dose for the most sensitive individuals in the population is the critical dose for comparison with cleanup radiological criteria. Estimates of bone marrow dose were developed during Task Group deliberations and do not appear in NV-140.

The AEC Task Group rejected the concept of averaging annual doses over the entire Atoll or over the entire population. This is of particular importance for the case where it was assumed that there was no clean-up with islands used for permanent residence without regard to radiation and radioactivity levels (Case 1). The DEIS matrix presents no information on annual bone marrow doses, presents doses for an "average individual on entire Atoll" for some clean-up options (cases) and presents maximum annual values for bone that were calculated using an equation in NV-140 that is considered adequate only for determining 30-year doses. (Other models are now used in calculating maximum annual doses to bone and bone marrow that accommodate important changes that occur with time and with age of the individual.) The following examples show reasons why we cannot agree with the DEIS presentation of doses in Section 5, "Cleanup and Habitation Alternatives," unless the presentation is appropriately modified.

Table 5-8, page 5-50

DEIS Case 1	WB= 6 Rem in 30 years Bone= 60 Rem in 30 years

These were determined for an average individual in the entire Atoll.

AEC Case 1	WB= 31 Rem in 30 years Bone= 220 Rem in 30 years

See AEC estimates for a population living on Belle, Section B, Volume II, pages 32-33, current condition, living pattern F. This example shows that important features of the radiological picture at Enewetak can be missed if dose estimates are averaged over the entire Atoll.

Table 5-9, page 5-51

DEIS Case 1 WB= 0.3 Rem in one year
Bone= 2 Rem in one year (mineral bone)

These were determined for an average individual in the Atoll.

AEC Case 1 WB= 1.6 Rem in one year
Bone marrow= 2 Rem in one year

See data for an individual on Belle, Section B, Volume II, pages 34-35, current condition, living pattern F. The significance of a bone marrow dose as high as the bone dose is that, traditionally, the standard for bone marrow is one third that for bone.

Table 5-10, page 5-53

Annual dose for an average individual for the entire Atoll should not be used to develop ratios to indicate comparisions with AEC annual dose criteria. There are several problems with this approach. First, use of estimates for an average individual ignores the fact that children are thought to be more sensitive to radiation injury than adults. Maximum annual doses presented in the Task Group report for use in the DEIS were derived through consideration of doses to the fetus and newborn, as well as to adults. Treatment of this important consideration seems to be missing in the DEIS except in material provided in the Appendix. Second, there are no standards for doses to an average individual for a geographical area containing a wide range of dose rates. The nearest category of Federal recommendations are guides for a population group where annual average doses are to be determined giving due consideration to the most sensitive members. By way of comparison, basic dose guides for such a group would be one-third of the guides for the individual. AEC criteria for annual exposures apply only to exposures of individuals using the condition specified by the Federal Radiation Council, namely, that this may be used when there is a sufficient level of radiological monitoring that exposures, including those of the most sensitive individuals, will be known. AEC criteria for exposures at Enewetak do not apply to an average individual on the entire Atoll or to a population group within which there would be a wide range of doses that make up the average.

Tables 5-11, 5-12 and 5-13, pages 5-54, 5-57, and 5-59

We have not subscribed in the past to an approach that considers as alternatives, clean-up of islands to various external radiation isopleths such as F or K as defined by the EG&G aerial survey. Such an approach is deficient in that it does not adequately treat the reduction, if any, of the more significant exposures that are expected to occur from internal emitters coming through the food chain for crops grown on the islands. Sections 5.6.1.1 and 5.6.1.2 and tables 5-11 and 5-12 are not consistent with the Task Group report.

2. Debris and Soil Disposal

Four other alternatives are mentioned, consisting of crater dumping (5.5.2.2), crater containment (5.5.2.3), return to the continental United States (5.5.2.4), and storage on Runit (5.5.2.5). Although a few advantages and disadvantages are mentioned for some of these alternatives, the specific environmental impacts of each are not discussed nor can the reader find which alternatives are proposed for which wastes.

In the section on returning radioactive debris to the continental U.S. (5.5.2.4), Richland, Washington is cited as an example of "one of the low-grade disposal areas in the western part of the United States." There are two radioactive waste burial areas which can be identified as being near Richland, Washington. One is operated by the AEC and ordinarily does not compete with private industry by accepting offsite-generated waste, either from private firms or from other Federal activities. The other is operated by a private firm which could or could not accept such wastes.

The statement that ocean dumping was rejected (5.5.2.1) is in contradiction to the later statement that "Pu contaminated surface soils would be removed from five islands and disposed of at sea" (first indented item, page 11-1). The quantities of radioactivity to be disposed of are not quantified, nor is the environmental impact discussed, in the remaining text of Section 11 (irreversible or irretrievable commitments of resources). Sea dumping is not mentioned in the description of the "proposed (preferred) cleanup operation" (Section 6) nor the discussion of adverse environmental impacts which cannot be avoided (Section 9). Radioactive sea dumping is not discussed in the section on environmental impacts, which is a conspicuous omission since Section 8.18 discusses the impact of dumping noncontaminated materials at sea.

Section 6.2.3 discusses the placement of plutonium-contaminated soil and scrap within a concrete matrix in LaCrosse crater. Section 8.19.1 states "maintenance of the crypt is a continuing problem" in referring to this plan, but neither section gives an indication of intent as to the responsibility for long-term surveillance and maintenance of this rather special case of transuranium waste storage.

The proposed method of disposal of Pu contaminated scrap and soil assumes that LaCrosse crater can be pumped out. Has it been clearly established that this can be done? The reef is often porous and cracks may have been caused by the detonation. We would suggest that DNA should consider whether the craters can and/or need to be pumped out for this particular option.

Page 2-1, Lines 14-15 - Should also include the fact that removal and disposal of plutonium-bearing soil in the 40-400 picocuries per gram range will be decided on a case-by-case basis. Suggest also include the following change: "Removal and disposal of plutonium-bearing soil which exceeds 400 picocuries per gram at all locations and 40 picocuries per gram on islands where housing may someday be located.

Page 2-2, lines 9-10 - the conclusion that plutonium debris will be encrypted in the LaCrosse crater seems premature at this point in the DEIS. Recommend deletion of this sentence.

Page 6-4, lines 10-11 - Recommend substitution of the words "appropriate disposal" in place of entombment with the radioactive scrap in LaCrosse center" and recommend deletion of the rest of the page. The text, as written, assumes that the entombment disposal action will be adopted.

Page 6-8, lines 10-11 - Recommend substitution of the words "and stored for eventual disposal" in place of "encapsulated in concrete in one or both of the craters on Runit."

Pages 8-29 and 8-30, Sections 8.18 and 8.19. Recommend that the ocean dumping option be left open as another possibility for disposal.

Page 11-1, lines 4-5. In referring to disposal at sea, this sentence is inconsistent with previous discussions in the DEIS concerning Pu contamination disposal. However, recommend that this ocean dumping option be retained as a possibility for disposal.

3. Miscellaneous Remarks

Page 3-10, last line on page - Delete the word "light."

Page 3-12, 6th line from the top - Delete "of water."

Page 3-15, Section 3.2.5, line 10 - Change "devastaged" to "devastated."

Page 3-44, 1st line - Change "life" to "live."

Page 3-46, Section 3.3.4.2, line 10 - Change "Engebi" to Enjebi."

Page 3-49, Section 3.5.1, 3rd paragraph - Change "patrilineal" to "ideally matrilineal" as per Tobin's paper "Land Tenure in the Marshall Islands, 1956." Essentially the iroij power comes from land holdings and land is owned by the women.

Page 3-52, Section 3.5.3, line 11 - Change "as island" to "an island."

Page 3-57, 2nd paragraph, line 3 - Change "Enewakese" to "Enewetakese," or better yet "people."

Page 3-62, last sentence in Section 3.8.1.1.1 and 3.8.1.1.2 - Breadfruit should be included with pandanus. (This would be consistent with the statement in NVO-140, that in predicting ^{137}Cs and ^{90}Sr concentrations in breadfruit, it is assumed that breadfruit and pandanus fruit will experience the same uptake from soil.)

Page 3-63, Section 3.8.1.1.3, lines 1, 2 and 3 - This sentence should be changed to reflect the lack of completeness of conclusive data on this subject. Change to, "The available data indicates that the body's uptake and retention of Pu through the gastrointestinal tract is a small percentage of the Pu ingested. This pathway is therefore less significant than other potential means of ingress to the body."

Page 3-63, Section 3.8.1.2, last sentence: As presented the statement is not correct. Sentence should read: After 15 years of wind action on Enewetak Atoll, much of the dispersion of surface contamination has already occurred. Further significant redistribution due to wind action seems unlikely, although test related radioactivity is found in surface air at detectable levels. The dust raised by resident activities is expected to increase airborne concentrations with further redistribution of the radioactivity."

Page 3-84, Section 3.8.2 - The fourth sentence indicates that all the Be has been removed, but the sixth sentence indicates that there is still some Be that needs to be cleaned up. Suggest the paragraph be consistent.

Page 5-3, line 1 - Change "as" to "has."

Page 5-13, Option 2 - This should be clarified since it does not appear consistent with Table 5-6 in that it states "... may use food grown on Enjebi other than pandanus and breadfruit." Whereas table indicates these are the two that can be grown on Enjebi with the appropriate restrictions.

Page 5-21/5-22, Section 5.4.1.1, first line - Change "islanders" to "people of Enewetak" or "Enewetak people."

Page 5-25, Section 5.4.2.2 - This doesn't agree with Figure 5-2 in that 5.4.2.2 implies that the southern islands are Jinedrol through Kidrenen and limits inter-island visitation, agriculture, as well as collection of birds and eggs to these islands whereas the figure extends the allowable islands for these activities to include Boko, Munjor, Inedral, and Van, all of which are north of Jinedrol.

Page 5-32 and 5-33 - Figure 5-3 is not consistent with text for Case 3 in that: Text states that residence would be restricted to Jinedrol through Kidrenen yet the figure shows Boko, Munjor, Inedral and Van also as living islands; both the figure (which show Enjebi as only a picnic island) and text (page 5-34) agree that there will be no cultivation on Enjebi yet the case summary on figure 5-3 shows "subsistance agriculture limited to southern islands plus Enjebi." It it is not clear what islands are included in the "southern islands."

Page 5-40, Section 5.4.4.3 - Change "does" to "dose."

Page 5-45, Section 5.4.5.3, next to last line - "solid replacement" should be "soil replacement."

Page 5-47, Section 5.5.2.1 - This section should be revised and updated to show that the possibility of ocean dumping is again being discussed.

Page 5-78, paragraph 2.h. - "pvoide" should be "provide."

UNITED STATES
ATOMIC ENERGY COMMISSION
WASHINGTON, D.C. 20545

December 23, 1974

Warren D. Johnson
Lieutenant General, USAF
Director
Defense Nuclear Agency
Washington, D. C. 20305

Dear General Johnson:

Please refer to my letter of December 9, 1974, transmitting AEC comments on the Draft Environmental Impact Statement for Clean Up, Rehabilitation, Resettlement of Enewetak Atoll - Marshall Islands.

It is requested that our comments be revised to include the following additional information:

During the last 8 years the Nuclear Energy Agency (NEA), formerly the European Nuclear Energy Agency (ENEA), has managed an ocean disposal program for radioactive wastes from the member countries. The following, by years, is a listing of the curies (Ci) of alpha activity in the materials so disposed. The alpha activity is assumed to be Pu 239.

1974 - 416	1970 - 233
1973 - 773	1969 - 390
1972 - 674	1968 - 721
1971 - 324	1967 - 92
	Total 3633 Ci - alpha

Other operations from 1949 to 1967, such as U.S. and U.K., disposed of wastes containing similar quantities of long-lived alpha active materials. Thus, a total of at least 7,000 alpha Ci have been disposed of into the ocean. If we assume 15 grams of Pu per Ci alpha activity, the total is at least 100 kilograms of Pu. Thus, it is evident the disposal of a few hundred grams of Pu from Enewetak Atoll would not materially add to the alpha activity already disposed in the deep ocean.

cc: H&N,Mr. Woolfenden) - 1/8/75
AFRRI, Mr. Slaback)

Reference is also made to paragraph 2, section 2, page 3, of the supporting AEC comments. Please delete the final sentence of that paragraph and replace with the following:

> The other is operated by a private firm licensed by the State of Washington. Under proposed regulations, this latter burial ground may not be permitted to accept plutonium-contaminated waste.

Sincerely,

James L. Liverman

James L. Liverman
Assistant General Manager
for Biomedical & Environmental
Research & Safety Programs

OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D. C. 20301

HEALTH AND ENVIRONMENT

13 Nov 1974

MEMORANDUM FOR Director, Defense Nuclear Agency

SUBJECT: DEIS, "Clean-Up, Rehabilitation, Resettlement of Eniwetok Atoll-Marshall Islands"

The Draft Environmental Impact Statement for the Clean-up of Eniwetok Atoll has been reviewed and is generally found to be satisfactory. The following items should be addressed to provide a more complete understanding of the program:

1. The estimated time frame of the various phases of the operation noted on pages 2 and 3 of the summary should be specified, especially the anticipated completion of phases 3 and 4 since this is a question of vital importance to the people concerned.

2. The relative hazard level to personnel relocated to the islands compared with presently accepted AEC standards for human health should be tabulated rather than the generalizations presented in the summary.

3. Some controls on movement of the relocated personnel must be established. There is no question that some personnel will test the system and attempt to visit or even settle on some of the forbidden northern islands. Since the hazard is a long-term phenomena and no immediate consequences of such an action would be evident, a comprehensive education program to insure that the relocated personnel understand the hazard and the consequences of such visits is a necessity.

4. A long-term continuous monitoring program of the conditions at all locations is believed to be a firm requirement until all hazard is removed.

5. Assuming more adequate disposal techniques become available in the future, consideration should be provided for implementation of such methods at some future date rather than permanent entombment on Runit.

John P. Meade

John P. Meade
Lt Colonel, USAF BSC
Director for
Categorical Programs

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
100 CALIFORNIA STREET
SAN FRANCISCO, CALIFORNIA 94111

DEC 12 1974

Warren D. Johnson, Director
Defense Nuclear Agency
Washington, D.C.

Dear Mr. Johnson:

The Environmental Protection Agency has received and reviewed the draft environmental statement for the following proposed action, Clean Up, Rehabilitation, Resettlement of Enewetak Atoll, Marshall Islands.

EPA's comments on the draft environmental statement have been classified as Category ER-2, specifically environmental reservations pending the resolution of comments noted in the attachment to this letter. Definitions of the categories are provided on the enclosure. The classification and the date of EPA's comments will be published in the Federal Register in accordance with our responsibility to inform the public of our views on proposed Federal actions under Section 309 of the Clean Air Act. Our procedure is to categorize our comments on both the environmental consequences of the proposed action and the adequacy of the environmental statement.

EPA appreciates the opportunity to comment on this draft environmental statement and requests one copy of the final environmental statement when available.

Sincerely,

Paul De Falco, Jr.
Regional Administrator

Enclosure

cc: Council on Environmental Quality, Wash., DC 20460

COMMENTS ON DRAFT EIS

CLEAN-UP, REHABILITATION, RESETTLEMENT

OF ENEWETAK ATOLL - MARSHALL ISLANDS

The analysis of this proposed action is divided into two sections: (1) Radiological Aspects; and (2) Other Environmental Aspects.

Radiological Aspects

Current Sampling Needs

A great amount of sampling and analysis has been done and the magnitude of the radioactive contamination has been relatively well defined. However, there are two areas in which more information is needed to aid in decision making:

(a) The water quality of the brackish water lens needs to be determined for those islands to be inhabited before a decision is made to use the water. Radiological, bacteriological, and chemical quality should be determined for a period of at least 12 months.

(b) Airborne radioactivity, especially plutonium, needs to be determined over a period of at least a year on all islands to be inhabited and on other heavily contaminated islands after chean-up and before lifting of quarantine. Due to the large amount of plutonium on the atoll and the uncertainties in predicting resuspension factors it is very important that the actual conditions be determined rather than calculated.

It is surprising that uranium isotopes were not detectable in air filter samples. Were analysis made for uranium?

Future Sampling

It is apparent (and recognized in the Draft EIS) that regular monitoring will be necessary for many years after resettlement and should include air, water, food, and body burdens of the Enewetakese. This requires some agency to accept the responsibility and obtain the funding for this necessary follow through.

Recommended Clean-Up and Disposal Plan

It is agreed that soil significantly contaminated with plutonium should be removed from islands in the atoll. EPA (letter of May 17, 1974) has previously accepted, in general, the radiation protection criteria and clean-up criteria prepared by AEC. However, these criteria should be considered as upper limits and the clean-up levels and population doses should be maintained as low as practicable. The Draft EIS appears to recognize this concept but there is uncertainty on how it is to be applied. For example, the Statement is vague on when a 40 pCi/gm limit will be applicable and when 400 pCi/gm will be satisfactory. This uncertainty should be clarified in the Final EIS.

The choice of crater entombment for disposal of contaminated soil appears to be the most feasible alternative and provides some degree of retrievability. The fact that this is only a semi-permanent solution should be recognized. Several other points that should be addressed in the Final EIS are: (1) more discussion on the technical advantages and disadvantages of ocean disposal rather than a rejection based on purely legal and international difficulties; (2) the remedial action that will be taken if the volume of Cactus and La Crosse craters is insufficient to contain all the contaminated soil; and (3) the action that will be taken if the Enewetakese reject the entombment option.

Recommended Rehabilitation and Resettlement Plan

The recommendation that habitation be limited to the Southern Islands is sound and the Statement quite properly does not promise an early end to restrictions on use of the Northern Islands. However, there are several aspects of the plan that have not been adequately explained.

The decision to permit subsistence coconut production on the northeastern islands is not justified in the EIS. Virtually all of the predicted dose received by the Enewetakese under the proposed plan is due to this decision. When using an "As Low as Practicable" concept a dose should be accepted only if it cannot be avoided by practicable means, regardless of whether the total dose is still under the RCG being used. This use should be deferred unless it can be shown that there is no practicable alternative to providing an adequate diet or that radionuclide contamination is actually much lower than predicted.

The possible marketing of copra produced on the atoll needs to be evaluated in an "As Low as Practicable" context prior to decision making in order to determine if the economic benefits to the Enewetakese outweigh the radiological cost of the population dose delivered to off-island populations.

The total quantity of plutonium and strontium radionuclides estimated to be present in lagoon sediments are somewhat greater than are present on the islands of the atoll. Apparently, the majority of the contamination is in the northwest portion of the lagoon. The Draft EIS does not discuss the short and long range implications of this source, nor does it indicate whether any consideration was given to the feasibility of minimizing the future radiation dose that will be obtained from the seafood pathway.

There is no discussion of the decision to permit fishing in all of the lagoon. Apparently, this recommendation came from the conclusion on page II-43 that there was "no statistically significant difference for dose estimation purposes between samples taken in different parts of the lagoon." The data depicted in Figures 160-161 suggests that 137Cs, 90Sr, 239Pu concentrations in convict sturgeon may be somewhat higher near Belle and Irene, where bottom sediment concentrations are also highest.

The recommendation to ban coconut crab collection in the Northern Islands is perhaps prudent but was reached without actually sampling any crabs in that part of the atoll. Also, the possibility of this restriction being observed is uncertain because it is a delicacy, in short supply, and the islands would be open for picnicing and fishing.

Clean-Up Operation

We have no specific comments to make about this phase except to note that there will be significant possibilities for inhalation exposures to workers and transport of radioactive material from greater to lesser contaminated portions of the atoll. Constant health physics support will be needed.

Other Environmental Aspects

Sewage Disposal During Clean-Up

The proposed discharge of raw sewage is of serious concern to EPA. The Trust Territory standards of water quality do not permit raw sewage discharges into surface waters. Although the discharge may not be subject to TTPI jurisdiction, it would be inappropriate for a Federal agency to carry out a discharge contrary to TTPI policy. In addition, the raw sewage may result in public health hazards to any users of these waters.

It is possible that these crude sanitary facilities may continue to be used for years. The later stages of clean-up may well occur after many of the Enewetakese have returned. There is a possibility that some tourism will develop and the environmental statement mentions that these existing facilities could be used.

EPA recommends that some form of sewage treatment be provided for the wastewaters generated by the clean-up personnel and subsequent visitors to the atoll.

Garbage and Trash Disposal During Clean-Up

Garbage and trash residue should not be dumped off the end of the island for the same reasons noted above. Burial may be an appropriate method of disposal provided it does not interfer with the brackish water lens that may be used for water supply.

Water Supply and Waste Disposal

The plan to extensively use roof catchment with large cisterns at individual residences and community buildings is good. However, it is probable that supplemental supplies will be needed. Plans to use septic tank leach fields and to bury garbage must be evaluated with great care due to the potential to contaminate the brackish water lenses which may serve as the source of supplemental water supply.

The environmental statement should discuss this serious potential conflict and present evidence that wastewater and garbage disposition will not degrade the drinking water supply. The Department of Health Services, Environmental Health Division of the Trust Territories should have a fundamental role in deciding on the water supply and waste disposal systems that are selected.

Environmental Impact of the Action

LO--Lack of Objections

EPA has no objections to the proposed action as described in the draft impact statement; or suggests only minor changes in the proposed action.

ER--Environmental Reservations

EPA has reservations concerning the environmental effects of certain aspects of the proposed action. EPA believes that further study of suggested alternatives or modifications is required and has asked the originating Federal agency to reassess these aspects.

EU--Environmentally Unsatisfactory

EPA believes that the proposed action is unsatisfactory because of its potentially harmful effect on the environment. Furthermore, the Agency believes that the potential safeguards which might be utilized may not adequately protect the environment from hazards arising from this action. The Agency recommends that alternatives to the action be analyzed further (including the possibility of no action at all).

Adequacy of the Impact Statement

Category 1--Adequate

The draft impact statement adequately sets forth the environmental impact of the proposed project or action as well as alternatives reasonably available to the project or action.

Category 2--Insufficient Information

EPA believes that the draft impact statement does not contain sufficient information to assess fully the environmental impact of the proposed project or action. However, from the information submitted, the Agency is able to make a preliminary determination of the impact on the environment. EPA has requested that the originator provide the information that was not included in the draft statement.

Category 3--Inadequate

EPA believes that the draft impact statement does not adequately assess the environmental impact of the proposed project or action, or that the statement inadequately analyzes reasonably available alternatives. The Agency has requested more information and analysis concerning the potential environmental hazards and has asked that substantial revision be made to the impact statement.

If a draft impact statement is assigned a Category 3, no rating will be made of the project or action, since a basis does not generally exist on which to make such a determination.

SUMMARY SHEET
DRAFT ENVIRONMENTAL IMPACT STATEMENT FOR CLEANUP, REHABILITATION, AND RESETTLEMENT OF ENEWETAK ATOLL, MARSHALL ISLANDS

1. This is a Draft Environmental Impact Statement for the proposed cleanup, rehabilitation, and resettlement of Enewetak Atoll, the Marshall Islands. The statement is an administrative action in compliance with the National Environmental Policy Act (NEPA), (47USC4332).

2. This statement addresses a proposed project to remove and dispose of debris, structures, and soils which pose physical or radiation hazards or which pose obstructions to human habitation or the productive use of the land. The Department of Defense has been assigned responsibility to plan the cleanup phase of the proposed project. This statement also addresses the problem of the economic and social measures required to resettle the Enewetak people in the Atoll after 25-30 years of absence. The Department of the Interior, through the Trust Territory of the Pacific Islands, is responsible for this latter aspect of the proposed project.

3. During the post World War II period, the Atoll was used as a proving grounds for development testing of modern weapons and weapons systems, particularly nuclear weapons. This resulted in the relocation of the inhabitants from the Atoll, the creation of hazards, both physical and radiological, and the consequent loss of much of the productive capacity of the Atoll. The intent of this project is to remove or reduce those existing conditions which would be a bar to safe habitation of the Atoll and to return the Enewetak people to the Atoll. The effects of this proposed action are expected to be permanent settlement of the people in a safe and productive environment. As the population grows from approximately 400 at present, the problems associated with a growing population

on a small isolated land area may be expected to be magnified. The effects of the engineering operation to produce the results desired will of course create some adverse effects such as fish kill, loss of habitat for fauna, soil erosion and other like effects. These latter effects are expected to be minimal and temporary when compared to the overall improvement which will result.

4. The Engineering Survey Report prepared for the Defense Nuclear Agency and the Enewetak Radiological Survey (NVO-140) prepared by the Atomic Energy Commission are essentially are essentially condition surveys which show the hazardous debris and structures and the radiological conditions of the Atoll. From these two source documents and the AEC Task Group Report, as well as from a Master Plan for the resettlement of the Atoll prepared for the Trust Territory of the Pacific Islands, it is possible to visualize many alternatives which can be addressed in the evaluation of the many human, physical, and cost variables which are present. In order to obtain an overview of the many possible solutions, a tabulation of twelve illustrative solutions has been made. These involve three separate cleanup procedures for each of four different habitation control plans. The consequences of all these combinations are tabulated. Factors involved in structuring these solutions are radiological conditions, living patterns, physical hazards, and the disposal of hazardous and radioactive materials and scrap. The tabular analyses presented for these twelve particular solutions include possible radiation doses and cost-benefit comparisons. Based on this orientation, five solutions hereafter referred to as Cases 1 through 5, are selected for detailed discussion. Of these, two are considered to be the bounding outside limits but three are considered to illustrate the nature of the most likely solutions.

Case 3 is considered to be the most responsive to the human, physical, and cost parameters presented in the three most likely solutions.

The estimated radiological dose is well below the radiation protection standards and guides recommended by the AEC Task Group; all hazards resulting from past construction and testing are to be removed; the cost is below the midpoint between Cases 2 and 4.

5. Under the conditions of Case 3, the Enjebi People would not be able to return to their ancestral residence island of Enjebi at an early time. This would require both the Enjebi and Enewetak People to live on the land formerly occupied only by the Enewetak People. Thus for some period of time, as yet undetermined, there would be less land available for agriculture; therefore, some supplement to their diet by importing food may be needed.

6. The Draft Environment Impact Statement was made available to the Council on Environmental Quality, concerned federal agencies and the public on September 9, 1974.

Natural Resources Defense Council, Inc.

1710 N STREET, N.W.
WASHINGTON, D.C. 20036
202 783-5710

New York Office
36 WEST 44TH STREET
NEW YORK, N.Y. 10036
212 986-8310

West Coast Office
664 HAMILTON AVENUE
PALO ALTO, CALIF. 94301
415 327-1080

24 September 1974

TO: Lt. General Warren D. Johnson
Director
Defense Nuclear Agency

FROM: Dr. Thomas B. Cochran
Staff Scientist

RE: Draft Environmental Impact Statement -- Enewetak

ENCLOSURE: "Radiation Standards for Hot Particles," A. R. Tamplin and T. B. Cochran, NRDC, 14 February, 1974

1. NRDC finds the "Draft Environmental Impact Statement, Clean Up, Rehabilitation, Resettlement of Enewetak Atoll -- Marshall Islands," to be incomplete and inadequate. Furthermore, the proposed (preferred) clean up operation is totally inadequate to protect the health of the Enewetak people from exposure to hot particles of plutonium which carry a high risk of producing lung cancer. The basis for these conclusions is presented in the report, "Radiation Standards for Hot Particles," by Drs. Arthur R. Tamplin and myself (enclosure). This report is intended to be an integral part of these comments.

2. "Radiation Standards for Hot Particles," was written in support of a petition by the Natural Resources Defense Council to the Environmental Protection Agency and the Atomic Energy Commission requesting (1) a reduction of the existing radiation protection standards applicable to the internal exposure of man to insoluble alpha-emitting hot particles and (2) the establishment, with respect to such materials, of standards governing the maximum permissible concentrations in air and maximum permissible surface contamination levels in unrestricted areas.

3. The petition was filed with the AEC on February 14, 1974. It is totally irresponsible for the AEC Task Group on Recommendations for Clean Up and Rehabilitation of Enewetak Atoll to issue its report on June 19, 1974, without acknowledging the serious implications of hot particles as detailed in our report.

4. It is NRDC's position that the clean up of Enewetak should meet the standards summarized on pages 51-52 of our report (enclosure).

Document "Radiation Standards for Hot Particles" not included at this time but will be included in final distribution.

RADIATION STANDARDS FOR HOT PARTICLES

A REPORT ON THE INADEQUACY OF
EXISTING RADIATION PROTECTION STANDARDS
RELATED TO INTERNAL EXPOSURE OF MAN TO INSOLUBLE PARTICLES
OF PLUTONIUM AND OTHER ALPHA-EMITTING HOT PARTICLES.

FEBRUARY 14, 1974

ARTHUR R. TAMPLIN

THOMAS B. COCHRAN

Natural Resources Defense Council
1710 N Street, N.W.
Washington, D. C.
20036

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Glossary

I. Introduction

This report is written in support of a petition by the Natural Resources Defense Council to the Environmental Protection Agency (EPA) and the Atomic Energy Commission (AEC) requesting (1) a reduction of the existing radiation protection standards applicable to the internal exposure of man to insoluble alpha-emitting hot particles and (2) the establishment, with respect to such materials, of standards governing the maximum permissible concentrations in air and maximum permissible surface contamination levels in unrestricted areas.

Before proposing modifications to existing radiation protection standards related to plutonium exposure[1], we review in the following section the gravity of the public health concern as plutonium becomes a principal article of commerce in the nuclear power industry.

1/ While much of this report focuses narrowly on plutonium-239, the discussion is, nevertheless, germaine to all radionuclides in insoluble particles with a high specific activity. (The definition of specific activity and other technical terms in this report are given in the Glossary). The justification for focusing on plutonium has been aptly stated by the International Commission on Radiological Protection (ICRP): "the emphasis on plutonium is clearly a reflection of the general consensus that, in terms of amount available, projected usage, extent of anticipated accidental human exposure, and radiotoxicity, plutonium is the most formidable radionuclide in the periodic table." [ICRP Publication 19, "The Metabolism of Compounds of Plutonium and Other Actnides," Pergamon Press, 1972, p.l.]

This is followed in Section III by a review of the specific radiation protection regulations that are in force in the United States today and which are at issue. This section focuses on the existing guidelines for Pu-239, but it is to be understood that, in this and subsequent sections, it should be applied to all alpha-emitting radionuclides that meet the hot particle criteria developed in this report. Before reading Section III, those unfamiliar with the national and international organizations which have primary responsibility for recommending or establishing radiation protection standards, may find it useful to read Appendix A, where these organizations and their authority are reviewed.

Section IV presents assumptions inherent in the existing radiation protection standards and identifies those assumptions that are inappropriate when applied to insoluble alpha-emitting particulates. The biological data which demonstrate that these assumptions are inappropriate when applied to hot particles are discussed in Section V.

Utilizing the data presented in Section V, the criteria that define a hot particle are developed in Section VI. Recommendations for exposure standards for hot particles are then developed in Section VII and summarized in Section VIII.

II. Plutonium Use and Public Health

Plutonium occurs in nature, although in such small amounts that it does not constitute a practical source of the element[2]. Plutonium is bred in nuclear reactors by the capture of neutrons in uranium-238. To date, the nuclear weapons program has been the principal source of plutonium. However, it is anticipated that the commercial nuclear power industry will become the principal source of this material within the next two decades. In today's commercial reactors plutonium is produced as a by-product in the production of electricity.

As a result of the growth of the nuclear power industry, the AEC estimates that the total cumulative production of plutonium in the commercial sector of the United States will be some 4.5 million kilograms by the year 2000[3]. Since plutonium, like uranium, can serve as a reactor fuel, both are recovered from spent reactor fuel in anticipation that they will be recycled. The reactor together with the variety

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2/ The ratio of the concentrations of plutonium-239 to uranium in ores varies from 4×10^{-13} to 1.5×10^{-11}. Katz, J.J., Chapter VI, The Chemistry of Actinide Elements, Methuen and Co., Ltd., London, 1957, pp. 239-330.

3/ Environmental Statement, Liquid Metal Fast Breeder Reactor Demonstration Plant, USAEC, WASH-1509, April 1972, p. 149.

of support activities required both to provide raw fuel and to recover and recycle the uranium and plutonium make up what is known as the nuclear fuel cycle. The AEC has projected that over 4 million megawatts of nuclear capacity will be installed between 1970 and 2020[4]. Over the lifetimes of these plants this installed capacity could result in a cumulative flow of approximately 200 million kilograms of plutonium through the nuclear fuel cycle.

In today's commercial reactors the plutonium is in oxide form, PuO_2[5]. At various facilities in the nuclear fuel cycle, aerosols of PuO_2 are released to the environment on a routine basis. In addition, there are numerous points in the fuel cycle where accidents, particularly those associated with fire or explosions, can release significant amounts of PuO_2 as aerosols that can be inhaled by man.

These small aerosol particles of PuO_2 are highly radioactive. An appreciable fraction of the inhaled PuO_2 particles are trapped in the deep respiratory tissue of the lung, where, because they are insoluble in human tissue,

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4/ <u>Updated (1970) Cost-Benefit Analysis of the U. S. Breeder Reactor Program</u>, USAEC, WASH-1184, January 1972, p. 34. Four million megawatts (Mw) corresponds to 4000 nominal-size nuclear reactors -- 1000 Mw each.

5/ Some advanced reactors of the future may use fuel in carbide and nitride, rather than oxide, form.

they can remain for long periods of time and deliver a very intense radiation dose to the surrounding lung tissue.

Plutonium is one of the most potent cancer producing agents known to man. A machinist of plutonium metal carried 0.08 micrograms of plutonium-239 imbedded at the site of the puncture wound in the palm of his hand. Within the four year period before it was excized, it produced a nodule which displayed precancerous changes[6]. There is little doubt from experimental animal studies that inhaled plutonium is one of the most potent respiratory carcinogens known. There is experimental and observed evidence that plutonium concentrations in the lungs of dogs as low as 0.2 microcuries (3 micrograms of plutonium-239) produce cancer[7]. Hence, the flow of 200 million kilograms of plutonium represents a flow of over 10^{17} cancer doses, a staggering number which, as will be demonstrated subsequently, may be an underestimate of the cancer doses by several orders of magnitude.

The persistance of this toxic material, once lost to the environment, is measured in terms of thousands of years. Roughly two-thirds of the plutonium flowing in the nuclear

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6/ Lushbauch, C.C. and J. Langham, "A Dermal Lesion from Implanted Plutonium," Archives of Dermatology, 86, October 1962, pp. 121-124.

7/ There are 0.061 curies per gram of plutonium-239. Two-tenths of a microcurie of plutonium-238 would have a mass of only 0.01 micrograms since plutonium-238 has a much higher specific activity, 17.47 curies per gram.

fuel cycle will be plutonium-239 which has a 24,400 year half-life. In other words, in 240,000 years the inventory of this hazardous material would be reduced by only a factor of 1000 due to natural radioactive decay. This material must be isolated from the environment in perpetuity.

III. Existing Standards for Plutonium Exposure

Radiation exposure standards have been established because radiation is known to produce cancer and genetic mutations in individuals irradiated. The mutations can in turn cause genetic defects in subsequent generations. The intent of the exposure standards is to limit this biological damage. The magnitude of the biological effect has been shown to be related to the radiation dose. The higher the dose the greater the effect. Therefore, the primary radiation exposure standard is one that limits the radiation dose. This primary standard is generally referred to as the maximum permissible dose and is given in units of rem/yr. We shall discuss the nature of this unit subsequently.

An individual can be exposed to radiation from sources that are external to his body as, for example, an X-ray machine or from radionuclides which emit X-ray like radiation deposited on the ground (this occurred with fallout from nuclear weapon tests). Alternately, an individual can be irradiated by internal sources; that is, by radionuclides incorporated in body tissues. These radionuclides gain entrance into the body through inhalation or through contaminated food or water. Once inside they behave like their non-radioactive counterparts. Radioactive iodine, for example, accumulates in the thyroid gland in the same fashion as stable iodine, and radioactive strontium or calcium accumulate in the bone similar to their naturally occurring non-radioactive counterparts. The radioactive iodine will thus deliver a dosage to the thyroid gland that is many times larger than that to the other organs or to the whole body, and the radioactive strontium and calcium will mainly irradiate the bone.

Because of the uneven distribution of radionuclides in the body organs, radiation exposure standards have been developed not just for the whole body, but also for individual organs. In this report we will be referring to the maximum permissible whole body and lung doses.

Largely as a matter of convenience, secondary or derived radiation standards have been developed. These secondary standards, which limit radionuclide concentrations or organ burdens, are often more easily employed than the primary dose standards. We shall examine two secondary standards in this report; the maximum permissible lung burden (MPLB) and the maximum permissible concentration in air (MPC_a). The MPLB is the total amount of a given radionuclide in the lung of an average size man that will result in the lung being irradiated at the maximum permissible lung dose (MPLD). The MPC_a is the concentration in air that will result in an average adult male obtaining a MPLB and hence a MPLD by breathing the air.

It is important to recognize that the MPLD is the primary standard; it applies to all radionuclides and radiation sources. The MPLB and the MPC_a are derived standards and are specific for a radionuclide. These derived standards are related to the biological properties of a radionuclide and to the form of radiation it emits.

Table I lists the existing exposure standards for employees of the nuclear industry that apply to Pu-239 in insoluble form. The MPLD of 15 rem/yr is included in the recommendations of the International Commission on Radiological Protection (ICRP)[8], the National Council on Radiation Protection and Measurements (NCRP)[9], and the Federal Radiation Council

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8/ ICRP Publication 9, Recommendations of the International Commission on Radiological Protection (Adopted September 17, 1966), Pergamon Press, New York, 1966, p. 14.

9/ NCRP Report No. 39, Basic Radiation Protection Criteria, NCRP Publications, Washington, D. C., Jan. 15, 1971, p. 106.

(FRC)[10]. The MPC_a is included in the ICRP recommendations[11] and is also an AEC radiation standard[12]. Of the standards in Table I only the MPC_a is designated in the AEC regulations. However, this MPC_a corresponds to that tabulated in ICRP Publication 2[13] which is derived on the basis of the MPLD listed in Table I. The MPLB is also derived on the basis of the MPLD[14]. The MPLB is not included in either the recommendations of ICRP, NCRP, the guidelines of FRC, or the AEC regulations. In summary, in Table I the MPC_a (designated in AEC regulations) is consistant with the MPLD and MPLB. In Table I the MPLD applies to all forms of ionizing radiation. The MPLB and MPC_a apply specifically to Pu-239 in insoluble form[15].

10/ FRC Report No. 1, Op. cit., p. 38. The FRC has been abolished and its duties transferred to EPA.

11/ ICRP Publication 2, Report of Committee II on Permissible Dose for Internal Radiation, Pergamon Press, New York, 1960. [Appeared in Health Physics, Vol. 3, Pergamon Press, June 1960.]

12/ 10 CFR 20, Appendix B.

13/ ICRP Publication 2, Op. cit.

14/ Mann, J.R. and A.R. Kirchner, "Evaluation of Lung Burden Following Acute Inhalation of Highly Insoluble PuO_2," Health Physics, Vol. 13, 1967, pp. 877-882.

15/ The MPLB could apply to most other alpha-emitting radionuclides with long half-lives, since the alpha particle energies do not differ appreciably from the Pu-239 alpha energy.

TABLE I

Existing Occupational Exposure Guidelines

that Apply to Pu-239 in Insoluble Form*

MPLD (ICRP, NCRP, FRC)	15 rem/yr
MPLB	0.016 uCi
MPC_a (ICRP, AEC)	4×10^{-11} uCi/ml

*Note: See Glossary for definitions of symbols.

The exposure guidelines for Pu-239 that apply to non-occupational exposure of the general public are tabulated in Table II. Two guidelines are applied here. One is for the limiting exposure to an individual and the other is for the average exposure of a population sample. These two guidelines differ by a factor of 3. The ICRP recommendations include only the guidelines for individuals. The MPLD values within the parentheses in Table II correspond to the latest recommendation of the NCRP[16]. These latest recommendations of the NCRP have not, at this time, been incorporated into either the AEC or EPA regulations.

16/ NCRP Report No. 39, *Op. cit.*, p. 95.

TABLE II

Existing Exposure Guidelines for Non-Occupational Exposure that Apply to Pu-239 in Insoluble Form*

	Individual	Population Average
MPLD (ICRP, NCRP, FRC)	1.5 (0.5) rem/yr	0.5 (0.17) rem/yr
MPLB	0.0016 (0.0005) uCi	0.0005 (0.00017) uCi
MPC_a (ICRP, AEC)	10^{-12} ($3x10^{-13}$) uCi/ml	$3x10^{-13}$ (10^{-13}) uCi/ml

* The MPLD values in parentheses refer to the latest recommendations of the NCRP. The MPLB and MPC_a values in parentheses correspond to the new NCRP dose recommendations.

IV. Calculating the Dose Due to Insoluble Alpha-Emitters

The purpose of this section is to examine the assumptions in the radiation standards above that are inappropriate when applied to insoluble alpha-emitting particulates such as aerosols of PuO_2. The assumptions are introduced through a review of basic definitions of radiation dose and the factors used to calculate the dose.

A. The Dose Equivalent

When an X-ray or the radiation emitted by a radionuclide passes through tissue it transfers energy to the cells in these tissues. This energy produces chemical changes in the molecule of the cells; for example, such a chemical change could be a mutation in a gene. The radiation dose is actually a measure of the energy transferred to or absorbed by the tissue. The basic unit of dose is the rad (one rad represents the absorption of 100 ergs of energy per gram of material).

In addition to X-rays, radionuclides emit gamma rays (high energy X-rays), beta particles (electrons), and alpha particles (helium nuclei). In radiobiological experiments, it was determined that, while these various types of radiation produced the same biological effects, such as cancer, the magnitude of the effect was not the same per rad. For example, it was found that 100 rad of alpha radiation would produce roughly 10 times as many cancers as 100 rad of X-rays. Moreover, it was found that because of the special way in which Pu-239 deposits in the bone, its alpha particles were 5 times more effective in producing bone cancer than the alpha particles from radium[17]. To account for these differences in the magnitude of the observed effects at the same absorbed dose in rad, the maximum permissible dose limits are given in rem rather than rad.

The MPLD is given in rem in Tables I and II. The

17/ ICRP Publication 11, "A Review of the Radiosensitivity of the Tissues in Bone," Pergamon Press, New York, N. Y., 1967, p. 21.

rem is the unit of Dose Equivalent (DE)[18]. The DE is obtained by multiplying the absorbed dose in rad by modifying factors to correct for these observed differences in the magnitude of the effect. As a consequence, the magnitude of the effect will be the same for a given DE regardless of the nature of the radiation or the manner of radiation.

B. <u>Modifying Factors</u>

At the present time, two modifying factors are employed. One is the Quality Factor (QF) which accounts for differences in producing biological effects among various forms of radiation. The other is the Distribution Factor (DF) which accounts for the modification of the biological effects when a radionuclide is nonuniformly distributed in an organ. For example, the DE for X-ray to bone tissue is determined by using QF=1 and DF=1, while that for Pu-239 in the bone is determined by using a QF=10 (to account for the greater effectiveness of alpha particle irradiation) and a DF=5 (to account for the peculiar distribution of Pu in the bone)[19]. A DE=50 rem from X-rays or Pu-239 would thus induce the same number of cancers in bone but the absorbed dose from the X-rays would be 50 rad while that from Pu-239 would be only 1 rad.

18/ NCRP Report No. 39, *Op. cit.*, p. 81.

19/ ICRP Publication 11, *Op. cit.*, p. 21.

In obtaining the derived values in Tables I and II, MPLB and MPC_a for Pu-239, a QF=10 was employed. This QF implies, as mentioned above, that the particles of Pu-239, which emit alpha particle radiation, are 10 times more effective in inducing cancer than X-rays. Although the irradiation of tissue by insoluble plutonium particles is highly nonuniform, no DF value has been assigned to these particles and hence, a DF=1 was employed in determining the derived values in Tables I and II. Ideally, the DF should be determined by the ratio of the observed effects in an organ following uniform and nonuniform radiation of the tissue with the same radionuclide; for example:

$$DF = \frac{\text{Number of cancers (nonuniform irradiation)}}{\text{Number of cancers (uniform irradiation)}}$$

Since direct experimental data are not available, it is necessary to derive the DF for insoluble Pu-239 particles from collateral data. In a subsequent section, we shall present the biological evidence that strongly suggests that a DF=1 grossly underestimates the DE for insoluble particulates of Pu-239 and, consequently, that the derived standards, MPLB and MPC_a for this radionuclide, are greatly in error.[20] In fact, it will be shown that the biological data strongly suggests that for such particles one should use a DF=115,000.

20/ This applies as well to other alpha-emitting actinides in insoluble particulate form.

Before turning to the biological data it is appropriate to discuss first the radiation field around a particle of PuO_2 and thereby define the fundamental questions that need to be answered by the collateral data from radiobiological studies.

The unique form of tissue irradiation displayed by insoluble particles of Pu-239 occurs because, when Pu-239 decays, it emits an alpha particle with an energy of 5.1 MeV. This particle has a range (produces biological damage) of only some 40-45 u (0.004 cm) in human tissue. In other words, a Pu-239 particle in tissue will only irradiate a volume of tissue enclosed in a sphere of 45 u radius. As one moves inward from the surface of this sphere, the radiation intensity increases geometrically. About half of the alpha particle energy is dissipated at 20 u (that is, with a volume that is 1/8 the total volume). This means that the average dose delivered in the first 20 u is 8 times that delivered in the remaining 20 u. The first column of Table III describes the radiation field around such a particle in soft tissue; e.g., the skin. Since the lung is a spongy tissue with a large air volume, the range of alpha particles is longer in the lung and consequently the mass of irradiated tissue is larger. Professor Donald Geesaman made a detailed analysis of plutonium particle irradiation of deep respiratory tissue[21]. The last two columns in Table III describe the radiation field around such a particle in the lung using Geesaman's lung model[22]. The dose rate to the entire organ is given in column 2 of Table III for comparison. From Table III it is significant to note that with an assumed DF=1, the lung dose from the same particle varies by more than 8 orders of magnitude depending on whether one averages the dose over the entire lung or calculates it on the basis of the tissue exposed.

TABLE III

Radiation Dose Rate Due to a Pu-239 Particle

(1 u in diameter, 0.28 pCi[23])

	Soft Tissue Irradiated[24]	Lung		
		Entire Organ	Tissue Irradiated[25]	Closest 20 Alveoli[26]
Mass of Tissue	0.4 ug	1000 g[27]	65 ug	19 ug
Dose Rate (rem/yr)	730,000	0.0003	4000	11,000

21/ Geesaman, Donald P., An Analysis of the Carcinogenic Risk from an Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue, UCRL-50387 and UCRL-50387 Addendum, Lawrence Livermore Laboratory, Livermore, Calif., 1968.

It would take 53,000 particles of the size illustrated in Table III to reach the MPLB of 0.016 uCi which results in 15 rem/yr to the entire (1000 g) lung. However, as Table III indicates, these particles would irradiate only 3.4 g of this 1000 g to the lung, but at a dose rate of 4000 rem/yr[28]. Thus, as Table III indicates, these particles result in an intense but highly localized irradiation. A fundamental question is, then: is this intense but localized irradiation more or less carcinogenic than uniform irradiation? Alternatively, is the DF for this particular form of irradiation equal to, greater than, or less than one? In the remainder of this section, we review the guidance, or more appropriately lack of guidance, for dealing with this hot particle problem.

22/ Geesaman, Donald P., UCRL-50387, pp. 8, 15.

23/ Langham, Wright H., The Problem of Large Area Plutonium Contamination, U. S. Dept. of H. E. W., Public Health Services, Seminar Paper No. 002, Dec. 6, 1968, p. 7.

24/ Long, A.B., "Plutonium Inhalation: The Burden of Negligible Consequence," Nuclear News, June 1971, p. 71.

25/ Geesaman, Donald P., UCRL-50387, pp. 8, 15. Based on Geesaman's model for a lung at one-half maximum inflation. Geesaman estimates a total of 68 alveoli at risk, each 8×10^{-6} cm^3 in volume, and deep respiratory zone tissue density of 0.12 g/cm^3.

26/ See footnote 23.

27/ Based on a lung mass of a standard man = 1000 g.

28/ This assumes that the radiation field of the 53,000 particles do not overlap.

C. The Hot Particle Problem

It is important to recognize that the ICRP has given no guidance with respect to nonuniform irradiation of the lung by insoluble alpha-emitters such as insoluble plutonium particles. In its Publication 9, the ICRP states:

> ...In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung.[29]

In effect, the ICRP is saying that there is no guidance as to the risk for non-homogeneous exposure in the lung, hence the MPC_a and the MPLB are meaningless for insoluble plutonium particles.

The NCRP offers the following and similar statement with respect to these particles:

> (210) The NCRP has arbitrarily used 10 percent of the volume of the organ as the significant volume for irradiation of the gonads. There are some cases in which choice of a significant volume or area is virtually meaningless. For example, if a single particle of radioactive material fixed in either lung or lymph node may be carcinogenic, the averaging of dose either over the lung or even over one cubic centimeter may have little to do with this case.[30]

This hot particle problem is also well recognized in the biological community. The following is extracted from a

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29/ ICRP Publication 9, Op. cit., p. 4.

30/ NCRP Report No. 39, Op. cit., pp. 79-80.

paper by Professor Donald P. Geesaman:

> So there is a hot particle problem with plutonium in the lung, and the hot particle problem is not understood, and there is no guidance as to the risk. I don't think there is any controversy about that. Let me quote to you from Dr. K. Z. Morgan's testimony in January of this year before the Joint Committee on Atomic Energy, U.S. Congress. [a] Dr. K. Z. Morgan is one of the United States' two members to the main Committee of the International Commission on Radiological Protection; he has been a member of the committee longer than anyone; and he is director of Health Physics Division at Oak Ridge National Laboratory. I quote: "There are many things about radiation exposure we do not understand, and there will continue to be uncertainties until health physics can provide a coherent theory of radiation damage. This is why some of the basic research studies of the USAEC are so important. D. P. Geesaman and Tamplin have pointed out recently the problems of plutonium-239 particles and the uncertainty of the risk to a man who carries such a particle of high specific activity in his lungs." At the same hearing, in response to the committee's inquiry about priorities in basic research on the biological effects of radiation, Dr. M. Eisenbud, then Director of the New York City Environmental Protection Administration, in part replied, "For some reason or other the particle problem has not come upon us in quite a little while, but it probably will one of these days. We are not much further along on the basic question of whether a given amount of energy delivered to a progressively smaller and smaller volume of tissue is better or worse for the recipient. This is another way of asking the question of how you calculate the dose when you inhale a single particle." [b] He was correct; the problem has come up again.

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[a] Morgan, K. Z., "Radiation Standards for Reactor Siting," in Environmental Effects of Producing Electrical Power Phase 2. Testimony presented at Hearings before the Joint Committee on Atomic Energy, 91st Congress, 1970. Washington, D. C., U. S. Government Printing Office.

[b] Eisenbud, M. Panel Discussion. In: Environmental Effects of Producing Electrical Power, Phase 2. Testimony presented at Hearings before the Joint Committee on Atomic Energy, 91st Congress, 1970. Washington, D. C., U. S. Government Printing Office.

In the context of his comment it is interesting to refer to the National Academy of Sciences, National Research Council report of 1961 on the Effects of Inhaled Radioactive Particles. [c] The first sentence reads, "The potential hazard due to airborne radioactive particulates is probably the least understood of the hazards associated with atomic weapons tests, production of radioelements, and the expanding use of nuclear energy for power production." A decade later that statement is still valid. Finally let me quote Drs. Sanders, Thompson, and Bair from a paper given by them last October. [d] Dr. Bair and his colleagues have done the most relevant plutonium oxide inhalation experiments. "Nonuniform irradiation of the lung from deposited radioactive particulates is clearly more carcinogenic than uniform exposure (on a total-lung dose basis), and alpha-irradiation is more carcinogenic than beta-irradiation. The doses required for a substantial tumor incidence, are very high, however, if measured in proximity to the particle; and, again, there are no data to establish the low-incidence end of a dose-effect curve. And there is no general theory, or data on which to base a theory, which would permit extrapolation of the high incidence portion of the curve into the low incidence region." I agree and I suggest that in such a circumstance it is appropriate to view the standards with extreme caution.[31]

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[c] U. S. NAS-NRC Subcommittee, Effects of Inhaled Radioactive Particles. Report of the Subcommittee on Inhalation Hazards. Committee on Pathologic Effects of Atomic Radiation. National Academy of Sciences - National Research Council, Washington, D. C. 1961. Publication 848. NAS-NRC/PUB-848, 1961.

[d] Sanders, C.L., R.C. Thompson, and W.J. Bair, "Lung Cancer: Dose Response Studies with Radionuclides." In: Inhalation Carcinogenesis. Proceedings of a Biology Division, Oak Ridge National Laboratory, conference held in Gatlinburg, Tennessee, October 8-11, 1969. M.G. Hanna, Jr., P. Nettesheim, and J.R. Gilbert, eds., U. S. Atomic Energy Commission Symposium Series 18, 1970. pp. 285-303. (CONF-691001).

31/ Geesaman, Donald P., "Plutonium and Public Health," Lawrence Livermore Laboratory, Calif., GT-121-70, April 19, 1970, reproduced in Underground Uses of Nuclear Energy, Part 2, Hearings before the Subcommittee on Air and Water Pollution of the Committee on Public Works, U. S. Senate, 91st Congress, 2nd Session, August 5, 1970, pp. 1530-1532.

To these comments, referenced by Geesaman, can be added the comments of Dr. A. B. Long:

> ". . . there is an urgent need to dispell the sense of security and certainty that the present limits for the maximum permissible lung burden and the maximum permissible air concentration bring . . . the public should be informed of the uncertainties that exist in these limits."[32]

V. <u>Biological Data Related to Cancer Risk from Insoluble Plutonium Particles</u>

We have shown that insoluble alpha-emitting particles result in intense but localized radiation. They can irradiate at very high doses without being organism- or organ fatal. We said that the available biological data strongly suggests that a DF=1 grossly underestimates the DE for insoluble particulates of Pu-239, and consequently, the derived standards MPLB and MPC_a for this radionuclide are greatly in error. We now turn to the experiments involving cancer induction by intense local exposure, since these are especially relevant in judging whether or not insoluble alpha-emitting particles constitute a unique risk. Geesaman collected and analyzed the pertinent experiments, and what follows

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32/ Long, A.B., *Op. cit.*, p. 73.

is essentially a review of his analysis[33], which has become known as the "Geesaman hypothesis."

A The Geesaman Hypothesis

Dr. Roy E. Albert and co-workers performed a number of experiments on the induction of cancer in rat skin[34-36]. Albert's study of radiation-induced carcinoma in rat skin gives some quantitative description of a high-dose carcinogenic situation. A skin area of 24 cm^2 was exposed to electron radiation with various depths of maximum penetration. The dose response curves are reproduced in Figure 1. In all cases the response at sufficiently high doses (1000-3000 rem) was large, ~1-5 tumors per rat by 80 weeks post exposure. It was noted by Albert that when the dose was normalized to a skin depth of 0.27 milimeters, the three response curves became continuous (See Figure 2). Since this

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33/ Geesaman, D.P., UCRL-50387 Addendum, Op. cit.

34/ Albert, R.E., F.J. Burns, and R.D. Heimbach, "The effect of penetration depth of electron radiation on skin tumor formation in the rat," Radiation Res. 30, 1967, pp. 515-524.

35/ Albert, R.E., F.J. Burns, and R.D. Heimbach, "Skin damage and tumor formation from grid and sieve patterns of electron and beta radiation in the rat," Radiation Res. 30, 1967, pp. 525-540.

36/ Albert, R.E., F.J. Burns, and R.D. Heimbach, "The association between chronic radiation damage of the hair follicles and tumor formation in the rat," Radiation Res. 30, 1967, pp. 590-599.

depth is near the base of the hair follicle which comprises the deepest reservoir of epithelial cells of the germinal layer, it was suggestive that this might be a critical region in the observed carcinogenesis. The suggestion gained significance from the observations that most of the tumors are similar to hair follicles, and that in the non-ulcerogenic dose range the number of tumors per rat was in nearly constant ratio (1/2000-1/4000) with the number of atrophied hair follicles. Thus the carcinogenesis in this experiment was remarkably correlated with the dose to and specific damage of a particular skin structure. When exposures were made with stripe and sieve patterns of roughly 1 mm scale, geometrical effects were observed: most notably the cancer induction in the sieve geometry was suppressed at doses of 1700 rad but not at doses of 2300 rad. The reduction, however, was again consistent with the reduction in damage as characterized by atrophied hair follicles.

To summarize this important experiment, a high incidence of cancer was observed after intense local doses of radiation, and the carcinogenesis was proportional to the damage or disordering of a critical architectural unit of the tissue, the hair follicles.

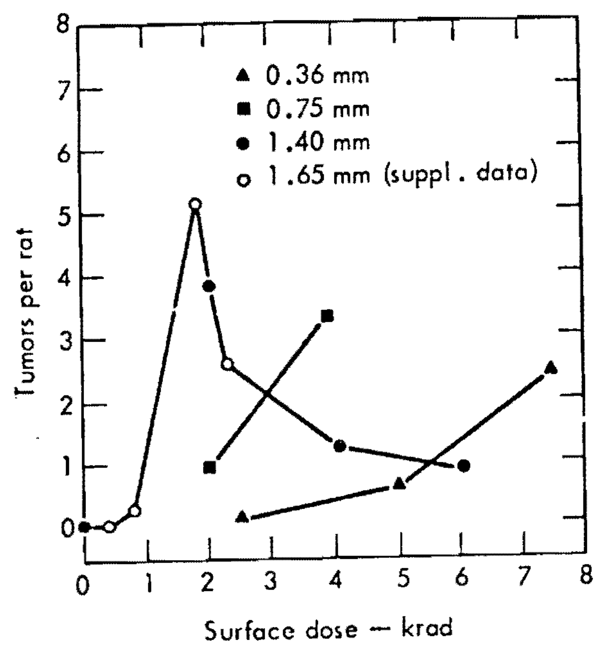

Fig. 1. Tumor incidence with respect to surface dose at 80 weeks for three penetration depths of electrons.

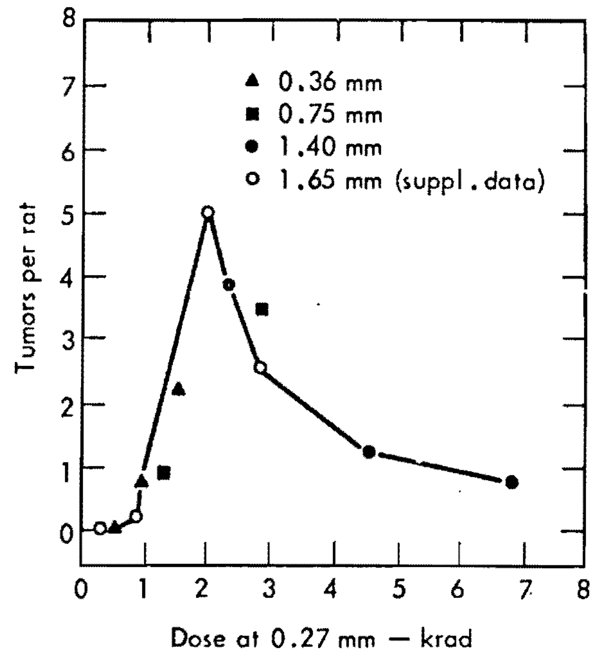

Fig. 2. Tumor incidence with respect to the dose at a depth of 0.27 mm in the skin at 80 weeks for three penetration depths of electrons.

Source of Figures: Albert, R. E., et al., Radiation Res. 30, Op. cit., pp. 515-524, Figures 5 and 7; reproduced in Geesaman, UCRL-50387 Addendum, Op. cit., p. 2.

Others have observed carcinomas and sarcomas in rats and mice after intense exposure of the skin to ionizing radiation[37-43]. Cancer induction is generally a frequent event in these experiments. Even at elevated doses, such as 12,000 rad of 1 MeV electrons, Boag and Glucksmann induced ~5 sarcomas/100 cm^2 in rats[37].

A few results for rabbits, sheep, and swine were obtained at Hanford[38-41]. Despite the small number of animals

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37/ Withers, H.R., "The dose-survival relationship for irradiation of epithelial cells of mouse skin," Brit. J. Radiol. 40, 1967, pp. 187-194.

38/ Hulse, E.V., "Tumours of the skin of mice and other delayed effects of external beta irradiation of mice using ^{90}Sr and ^{32}P," Brit. J. Cancer 16, 1962, pp. 72-86.

39/ Boag, J.W. and A. Glucksmann, "Production of cancers in rats by the local application of Beta-rays and of chemical carcinogens," Progress in Radiobiology, J.S. Mitchell, B.E. Holmes, and C.L. Smith, eds. Proceedings of the Fourth International Conference on Radiobiology held in Cambridge, 14-17 August 1955. Edinburgh, Oliver and Boyd, 1956, pp. 476-479.

40/ George, L.A. and L.K. Bustad, "Gross effects of beta rays on the skin," Hanford Atomic Products Operation, Biology Research Annual Report for 1956, HW-47500, 1957, pp. 135-141.

41/ George, L.A. II, R.L. Pershing, S. Marks, and L.K. Bustad, "Cutaneous fibrosarcoma in a rabbit following beta irradiation," Hanford Atomic Products Operation, Biology Research Annual Report for 1959, HW-65500, 1960, pp. 68-69.

42/ Ragan, H.A., W.J. Clarke and L.K. Bustad, "Late effects of skin irradiation," Battelle-Northwest Laboratory Annual Report for 1965 in the Biological Sciences, BNWL-280, 1956,pp. 13-14.

43/ Karagianes, M.T., E.B. Howard and J.L. Palotay, Battelle-Northwest Laboratory Annual Report for 1967 to the USAEC Division of Biology and Medicine, Vol. I, Biological Sciences, BNWL-714, 1968, pp. 1.10-1.11

involved, surface doses of 16,000 rad from a P^{32} plaque induced an average of 1 cancer/animal which is indicative that larger mammals are similarly susceptible to skin cancer after intense radiation insult. Again, these gross observations demonstrate that enhanced tumor incidence does occur after very high doses.

Intense localized radiation of the subcutaneous and intraperitoneal tissue of animals by Pu-239 has also been shown to cause a high frequency of cancer induction[43-45].

Now what are these experiments trying to tell us? Certainly a reasonable interpretation of these experimental results is: when a critical architectural unit of a tissue (e.g., a hair follicle) is irradiated at a sufficiently high dosage, the chance of it becoming cancerous is approximately 10^{-3} to 10^{-4}. This has become known as the "Geesaman hypothesis."

B Related Human Experience

Since the above experiments relate to cancer induction in animals, it is pertinent to ask whether man is more or less

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44/ Sanders, C.L. and T.A. Jackson, "Induction of Mesotheliomas and Sarcomas From 'Hot Spots' of PuO_2 Activity," Health Physics, Vol. 22, No. 6, June 1972, pp. 755-759.

45/ Lisco, Herman, et al, "Carcinogenic Properties of Radioactive Fission Products and of Plutonium," Radiology, Vol. 49, No. 3, Sept. 1947, pp. 361-363.

sensitive to such intense localized radiation. C. C. Lushbaugh reported on a lesion that developed as the result of residual Pu-239 from a puncture wound[46]. The particle contained 0.08 ug (0.005 uCi) of Pu-239. Commenting on the histological examination of the lesion, the authors state, "The autoradiographs showed precise confinement of alpha-tracks to the area of maximum damage and their penetration into the basal areas of the epidermis, where epithelial changes typical of ionizing radiation exposure were present. The cause and effect relationship of these findings, therefore, seemed obvious. Although the lesion was minute, the changes in it were severe. Their similarity to known precancerous epidermal cytologic changes, of course, raised the question of the ultimate fate of such a lesion should it be allowed to exist without surgical intervention..." In this case, less than 0.1 ug of Pu-239 produced precancerous changes in human tissue. The dose to the surrounding tissue was very intense. There is every reason to believe that a smaller quantity of Pu-239 would have produced similar changes. This precancerous lesion indicates that a single Pu-239 particle irradiates a significant (critical) volume of tissue and is capable of inducing cancer. The Lushbaugh study was

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46/ Lushbaugh, C.C. and J. Langham, *Op. cit.*, pp. 461-464.

published in 1962. At that time the total number of puncture wounds in man was less than 1,000[47]. The treatment of such wounds was excision so that the total number of wounds displaying residual contamination by plutonium particles was certainly less than 1,000. Therefore, this wound data would suggest that insoluble plutonium particles could offer a risk of cancer induction in man that is even greater than 1/1000 per particle. In other words, when a critical unit of tissue is irradiated, man may be more susceptible to cancer than the Albert data as analyzed by Geesaman would suggest.

A second case of plutonium particle induced cancer is that of Mr. Edward Gleason. He was not associated with the nuclear industry but was a freight handler who unloaded, rotated and reloaded a crate that was contaminated by the leaking carboy of Pu-239 solution which it contained. He subsequently developed an infiltrating soft tissue sarcoma on the left palm which eventually resulted in his death. Although this case is not as clear cut as the case of the plutonium worker, there is an overwhelming medical probability that his cancer was induced by plutonium. Mr. Gleason's unfortunate contact with Pu-239 lead to a lawsuit,

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47/ Vanderbeck, J.W., "Plutonium in Puncture Wounds," HW-66172, Hanford Laboratories Operation, July 25, 1960.

Edward Gleason, et al v. NUMEC. This suit was eventually settled out-of-court. A discussion of the evidence in this case by one of the authors is presented in the Appendix B of this report.

These two cases, drawn from the relatively small number of individuals so contaminated, strongly suggest that Pu-239 particles offer a unique carcinogenic risk. They indicate that a single particle is capable of delivering an intense radiation dose to a critical volume of tissue and that this disruptively irradiated tissue, like an atrophied hair follicle, has a high probability (maybe as high as 1/1000) of becoming cancerous.

C. Related Lung Experiments

The skin experiments with animals are remarkable in that a highly disruptive dose of radiation to a small portion of repairable mammalian tissue produced frequent carcinogenesis. The chance of producing one cancer per animal is essentially unity. It is reasonable to expect that a comparable development could occur in lung tissue. While a number of radioactive substances have been used to induce lung cancers in mice and rats[48], it is difficult to derive any characterization of carcinogenesis from these experiments.

48/ Cember, H., "Radiogenic lung cancer," Progress in Experimental Tumor Research, F. Homburger, ed. New York, Hafner Publishing Company, Inc., Vol. 4, 1964, pp. 251-303.

The work of Laskin, et al, though not specifically involving deep respiratory tissue, does demonstrate a source intensity-response curve for lung tissue[49]. A Ru-106 cylindrical source was implanted in the bronchi of rats, and cancers were observed to arise from the bronchial epithelium. The response curve indicates a substantial response (7 percent) even at 0.008 uCi burden, and a slow, approximately logarithmic increase of tumor incidence over three orders of magnitude in the source intensity. Corresponding first-year doses to adjacent bronchial epithelium varied from 10^3 rad to 10^6 rad[50]. Animals were followed until death and it was observed that the tumor incidence generally increased with the dose accumulated at death. The lowest accumulated dose associated with a cancer was 1400 rad. For an accumulated dose of the order of 10^6 rad the incidence was approximately two-thirds. Cember fortified glass beads (0.3 u diameter) with several microcuries of Sr-90, and single beads were implanted in the lungs of rats. Tumors were observed in 7 of 23 animals. In a second experiment Cember exposed rat lungs to Ce-144 particles. For

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49/ Laskin, S., M. Kuschner, N. Nelson, B. Altshuler, J.H. Harley and M. Daniels, "Carcinoma of the lung in rats exposed to the beta-radiation of intra-bronchial ruthenium^{106} pellets. 1. Dose response relationships," J. Natl. Cancer Inst. 31, 1963, pp. 219-231.

50/ Altshuler, B., "Dosimetry from a Ru^{106}-coated platinum pellet," Radiation Res. 9, 1958, pp. 626-632.

a burden range of 0.5 uCi to 50 uCi the observed tumor incidence fluctuated between 0.04 and 0.3[51].

All of these lung experiments involved intense exposures and a significant level of carcinogenesis. Severe damage and disruption of tissue were associated with the exposures.

The most relevant lung experiment is Bair's $Pu^{239}O_2$ inhalation study with beagles[52-54]. Exposure was to particulates of 0.25 u or 0.5 u median diameter; burdens were in the uCi range. Twenty of the 21 dogs that survived more than 1600 days post exposure had lung cancer. Many of these cancers were multicentric in origin. The cancers again appeared in conjunction with severe lung injury. Since the natural incidence of the disease is small, it appears that at this level of exposure the induction of lung cancer is a certainty during the normal beagle life span. At the same

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51/ Cember, H., Op. cit.

52/ Bair, W.J., J.F. Park, and W.J. Clarke, "Long-term study of inhaled plutonium in dogs," Battelle Memorial Institute (Richland), AFWL-TR-65-214, 1966 (AD-631 690).

53/ Park, J.F., W.J. Clarke and W.J. Bair, "Chronic effects of inhaled $^{239}PuO_2$ in beagles," Battelle-Northwest Laboratory Annual Report for 1967 to the USAEC Division of Biology and Medicine, Vol. I, Biological Sciences, BNWL-714, 1968, pp. 3.3-3.4.

54/ Park, J.F., et al, "Progress in Beagle Dog Studies with Transuranium Elements at Battelle-Northwest," Health Physics, Vol. 22, No. 6, June 1972, pp. 803-810.

time, since the pathological response is saturated in this experiment, it is inappropriate to draw any inference about the magnitude of the response at smaller burdens. The smallest burden (at death) in a dog showing lung cancer was 0.2 uCi. Presumably this would correspond to a particle burden of about 10^7 particles. Burdens which are smaller by orders of magnitude may still induce a substantial incidence of cancer. Indeed, the cancer risk may, as for skin and soft tissues, correspond to a risk per particle in the neighborhood of 1/1000 to 1/10,000.

VI. Critical Particle Activity

Not all particles would be expected to result in these high cancer probabilities. As the particle size or specific activity per particle is reduced so is the dosage to the surrounding tissue. Indeed, at sufficiently small particle size or specific activity, one would expect the radiation insult to behave similar to uniform irradiation. The study of Albert on induction of cancer in rat skin indicates a precipitous change in the dose response curve as the dosage exceeds 1,000 rem[55]. (See Figure 2). This suggests that a particular level of tissue damage must occur before this unique carcinogenic response occurs. The experiments of

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55/ Albert, R.E., et al, Radiation Res. 30, Op. cit., pp. 515-524, Figure 7; reproduced in Geesaman, UCRL-50387 Addendum, Op. cit., p. 2.

Laskin, et al, indicate a significant carcinogenic response in the lung at 1400 rem, suggesting a comparable sensitivity of lung tissue[56]. Geesaman indicates that the tissue repair time in the lung is of the order of one year[57]. It therefore seems appropriate, but not necessarily conservative, to accept as guidance that this enhanced cancer risk occurs when particles irradiate the surrounding lung tissue at a dose rate of 1000 rem/yr or more.

TABLE IV

Particle Activity and Size to Give a Dose of 1000 rem/year to the Surrounding Lung Tissue[58]

	Particle Activity (pCi)	Particle Diameter (u)[59]	
		$^{239}PuO_2$	$^{238}PuO_2$
3/4 max inflated (138 alveoli)	0.14	0.8	0.12
1/2 max inflated (68 alveoli)	0.07	0.6	0.09
Closest 20 alveoli	0.02	0.4	0.06

56/ Laskin, et al, Op. cit.

57/ Geesaman, Donald P., UCRL-50387, Op. cit., p. 11.

58/ Ibid

59/ Based upon specific activity given by Langham, W.H., Op. cit., p. 7.

As seen from Table IV, using Geesaman's lung model, a particle with an alpha activity between 0.02 pCi and 0.14 pCi is required to give a dose of 1000 rem/yr to irradiated lung tissue. For purposes of establishing a maximum permissible lung particle burden we will use 0.07 pCi from long half-lived (greater than one year) isotopes as the limiting alpha activity to qualify as a hot particle. Thus, throughout the remainder of this report, hot particle will imply a particle with at least this limiting alpha activity which is insoluble in lung tissue.

A. Exposures at Rocky Flats

The AEC has a plutonium facility associated with its nuclear weapons program at Rocky Flats, Colorado. This facility is operated under contract to the AEC by the Dow Chemical Company. The employees, the environment and undoubtedly the surrounding population have been contaminated with plutonium particles as a result of the operation of this plant.[60-62] It is, therefore, pertinent here to examine the information

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60/ Mann, J.R. and A.R. Kirchnev, Op. cit.

61/ Poet, S.E. and E.A. Martell, "Plutonium-239 and Americium-241 in the Denver Area," Health Physics, Vol. 23, 1972, pp. 537-549.

62/ Richmond, Chet, Transcript of Plutonium Information Meeting of the Advisory Committee on Reactor Safeguards, Los Alamos, N. Mex., 5 January 1974, pp. 319-320.

available on the exposure of employees of the Rocky Flats facility and to relate this to the hot particle problem.

J. R. Mann and R. A. Kirchner discuss the exposures that resulted from a plutonium fire at Rocky Flats on 15 October 1965.[63] Some 400 employees were working in the room at the time the fire occurred. These employees were subsequently placed in a whole body counter to determine their lung burdens of Pu-239. However, Mann and Kirchner reported only on those 25 employees who were exposed above the MPLB of 0.016 uCi.

Table V presents the information on the exposure of these 25 employees. Utilizing the other information presented by Mann and Kirchner, we have also estimated in Table V the fraction of the lung burden activity (uCi) associated with hot particles and the number of hot particles that this represents.

63/ Mann, J.R. and R.A. Kirchner, Op. cit.

TABLE V

Rocky Flats Exposure*

Number of Cases	Total Lung Burden (uCi)	Hot Particles Lung Burden (uCi)	Number of Hot Particles
1	0.272	0.033	137,000
1	0.160	0.019	79,000
1	0.111	0.013	54,000
3	0.064	0.008	33,000
19	0.024	0.003	12,500

* Mann and Kirchner presented the lung burdens as number of MPLB. These have been converted to uCi in column two using MPLB=0.016 uCi. (For the groups with 3 and 19 cases, we selected the midpoint of the reported range.) The hot particle burden in column three was estimated by multiplying the total burden by 0.17, the fraction of the activity on particles above 0.6 u, and 0.70, the fraction of initial deposited activity that was involved in long term retention in the lung. Based on particle size data reported by Mann and Kirchner, we estimate the average hot particle activity is about 0.24 pCi. The numbers of hot particles in the last column were obtained by dividing the hot particle burdens in column three by the average hot particle activity (0.24 pCi).

Allowing a risk of cancer equal to 1/2000 per hot particle, suggests that the individuals whose exposures are presented in Table V stand a very high chance of developing lung cancer -- the probability is essentially unity. In this respect, it is significant to note that in the experiments reported by Park, et al, the beagle dog with the smallest lung burden, i.e., 0.2 uCi, developed lung cancer.[64] The highest burden in Table V is comparable to the lowest beagle exposure; the lowest exposure in Table V, the 19 cases with lung burdens in the 0.024 uCi range are only an order of magnitude less than the lowest beagle exposure. We would suggest that this is potentially a serious situation.

As of this time, none of these individuals has developed lung cancer.[65] However, it is only 9 years since the exposure and there is good reason to suggest that the latent period (the time between exposure and the development of cancer) is much longer than this. In the beagle dog experiments, the lowest lung burden was associated with a latent period of 11 years. The latent period may be longer in man and particularly at these lower dosages and the small number of cases involved. Therefore, while these exposed individuals will be expected to supply pertinent data relative to this hot particle cancer risk over the next 10 to 20 years, these exposures give us no information at this time that would warrant modifying the risk per particle or the critical particle activity.

64/ Park, J.F., et al, Health Physics, Op. cit. p. 805.

65/ Richmond, Chet, Op. cit., p. 320.

B. Manhattan Project Workers

Another study of human respiratory exposure to plutonium relates to 25 young men exposed to plutonium during the Manhattan Project.[66] The latest examination of this group found them to be free of lung cancer although the report states, "The bronchial cells of several subjects showed moderate to marked metaplastic changes, but the significance of these changes is not clear." Such metaplastic changes are a possible indicator for detecting incipient or actual lung cancer. In one case the report indicates that the subject was a heavy smoker (3 packs/day) and undoubtedly this contributed to the changes. Nevertheless, these findings suggest that lung cancer may become manifest in some of these subjects in the future. Indeed, one would not be surprised to find one lung cancer even in such a group of non-exposed subjects. During the latest examination of these workers, *in vivo* measurement of the plutonium lung burdens were conducted with these results:

> An average MDA for a 2000-sec counting time is about 7 nCi if one uses the 95% confidence level.[67] For the 68% confidence level and a similar counting time, the comparable value is about 3.5 nCi.

66/ Hemplemann, L.H., *et al*, "Manhattan Project Plutonium Workers; A Twenty-Seven Year Follow-Up Study of Selected Cases."

67/ MDA refers to the minimum detectable amount.

> Positive counts were obtained for 14 of 21 persons measured. These counts suggested chest burdens ranging from 3 to about 10 nCi. However, in no case did the estimated chest burden exceed the MDA at the 95% confidence level. Seven of the 14 subjects with positive chest counts had estimated chest burdens of 7 nCi or greater and may be considered (at the 68% level of confidence) to have statistically significant chest burdens of from 7 to 10 nCi.[68]

Since the plutonium is still in the lung cavity, 27 years post-exposure, it is correct to assume that it was initially in the insoluble form and hence pertinent here.[69] At the time of this measurement, however, most of the material would be expected to be in the lymph nodes. Nevertheless, we could estimate the initial particle burden in these subjects from these data if we knew the initial particle size at the time of contamination. This particle size data is unavailable.

The nature of the contaminating events suggest that the particle size might have been somewhat larger than those that result from plutonium fires where most of the respirable activity resides on particles in the size range of 0.1 u to 0.5 u in diameter.[70] Much of the contamination of the

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68/ Hemplemann, L.H., *Op. cit.*, p. 474.

69/ ICRP Publication 19, The Metabolism of Compounds of Plutonium and Other Actnides, Pergamon Press, New York, 1972, p. 7.

70/ Mann, J.R. and A.R. Kirchner, *Op. cit.*, p. 880.

Manhattan workers resulted from aspiration of droplets of liquid solutions of plutonium into the air wherein much larger particle sizes would result. At the same time, the activity of the plutonium in the particle would be considerably less than that for a particle of PuO_2. For example, it is stated that 14 of the 25 subjects with measurable body burdens of plutonium worked in the recovery operation and that this occurred when working with solutions containing 1-40 g/liter of plutonyl nitrate to which H_2O_2 was being added with vigorous stirring in an open hood. This resulted in considerable fizzing and the discharge of droplets into the air outside the hood. A droplet 1 u in diameter (0.5 u^3) from the solution with the highest concentration (40 g/liter) would therefore contain only $6x10^{-4}$ pCi compared with a 0.07 pCi particle of PuO_2 [71] (a specific activity that is lower by a factor of 100).[72] In other words, the particles involved in this study do not qualify as hot particles. They are delivering dosages lower than 1000 rem/yr to the

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71/ Recall from Table IV that a 0.07 pCi, the limiting activity for a hot particle, would give a dose of 1000 rem/yr to the surrounding tissue in a lung inflated to 1/2 maximum.

72/ Of the particles of an inhaled aerosol that are deposited in the deep respiratory zone of the lung, virtually all are less than 5 u in diameter [Geesaman, UCRL-50387, Op. cit., p. 3]. A 5 u droplet from the 40 g/liter solution would correspond roughly to the limiting activity of a hot particle.

surrounding tissue (roughly 10 rem/yr).

C <u>Weapons Test Fallout</u>

Another source of human contamination that is suggested as being pertinent to this problem is the plutonium in the fallout from nuclear weapon tests. The plutonium from weapon tests is incorporated in or deposited on particles that contain other materials and, like that for the Manhattan workers, the specific activity in these particles is much smaller than that in hot particles.

VII Exposure Standards for Hot Particles

Thus the existing biological evidence strongly suggests that an insoluble particle of Pu-239 deposited in deep respiratory tissue represents a risk of cancer induction between 1/1000 and 1/10,000. Prudent public health practices should assess the risk associated with environmental plutonium and establish exposure guidelines on the basis of these probabilities.

The existing standards for uniform radiation exposure of the whole body or lung can be used as the basis for establishing particle exposure standards by equating the risk of cancer induction between the two types of exposure (uniform vs. grossly non-uniform). The most recent assessment of the risk associated with uniform irradiation of man was performed by the NAS-MRC Advisory Committee on the Biological Effects of Radiation. Their report, published in 1972, is referred to as the BEIR Report.[73]

A. Occupational Exposure

The existing occupational exposure standard for uniform whole body irradiation is 5 rem/yr and for the lung, 15 rem/yr. the BEIR Report estimates that exposure of the whole body of an individual to 5 rem/yr would lead to a cancer risk between 4.5×10^{-4} and 2.3×10^{-3}/yr.[74] Their best estimate is 10^{-3}/yr.[75] Their estimate of the risk of cancer to the individual from a lung exposure of the 15 rem/yr is 3×10^{-5}/yr.[76] Allowing a risk of cancer induction between 1/1000 and 1/10,000 per particle, Table V presents the maximim permissible lung particle burdens (MPLPB) that result in risks comparable to these uniform radiation standards for occupational exposure.

The MPLPB values in Table V represent a very substantial reduction in the MPLB. A hot particle of Pu-239 at the lower limit activity contains only 0.07 pCi while the MPLB for occupational exposure is 1.6×10^{4} pCi. Thus the

73/ NAS-NRC, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation," (BEIR Report), NAS-NRC, Washington, D. C. , Nov. 1972.

74/ Ibid, p. 91.

75/ Ibid, p. 91.

76/ Ibid, p. 156.

TABLE V

Occupational Exposure Guidance for Insoluble Alpha Emitters, Maximum Permissible Lung Particle Burden (MPLPB)[77]

Cancer risk due to 5 rem/yr whole body exposure[78]	Assumed Risk in Particle		
	1/1000	1/2000	1/10,000
4.5×10^{-4}	0.45	0.9	4.5
10^{-3} (best estimate)	1.	2.	10.
2.3×10^{-3}	2.3	4.6	23.

largest MPLPB in Table V, 23 particles, represent a reduction of the existing MPLB and MPC_a by a factor of 10,000. It is recommended here that the best estimate of the effects of uniform exposure by the BEIR Committee be used together with a risk of cancer induction of 1/2000 per hot particle in determining the MPLPB for insoluble alpha-emitting radionuclides in hot particles. This is a somewhat arbitrary compromise and is not the most conservative value that could be recommended. Thus, the recommended MPLPB for occupational exposure from hot particles of alpha-

77/ The number of particles required to give a cancer risk equal to that from uniform radiation.

78/ Source: BEIR Report, Op. cit., p. 91. The MPLPB corresponding to a lung cancer risk of 3×10^{-5} due to 15 rem/yr lung dose [BEIR Report, Op. cit., p. 156] are 0.03, 0.06 and 0.3 for assumed particle risks of 1/1000, 1/2000 and 1/10,000 respectively.

emitting radionuclides in the deep respiratory zone is 2 particles. This corresponds to a MPLB of 0.14 pCi and represents a reduction of 115,000 in the existing MPLB. This implies that the DF for hot particles is 115,000. Moreover, it requires a reduction of the MPC_a for Pu-239 by 115,000 to a value of $3.5x10^{-16}$ uCi/ml unless it is determined that the plutonium is not in hot particles.

B. Exposure of the General Public

As indicated in Table II, the MPLB for non-occupational exposure (members of the public) is tenfold less than that for occupational exposure. Such an exposure limit for a hot particle would be 0.2 particles. Exposure at this level implies that on the average one out of five individuals would be contaminated by a particle and the other four would not. Obviously the exposed invididuals would be assuming a disproportionate fraction of the risk. In fact, since an individual is exposed to whole particles, any non-occupational exposure to hot particles would be an overexposure. This condition does not meet the recommendations and admonitions of the FRC, ICRP and NCRP.

> Under certain conditions, such as widespread radioactive contamination of the environment, the only data available may be related to average contamination or exposure levels. Under these circumstances, it is necessary to make assumptions concerning the relationship between

> average and maximum doses. The Federal Radiation Council suggests the use of the arbitrary assumption that the majority of individuals do not vary from the average by a factor greater than three. Thus, we recommend the use of 0.17 rem for yearly whole-body exposure of average population groups. (It is noted that this guide is also in essential agreement with current recommendations of the NCRP and the ICRP.) It is critical that this guide be applied with reason and judgment. Especially, it is noted that the use of the average figure, as a substitute for evidence concerning the dose to individuals, is permissible only when there is a probability of appreciable homogeneity concerning the distribution of the dose within the population included in the average.[79]

Strict adherence to these guidelines implies that the ambient air standard should be zero particles.[80] While a variety of suggestions could be proposed, we recommend a slight deviation from these guidelines and the acceptance of the disproportionate risk implicit in the 0.2 particle standard. This is a workable solution since best estimates of lung burdens can be fractional quantities. Thus, we recommend that the MPLPB for members of the public be 0.2 hot particles, and the average lung burden for members of the public be 0.07 hot particles, a factor of 3 less than the maximum.

79/ FRC Report No. 1, *Op. cit.*, p. 27.

80/ Had we based the standard on a 1/10,000 risk per particle (See Table V), the MPLPB would have been one particle and this problem would not exist.

The MPLPB=0.2 particles implies that the existing MPC_a for non-occupational exposure to Pu-239 should also be reduced by a factor of 115,000 to a value of 9×10^{-18} uCi/ml unless it is determined that the plutonium is not in hot particles.

C. Exposure from Accidental Releases

There are no direct statements by standard-setting organizations regarding an "acceptable" exposure associated with release of radioactivity in an accident.[81] For purposes of evaluating sites for nuclear reactors, establishing site boundaries, and preparing safety analysis reports, however, the AEC has adopted specific criteria. The reactor site boundary (surrounding the exclusion area) must meet the following criteria (10 CFR 100.11(a)(1)):

> (1) An exclusion area of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product release would not receive a total radiation dose to the whole body in excess of 25 rem[2] or a total radiation dose in excess of 300 rem[2] to the thyroid from iodine exposure.

81/ Fish, B.R., G.W. Keilhalte, W.S. Snyder, and S.D. Swisher, Chapter 7 of early draft version of B.R. Fish, et al, "Calculation of Doses Due to Accidental Released Plutonium from an LMFBR," ORNL-NSIC-74 (Nov. 1972), p. 128. This chapter was deleted from the final version at the direction of AEC-Division of Reactor Development and Technology because it was judged to be not directly applicable to the objective of the study, and the information base from which it was developed was already available in other documents. AEC-DRDT further stated that it was not removed because of the quality of the work.

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[2]The whole body dose of 25 rem referred to above corresponds numerically to the once in a lifetime accidental or emergency dose for radiation workers which, according to NCRP recommendations may be disregarded in the determination of their radiation exposure status (see NBS Handbook 69 dated June 5, 1959). However, neither its use nor that of the 300 rem value for thyroid exposure as set forth in these site criteria guides are intended to imply that these numbers constitute acceptable limits for emergency doses to the public under accident conditions. Rather, this 25 rem whole body value and the 300 rem thyroid value have been set forth in these guides as reference values, which can be used in the evaluation of reactor sites with respect to potential reactor accidents of exceedingly low probability of occurrence, and low risk of public exposure to radiation.

Fish, et al, made the following comments regarding the applicability of these criteria to the case of plutonium release. These comments are also applicable to hot particle case.

> First, the wording of sections 100.11(a)(1) clearly limits the application to the irradiation of the whole body and the thyroid; no other organ or tissue is mentioned or implied. Furthermore, only fission products in general and iodine in particular are identified as reference substances. Finally, footnote (2) states unequivocally that the guides are not to be considered as acceptable limits for emergency doses to the public under accident conditions.[82]

Without addressing whether the guideline values, 25 rem to the whole body and 300 rem to the thyroid, should

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82/ Ibid, p. 129.

be considered as acceptable limits, or whether design basis accidents that are currently evaluated under these criteria are "of exceedingly low probability of occurrence," we recommend that 10 CFR 100.11(a)(1) be modified as follows in order to establish a hot particle standard that is equivalent to the risk associated with 25 rem whole body irradiation:

> (1) An exclusion area of such size that an individual located at any point on its boundary for two hours immediately following onset of the postulated fission product or other radionuclide release would not receive a total radiation dose to the whole body in excess of 25 rem[2] or a total radiation dose in excess of 300 rem[2] to the thyroid from iodine exposure, or receive a lung particle burden in excess of 10 hot particles.[3]

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[2] (Unchanged from original text)

[3] A hot particle is a particle that contains sufficient activity to deliver at least 1000 rem/yr to the surrounding lung tissue. For isotopes having half-lives greater than one year, this would correspond to particles containing at least 0.07 pCi of alpha activity.

We also recommend that similar criteria be established limiting hot particle releases for nuclear facilities not now covered under 10 CFR 100.

D. Surface Contamination

Hot particles deposited on land surfaces can be resuspended into the air by any number of means, including wind, automobile traffic, human or animal movements, Following an accident wherein surfaces are contaminated with hot particles, it is necessary to have a standard to apply to decontamination measures.

The number of particles that can be resuspended from surfaces has been the subject of a number of experiments. These experiments have usually resulted in the determination of a resuspension factor (RF). The RF is defined by:

$$\text{RF } (m^{-1}) = \frac{\text{concentration in air } (\mu Ci/m^3)}{\text{concentration on surface } (\mu Ci/m^2)}$$

R. L. Kathren has reviewed the data obtained on RF values.[83] He indicates that, "reported [RF] values for plutonium and its compounds range over 11 orders of magnitude." This 11 orders corresponds to values between 10^{-1} to 10^{-11} m^{-1}. Kathren indicates that, "an RF of 10^{-4} m^{-1}, although conservative is appropriate."[84] Langham indicates that a member of the Danish scientific team used an RF=10^{-3} m^{-1} during the Thule deliberation.[85] We would recommend that

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83/ Kathren, R.L., "Towards interim acceptable surface contamination levels for environmental PuO_2," BNWL-SA-1510, Battelle Northwest Laboratory, Richland, Washington, April 1968, pp. 3-4.

84/ Ibid, p. 4.

85/ Langham, Wright H., Op. cit., p. 5. The Thule Deliberations refer to the deliberations following the accidental crash of a B-52 bomber carrying nuclear weapons near Thule Air Force Base in Greenland. The high explosives in the weapons detonated and dispersed the plutonium.

the value selected by Kathren be used when the RF is unknown to determine the ambient ground contamination standard. Applying an $RF=10^{-4}\ m^{-1}$ to the ambient MPC_a standard recommended in the previous section, we obtain a maximum permissible surface contamination (MPSC) level for hot particles of $9x10^{-8}$ uCi/m^2.[86] This is roughly 1 hot particle/m^2. In areas where an RF greater or less than $10^{-4}\ m^{-1}$ could be shown to apply, the MPSC could be altered appropriately.

E. <u>As Low as Practicable Hearings</u>

It is to be understood that the above recommendations do not represent endorsement on our part of the risk inherent in the existing radiation protection guidelines upon which these recommendations are based. Rather, we offer the admonition that the exposures should be kept as far below these guidelines as is practicable. Therefore, we further recommend that these guidelines be incorporated into the existing regulations without delay and that the appropriate agency or agencies convene hearings to determine for the regulations what constitutes as low as practicable limits for exposure to hot particles.

86/ This value is derived as follows: The recommended MPC_a for hot particles is $9x10^{-18}$ uCi/ml which corresponds to $9x10^{-12}$ uCi/m^3. The maximum ground contamination level, using $RF=10^{-4}\ m^{-1}$, is $9x10^{-12}/10^{-4} = 9x10^{-8}$ uCi/m^2.

VIII Summary of Recommendations

The following recommendations apply to alpha-emitting hot particles where a hot particle is defined as a particle that contains sufficient activity to deliver at least 1000 rem/yr to the surrounding lung tissue. For isotopes having half-lives greater than one year, this would correspond to particles containing at least 0.07 pCi of alpha activity.[87]

It is recommended that:

1. For occupational exposure

   MPLPB = 2 hot particles

   MPC_a for Pu-239 = 3.5×10^{-16} uCi/ml[88]

2. For non-occupational exposure

   MPLPB = 0.2 hot particles

   MPC_a for Pu-239 = 9×10^{-18} uCi/ml[89]

87/ These particulates would consist of compounds of Pu and the other actnides which fall into Class Y material in the ICRP Task Group Lung Model. These materials would be retained for years in the lung. See for example, ICRP Publication 19, Op. cit., p. 6. Since only particles in the size range of 5 u and below in diameter would be deposited in the deep respiratory tissue, this in effect sets an upper limit for the particle size of interest here. If the half-life is less than or close to 1 year the limit of 0.07 pCi can be adjusted upward through appropriate calculations.

88/ This MPC_a applies for particles containing 0.07 pCi of Pu-239. For particles containing more than 0.07 pCi the MPC_a could be increased proportionately. For particles containing less than 0.07 pCi the existing $MPC_a = 4 \times 10^{-11}$ pCi/ml would apply. The MPC_a for hot particles of other isotopes and mixtures of isotopes should be established on a similar basis with consideration given to the half-life of the isotope.

89/ Ibid.

3. For accidental releases exposure (10 CFR 100.11(a)(1))

   MPLPB (2 hours exposure) = 10 hot particles

4. For unrestricted areas

   MPSC = 1 hot particle/m^2 [90]

5. Hearings should be convened to determine as low as practicable regulations.

90/ This value is meant for guidance with respect to decontamination of an unrestricted area that has been contaminated with hot particles. In areas where an RF greater or less than 10^{-4} m^{-1} could be shown to apply, the MPSC could be altered appropriately.

APPENDIX A

Radiation Standards Setting Organizations and Their Roles

The organization which recommends basic radiation criteria and standards at the international level is the International Commission on Radiological Protection (ICRP). It was established in 1928 under the auspices of the Second International Congress of Radiology. During the early period and until 1950, the ICRP was concerned primarily with recommendations designed to provide protection to members of the medical profession in their diagnostic and therapeutic use of X-rays and gamma radiation from radium. However, since the advent of atomic energy, and radiation uses on a large scale, it has extended its efforts to include studies of radiation protection matters covering the whole gamut of radiation applications. It works together with its sister commission, the International Commission on Radiation Units Measurements (ICRU), and relies on the ICRU for background knowledge on radiation measurements.

The National Council on Radiation Protection and Measurements (NCRP) was organized in 1929, a year after the ICRP, as a combined effort of several radiation protection committees in the United States to consolidate their scattered efforts and to present a unified voice at meetings of the ICRP.[1] The ICRP and NCRP are private groups whose recommendations are purely advisory.

In 1934 the NCRP adopted the simple level of 0.1 roentgen per day, measured in air as the tolerance dose. In 1940, it recommended a permissible body burden of 0.1 microgram for ingested radium. The latter standard, still in effect today, corresponds to an average dose to the skeleton of about 30 rem/yr or a dose to the critical endosteal tissue out to a distance of 5-10 microns of about 10 rem/yr.

1/ Initially the NCRP was known as the Advisory Committee on X-rays and Radium Protection; in 1946 the name was changed to the National Committee on Radiation Protection and Measurements, and in 1964 it received a Federal charter and took its present name.

In 1949, the maximum permissible dose for radiation was lowered to 0.3 roentgen per week. It was lowered again in 1957 to 5 rem/yr as the permissible dose for radiation workers. This standard is still in effect.

The AEC has also played a significant role in setting radiation standards. However, the AEC's regulatory authority over materials was, and still is, limited by the Atomic Energy Act of 1954, as amended, to source, by-product, and special nuclear material. Before the Federal Radiation Council (FRC) was formed, the AEC, when setting radiation standards, generally followed closely the recommendations of the NCRP, which in turn paralleled the ICRP recommendations.

In 1959, after the advent of the atomic age had aroused public fears over fallout from nuclear weapons, the U. S. government, because of uncertainty of government influence over radiation protection standards, organized the FRC. It was authorized by Congress to "...advise the President with respect to radiation matters directly or indirectly affecting health, including guidance for all federal agencies in the formulation of radiation standards and in establishment and execution of programs in cooperation with the states..."[2] The final authority with respect to radiation standards rested not with the FRC but with the President. Such a subordinate agency as the AEC, for example, had to make its rules, e.g., those governing licensed reactors, compatible with the overall guides developed by the FRC.

Throughout the 1950's the ICRP and NCRP continued to revise and refine the basic recommendations concerning permissible radiation exposure standards. Standards were recommended for some non-occupational groups and for the whole population. Maximum permissible body burdens and maximum permissible concentrations of radionuclides in the air and in water were recommended as secondary standards. Most of these recommendations were incorporated by the FRC and the AEC.

In 1970 the FRC was abolished and its duties were transferred to the EPA. Since that time, the setting of population exposure standards has resided in EPA. Population standards,

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2/ FRC Report No. 1, Background Material for the Development of Radiation Protection Standards, Government Printing Office, Washington, D. C., May 13, 1960, p. 1.

in this case, mean exposure to persons "outside the fence" of an AEC (or AEC-licensed) facility. Criteria, required to meet these standards, for plant operation and design remained with the AEC. Hence, present responsibility for assessment of health effects resides in EPA, while the responsibility for developing technology to control emissions resides in AEC. The Office of Management and Budget (OMB) in a recent letter to EPA and AEC clarified the delegation of responsibility between these agencies for promulgating regulations to limit the radioactivity that may be emitted from facilities in the nuclear power industry. OMB stated:

> AEC should proceed with its plans for issuing uranium fuel cycle standards, taking into account the comments received from all sources, including EPA; that EPA should discontinue its preparations for issuing, now or in the future, any standards for types of facilities; and that EPA should continue, under its current authority, to have responsibility for setting standards for the total amount of radiation in the general environment from all facilities combined in the uranium fuel cycle, i.e., an ambient standard which would have to reflect AEC's findings as to the practicability of emission controls.[3]

There are other agencies and groups which are concerned with radiation standards and in some cases have regulatory authority. These include, but are not limited to, the Department of Health, Education and Welfare, Department of Labor, Bureau of Mines, the American National Standards Institute, and state agencies. The radiation standards of these organizations are not at issue here. For the most part they play a secondary role, or where applicable, follow the guidance of the NCRP, EPA and AEC.

3/ Memorandum for Administrator Train and Chairman Ray from Roy L. Ash, Dec. 7, 1973.

APPENDIX B

Statement Submitted to Attorneys for Mr. Edward Gleason

Re: Edward Gleason, et al vs. NUMEC

by: Arthur R. Tamplin

The following is my analysis of the origin of Mr. Edward Gleason's soft tissue sarcoma that ultimately resulted in his death and of the Consultation Report, submitted by Dr. Niel Wald, dated Jan. 29, 1973.

Mr. Gleason unloaded, rotated, and loaded a crate containing a leaking carbov of plutonium-239 (Pu-239) solution. This could not have occured without contaminating the palmar surface of his left hand, which was bare. The question is: did this Pu-239 contamination cause Mr. Gleason to develop a sarcoma? Since radiation induced cancers are identical with those that occur spontaneously, it is necessary to consider the relative chances that the cancer was spontaneous or Pu-239 induced.

The United States Vital Statistics, record a death rate for malignant neoplasms (other than melanoma) of the skin in the upper extremity of less than one per million per year. Since synovial sarcoma is a rare form that often metastasizes and hence has a poor prognosis, its occurrence rate is certainly less than the total skin cancer death rate of one per million per year. Thus it is highly unlikely that anyone who handled this crate would spontaneously develop this sarcoma on the contaminated hand (less than one chance in a million).

Now let us consider what the chances are of the development of cancer as a result of plutonium contamination of the skin. Experimental data from plutonium contaminated animals demonstrate that injection of 1 microgram of Pu-239 into the skin of rats promptly produced cancer in up to 5% of the animals (Exhibit 1). The particular tumors are fibrosarcomas.

Now the analysis done by LASL indicated that the Pu-239 concentration was about 160 micrograms per milliliter. This is reason to suspect, since the volume of liquid was reduced, the Pu was actually more concentrated in 1963. But setting that aside, one drop would be expected to contain between 8 and 16 micrograms of Pu-239. One-one hundredth of a milliliter (a very small amount of liquid) would have been sufficient to produce sarcomas in animals. There is little reason to doubt that this small amount of liquid (0.01 milliliter) or even more found its way below the surface of Mr. Gleason's palm. In this event, his chance of developing cancer would be one in twenty. This is at least 50,000 times higher than his chances of developing the cancer spontaneously. In other words, the evidence is overwhelming in favor of the tumor resulting from Pu-239 contamination.

The above relative probability is based upon data from animals. It is quite possible that man is more sensitive than animals to cancer induction by Pu-239. In fact, the biological evidence strongly suggests that man is more sensitive. Exhibit 2 is a case report of a nodule removed from a man. This nodule contained only 0.08 ug of Pu-239. Commenting on the histological examination of the lesion, the authors states,"The autoradiographs showed precise confinement of α-tracks to the area of maximum damage and their penetration into the basal areas of the epidermis, where epithelial changes typical of ionizing radiation exposure were present. The cause and effect relationship of these findings, therefore, seemed obvious. Although the lesion was minute, the changes in it were severe. Their similarity to known precancerous epidermal cytologic changes, of course, raised the question of the ultimate fate of such a lesion should it be allowed to exist without surgical intervention..." In this case, less than 0.1 ug of Pu-239 produced precancerous changes in human tissue. The dose to the surrounding tissue was very intense. There is every reason to believe that a smaller quantity of Pu-239 would have produced similar changes.

When I consider the above human and animal data together with the relative probability of 50,000, I can come to no other conclusion than that this sarcoma was a direct result of the contamination of Mr. Gleason's left palm by Pu-239.

Turning now to Dr. Wald's Consultation Report, it can be stated that he has presented no evidence to disprove the claim that this sarcoma was caused by Pu-239 contamination. I shall discuss Dr. Wald's report in the order that it was written.

According to the Division of Inspection Report submitted by Anson M. Bartlett on April 11, 1963, pages 29-30, the January 19 examination was conducted not on Mr. Gleason, but on his home, clothing and automobile. The single urine and feces samples collected subsequent to January 20 gave negative results. The only thing that this demonstrates is that no detectable level of Pu-239 was found. Even following the injection of large volumes of Pu-239 solution into the skin and muscle of animals, the Pu-239 is slowly absorbed and appreciable fractions, up to 70%, remain at the site of injection. Moreover, of the quantity absorbed only a small fraction appears in the urine or feces (see page 3, Exhibit 3 and Exhibit 4). In Mr. Gleason's case we are concerned with only a very small volume of solution and hence we should not be surprised if we obtain negative results in an individual urine or feces sample. (See also Exhibit 5)

The physical examination performed by Dr. Roy E. Albert on January 23, 1963, has no relevance. One would expect no overt signs of radiation injury at this early date from the small quantity of Pu-239 which is at issue here. We are concerned here with the long term effects, not the acute effects.

The medical history of Mr. Gleason as recorded by Dr. Wald appears to be accurate, however, he omitted the conclusions of the Pathology Report of the Hospital for Special Surgery wherein the unanimous opinion of the pathologists was stated to be that this lesion was a synovial sarcoma.

The negative findings in the feces and urine in April of 1970 are of no more relevance than the similar findings in the January 1963 samples. The whole body counter has a detection limit of 0.3 u Ci of Pu-239. At issue here are quantities below 0.06 u Ci and, hence, well below the detectable limit.

There are three reasons for setting aside the negative findings in the initial tissue removed from Mr. Gleason. First, since the pathologist report indicated "no evidence of atypical or malignant changes," it is quite possible that this mass was unrelated to the sarcoma. Recall here that the histology of the small nodule in Exhibit 2 showed severe changes that resembled precancerous changes. Third, the site of contamination was not necessarily removed with the mass or it could have trimmed from the mass prior to production of the paraffin blocks and slides. Consider here that the nodule in Exhibit 2 was only 1/10 of a millimeter in diameter. Since Mr. Gleason eventually developed an infiltrating soft tissue sarcoma, and this original tissue removed showed no atypical change, there is no basis for assuming that the origin of the sarcoma was included in this tissue mass.

The negative results on the clavicle specimen are also equivocal. The issue here is a small quantity of Pu-239 that remained localized in the palmar area of the left hand. This bone specimen indicates only that the amount of systemically absorbed Pu-239 was too small to be detected in this bone specimen.

None of these clinical findings are able to set aside the strong possibility that Mr. Gleason's sarcoma was a direct result of the plutonium contamination. The most likely course of events is that a small quantity of the Pu-239 solution (less the 0.01 milliliter) was deposited in the tissue below Mr. Gleason's palm. This may have occured through a small cut or via a sliver. The body then reacted to this material as a foreign body, and encapsulated it. Eventually, a lesion similar to that discussed in Exhibit 2 developed. This nodule progressed beyond the precancerous stage to become an infiltrating soft tissue sarcoma. The chances are some 50,000 times greater that the sarcoma developed in this fashion than that it occured spontaneously.

I think that it is important to point out that all of the information relevant to this case was available in 1963. Had Mr. Gleason been informed of the potential cancer risk subsequent to the incident, he could have informed his physicians. As a result they would probably have treated him more cautiously and the tradegy could have been substantially mitigated.

Exhibits

1 Lisco, Herman, et al, Radiology, Vol. 49, No. 3, Sept. 1947, pp. 361-363.

2 Lushbaugh, C.C., et al, Arch. of Dermatology, Vol. 86, Oct. 1962, pp. 461-464.

3 Vanderbeck, J. W., HW-66172, Hanford Laboratories Operation, July 25, 1960.

4 Matsuoka, Mr., et al, Health Physics, Vol. 22, June 1972, pp. 713-722.

5 Lisco, Herman and Walter E. Kesiekeski, American J. of Pathology, Vol. 29, No. 1, Jan. - Feb. 1953, pp. 305-321.

GLOSSARY

Absorbed Dose:	The absorbed dose of any ionizing radiation is the energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest. The unit of absorbed dose is the rad. One rad is 100 ergs/gram.
AEC:	Atomic Energy Commission.
Ci:	Abbreviation for curie.
Curie:	The quantity of a radioactive nuclide disintegrating at the rate of 3.7×10^{10} atoms per second.
D:	Abbreviation for Absorbed Dose.
DE:	Abbreviation for Dose Equivalent.
DF:	Abbreviation for Dose Distribution Factor.
Dose Distribution Factor:	A modifying factor used in calculating dose equivalent which accounts for non-uniform distribution of radiation.
Dose Equivalent:	The product of absorbed dose D, quality factor (QF), dose distribution factor (DF), and other necessary modifying factors (The dose equivalent is numerically equal to the absorbed dose in rads multiplied by the appropriate modifying factors). The unit of dose equivalent is the 'rem.'
EPA:	Environmental Protection Agency.
FRC:	Federal Radiation Council. The FRC has been abolished, and its functions taken over by EPA.
g:	Abbreviation for gram.
Half-life:	Time required for a radioactive substance to lose 50 percent of its activity by radioactive decay. Each radionuclide has a unique half-life.

ICRP: International Commission on Radiological Protection.

m: Abbreviation for meter.

micron: One-millionth of a meter.

ml: Milliliter = 0.001 liters.

MPC_a: Maximum permissible concentration (of a radionuclide) in air. The average concentration above background of a specific radionuclide to which an individual can be exposed without exceeding the guidelines.

MPC_w: Maximum permissible concentration (of a radionuclide) in water. (See definition above.)

MPLB: Maximum permissible lung burden.

MPLD: Maximum permissible lung dose.

NCRP: National Council on Radiation Protection and Measurements.

nCi: Abbreviation for nanocurie, which is one-billionth of a curie, or 10^{-9} curie.

pCi: Abbreviation for picocurie, which is one-millionth of a microcurie, or 10^{-12} curies.

QF: Abbreviation for Quality Factor, which is assigned on the basis of a number of considerations. A quality factor is a modifying factor used in calculation of dose equivalent which accounts for differences in producing biological effects among various forms of radiation (e.g., alpha, and X-radiation).

Rad: Unit of absorbed dose (D), which is 100 ergs/gram. The rad is a measure of the energy imparted to matter by ionizing radiation per unit mass of irradiated material at the place of interest.

Radionuclide: A nuclide of an element that is radioactive.

Rem: Unit of dose equivalent. When the appropriate modifying factors are used to calculate dose equivalent one rem is the quantity of any type of ionizing radiation which when absorbed in man produces an effect equivalent to the absorbtion of one rad of X- or gamma-radiation at the place of interest.

Roentgen: The quantity of X- or gamma-radiation such that the associated corpuscular emission per 0.001293 grams of air produces, in air ions carrying one electrostatic unit of electricity of either sign. For the purposes here, the roentgen is roughly equivalent to the rad.

Specific activity: Total radioactivity of a given material (isotope, element, or compound) per gram of the material -- curies/gram.

u: Abbreviation for micron, which is one-millionth of a meter.

uCi: Abbreviation for microcurie, which is one-millionth of a curie.

ug: Abbreviation for microgram, which is one-millionth of a gram.

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14 November 1974

Lt. General Warren D. Johnson
Director
Operations & Administration
Headquarters, Defense Nuclear Agency
Washington, D. C. 20305

RE: Environmental Impact Statement -- Enewetak

Dear Lt. General Johnson:

Enclosed is a copy of "The Hot Particle Issue: A Critique of WASH-1320 as it Relates to the Hot Particle Hypothesis," by Dr. Arthur Tamplin and me.

NRDC requests that this critique by included in any subsequent versions of the Environmental Impact Statement on Enewetak.

Sincerely,

Thomas B. Cochran

Thomas B. Cochran

Document "The Hot Particle Issue: A Critique of WASH 1320 as it Relates to the Hot Particle Hypothesis" not included at this time but will be included in final distribution.

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The Hot Particle Issue:

A Critique of WASH 1320*
as it Relates to the
Hot Particle Hypothesis

by

Arthur R. Tamplin

Thomas B. Cochran

November 1974

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* "A Radiobiological Assessment of the Spatial Distribution of Radiation Dose from Inhaled Plutonium," WASH 1320, U. S. Atomic Energy Commission [September 1974].

I. Background

On February 14, 1974, the Natural Resources Defense Council (NRDC) petitioned the Atomic Energy Commission (AEC) and the Environmental Protection Agency (EPA) to amend their radiation protection standards applicable to "hot particles" of plutonium and other actinides where hot particles were defined more fully in an accompanying report.[1] The report (referred to herein as the Tamplin-Cochran Report) concluded that the existing radiation protection standards are grossly inadequate to protect workers and the public from the high cancer risk posed by exposure to the atmospheric release of plutonium particulates from the nuclear power and weapons industries. The report recommended (and the petition requested) that the current standards be made more restrictive by a factor of 115,000. In the petition NRDC indicated that matters of importance to the public health and safety such as this require prompt action. Allowing a reasonable period for public comment NRDC recommended that the proposed standards be set within six months (by August 14, 1974).

On March 15, 1974, the AEC released its Draft of the Liquid Metal Fast Breeder Reactor Program Environmental Impact Statement (DRAFT LMFBR EIS). This statement contained a 15-page discussion of the hot particle problem.[2] This discussion, based

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1/ Tamplin, A. R. and T. B. Cochran, "Radiation Standards for Hot Particles," Natural Resources Defense Council, Washington, D. C., 14 February, 1974.

2/ DRAFT LMFBR EIS, Vol. II, Part 2, Section 4.G.5, pp. 4.G-89 to 4.G-105, March 1974.

on an earlier report by John W. Healy (referred to herein as the Healy Report) of Los Alamos Scientific Laboratory,[3] was used as justification for ignoring the approach taken in the Tamplin-Cochran Report for estimating the lung cancer incidence associated with the inhalation of plutonium particulates (hot particles) and using instead the assumption of uniform lung exposure even where hot particles are concerned.

On March 28, 1974, the AEC gave notice in the Federal Register (39 Fed. Reg. 11450) of NRDC's filing of its petition and requested public comments by May 28, 1974.

On April 16, 1974, NRDC submitted to the AEC a critique of the hot particle discussion in the DRAFT LMFBR EIS.[4] Since the hot particle discussion in the DRAFT LMFBR EIS drew heavily from the Healy Report (much of it reproduced verbatim), the NRDC comments were a critique of the Healy Report itself.

On August 5, 1974, the AEC announced that it was releasing a draft Generic Environmental Statement on Mixed Oxide Fuel (DRAFT GESMO), i.e., recycled plutonium in light water reactors. NRDC in a letter of February 21, 1974, had requested that the AEC give in this generic environmental statement a full and candid

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3/ Healy, J. W., "Contamination Limits for Real and Personal Property," Los Alamos Scientific Laboratory, Los Alamos, New Mexico, LA-5482-PR, January 1974.

4/ NRDC Comments on WASH 1535, Draft Environmental Impact Statement, Liquid Metal Fast Breeder Reactor Program, Re: Volume II, Part 2, Section 4.G.5, Particle Lung Dose Effects, pp. 4.G-89 to 4.G-105, 6 May 1974.

discussion of the recommendations and supporting evidence presented in the NRDC petition and accompanying report.

In the DRAFT GESMO, just as in the DRAFT LMFBR EIS, the uniform exposure assumption was used to calculate the lung cancer risk from hot particle exposures. The first paragraph of the following quote from the DRAFT GESMO gives the justification for this assumption. The two remaining paragraphs describe the AEC's treatment of the NRDC petition and the Tamplin-Cochran Report in the DRAFT GESMO.

> Over the past 30 years concern has arisen from time to time about the possibility that radioactivity concentrated in discrete particles might be more potent when in contact with living tissue than the same activity diffusely distributed through the same tissue (hot particle hypothesis). Numerous studies to investigate this hypothesis provide evidence that present standards have been established on a sound basis.[2] The standards setting bodies have not set different limits for these two types of exposure to radioactivity. Diffuse radiation of tissues is used to calculate dose. Hence this approach, that is diffuse irradiation of tissues, has been used in the preparation of this statement.
>
> The AEC has been asked by the Natural Resources Defense Council, Inc. (NRDC) to consider the "hot particle" hypothesis in this generic environmental statement on the use of mixed oxide fuel. Appendix D presents key elements of a report by Arthur R. Tamplin and Thomas B. Cochran[3] submitted by NRDC as well as selections from a report by J. W. Healy.[2] The Healy study is a broad review of investigations on this subject and generally supports the prevailing position of the standards setting bodies.
>
> The Natural Resources Defense Council, Inc. has raised again the question of the effect of "hot particles" in a petition filed with the Atomic Energy Commission, requesting that a reduced limit be imposed upon the concentration of plutonium in air for particles of a specified high activity. This matter is being given careful consideration in a separate proceeding.[5]

5/ DRAFT GESMO, p. IV J-7.

NRDC filed its petition requesting the reduction in the plutonium standards with the agencies charged with the responsibility. In its first official statement on this issue subsequent to the NRDC petition, the AEC presented in the DRAFT LMFBR EIS an argument based on the Healy Report. NRDC responded with a critique (NRDC's comments on the DRAFT LMFBR EIS), setting aside the Healy Report by rebutting each of the points raised in the DRAFT LMFBR EIS and showing why the references cited do not support the hypothesis that hot particles can be analyzed in the same manner as uniform organ exposures, either for purposes of estimating carcinogenic risks or for establishing radiation standards. Four months after submitting those comments, we were presented with the second AEC pronouncement on the hot particle issue (DRAFT GESMO). Here, the AEC used as justification the original Healy Report and made no reference to NRDC's comments. There was absolutely no justification for this aberrant behavior by the AEC.

We are now presented with the third pronouncement on this subject by the AEC in the report by Bair, Richmond and Wachholz (referred to herein as the BRW Report).[6] As we shall show in our critique, it is for the most part an elaboration on the Healy report. Moreover, this report also fails to acknowledge and discuss our comments on the Healy Report submitted some six months

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6/ Bair, W. J., C. R. Richmond and B. W. Wachholz, A Radiobiological Assessment of the Spatial Distribution of Radiation Dose from Inhaled Plutonium, WASH-1320, USAEC, September 1974.

ago on April 16, 1974, relative to the DRAFT LMFBR EIS. In this respect, it is also significant to note that on May 22-24, 1974, the AEC sponsored a symposium on the biological effects of plutonium at Los Alamos, New Mexico. Attendance was by invitation. The authors, Bair, Richmond and Wachholz were invited but we were not invited. When we submitted our report and petition to the AEC, we had hoped that this would lead to a dialogue that would serve to resolve this important issue. However, it appears that the AEC refuses to engage in this dialogue either face-to-face or in writing. It appears to us that the simplest elements of professional responsibility would require that they respond to our refutation of their arguments rather than continually raising the same arguments in successive publications. To this end, we again respond to their arguments. We begin by reviewing the principal elements of the hot particle hypothesis.

II. The Hot Particle Hypothesis

The "hot particle hypothesis" is relatively simple. With respect to alpha-emitting particles in the lung, it is:

> If a particle deposited in the deep respiratory tissue is of such activity as to expose the surrounding lung tissue to a dose of at least 1000 rem in 1 year, this particle represents a unique carcinogenic risk. The biological data suggest that such a particle may have a cancer risk equal to 1/2000.

This hypothesis implies that if a particle exposes the surrounding lung tissue to a dosage greater than 1000 rem in 1 year, the cancer risk is still 1/2000. (This of course causes a larger particle to be less effective on a per μCi basis, but not on a per particle basis.) The hypothesis implies nothing about particles that expose the tissue to less than 1000 rem in one year.

The basic support for the hypothesis derives from a number of experiments wherein a small volume of tissue was exposed to high dosage. In these experiments cancer was the almost inevitable result. Although it is not explicitly stated, these experiments are relevant to the following NCRP criteria:

> (206) Simplifications in practice hinge largely on reporting a single representative protection dose for a limiting organ system even when the actual irradiation is grossly non-uniform. The representative dose is taken as the highest that can be obtained by averaging over a prescribed significant volume. The implication of this concept, or at least the convention that is followed, is that any redistribution of a given dose within such a volume does not materially alter the radiation response. It is usually assumed that the "significant volume" should be of the order of one cubic centimeter. This will be grossly conservative.
>
> (207) There will be some cases in which selection of a significant volume is inappropriate. Most notably these will include cases where the radiation agent is an alpha particle emitter deposited in thin sheets. As an example, the deposition of radon daughter products on the bronchioepithelial lining of the lungs is a case in which the effective radiation field is virtually two-dimensional only. In such cases, one may plausibly consider a significant area of tissue surface, perhaps equally arbitrarily taken as one square centimeter. Realistic modeling of such cases suggests a much smaller region as the reasonable effective target.[7]

The hypothesis is essentially an extension of these criteria. The quantitative parameters in the hypothesis are derived from a series of experiments conducted by Dr. Roy C. Albert on rat

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7/ NCRP Report No. 39, Basic Radiation Protection Criteria, NCRP Publications, Washington, D. C., January 15, 1971.

skin.[8-10] In these experiments, Dr. Albert observed that the radiation induced cancers were remarkably correlated with the disruption of a critical architectural unit of the skin, the hair follicle. The cancers were induced in the rough proportion of 1 cancer per 2000 atrophied hair follicles when the dosages exceeded some 1000 rem.

The hot particle hypothesis thus suggests that if these skin experiments were performed with small particles, each capable of disrupting a single hair follicle, the observed cancer induction would correspond to one cancer per 2000 particles.

So far as the lung is concerned, the hypothesis contains the corollary that the lung also has such a critical architectural unit that can be disrupted by a single particle and that this also presents a cancer risk of 1/2000.

The potential hazard of a single hot particle embedded in the tissue of humans is illustrated by the observation of Lushbaugh and Langham.[11] They excised a nodule that developed

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8/ Albert, R. E., F. J. Burns, and R. D. Heimbach, "The effect of penetration depth of electron radiation on skin tumor formation in the rat," Radiation Res. 30, 1967, pp. 515-524.

9/ Albert, R. E., F. J. Burns, and R. D. Heimbach, "Skin damage and tumor formation from grid and sieve patterns of electron and beta radiation in the rat," Radiation Res. 30, 1967, pp. 525-540.

10/ Albert, R. E., F. J. Burns, and R. D. Heimbach, "The association between chronic radiation damage of the hair follicles and tumor formation in the rat," Radiation Res. 30, 1967, pp. 590-599.

11/ Lushbaugh, C. C. and J. Langham, "A dermal lesion from implanted plutonium," Archives of Dermatology 86, October 1962, pp. 121-124.

around a Pu-239 particle imbedded in the palm of a machinist. Commenting on the histological examination of the lesion, the authors state:

> The autoradiographs showed precise confinement of alpha-tracks to the area of maximum damage and their penetration into the basal areas of the epidermis, where epithelial changes typical of ionizing radiation exposure were present. The cause and effect relationship of these findings, therefore, seemed obvious. Although the lesion was minute, the changes in it were severe. Their similarity to known precancerous epidermal cytologic changes, of course, raised the question of the ultimate fate of such a lesion should it be allowed to exist without surgical intervention....[12]

Considering the above observations, it would be surprising indeed if a physician would not suggest surgical intervention in a case where a patient had a few such imbedded particles. We feel that this lesion alone should cause one to be very cautious in estimating the hazard of hot particles.

That such lesions can develop in lung tissue is supported by the observations of Richmond, et al., on the lesions induced in experiments wherein hot particles were introduced into blood vessels of the lungs of rats:

> Such a lesion with collagenous degeneration and subsequent liquefaction, due to the large local dose of radiation at a high dose rate, has been reported by Lushbaugh et al.,(9) whose description of a plutonium lesion found in the dermis is very similar to that observed for plutonium in the lung.[13]

12/ Ibid., p. 463.

13/ Richmond, C. R., et al., "Biological response to small discrete highly radioactive sources," Health Physics 18, 1970, p. 406.

The above represents the distilled essences of the Tamplin-Cochran Report which was an extension of some earlier publications of Professor Donald Geesaman.[14] It is important to restate that the hypothesis suggests that the disruption of a critical architectural unit of a tissue is a significant carcinogenic event.

The actual killing of cells and the development of a fibrotic lesion surrounding the hot particle is the suggested mechanism of carcinogenesis. As Geesaman stated:

> Summing up, intense radiation exposure of mammalian skin and lung tissue commonly results in cancers. Tissue injury and disturbance are a primary consequence of intense radiation insult, and are observed in association with carcinogenesis. Albert has exhibited a simple proportionality between skin carcinomas and atrophied hair follicles. No general description of precarcinogenic injury exists, but in a crude sense the available observations are compatible with the idea of an injury-mediated carcinogenesis. Cancer is a frequent instability of tissue. Since tissue is more than an aggregate of cells, and has a structural and functional unity of its own, it would not be surprising if some disrupted local integrity, a disturbed ordering, comprises a primary pathway of carcinogenesis. The induction of sarcomas with inert discs of Mylar, cellophane, Teflon and Millipore (Brues, *et al.*[17]) is indicative that such a mechanism exists. Presumably mitotic sterilization is an important factor in any carcinogenesis mediated by radiation-induced tissue injury. The functional relation of this factor in the carcinogenic response may be quite different from a linearity in the surviving mitotic fraction.

14/ Geesaman, D. P., An Analysis of the Carcinogenic Risk from an Insoluble Alpha-Emitting Aerosol Deposited in Deep Respiratory Tissue, UCRL-50387 and UCRL-50387 Addendum, Lawrence Livermore Laboratory, Livermore, California, 1968.

> While regrettably unquantitative, the hypothesis of an injury-mediated carcinogenesis is suggestively descriptive. If the respiratory zone of the lung contains a structure analogous to the rat hair follicle, and if a radioactive particulate deposited in the respiratory zone has the capacity to disrupt one or more of these structures and create a pre-cancerous lesion, then cancer risks of the order of 10^{-3} to 10^{-4} per particle can be expected.[15,16]

The lesion excised by Lusbaugh and Langham[17] from human palmar tissue and the observation by Richmond, et al.,[18] that similar lesions are produced in the lung by hot particles strongly argue that a comparable sensitive structure is present in the lung and other tissues. Thus, the uncertainties in the hot particle hypothesis involve these quantitative parameters:

a) Is the risk of cancer per disrupted tissue mass comparable to that per disrupted hair follicle?

b) Is a particle capable of irradiating the surrounding tissue mass at the rate of 1000 rem/year sufficient to produce such a lesion?

The thrust of the NRDC petition to modify the plutonium exposure standards is that, until these uncertainties are resolved, the prudent public health principle is to accept the hot particle hypothesis rather than the less conservative hypothesis that average organ dose from hot particles provides

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15/ Geesaman, D. P., UCRL-50387 Addendum, op. cit., pp. 6-7.

16/ Brues, et al.[17], refers to Brues, A. M., H. Auerbach, G. M. De Roche, and D. Brube, "Mechanisms of carcinogenesis," Argonne National Laboratory, Biological and Medical Research Division Annual Report for 1967, ANL-7409, 1967, pp. 151-155.

17/ Lushbaugh, C. R. and J. Langham, op. cit.

18/ Richmond, C. R., et al., op. cit.

a reasonable basis for protection. The implication is, of course, that while the evidence discussed in the Tamplin-Cochran Report supports the hot particle hypothesis there is no substantial body of scientific evidence that can reject the hypothesis. The purpose of this report is to demonstrate that the evidence is also not to be found in the BRW Report.

III. Points of Analytical Confusion

Before reviewing the BRW Report in detail the following general observations are presented in order to draw clear distinctions among several analytical approaches or concepts that appear to be the source of some confusion to analysts addressing the hot particle issue. These approaches are: (1) The assignment of a risk per hot particle, independent over a range of particle sizes and activities; (2) the comparison of the risk associated with a fixed amount of activity (or absorbed dose) when spread uniformly over tissue with the risk when the same activity (or absorbed dose) is spread non-uniformly over the same tissue; (3) the concept of "wasted radiation" and/or "overkill." It is essential that these three approaches or concepts and their relationships (or distinguishing features) be clearly understood before judging the relevance of experimental data to the hot particle issue. We begin by reviewing each approach or concept and then examine their relationships of (2) and (3) to (1).

(1) Risk Per Hot Particle -- The assignment of a risk per hot particle is based on a hypothesis that when the radiation dose to the irradiated tissue mass surrounding a radioactive particle is sufficient to disturb a critical architectural unit of the tissue, such a disrupted tissue mass poses a unique carcinogenic risk. A value is assigned for the tumor risk associated with the disrupted tissue. Since for small particles there is a one to one correspondence between the disrupted architectural unit and the associated radioactive particle, this tumor risk is the risk per particle. In the Tamplin-Cochran Report, a lower limit on the radiation dose (and therefore alpha activity) to disrupt the architecture was assigned (1000 rem to the irradiated tissue) and used to define a hot particle. No opinion was offered with respect to the appropriate risk function for doses (or activities) below this cutoff value. In the lung there is an upper limit on the size of particles that are deposited in the deep respiratory tissue. Hence, in the lung there is a "window" on the hot particle size and activity. In analyzing experimental data vis-a-vis the hot particle hypothesis the relevant parameter is the tumor risk per hot particle.

(2) Uniform Versus Non-Uniform Exposure -- Present radiation standards are based on (i.e., establish limiting values for) the concept of radiation dose equivalent (units of rem) to the whole body and certain critical organs. In the calculation of the rem dose a "dose distribution factor" is assigned in order that the risk associated with a non-uniform distribution of a given type of radiation exposure to the critical organ is

consistent with uniform exposure by the same type of radiation. Consistent with this approach experiments have been designed and analyzed to assess the difference between uniform and non-uniform distributions of dose to critical organs. For internal alpha-emitters the absorbed dose (in rads) to a critical organ is proportional to the total activity in the organ.[19] Hence, tumors per microcurie has been the primary parameter used when comparing tumor risk for uniform versus non-uniform dose distributions.

(3) Wasted Radiation -- The concept of "wasted radiation" or "overkill" has been invoked to describe that fraction of the radiation which kills cells, where these dead cells are assumed not to contribute to tumor production. For example, the dose rate in the immediate vicinity of a single alpha-emitting particle in the lung (or other tissue) can be high enough (given a sufficient particle activity) such that even a limited residence time in the tissue will result in the death of cells within a given radius. Since such cells can not reproduce it has been hypothesized that they would not lead to cancer.[20] An alternative hypothesis, consistant with the hot particle hypothesis, is that the presence of dead cells, cellular products or fibrosis may be required for tumor production.

19/ This is also generally true for beta-emitters.

20/ The concept of "wasted radiation" also has been invoked to describe the radiation dose during the period from the inception of initial malignancy until detection or death. The concepts of overkill and wasted radiation have been used interchangeably.

In order to demonstrate the relationships among the three approaches and concepts described above it is useful to analyze some hypothetical experiments. We do this below:

Tumors/μCi or Tumors/Particle -- Suppose one ran a series of related experiments involving hot particles in tissue where the tissue mass and the total activity were held constant across experiments (e.g., the same number of lungs exposed to 12 nanocuries total activity in each experiment), and the experiments differed only in the number of particles and the activity per particle. Consistent with the hot particle hypothesis (one tumor per 2000 hot particles) suppose one observed a tumor incidence given below in the second column from the right.

Experiment	Number of Hot Particles	Activity per Particle (pCi)	Number of Tumors Observed	Tumors per nCi
1	6000	2	3	0.25
2	4000	3	2	0.17
3	2000	6	1	0.08
4	200	60	0	0.00

From the observed number of tumors and the total activity (12 nCi), the tumors per nanocurie are calculated in the last column. Holding the total activity and tissue mass as constant while increasing the number of particles tends to make the exposure more uniform. Hence the results, when analyzed on a tumor per nanocurie basis (the last column), appear consistent with the view that uniform exposure carries a higher risk than non-uniform exposure. But these same experimental results are exactly consistent with the hot particle hypothesis. What does this tell us? First, it clearly demonstrates that an analysis of an experiment, or series of experiments, on a tumor per nanocurie or microcurie basis, the results of which appear consistent with the concept that uniform exposure carries a higher tumor risk than non-uniform exposure, is not in itself a refutation of the hot particle hypothesis. In fact, if the hot particle hypothesis is correct, an analysis based on tumor per microcurie is irrelevant. One can just as easily design a series of experiments consistent with the hot particle hypothesis, which when analyzed on a tumor per microcurie basis suggests the opposite, that is, uniform exposure carries a smaller risk than non-uniform exposure, as is the case with respect to the two experiments below.

Experiment	Number of Particles	Total Activity (nCi)	Number of Tumors Observed	Tumors per nCi
1	6000	12	3	0.25
2	4000	6	2	0.33

Again, if the hot particle hypothesis is correct, the analysis based on tumors per microcurie would be irrelevant. If tumor production depends on the number of disrupted architectural units independent of particle activity (over a range of activities), analyzing the data on a tumor per microcurie basis clearly makes no sense. One would not expect, *a priori*, a correlation between tumors per microcurie and numbers of particles (uniformity of dose). To the contrary one should not be surprised to see conflicting experimental results (i.e., some experiments suggesting uniform exposure carries a higher risk and other experiments suggesting the opposite). The relevant parameter to judge the hot particle hypothesis is tumors per hot particle, not tumors per microcurie.

At this point we might add that in addressing the hot particle issue, an analysis based on tumors per microcurie (or tumors per rad), where the radiation exposure is from other than hot particles (and therefore a different carcinogenic response mechanism may be controlling), is also irrelevant and is simply a compounding of mistakes.

We do not imply that comparisons of the risks associated with uniform and non-uniform exposure serves no useful purpose. Consider, for example, radium-226 and plutonium-239 which are both alpha-emitters and both bone seekers, that is both are preferentially deposited in the skeleton. The cancer risk per microcurie deposited in the skeleton (or per rad) is about five times higher for plutonium than radium. This suggests that plutonium is preferentially deposited in tissue more sensitive to the development of bone cancer, and that in calculating the dose equivalent (rem) to the skeleton due to plutonium the use of a dose distribution factor of 5 is appropriate. However, this clearly has no relevance to the hot particle hypothesis which is an entirely different effect, aside from the fact that the distribution factor for plutonium in the bone is based on soluble plutonium and not hot particles.

Hot Particles and Wasted Radiation -- Turning next to the concept of wasted radiation, suppose one were to implant one hot particle of alpha activity in a critical organ such as the lung. Under the hot particle hypothesis it would carry a tumor risk equal to the assigned risk per particle, one in 2000. As long as the particle activity remained above the cutoff limit defining a hot particle, changing the activity, for example doubling it, would not change the lung tumor risk. If the activity and therefore the radiation dose were doubled without a change in the tumor risk, one could invoke the concept of "wasted radiation" or "overkill." At least one-half the activity (more than one-half if the particle activity were greater than twice the minimum defining a hot particle) would be "wasted." The hot particle hypothesis is consistent with the concept of "wasted radiation." But more important, the concept of "wasted radiation" is clearly irrelevant in judging the validity of the hot particle hypothesis. What is important, is the assessment of the risk per particle over the range of particle sizes defining hot particles. The relevant parameter in this assessment is again, <u>the tumor risk per hot particle</u>.

IV. Page by Page Critique of the BRW Report

In this section we will present a page by page critique of the BRW Report. To avoid confusion we will use their method for bibliographic citation. Their bibliography is reproduced at the end of this section.

<u>Page 1</u>. <u>"Summary and Conclusions."</u> We will comment on the conclusions in this section as we review the related material in the main text of the report, only noting here that the conclusions are without merit.

Page 3. "I. Statement of the Problem." We generally agree with this statement of the problem, noting only that the hot particle hypothesis is based on damage to a critical architectural unit as opposed to individual cells. The discussion here is essentially the same as the discussion on pp. 15-17 of the Tamplin-Cochran Report and Table I in the BRW Report is comparable to Table III in the Tamplin-Cochran Report.

Pages 5-7. "II. Background." This is a general discussion of consideration of irradiation from radioactive materials in particulate form by several organizations concerned with radiation protection, including the ICRP, NCRP and National Academy of Sciences--National Research Council (NAS-NRC). The thrust of this discussion is that (1) non-uniformity of dose has been recognized, been of interest, and periodically reviewed since the early days of the Manhattan Project, and (2) organizations with responsibility for recommending radiation standards, such as ICRP, NCRP and NAS-NRC, have never recommended a change from the current practice of basing radiation standards on the mean dose to organ. While the hot particle problem is well recognized in the biological community, and while we agree with the observations above, we do not believe the conclusion reached on page 7 by the authors of the BRW Report is appropriate, namely:

> The fact that these organizations have not changed or recommended changes in the procedures used for calculating dose to the lung as the result of their deliberations is an implication of implicit guidance on this particular problem.

To the contrary, had these organizations intended that this conclusion be drawn, they would have made it explicit. In its Publication 9, the ICRP (1966) states (p. 4):

> ...In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung.

And the NCRP (1971) offers the similar statement (pp. 79-80):

> (210) The NCRP has arbitrarily used 10 percent of the volume of the organ as the significant volume for irradiation of the gonads. There are some cases in which choice of a significant volume or area is virtually meaningless. For example, if a single particle of radioactive material fixed in either lung or lymph node may be carcinogenic, the averaging of dose either over the lung or even over one cubic centimeter may have little to do with this case.

The appropriate interpretation of these remarks by the ICRP and NCRP is that there is no guidance as to the risk for non-homogeneous exposure in the lung. The intent of these remarks is to call attention to exceptions to the general rule, rather than to implicitly advocate averaging the dose over the critical organ when the dose is grossly non-uniform.

Page 7. With regard to the quotation from the ICRP Task Group in Publication 14 (ICRP 1969), it is not at all clear that the Task Group reviewed Geesaman's work before preparing this ICRP report. Moreover, while the opinion of the Task Group may be worth noting, it is important to note that it is only an opinion and is totally unsupported in ICRP Publication 14. Considering this in 1974, it is significant that in the intervening 5 years since the issuance of Publication 14, adequate support for that opinion has not been forthcoming and as we demonstrate here is not to be found in the BRW Report. Quite the contrary, the analysis of Geesaman and the Tamplin-Cochran Report have emerged to support the opposite. The BRW Report states that new data tend to support the ICRP Task Group's opinion. With this, as we show in this critique, we totally disagree.

Pages 9-23. "III. Animal Studies."

Pages 9,10. "A. Retention of Plutonium in Lung"

This section discusses the long retention time of PuO_2 in human lung. There is no controversy here.

Pages 10-12. "B. Spatial Distribution of Plutonium Within Lung"

This section, while attempting to indicate that Pu particles in the lower respiratory region are not static, does admit on page 12 that autoradiographic evidence demonstrates that such particles are immobilized in scar tissue and possibly in Type I alveolar epithelial cells. The long residence time of Pu particles in the lung suggests that such immobilization must occur.

Pages 12-23. "C. Pulmonary Neoplasia"

These pages present the animal data on Pu induced lung cancers. The data on both soluble and insoluble Pu compounds are presented. It is only those experiments that involve insoluble alpha-emitting hot particles that are of interest here. Of those experiments discussed here, it is only those involving PuO_2 that are pertinent. Since these experiments are recanted in the subsequent section of the BRW Report, we will briefly discuss only a few of them here.

Page 13. Mention is made here of an experiment (Bair, et al., 1962) wherein 800 mice were subjected to inhalation of 0.1 to 2 nCi per gram of lung. At time of death, these animals had retained only 0.1 to 10 pCi in their lung. Moreover, the report states that since so few autopsies were performed, the lung tumor incidence is unknown. In other words, this experiment is of little value to the hot particle problem.

The beagle dog experiment (Park, et al., 1972) (Park and Bair, 1974) did involve Pu hot particles. However, as we indicated in the Tamplin-Cochran Report, since the tumor incidence was essentially 100%, this experiment does little to resolve the uncertainties in the hot particle hypothesis.

Page 15. The Pu-238 experiment by Sanders (1973) involved PuO_2 derived from crushed microspheres. However, Sanders indicates that this material was "soluble" in his experiment and that the irradiation was uniform. The observed rapid clearance from the lungs supports this contention.

The baboon studies (Metivier, et al., 1972) relates to hot particles but at quite large particle concentrations which, as in the beagle experiment, makes it difficult to draw inference relative to lower concentrations.

Pages 16-23. "D. Experiments of Special Relevance to Non-Uniform Dose Distribution"

Page 16. This page is a confusing discussion of "wasted radiation" and "overkill." As we stated in the previous section of this critique, the hot particle hypothesis designates a minimum particle activity--one that delivers a dose of 1000 rem/year to the irradiated tissue. Such a particle is suggested to have a chance of producing cancer equal to 1/2000. Particles with greater activity have the same chance, hence the concept of "overkill" or "wasted radiation" is included in the hot particle hypothesis.

This page also contains the following sentence and footnote:

> For a single radioactive particle of 239 PuO_2 in the lung (or other tissue), the dose rate near the particle can be high enough to cause the death of all cells within a given radius even if the residence time of the particle is short. Such cells will not be able to reproduce and subsequently result in cancer.*
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> *The presence of dead cells, cellular products or fibrosis may be required before a cellular transformation can express itself as a cancer. However, this concept has not been generally accepted.

This same statement and footnote appeared in both the Healy Report and the Draft EIS for the LMFBR with the significant exception of the last sentence in the footnote. Even if this last sentence were true, which we doubt, it is irrelevant because matters of science are not determined by public opinion polls. Nevertheless, we are curious concerning the method employed by the authors of the BRW Report to establish this conclusion.

We have previously indicated that the hot particle hypothesis implies an injury-mediated mechanism of carcinogenesis as the footnote suggests (see pp. 9-10). There is no need to repeat that discussion here. However, we submit that lesion discussed by Lushbaugh and Langham (1962) is by itself so incriminating of hot particles that we are amazed that the authors of the BRW Report are so reluctant to acknowledge the potential hazard of such particles.

It is, however, obvious that this reluctance led to confusion on their part. For example, the paragraph, from which the above quote was extracted, ends on page 17 with this statement:

> The relevant parameter is tumors per microcurie because the basic question is how the risk from hot particles compares with the risk from uniformly distributed radiation doses.

In the previous section of this critique we demonstrated that the test of the hot particle hypothesis must be on the basis of tumors per particle not tumors per microcurie simply because particles can contain more than the minimum activity (and hence, be "wasteful" on a per µCi basis). If the AEC had chosen to engage in a dialogue with us, this simple but fundamental matter could have been resolved and much of the extraneous material in this BRW Report could have been eliminated (if not the entire report).

<u>Page 17</u>. This page contains the following paragraph:

> Two approaches have been used in skin experiments. The first was to determine whether isolated small areas of irradiated skin gave the same yield of tumors per unit as large-area skin irradiations. The focal irradiation pattern with low LET radiation, electrons (Albert <u>et al.</u>, 1967b), was less efficient than the large area exposure in producing tumors. However, with high LET radiation (protons) there was no difference (Burns, <u>et al.</u>, 1972). If these results can be extrapolated to alpha radiation, they suggest that the risk from particulate sources is no greater than from uniformly distributed sources.

Apparently the authors of this paragraph do not understand the purpose and significance of the experiment by Burns, <u>et al.</u>, (1972) and this is reflected in the last sentence which makes no sense.

The purpose of the experiment by Burns, et al., was to determine the basis for the lower tumor producing efficiency of electrons where the irradiation was performed in a sieve pattern. Since the electrons are highly scattered, the focal radiation dose was uncertain. With the relatively non-scattering protons, the sieve pattern produced the same number of tumors per area irradiated.

These experiments demonstrate that if 24 cm^2 of rat skin are irradiated to 1000 rem, one tumor will develop per animal. If you irradiated 12 cm^2 to 1000 rem, one tumor will develop per two animals; 6 cm^2 should produce one tumor per four animals and so on. Moreover, the data strongly suggest that as the area irradiated is reduced to that corresponding to a single hair follicle, one tumor will develop per 2000 animals.

The next paragraph discusses the experiments of Albert, et al., and ends with the following discussion:

> A plausible explanation for the experimental results is that each follicle has a population of stem cells at a depth of 0.3 mm that are concerned with the production of sebaceous cells and hair. These stem cells apparently constitute the most sensitive potential oncogenic cell population to ionizing radiation in the rat skin since all the tumors were mainly of hair follicle origin (Albert, et al., 1969). Neoplastic transformation of a significant number of these target cells required large radiation doses which in turn killed most of the target cells and thus caused follicle atrophy.

This is a possible explanation but it does not set aside the hot particle hypothesis. The killing of cells and the consequent disruption of the tissue may well be sufficient by itself for such "neoplastic transformation." The induction of tumors with mylar film and millipore filters by Brues, et al.,[21] would support this as would the precancerous cytological changes observed around the lesion excised by Lushbaugh and Langham (1962) and around the microspheres in rat lungs by Richmond, et al., (1970).

Page 18. This page goes on to discuss other skin tumor experiments and the first column ends by stating that the evidence does not support the hot particle hypothesis as detailed in the Tamplin-Cochran Report. We offer the above paragraph and this entire critique as refutation of that contention.

The experiments of Richmond, et al., (1970) are discussed. This discussion, however, fails to note that Richmond, et al., stated that the lesions observed in the rat lungs following exposure to these hot microspheres were similar to that observed by Lushbaugh and Langham (1962) in human palmar tissue.

Page 19. The experiment of Passonneau (1952) is mentioned here. It was also discussed on page 17. This experiment is simply a variation of the experiments of Albert, et al., (1967a, 1967c, 1969).

Pages 19-20. These pages discuss the experiments of Richmond with Sullivan and Voelz as reported in:

Richmond, C. R. and G. L. Voelz (eds.)

LA-4923-PR, pp. 18-34 (April 1972),
LA-5227-PR, pp. 1-11 (March 1973),

and Richmond, C. R. and Sullivan, E. M. (eds.)

LA-5633-PR, pp. 1-9 (May 1974).

21/ Brues, A., et al., op. cit.

These are a series of progress reports on experiments wherein microspheres of $^{239}PuO_2$ and $^{238}PuO_2$ incorporated in ZrO_2 particles (10 μ diameter) are injected into the jugular vein of hamsters. These particles lodge in the capillary network of the lung.

The BRW Report suggests that these experiments are a strong argument against the hot particle hypothesis. We shall show that while the experiments raise some questions concerning the quantitative parameter in the hot particle hypothesis, they also support the hypothesis.

In the initial experiment 2000 particles per animal were injected according to the following dosage schedule (60 animals per dosage level).

Isotope	Level	pCi/particle	nCi/animal
Pu-239	1	0.07	0.14
	2	0.22	0.44
	2A	0.42	0.84
	3	0.91	1.82
	3A	1.60	3.20
Pu-238	4	4.30	8.60
	5	13.30	26.60
	6	59.40	119.00

Only two lung tumors developed in the experiments and they occurred in the level 2A exposure group. However, the latest progress report (LA-5633-PR) mentions histological changes occurring in the lungs of long term animals (15-20 months) in the 4-6 exposure levels. Concerning these changes, Richmond and Sullivan (1974, p. 7) stated:

> There has been no increase in frank tumors observed within the past year; however, the epithelial changes described above could be considered as precursors of peripheral adenomas.

This suggests an incipient carcinogenic response to the particles but the life span of the rats and hamsters is too short for the development of a frank tumor.

Similar histological changes were observed in rats injected with these microspheres by Richmond, et al., (1970) who pointed to the similarity of these particle induced lesions in the rat lung to that observed by Lushbaugh and Langham (1962) in human palmar tissue.

For reference, in the beagle dog experiment lung tumors developed (in all animals that survived 1600 days) some 5 to 11 years after the initial alveolar deposition of 3 to 50 nCi/gram of bloodless lung (Park and Bair, 1972). The exposures were by inhalation, not injection.

On a nCi/gram basis, the beagle exposures would correspond to exposure levels 3 and above in the Richmond experiments. But the medium activity per particle in the beagle experiment corresponds to those in exposure levels 1 and 2 in the Richmond experiments which suggests that with longer exposure periods, lower activity particles (corresponding to levels 1 and 2) can produce the histological changes observed in the rat and hamster lung and in human palmar tissue. At the same time, since the beagle exposures involved a spectrum of particle sizes, it must be conceded that the carcinogenic response in the beagles could have been elicited by the larger, higher activity particles.

In either case, the beagle dog data suggest that the induction time for the hot particle mechanism of carcinogenesis exceeds the life span of the hamster by some three years or more.

Thus, the absence of a large carcinogenic response in the hamsters does not set aside the hot particle hypothesis.

The Richmond experiments point out one of the uncertainties in our quantification of the hot particle hypothesis but they do not resolve it. We suggest that a lower limit for a hot particle be one that contain sufficient radioactivity to deliver an average dose of 1000 rem/year to the exposed tissue. For an alpha-emitting hot particle, this limit corresponds to 0.07 pCi. In LA-5633-PR the authors state with respect to this histological change (p. 7), "This lesion has been observed almost entirely in the higher activity levels (levels 4-6 and in animals given relatively small numbers of spheres (2000-6000)." A level 4 particle contained 4.3 pCi, some 60 times our limiting activity. But, at the same time, had these experiments been performed with animals that have longer life spans, it is quite possible that these histological changes would have developed around particles containing our suggested limiting activity.

Nevertheless, a 60 fold increase in activity requires only a 4 fold increase in particle diameter--for Pu-239, a change from 0.6 μ to 2.4 μ; for Pu-238, a change from 0.09 μ to 0.36 μ and for high burn-up nuclear fuel, a change from 0.4 μ to 1.6 μ. These particles are still in the range that permits deposition in the lower respiratory zone. Thus, these experiments do not set aside the hot particle hypothesis. Rather they suggest additional experiments involving longer lived animals to determine whether this histological change progresses into frank tumors and whether lower activity particles also produce these changes.

If an experiment comparable to these with hamsters were initiated with beagles, it would serve to resolve these uncertainties. Such an experiment would take some 15 years to complete. In the meantime, we propose that prudent public health practice dictates that exposure standards should be established on the basis of the hot particle hypothesis.

The experiments of Little, _et al._, (1970a, 1970b, 1973) are said to add significance to the microsphere experiments. As we show subsequently, the experiments of Little, _et al._, involved uniform exposure to Po-210 at high dosage (above 8000 rem). These experiments therefore do not involve hot particles and there is no _a priori_ reason for assuming that they involve the same carcinogenic mechanism as hot particles.

Pages 20-21. The experiments of Shubert, _et al._, (1971) and Brooks, _et al._, (1974) are discussed here. These experiments made a determination of the frequency of chromosomal aberrations in liver cells following uniform and particulate irradiation. It is important to note that a causal relationship between chromosomal aberrations and subsequent cancer development is only a hypothesis. Moreover, as we have stated previously, the actual killing of cells and the subsequent disruption of the normal tissue architecture may well be the carcinogenic mechanism for hot particles. Thus, these experiments are of little value in resolving this issue.

Pages 21-22. The experiments of Little, _et al._, (1970a, 1970b, 1973) and Grossman, _et al._, (1971) are discussed here. In these experiments hamsters were exposed to Po-210 lung doses ranging from 8,000 to 20,000 rem. In some experiments the Po was absorbed on hematite particles. However, calculations demonstrate that the activity per particle ranged from 10^{-4} to 10^{-3} pCi[22] and, consequently, that these were not hot particles. Therefore, the conclusion of Little, et al., (1973) quoted on page 22 is not relevant to the hot particle issue.

We note in passing, however, the nature of the experiments was that the entire lung was irradiated to very high dosage although there was some aggregation of particles. A large carcinogenic response was initiated in each exposure group. The preliminary data reported here indicate that the life span of the hamster is longer when the dosages are this high and the Po-210 is on particles. However, it is not sufficient to demonstrate a reduction in overall tumor response. Like the beagle experiments, the carcinogenic response in these experiments appears to be saturated because of the high dosage delivered to the whole lung or a major fraction thereof. No conclusions can be drawn relative to lower doses nor relative to hot particles. With respect to lower dosages, the work of Sanders (1973) demonstrates a large tumor incidence in rats at a dosage of 320 rems.

Pages 22-23. These pages discuss the experiments of Cember, et al. The major thrust of the Cember article deals with ^{144}Ce particles in the lung. The ^{144}Ce was introduced admixed with stable Ce as either CeF_3 or $CeCl_3$ in particles of about 1 μ in diameter (0.5 μ^3). ^{144}Ce emits a beta particle

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22/ NRDC Comments on WASH 1535, op. cit., p. 39.

of 0.275 MeV and its daughter product ^{144}Pr emits a beta of 3 MeV. The rate of energy loss for these beta particles in tissue is about 0.2 Kev/μ compared to some 94 Kev/μ for plutonium alpha particles.

This difference in energy loss per micron indicates that the activity of the ^{144}Ce emitters would have to be some 500 times that of the ^{239}Pu in order to deposit the same energy in the tissue irradiated by ^{239}Pu alpha particles. Moreover, since the QF for alpha particles is 10, the ^{144}Ce particles must have an activity (10) x (500) or 5,000 times that of a $^{239}PuO_2$ particle to qualify as a hot particle. Since the limiting activity of a $^{239}PuO_2$ particle is 0.07 pCi, a hot particle of $^{144}CeCl_3$ would have to contain more than 350 pCi. After correcting for the half-life of ^{144}Ce (288 days) a hot particle would have to contain some 500 pCi.

The geometric mean diameter of the particles in these experiments was 1 micron. The highest exposure group received 50 μCi of ^{144}Ce in 30 μg of CeF_3. Allowing a density of 6 g/cm^3 for the CeF_3, the beta-activity per particle of 1 μ diameter is only 5 pCi. In other words, these experiments did not involve hot particles as defined above. The carcinogenesis observed in these Cember experiments, which was considerable, was related to high total and rather uniform organ dosage (1,000-30,000 rad).

<u>Page 23</u>. Here the experiments of Sanders (1973) and Moskalev (1972) are discussed. Large carcinogenic responses were observed in the lungs of rats at doses of 100 to 500 rem

using "soluble" Pu compounds. One conclusion that is justified by the results of these studies is that the exposure standards for plutonium may be much too high (at least 100 times too high) even when hot particles are not involved. The results of Sanders indicate that a uniform dose of 15 rem doubled the natural incidence of lung cancer in the exposed rats. A worker is allowed this dose each year and a member of the population could accumulate this dose in 10 years.

One further point could be made concerning the study of Sanders. It is not at all clear from the description given in the reference that the exposures did not involve a few hundred hot particles. If this were so, these particles could have been partly responsible for the observed cancers.

The preliminary studies by Lafuma (1974) do not appear to be published and we have no copy of the seminar given in France. Indications are, however, that it is not different from the experiments discussed above.

Again we offer the above and this entire critique as refutation of the conclusion reached in the last paragraph of this section.

Pages 25-29. "IV. Human Experience."

This chapter of the BRW Report discusses the exposure of humans to Pu. The major thrust of the chapter involves workers from the Manhattan Project and from the Rocky Flats plutonium facility in Colorado. We discuss these in the Tamplin-Cochran Report but the authors of the BRW Report overlooked or ignored the salient features of our discussion.

Pages 25-26. The Manhattan workers are discussed on these pages. On pages 38 to 40 of the Tamplin-Cochran Report, based upon information from Hempelmann, et al., (1973a, 1973b) we calculated that the exposures of these workers did not involve hot particles. The authors of the BRW Report inexplicably ignored this discussion and made the unjustifiable assumption that the particles here corresponded to those associated with a fire at the Rocky Flats plutonium facility. As a consequence, the discussion of expected cancers on page 26 is without merit.

Pages 26-27. The discussion of chromosome aberrations has no relevance to the hot particle problem.

Pages 27-28. The exposure of employees of the Rocky Flats plutonium facility in October 1965 is discussed here. In the Tamplin-Cochran Report we pointed out that the induction period in man for hot particle carcinogenesis is unknown. In the beagle dog experiment (Park and Bair, 1972) it was 11 years before the dog with the lowest burden developed lung cancer. Thus, although no cancers have developed in the Rocky Flats workers at this time (9 years post exposure) the possibility exists that a number of cancers will appear in the next 10-15 years.

Page 28. The lesion excised by Lushbaugh and Langham (1962) is discussed here. To the extent that a lesion with changes similar "to known precancerous epidermal cytologic changes," that raise the question of its fate without surgical intervention differs from a precancerous lesion, we were remiss in the Tamplin-Cochran Report.

Page 29. As we indicated in the Tamplin-Cochran Report, the Pu in fallout did not occur in hot particles and hence, fallout Pu is irrelevant to the issue.

Pages 31-35. "V. Theoretical Consideration."

At the outset, it is important to note that one hypothesis cannot be used to set aside another. Each hypothesis must stand alone with respect to supporting experimental data.

Pages 31-33. "A. Dosimetry." This is general information about which there is little controversy.

Pages 33-35. "3. Models for Dosimetry and Tumor Probability." We agree with the concluding remarks of this section. The models discussed here relate tumor probability to cellular radiation dose. Depending upon the assumption, they can give a variety of tumor probabilities.

We would simply add that the lesion excised by Lushbaugh and Langham (1962) coupled with the observations of similar lesions induced in the lungs of rats and hamsters should be sufficient to cause anyone to be skeptical of a tumor induction model which indicates a low tumor probability for a hot particle.

Pages 35-39. "B. Radiation Carcinogenesis Relative to Spatial Distribution of Dose."

In the first paragraph of this section, the authors state that one should use experimental data, "meager as it is," rather than models based upon other organ systems. They indicate that this is "particularly true" when rat skin data are used to infer human lung effects. It is doubtful whether anyone would disagree with this. However, in the case of hot particles, the experimental data are not only meager, they are very disquieting. Since this is a public health matter of importance and not just an academic exercise, prudence dictates that exposure standards should be based upon supportable and conservative hypotheses.

Pages 35-36. The next few paragraphs discuss the concept of "wasted" radiation as it relates to the hypothesis of linear dose-effect response. When uniform irradiation is employed cancer induction is generally shown to be directly proportional to the dose from low doses up to a few hundred rad. The linear hypothesis relates these observations to cellular effects that result from single-track ionizing events. But even with uniform irradiation as one proceeds to higher dosages the response curve changes; for example, the curve steepens or the effects plateau and often decline. Obviously this indicates that other phenomena are becoming dominant. The hot particle hypothesis relates to such a different phenomenon (an injury-mediated mechanism of carcinogenesis). As such, it is not intended to be consistent with the linear hypothesis.

The mechanism of radiation carcinogenesis is not understood even in the range of the linear hypothesis. This is evident in the next several paragraphs of this section of the BRW Report. Actually much of the discussion here is supportive of an injury-mediated mechanism wherein the altered tissue architecture creates a milieu highly favorable to tumor development; for example, the quote of Mayneord (1968).

Page 36. The discussion of contact inhibition as it related to normal or "transformed" cells is again consistent with the hot particle hypothesis. It is the disturbed tissue architecture that can disrupt the normal contact inhibition. As we mentioned earlier in this critique, the induction of cancer by mylar film and millipore filters in the experiments of Brues, *et al.*, supports such a mechanism.[23]

The paragraph that begins, "Thus, both acute and late..." is purely speculative and is no more supported by the previous discussion than is the hot particle hypothesis.

Pages 36-38. The following ten paragraphs in this section are actually a discussion of an injury-mediated mechanism of carcinogenesis.

Page 38. This is followed by the paragraph,

> At present there is no compelling reason to believe that the critical structure or volume required for radiation-induced promotion of cancer arising from cancer-potential cells of hair follicles is limited to the hair follicle. There is also no cogent evidence that the lung has analagous discrete susceptible architectural units with critical tissue volume as small as the sphere of alpha particle range from an isolated "hot particle."

We would propose that there is also no compelling reason for not believing it and that prudent public health practice dictates that such a critical structure should be assumed in establishing exposure standards for hot particles.

Pages 38-39. The next two paragraphs are speculative and are followed by the paragraph:

23/ Brues, A., *et al.*, *op. cit.*

> Considering the amount of human data available for carcinogenic risk estimates, and the variability and uncertainty concerning dosimetric factors (e.g., relevant doses, differences in spatial and temporal dose distribution, etc.), it has thus far been regarded as necessary to select single values of quantities that characterize the exposure of an organ or that organ in a group of individuals. Mean accumulated tissue dose is the only criterion that can be used practically at present until adequate knowledge of more relevant criteria becomes available. Furthermore, when the energy is deposited non-uniformly and its influence in the exposed organ or a group of individuals is not known, the non-uniformity cannot be dealt with until more adequate data are available. The linear (proportional) hypothesis is the only one that normally permits the use of mean dose as the significant dose factor for conditions of non-uniform exposure and exposure rate in an organ or among individuals, the purposes of estimating risk or setting dose limits in the absence of adequate data on distribution of dose and dose rates.

While this paragraph may have been offered as an explanation for, or even as an excuse for, the present radiation exposure standards, we fail to see how it justifies the standards in the future. So far as hot particles are concerned, we have submitted a supportable hypothesis to supplant the linear hypothesis in establishing hot particle exposure standards. The standards are a practical problem of the moment and should be established on the basis of conservative and supportable hypothesis today. It is irresponsible to leave the health of workers and the public in jeopardy while awaiting more definitive data.

The remaining paragraph is a speculative attempt to set aside the hot particle hypothesis. In this respect, it is interesting to note that this section of the report failed to recant the observations of Lushbaugh and Langham (1962) wherein a 'precancerous' lesion was induced in the palm of a mechanic by a single plutonium hot particle. Nor did it discuss the observations of Richmond, et al., (1970), Richmond and Voelz (1972, 1973) or Richmond and Sullivan (1974) that similar lesions were induced in the lungs of rats and hamsters by plutonium hot particles. These are observations, not speculation, and they support the hot particle hypothesis.

Pages 39-40. "C. Assessment of Experimental Animal Data."

This section begins with a discussion of a probit transformation of experimental data on animals relating lung cancer and radiation dosage to which the authors correctly ascribe no statistical validity. Nevertheless, so far as the Pu or other alpha data are concerned there is little that is related to hot particles and that which is, such as the beagle data (Park and Bair, 1972), represents a saturated response. The Pu-238 experiments of Sanders (1972) also demonstrate a saturated response at a level of 40 rad or 400 rem. Moreover, Sanders indicates that Pu was soluble in his experiment.

In the second paragraph they indicate that these plots demonstrate a RBE of about 10 for alpha radiation in accord with radiobiological experience. In the third paragraph, they make an assumption concerning the non-uniform distribution of the alpha irradiation and transpose the alpha curve in accord with this assumption. Considering the nature of the alpha experiments (their particle size, solubility, and saturation effects) there is no justification for this assumption and transformation. For example, Sanders states that his irradiation was uniform.

We see little merit to this entire discussion and the conclusions in the 5th and 6th paragraphs that result from it are entirely unjustified.

Page 41. The final 5 paragraphs in the BRW Report discuss a number of animal experiments that supposedly are contrary to the hot particle hypothesis. The first involves the results of Laskin, *et al.*, (1963) wherein Ru-106 pellets were implanted in the bronchi of rats. The results indicated a tumor incidence of 7.3% in animals exposed to a few thousand rads with the incidence rising to 66% in those exposed to 10 rads. This dose was calculated as that delivered to the basal layer of the epithelium. One can readily show that this experiment is consistent with the hot particle hypothesis.

The pellets were some 5000 μ in length. They would therefore be expected to produce lesions larger than the 200 to 300 μ lesions observed around hot particles. The result demonstrated a 7% tumor incidence in the 10^3 rad range with one tumor occurring in an animal exposed to 1400 rad. Thus, the cancer risk associated with this much larger lesion at a dose of some 1000 rad was roughly 1/10 or some 200 times greater than that which we assigned to the smaller lesion around a hot particle. This is entirely consistent with the hot particle hypothesis including the 1000 rem/year activity limit. Moreover, the incidence rose to 66% at higher dosage. The data of Richmond and Voelz (1972, 1973) and Richmond and Sullivan (1974) with Pu microspheres demonstrated that these lesions develop more rapidly as the particle activity is increased. This suggests that if a sufficient induction period were allowed, the incidence for the large pellet-produced lesion could be unity. Again, this is consistent with the hot particle hypothesis.

The remaining experiments discussed here involved Co-60 implants in a variety of animal species (Warren and Gates, 1968) and whole body x-irradiation of rats (Koletsky and Gustafson, 1955, and Castaneva, et al., 1968). Concerning these experiments, the BRW Report authors state:

> Data in figure V-4 for five species of animals given ^{60}Co wire implanted in their lungs show lung tumor incidences ranging from about 8 to 40%, in all but one instance, for total doses of 10^5-10^6 rad to either the entire lung or to the esophagus. It is of interest that the entire lung is irradiated, including any and all possible "critical architectural units," at high dose rates, yet the tumor incidence is not unity. Also of interest is the similar response shown for the several species used with the possible exception of the rat lung, the highest cancer incidence point. The observation of tumor incidences well below unity is true also for the whole-body exposures to X-irradiation in which the entire lungs and body of rats received doses near 10^3 rad.

All of these experiments involved whole body exposure at fairly high dosage. These exposures elicited a generalized carcinogenic response and a significant life shortening effect. Since lung cancer was competing with this overall response, it is incredible that the authors of the BRW Report expected the lung cancer incidence could have reached 100%.

In the Co-60 experiments, the life shortening effect amounted to 80% in all strains and species except for rabbits which died earlier. At the same time, 33% of the animals developed cancer in one or more of the three tissues studied: lung, bone, and esophagus. If all tissues had been studied the cancer incidence would have been higher. Nevertheless, in the rat, lung cancer had a competitive edge and reached an incidence of 75%. In the X-ray study of Koletsky and Gustafson (1955) the life shortening approached 50% and the incidence of malignant neoplasms was 35% at a whole body dosage of 660 rad. In the control group the incidence was 8%. The Castaneva, et al., (1968) results showed a malignant tumor incidence of 100% and a 20% life shortening even at a dosage of 430 rad. The control rats in these experiments had a 30% malignant tumor incidence. These experiments are typical of many such experiments and show the overall response to whole body radiation. The relationship to the hot particle problem, if any, is obscure and remote. There is no *a priori* reason to believe that the same carcinogenic mechanism is involved.

V. Summary and Conclusion

The Tamplin-Cochran Report presented a hot particle hypothesis based on an injury-mediated mechanism of carcinogenic response. In order to assist in setting radiation protection standards we proposed quantative values for 1) the minimum activity defining a hot particle and 2) the carcinogenic risk per hot particle. The "hot particle hypothesis" is relatively simple. With respect to alpha-emitting particles in the lung, it is:

> If a particle deposited in the deep respiratory tissue is of such activity as to expose the surrounding lung tissue to a dose of at least 1000 rem in 1 year, this particle represents a unique carcinogenic risk. The biological data suggest that such a particle may have a cancer risk equal to 1/2000.

The BRW Report has been offered as a refutation of the hot particle hypothesis quantitatively presented in the Tamplin-Cochran Report. The BRW Report cites numerous experimental studies, most of which are not relevant to the hot particle issue. Those which are relevant we have shown to be consistant with our hot particle hypothesis. Thus, the BRW Report is not in any way a refutation of the hot particle hypothesis.

While it must be recognized that there are uncertainties with respect to the quantitative values we have chosen, until those uncertainties can be resolved by appropriate experimental data, it is incumbant upon the AEC and EPA to adopt radiation protection standards comparable to those in the Tamplin-Cochran Report. Furthermore, we submit that these more restrictive standards should be quickly promulgated because it is irresponsible to leave the health of the public and workers in jeopardy while awaiting more definitive data.

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REPLY VIA AIR MAIL TO

February 1, 1975

Warren D. Johnson, Lt.Gen./USAF
Director, Defense Nuclear Agency
Washington, D. C. 20305

Dear Don:

Enclosed are the Comments of the People of Enewetak upon the DEIS for the Clean Up, Rehabilitation, Resettlement of Enewetak-Marshall Islands. Thank you very much for your forbearance with our various requests for extension of the deadline.

Sincerely,

Ted

Theodore R. Mitchell

Enclosures (as stated - 10)

Document "Comments of the People of Enewetak Concerning the DEIS" not included at this time but will be included in final distribution.

Comments

of the

People of Enewetak

Concerning

The Draft Environmental Impact Statement

CLEAN UP, REHABILITATION, RESETTLEMENT

OF

ENEWETAK ATOLL-MARSHALL ISLANDS

(DATED September 1974,
issued by the Defense
Nuclear Agency, Washington,
D. C. 20305)

Prepared by

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February 1, 1975

1. Introduction

The impetus for development of this program comes from the long-expressed desire of the People of Enewetak to return to their homeland. Although resigned to their nearly thirty year exile at Ujelang Atoll, they have never given up hope of returning to Enewetak, if but only if, it is radiologically safe for them to do so. They are aware of the substantial social and economic problems which necessarily attend the relocation and resettlement of their more than 400 persons, but the difficulty of assessing the risk from the extensive radioactivity present at the Atoll as a result of the nuclear weapons testing program there is by far the most troublesome. It is difficult enough for the layman to comprehend what the experts in the various radiological science fields are saying about the effects of radioactivity, but that difficulty is compounded many times over the differences of opinion found among the experts, by the realization that even the experts agree that the long term effects of some of the more dangerous radionuclides are not known by anyone at this time and may not become known for many years to come, and it is unsettling to learn that the standards used for the kinds and amounts of radionuclides to be tolerated in the environment and in man are criticized by reputable experts as unreliable and inadequately conservative.

Their individual and collective desire to return to their ancestral homeland is difficult for Americans to fully appreciate. To them land is not a commodity, a thing apart, to be brought or sold. In their culture the land and marine environment of the atoll are fully integrated with the human members of the society. It is an economic resource and more. Ownership and use of the land reflects and is inextricably linked to the social organization and to the culture as a whole. To be sure, their society has undergone and continuously is undergoing change as a result of forces both within and without, but the extraordinary significance of their being able to resettle to the atoll discovered by their ancestors remains constant.

Thus, the People of Enewetak are both the prime beneficiaries and the prime risk-takers in this resettlement program. And it is in the assessment and, if possible, elimination of the radio-biological health risk that they are the most dependent upon the United States government. The Defense Nuclear Agency and the Atomic Energy Commission have already devoted great amounts of time and money to assessment and remedy of radiological problems presented by this program, but more will have to be done and it will have to be done over a long period of time. And throughout, the People of Enewetak will rely upon the responsible agencies of the United States government to do everything possible to assess and minimize the risk due to the residual radioactivity in the Enewetak biosphere. Nothing said in these comments, for example, should ever be taken as an assumption of risk by the people of Enewetak. When they left the Atoll in 1947 at the insistence of the United States government it was radiologically safe. That is the state in which it should be for their return.

Of course, it cannot ever be restored to that condition, but that must be the assumed objective in order that remedial measures can more likely fall within the safest possible limits, and so that on-going efforts will be made to continually add to the knowledge of radiological conditions at Enewetak and refine and improve both risk assessment and remedial measures as the various relevant sciences develop over the years.

Not only is the United States trustee for these people, but it has an especial humanitarian obligation to them because of the uniquely dangerous potential effects due to the use to which the trustee put the Atoll. It is an absolute kind of responsibility to both return the people to their home and eliminate the likelihood of so much as a single radiation induced illness or anomaly.

A full measure of gratitude is due and hereby given, however, to the considerable efforts which the United States has made thus far. The planning for resettlement, the radiological survey, the planning for the clean-up, all represent a very large contribution to the ultimate success of the program. And we do not wish to dampen the enthusiasm and interest of the many persons in and out of the government who have given devoted effort thus far. The comments made here are offered in the spirit of cooperation, with the realization that they will be received in that same spirit.

2. Social and Economic Problems Associated with Resettlement

Further consideration of the social and economic problems associated with the resettlement must be given. This is perhaps one of the weakest aspects of the DEIS as it now stands.

Attention is given to both short and long range economic planning (Vol. I, § 7, Vol. II, Tab D), but in consultation with the people themselves specific objectives and specific economic development possibilities must be found so that the shared aim of economic self-sufficiency can be achieved. We realize that with all the other aspects of this complex project demanding attention up to now, this was not intentionally underemphasized. But as the program moves into its clean-up phase more attention must be given to meeting the future economic needs of the people. This is especially true because since the writing of the DEIS it has become known that adverse radiological conditions in the northern part of the Atoll do not permit the rehabitation of Engebi islet and severely if not completely restrict the use of the northern islets for the foreseeable future.

The Enewetak Planning Council must continue to be relied upon to make the final value judgments upon one proposal or another and upon the development of the economy as a whole so that it will be consonant with their own capabilities and values, but one or more specialists should be engaged by the government and made available in an advisory capacity. They must be carefully selected both in terms of expertise in the field and suitability to this kind of cross-cultural task and to the maximum feasible extent the Planning Council should participate in the selection.

Resettlement to Enewetak Atoll from Ujelang will involve an unusual amount of stress for individual members of the group and for the group as a whole. Physical stress will, if all goes as planned, be at a minimum, but we have in mind here the emotional stress upon the individual and the stress upon group processes. This matter is not addressed at all by the DEIS.

Ultimately, of course, it is for the people to manage the transition well and to adapt with their society intact, but experience with similar resettlement schemes is available and should be used to increase the likelihood of successful resettlement. The people themselves can benefit from greater awareness of the stresses they will experience and those outsiders involved in planning and working with them must have the same understanding.

Dr. Thayer Scudder of the California Institute of Technology, a recognized authority on the subject and an experienced consultant, should be considered for this assignment and if the Planning Council agrees, he should be engaged in this capacity. Dr. Scudder has taken a quick look at the DEIS at our request. His comments attached hereto as Appendix I provide valuable insights and his contribution to planning and execution of the program would appear to be necessary. (The article which he enclosed is also useful. It is "The Impact of Human Activities on the Physical and Social Environments: New Directions in Anthropological Ecology," by E. Montgomery, J. W. Bennett and T. Scudder, 2 Annual Review of Anthropology 1973.)

Participation of another anthropologist versed in Marshallese culture is also in order, to assist both the Enewetak people and the outsiders involved in the program. Working in conjunction with someone like Dr. Scudder, the total contribution would be invaluable. Dr. Robert Kiste at the University of Minnesota has been consulted by the governmental planners and meets these requirements exceptionally well.

Short of involving so many advisors and planners that decesions and action are unduly impeded, it is essential that those representing all the relevant disciplines work together as a group with the Enewetak Planning Council and the governmental decision-makers. To some extent this is what has been done during planning to date, but for the remainder of the program, the relevant disciplines should be identified as such, appropriate representatives engaged and organized into a more or less formal advisory council.

3. Radiological Considerations

3.1. The Radiological Survey

The survey of radiological conditions at Enewetak Atoll in 1972 under the auspices of the Atomic Energy Commission is, we believe exceptionally good as far as it goes, but we have been advised by capable experts in the field that more work remains to be done and that the qualifications of the four-member Task Group which supervised the conduct of the survey, the assessment of its data and developed final recommendations are open to question. It is also apparent that as detailed and elaborate as that survey was, follow-up gathering of data and careful assessment of that data is absolutely essential, particularly with respect to the risk to health from all low-level, long-life radionuclides and especially the danger posed by those alpha-emitting radionuclides known as hot particles, such as Plutonium-239 and Americium-241.

We do not wish to detract from the qualifications of the members of the Task Group, but in a field involving so many specialties and where equally expert opinions differ markedly, it is imperative that the Task Group for follow-up studies be enlarged to include scientists known to take the most conservative approach to radiation protection, such as Drs. E. A. Martell at the National Center for Atmospheric Research, Arthur R. Tamplin at Lawrence Livermore Laboratory, and Donald P. Geesaman at the University of Minnesota. Their presence in the Task Group, or their participation in some other direct way in designing methods to be used for the gathering of information and its evaluation is strongly recommended.

The 1972 radiological survey (NVO-140) must be regarded as an impressive beginning of long-range radiological assessment and monitoring of the Enewetak environment with appropriate emphasis placed upon not only the marine and terrestrial environments but upon the radionuclide pathways to man. As we shall discuss more fully below, more information is needed about the presence of hot particles. The long range effects of Strontium-90 and Cesium-137 and other nuclides in the food web cannot be known without experimental planting. (DEIS Vol. II, Tab B, p. 29.) These are only examples. And as time goes on, scientific knowledge of the nature and effect of radioactivity is bound to improve and new techniques for remedial measures will be found. These scientific advancements will be lost to the Enewetak people unless the United States government assumes a long-range commitment of the kind we suggest here. And in so doing it is highly probable that important contributions to the development of greater understanding of radioactivity and its effects will result, to the benefit of the United States and the world at large.

3.2. The Hot Particle Problem

It is with the kind assistance of Drs. E. A. Martell, Donald P. Geesaman, Arthur R. Tamplin and Thomas B. Cochran that we derive our comments here concerning this unique radiological hazard. Drs. Tamplin and Cochran submitted formal comments upon this DEIS to the Defense Nuclear Agency under date of September 24, 1974, and we fully accept and endorse what they have said there. Their observations and concerns are entirely consistent with those of Martell and Geesaman, expressed to us in personal communications.

For a discussion of the seriousness the hot particles problem we attach as Appendix II, E. A. Martell, "Basic Considerations in the Assessment of the Cancer Risks and Standards for Internal Alpha Emitters," (Statement presented at the public hearings on plutonium standards sponsored by the United States Environmental Protection Agency, Denver, Colorado, January 10, 1975.) To further emphasize our grave concern about this problem, we attach comments and materials provided to us by Dr. Donald P. Geesaman as Appendix III. We subscribe fully to the views they express and we insist that they be dealt with fully in the final impact statement.

It is beyond question that the presence of Plutonium-239, Americium-241 and perhaps other alpha-emitting radionuclides at Enewetak Atoll constitutes one of the most serious health risks for the returning population. It is highly likely that inhalation of very small amounts of plutonium gives rise to a high risk of lung cancer. And the DEIS completely fails to address the recent findings of Martell and others that hot particles may very well be a causative factor in a number of other disorders. See Appendices II and III. The DEIS deals only with inhalation risk, yet Americium is known to present a risk for the liver, spleen and bone of man through take-up from the gastrointestinal tract. (Martell, Personal Communication.)

Concerning the adequacy of the radiological survey with respect to internal alpha emitters, Dr. Martell had this to say:

> It is noted that the survey results for the Enewetak Lagoon sediments show an average of 463 mCi $^{239+240}Pu/km^2$, 172 mCi $^{241}Am/km^2$ and 586 mCi $^{90}Sr/km^2$ (Table 3-11, p 3-75, DEIS Volume I). In addition, the ^{241}Am concentrations range up to 8.2 pCi/g averaged over the top 15 cm depth of soils, with $^{241}Am/^{239}Pu$ ratios varying widely and ranging up to 3.5 (NVO-140 Vol. 1, p 507). Due to further radicactive decay of ^{241}Pu, the ^{241}Am activity concentrations can be expected to double over the next 50 years. In addition, densely vegetated soils on each island show the highest radioactivity concentrations.
>
> The DEIS limits consideration of $^{239+240}Pu$ to inhalation risks. However significant uptake of Pu from the gastrointestinal tract has been observed in young mammals and similar uptake may occur in young children. In addition the uptake of americium in soils by vegetation is substantially higher than plutonium

uptake. Similarly americium is readily taken up from the gastrointestinal tract and accumulated in the liver, spleen and bone of mammals, and thus undoubtedly in man.

Based on these considerations it is possible that uptake of americium in the food chain and its accumulation in the liver and skeletal tissue of man may be the critical path for exposure to internal alpha emitters in the Enewetak Atoll area. The radiological survey is seriously inadequate with respect to americium distribution in both vegetation and in edible marine life to assess the consequent body burdens and heald consequences to future atoll inhabitants. (Personal Communication.)

Dr. Geesaman independently identifies the same inadequacy in the DEIS and also finds a need for further study of the mechanisms by which plutonium contamination in the soil may find its way into the body.

The resuspension measurements and calculations which relate the air contamination to the soil contamination are not immediately compelling, and deserve a much more careful analysis than I have given them. I would be surprised if the analysis is meaningful to factor of 100, when used to determine public health guidelines. Resuspension is poorly understood, it is sensitive to windspeed, soil characteristics, vegetation, humidity, rainfall, mechanical distrubance, physical and chemical history of plutonium particles in soil. How then does one consider the exposure of children throwing dry sand on a windy day at the beach? I would anticipate large fluctuations about the implicit exposure levels, which, even for the limiting soil contamination guidelines and predicted air concentrations associated with these guidelines, will be approximately a maximum permissible lung burden. (Personal Communication.)

Each of the questions raised here and in the related appendices must be addressed fully and carefully prior to resettlement of the people of Enewetak Atoll.

3.3 Plutonium Soil Standards

Concerning the standard employed by the DEIS for maximum permissible plutonium contamination of soils at Enewetak, Dr. Martell points out that "There are no ICRP standards for soil levels of Pu and the actinides or for lifetime exposures to internal alpha emitters." (Personal Communication.) And he provides the following critique of the standards adopted by the AEC Task Group for Enewetak:

> The recommendation that plutonium contaminated soils, with levels not exceeding 40 pCi $^{239+240}$Pu/g of soil averaged over 15 cm depth, is suitable for human habitation, can be very seriously questioned.
>
> The State of Colorado Board of Health has adopted interim standards for Pu contamination limits in soils

in land areas for residential use, specifying that ^{238}Pu levels shall not exceed 2 dpm (0.91 pCi) per gram of surface soil (i.e., averaged over the top 1 cm depth of soil). It is noteworthy that the AEC has not established that this standard is unduly conservative and it is not apparent that the AEC has requested the ICRP or NCRP to make specific recommendations with respect to standards for Pu in soils applicable to chronic exposure to the general public, including children.

I note that the DEIS recommends no remedial action for soils containing $<$ 40 pCi or $<$ 88 dpm Pu/g, averaged over the top 15 cm depth. This is much more than 44 times the Colorado interim standard (2 dpm per g in the top 1 cm) because for most Enewetak soils the top cm contains substantially higher levels of Pu per gram than the 15 cm depth average. Thus, for example, at location 101 on Pearl, the top 1 cm depth shows 400 pCi ^{239}Pu/g, whereas the average over 15 cm depth is about 60. Thus the recommended standard for Enewetak is about 100 to several hundred times that adopted in Colorado.

There are recent research developments which are expected to lead to reductions in acceptable organ burdens of Pu in man by a factor of 100 to 1000 or more. In my opinion it is likely that a 10 pCi lung burden of insoluble alpha emitting particles will give rise to significant adverse health effects for lifetime exposures. The typical burden of insoluble particles of respirable size ($<$ 5.0 Um diameter) is about one gram in human adults. For this reason I would recommend that surface soils should not exceed about 1 pCi of $^{239}PuO_2$ and other insoluble alpha emitting particles per gram of insoluble particulates of respirable size in the airborne dust resulting from the disturbance and resuspension of surface soils. On this basis even the Colorado standard may give rise to excessive organ burdens.

Drs. Cochran, Tamplin and Geesaman all raise the same or similar objections to the DEIS plutonium standards.

Further explanation of the plutonium cleanup criteria developed by the AEC Task Group is necessary. (DEIS, Vol. II, Tab B, pp. III-8 to III-11.) We have already mentioned the questionable wisdom of the 40 pCi/g standard. For any concentrations exceeding 400 pCi/g the Task Group recommendations require removal of the soil. But in the range between 40 and 400 pCi/g, the DEIS standards call for "corrective action ..... on a case-by-case basis." (Vol. II, Tab B, p. III-9.) Certain criteria are offered for guidance in the exercise of this judgment, but they appear to be entirely too unspecific and subjective. Once a decision is made to take corrective action,

> the objective is to achieve a substantial reduction in plutonium soil concentrations, and further, to reduce concentrations to the lowest practicable level, not to reduce them to some prescribed numerical value. (*Ibid.* Emphasis added.)

Nor is it entirely clear who will be making these "case-by-case" decisions. Presumably it is the "team of experts" referred to in the recommendations of the Task Group (Vol. II, Tab B, p. 27), but we are not told who they are or how they will be selected.

This whole approach must be explained and justified, especially at a time when the EPA is conducting hearings around the country on plutonium soil standards for precisely the purpose of developing "numerical values" for the maximum concentrations permissible. The range between 40 and 400 pCi/g is a wide one indeed and if 40 is too high, then to make decisions on a "case-by-case" basis within that range is to have no standard at all.

Before any final standards are set for the radiological cleanup of Enewetak, the International Commission on Radiological Protection should be called upon for plutonium and actinide standards applicable to air, water, soils and food concentrations for both soluble and insoluble activities, applicable to long-range exposure to the general public. Application should also be made to the U.S. Environmental Protection Agency for special hearings for the same purpose. Consideration should also be given to the desirability of requesting the United Nations Scientific Committee on the Effects of Atomic Radiation to conduct hearings and set these standards. (We are indebted to Dr. Martell for these suggestions.)

At any and all of these hearings, every effort should be made to elicit the widest possible range of information and opinion bearing upon the question. Once such standards are set, they should govern the planning and cleanup activities at Enewetak.

3.4 <u>Removal and Disposal of Radiocontaminated Materials</u>

These comments relate to the proposed removal and disposal of contaminated scrap metal and soil treated in the DEIS at Vol. 1, §§5.3.3.3 and 5.5.

All radiocontaminated scrap metal on the Atoll has been identified and will be removed, as of course it must be, but the precise method of disposal has not been determined. Four alternative methods are discussed: ocean dumping of the loose scrap, concrete encapsulation in the Cactus and Lacrosse craters at the north end of Runit islet, or removal to the United States mainland for storage. We appreciate the practical and political difficulties presented by the various disposal methods which would remove the scrap from the Atoll entirely, but the People of Enewetak are adamantly opposed to any disposal upon or within the environs of the Atoll. Ocean dumping, according the DEIS (Vol. I, § 5.5.2.1), was rejected "in view of the difficulty in obtaining a permit and certainty of international complications." Disposal to the United States mainland was disfavored for similar reasons. (Vol. I, § 5.5. 2.4.) Disposal on the Atoll must be rejected and the other methods should be explored, the necessary permits and authority obtained and disposal off the Atoll selected as the preferred method.

Removal and disposal of contaminated soil presents more serious cost and practical difficulties, but here again the complete removal and off-Atoll disposal of all contaminated soil must be the stated objective of the program.

Even using the high plutonium contamination standard set by the Task Group (40 pCi/g, etc.), the total amount of Atoll soil which would have to be removed and disposed is 779,000 cubic yards. (Vol. I § 5.5.2.) If the soil standards are lowered as they should be, that volume will increase.

It is suggested in the DEIS that cost, legal, political and technical problems aside, the removal of contaminated soil and its replacement with clean soil may not "assure radiological safety" and may present "serious ecological damage of unknown proportions." (Vol. I, § 5.3.3.3.) We fully favor this conservative approach to these problems (just as we do when the question is one which may reduce the program cost, i.e., high soil contamination standards), but a clear decision must be taken to study and fully assess the relation of soil removal to dose reduction (including the risk from airborne hot particles) and the likely ecological effects of soil removal and replacement. These studies should be commissioned immediately and prosecuted with all deliberate speed. In the meantime, complete soil removal and replacement should be adopted as the prime objective.

In addition, maximum effort must be made to overcome technical, legal and political impediments to off-Atoll disposal of contaminated soil.

3.5 Radiological Monitoring of Cleanup

The AEC Task Group has wisely recommended the establishment of "team of experts" to monitor the execution of the radiological cleanup phase of the program. (DEIS, Vol. I, pp. 5-79, 6-5) Even if the Task Group is enlarged as we have suggested and specific soil standards are developed and implemented, this monitoring group will perform a crucial function. Thus, it is important that its membership be carefully selected. It is imperative that radio-scientists of the most conservative cast be included in the monitoring group. Here again, we suggest that the names of Drs. Martell, Geesaman, Tamplin and Cochran.

And the on-site authority of the monitoring group should be clearly defined, with all important or unexpected problems to be referred to the enlarged Task Group.

3.6. Test Plantings, Groundwater and Air Sampling

We are in full agreement with the AEC Task Group recommendations for test plantings, lens water and air sampling. (Vol. I, pp. 5-80 to 5-81.) But it is not clear whether these recommendations have been implemented. They must be and the studies should be commissioned to the best scientists and technicians available, under the over-all guidance of the enlarged Task Group. All of these studies must deal explicitly with the hot particle problem.

3.7. Radiobiological Health Followup

AEC Task Group recommendation 12 (Vol. I, p. 5-81) calls for "Baseline surveys of body burdens and urine content of Cs-137 and Sr-90... for the Enewetak people prior to return to Enewetak Atoll, and periodically thereafter." But here, too, it is not clear whether a firm commitment to long-range radiological health monitoring of the Enewetak population has been made, and, if so, precisely how it will be implemented.

A fully adequate radiological health program must be designed, funded and implemented. It can and should include the people of Bikini, who will one day soon be resettled, the exposure victims at Rongelap and Utirik Atolls and the Enewetak people.

The final impact statement should address this question and state clearly whether such a program is planned and what it will include. It too must deal with the health effects of hot particles and all forms of low level radiation, with emphasis on internal emitters.

3.8. Unknown Concerns

We have tried to identify all the radiological needs of this program which require further attention, all with the ultimate safety of the People of Enewetak in mind, but we cannot be certain that we have done a complete job. Hence, we call upon the United States government to continue to assume the important responsibility of giving the best and most careful attention to these matters for the long range future.

4. Considerations Related to Cost

Funding requests for the initial phase of this program have been previously presented to the United States Congress. They did not receive very favorable or sympathetic consideration, to put it mildly, by the members of the House Armed Services and Appropriations Committees. In general, the objections related to the great cost of the entire program and evidenced a reluctance to commit the United States government to the first phase of a program, the ultimate cost of which would be in the neighborhood of $49,000,000. Hence, the request was disapproved. In the House and Senate Interior committees to which the rehabilitation and resettlement phases were referred in a legislative package separate from the cleanup, sympathetic and favorable action was taken and $12,000,000 was authorized.

Notably absent from the presentations made to the Congress and from the inquiries of the Congressmen themselves was realization of the enormous benefit which (in the view of the United States) has been derived from the use of Enewetak Atoll for nuclear testing and related national security activities. In the Armed Services hearings, the total projected cost of this program was divided by the number of Enewetak people and the suggestion made that perhaps the money should simply be given to the people.

We do not have accurate figures for the total cost of the atomic energy program, the nuclear weapons testing program, nor for the amount of money actually spent for programs at Enewetak. But judging by figures we have seen (for example, Congress And The Nation, Vol. I, p. 262, Congressional Quarterly Service, 1965) indicate that the cost was on the order of several billions of dollars in the AEC budget, and that says nothing about the undoubtedly large sums contained in one or more places in the Defense budget. We will suggest a figure of, say, $50 billion for the sake of discussion. That represents the agreed minimum value to the benefit to the United States of the same activities, the effects of which must now be remedied. Beyond the dollar value, the United States must assign a value to the benefit to national security of the testing program, however debatable that benefit may be in and of itself.

The cost of the direct benefits in this program for the Enewetak people, such as housing, community development, etc., are a very small fraction of the total, about $5,000,000. And even that portion of the total funding is directly attributable to their forced removal by the United States to make way for the testing program.

And as we have said before, the United States undertook trusteeship of the Micronesian Islands of its own free will (without consent of the Micronesians) and put Enewetak Atoll, the property of the trust, to its own use for the very nuclear testing which deposited the radioactivity.

This is the only perspective by which to consider and decide upon the outside cost limits of this program. The costs of the radiological and engineering cleanup of the Atoll are properly to be considered ordinary and necessary costs of <u>the testing program</u>. Indeed, the cleanup should have been planned from the beginning and funded and done at the end of the testing program about 1958.

The Enewetak People do not want money in any amount, they want and are entitled to their land, in safe and habitable condition.

In the presentation of future requests to the United States Congress, this general approach should be taken and the leadership of the people themselves should be called to testify.

"Case 3", outlined in Section 5.4.3, Vol. I of the DEIS, is offered as the preferred plan for cleanup and resettlement of the

Atoll. Essentially, it represents a compromise of cost, radiological and other factors, which will be far short of the theoretically ideal "Case 5". (Vol. I, § 5.4.5). Exclusive of contaminated soil and scrap disposal costs, the cleanup cost for Case 3 is $35.5 million and for Case 5 it is $81.6 million. Comparative soil disposal cost estimates are $7 million for Case 3 and $92.2 for Case 5.

We appreciate the political and practical realities of seeking sums on the order of $100 million from the United States Congress in these times of grave concern about the economy, but given the rationable stated above, it is Case 5 for which funding should be sought and for which funding should be given.

Finally, quite apart from any cost-benefit analysis of the nuclear testing program, as a result of a recent decision of the United States Court of Appeals for the Ninth Circuit (<u>People of Saipan, etc. v. U.S. Dept. of the Interior, etc.</u>, 502 F.2d 90 (1974)), the obligations imposed by the Trusteeship Agreement under which the United States administers the Micronesian Islands has become legally binding and enforceable. Under the terms of Article 6 of the Trusteeship Agreement, the United States is required to "promote the economic advancement and self-sufficiency" of the Enewetak People; to "protect [them] against the loss of their lands and resources"; to "promote the social advancement" of the Micronesians; and to "protect [their] health." These are the express obligations. Beyond that, like any trustee, the United States bears implied duties to protect and promote the best interests of the beneficiary in every way.

Litigation by the beneficiary against the trustee to enforce these obligations would unseemly and costly. Every United States official involved, including members of the Congress, should freely and willingly undertake to fulfill them by planning, funding and conducting a cleanup, rehabilitation and resettlement program for the Enewetak People which approximates the ideal.

5. Conclusion

We have made a number of recommendations in the course of these comments to which we hope the program sponsors will give consideration in the preparation of the final impact statement. The recommendations relating to assessment of the radiological risk, if accepted, may or may not result in delay for the project as now planned. We hope not, but certainly the further study required and the development of soil, air and food contamination standards for plutonium may have a direct affect upon the initial cleanup phase. We urge the Defense Nuclear Agency to proceed with funding requests and planning for the base camp and to seek commitments from the United States Congress for the estimated cost of the program as a whole based on the "Case 5" projections. But at the same time all of the radiological investigations recommended here should be undertaken and high confidence results obtained as soon as possible so that they can be used to revise and improve the radiological cleanup phase before moving forward with it.

It bears repeating here that we are mindful of the immense amount of time, effort and money which has been devoted to development of this program to date by many officials in the Defense Nuclear Agency, the Atomic Energy Commission, the Department of the Interior and its Trust Territory administration, to mention only the principal agencies. We are deeply grateful the professional and humanitarian commitment of all of these people and special appreciation is due Lt. Gen. Warren D. Johnson, Director, Defense Nuclear Agency for all that he has done and will continue to do.

Respectfully submitted by

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October 29, 1974

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Dear Ted,

I have now read through the three volumes of the Draft Environmental Impact Statement dealing with the Clean Up, Rehabilitation, Resettlement of Enewetak Atoll-Marshall Islands. One thing that you have going for you is that the peopleof Enewetak wish to return home, and have been pressing for this return for years. Many of the stresses associated with the type of compulsory relocation that I have studied including the undermining of local leadership, are simply not present although I would suspect a carry-over from the past.

Another favorable factor has been the willingness of everyone involved to date (a) to listen to the local people (at least through their council of 12) and (b) to take into consideration their wishes in planning their return. On the other hand, any kind of settlement scheme involves stress to the settlers and as you note in your letter of October 11, little attention has been paid to the potential impacts of this stress.

Because my predictive theory deals primarily with compulsory relocation at the time of forced removal, rather than 28 years later!, I will have to cast the net wider (which of course is a much more risky business) and deal with settlement schemes in general, compulsory resettlement being an extreme example of this more general category. As I am sure you are well aware, the history of settlement schemes throughout the world is a grim one -- with probably over 90% being unsuccessful from the point of view of both settlers and settlement authorities. It is hard to imagine a more difficult task that creating from scratch new communities, which are both socially and economically viable. Though the situation is more favorable when the people are willing participants, in the Enewetak case no settler selection is possible since everyone who wishes to return -- young and old, conservative and progressive, hard working and lazy, must

APPENDIX I

be accommodated. In commenting on the Impact Statement I wish to discuss in sequence (1) Housing (2) Social Services (3) the Economic System and (4) Social Factors associated with settlement. Let me emphasize right now that (1) and (2) are by far the easiest to handle -- and (1) and (2) represent the greatest strengths of the Impact Statement. But while it is relatively easy to provide improved housing and social services, it is much harder to create viable land and water use systems -- indeed it is here that most settlement schemes fail. And it is much harder to handle the social factors associated with settlement as well as the institutional factors dealing with the interrelationships between settler institutions and those of the agencies involved in their future -- all of which must be viewed as part of a single (and very complex) social system.

(1) Housing. Though Holmes and Narver should be complimented on the extent to which they have taken into consideration the stated desires of the Enewetak people and their system of land tenure in proposing house types, as I understand the situation, the people have yet to live in houses of the type proposed. If so, we must distinguish between what they think they want and what subsequently they decide they want after living in the new houses for a complete year. I strongly urge that a small number of pilot houses be built for at least some of those involved in the initial cleanup operation, so that the people will have a chance to assess their strengths and weaknesses -- to work the bugs out of them, so to speak, before the main construction program tends to rigidify their family structure and social organization in concrete for years to come. One thing that planners and architects tend to forget when providing housing in permanent materials, is that discrete structures in non-permanent materials provide more flexibility. Before pouring concrete one should try to anticipate some of the implications which inevitably will arise (and which <u>will</u> have an impact on the peoples' lives) and make corrections where desirable. Problems of maintenance also need to be anticipated in advance and local people trained to maintain their own structures.

A major problem associated with many settlement schemes relates to provision and maintenance of adequate water supplies. Though the plans incorporated in the reports look good to me, I just want to mention this general difficulty for the record, and to emphasize the need to provide the simpliest facilities possible in terms of (1) peoples' needs and (2) their hopes -- with the second factor being far less important than the first. I have seen too many projects where people, after several years, must fall back on inadequate local water supplies simply because government-provided facilities are inadequate to start with, or because costs for their maintenance are not provided, or because local people are not trained to properly use and maintain them. While I was very favorably impressed by the thinking on water supplies within the reports, I wonder if enough thought has gone into problems concerning their long term maintenance.

(2) Social Services. While impressed again by the thoroughness with which the desires of the local people have been taken into consideration, it is hard to comment on social services without knowing more about the breakdown of the population itself. None of the reports tell us much about the current educational and literacy status of the people, and about their goals for self and children -- other than to return to Enewetak. Though obviously their expectations for imported items has gone up during their 28 years of exile, what about their occupational desires, and especially the occupational desires of the younger people? One thing that bothered me about the reports is that while four room schools are proposed for both the driEnewetak and driEnjebi, nothing is written about the type of education system proposed for these schools and the type of teachers to be recruited. Let me generalize this comment to all types of service personnel, since I was also concerned about the lack of attention paid, under agriculture and fishing, to extension personnel, let alone to the relationship of the different types of service personnel to each other. I am raising here the fundamental question as to what different categories of people will be willing to do, occupationally, once they return and how best to facilitate their future economic and social independence and development.

(3) Viable Land and Water Use Systems. The Master Plan was based on the assumption that all the islands in the atoll could be used for subsistence and cash crop agriculture -- with a total available acreage of approximately 1000. As a result, however, of the AEC Task Force recommendations, this total has been cut to a maximum of 722 usable acres for a current population of over 400 people. Bearing in mind the poor quality of the soil and the rapid rate of population increase, it seems to me absolutely essential that the people retain access to Ujelang Atoll. Even then the available land area on a per capita basis is considerably less than that utilized by the people prior to their first relocation. The situation is worrisome and points up the need (a) to obtain the best possible seed for coconuts for both subsistence and cash crops purposes, with the search bearing in mind the major advances in productivity that have occurred on research stations in the Ivory Coast and in the Phillipines. (b) to push mariculture hard while keeping the means of production strictly in local hands so as to spread employment. Equipment (outboards for example) should be

standarized and kept as simple as possible (seagull type engines vs Johnstones). A number of interesting case histories come to mind here including the lobster cannery which is the principle employer among the several hundred islanders on Tristan da Cunha in mid-Atlantic who were moved from their home after a volvanic eruption in 1961 and returned there later in the 1960s. (c) provide a first rate unified extension service (d) ensure a dependable and sufficient water transport service and pier and port facilities to connect Enewetak to neighboring islands (including Ujeland and the relevant market centers). (e) actively attempt to diversify the economy, always bearing in mind local desires, interests, needs and expectations. Especially attractive is the suggestion that the function of the Eniwetok Marine Biological Laboratory (which apparently will continue under AEC sponsorship) be expanded to include technical assistance to the people. Couple this with the possibility of a Community College for the Marshalls which would use the facilities already present on Enewetak, and one has one way of providing a unified extension service while possibly broadening the economic base of the people. Such possibilities however need be carefully evaluated concerning the extent to which the people will actually be involved and the extent to which they will actually profit. This caution applies even more to the development of a tourist industry which even at best is a mixed blessing on small islands.

It seems to me that the future of the people of Enewetak depends on the extent to which the people regain their independence and the extent to which their atoll can become economically self-sufficient. It is my impression that the authors of the Defense Nuclear Agency report do not understand how much recommended Case 3 alters the assumptions on which the original Master Plan was based. This alteration also has major implications for social factors as I hope to show below.

(4) Social Implications of Settlement. Depending on whether they are driEnjebi or driEnewetak, the present move home will represent the fifth or sixth time that the people of Enewetak have been moved since 1944. Since the original move was compulsory, and hence falls within the scope of my own research, I suspect that it was accompanied by a great deal of stress, which, for analytical purposes, can be divided into psychological, physiological and socio-cultural stress. According to my own model of how people respond to compulsory relocation, this stress (or transition) period does not come to an end until (a) the people once again get back on their feet economically or at least reach the position that they held before relocation, and (b) feel at home in their new habitat. Since neither of these factors applies to the people of Enewetak after nearly 28 years, I would suspect that the older people (that is, those who were old enough to remember the trauma

associated with the original moves) are still under stress. What this means, however, is hard to access at a distance since my theory applies primarily to the months and years immediately preceding and following forced removal. All I can say is that the mental and physical health of the people should be carefully assessed before their shift home and before they are involved in major new ventures -- ventures which would require radical changes in their activities and life style. I say this since the theory predicts that populations undergoing forced removal behave as if a social system was a closed system; that is they change no more than they have to in order to continue doing what they did in the past and the changes which occur are incremental rather than sudden. The insistence of the people through out all these years that they be allowed to return "home" is consistent with the theory here. But once the people get home and the euphoria of having "won" fades, what then? What can be expected when they begin to settle down with three times the number of people on an idealized homeland which can be only partially utilized. With these questions in mind, I would like now to consider three points.

(1) It is very important to recall that approximately 80% of the population is under 30 years of age according to the population figures. In other words, the large majority of the people will either have no memory at all or only a vague memory of life on Enewetak. It is this age bracket which strikes me as a major unknown. To what extent do the Council of 12 really speak for them? To what extent do they wish to return to the life style of their parents and grandparents? I can not answer this question at a distance, in large part because the Enewetak population within the three volume Impact Statement is treated as if it was homogeneous. But I doubt very much that such is the case, a doubt that is reinforced by the odd statement in the reports -- for example, "A number of people have been exposed to education away from Enewetak and have developed strong tastes for imported foods and other luxuries" and the people have "achieved a good understanding of the behavior and values of Americans, and several have distinguished themselves in government and mission schools." In assessing the impacts of the return on the people I suspect we need at least differentiate from the very beginning between the older 20% and the remainder.

(2) Compulsory resettlement projects always run the risk of the relocatees developing a dependency relationship with the relocating authorities. I would suspect that a strong sense of dependency characterizes the older people from Enewetak and that this will continue during the next decade. Even if the dependency does not already exist, most of the people are going to be dependent on outsiders for years to come simply because it will take at least seven years to

prepare lands for planting, to plant them and then to harvest the resulting tree crops. Should the cash cropping of coconuts proceed according to schedule only then will the people begin receiving what Holmes and Narver hope will be an annual cash income of perhaps $40,000 or slightly less than $100 per capita in terms of present population. In the meantime the people will have to use their trust fund (which currently produces $60,000 per annum in income or somewhat less than $150 per capita) to provide for their external needs and to depend on the U.S. government and other donors. Reliance on both the trust fund and on further external assistance continues and increases the risk of a dependency relationship which can be expected to make subsequent development more difficult. Already the people have acquired a taste for outside staples which apparently on occasion can make up as much as 80% of the diet. These include rice, flour, sugar, tea, canned meat, and fish; in other words the usual foods that low income people desire after they come into closer contact with the outside world. So we have the combined problems of rising expectations and dependency, both of which have to be taken into consideration in planning subsequent development for the atoll. Neither makes the task easy. Once the euphoria of regaining the homeland passes, disallusionment may well come, along with new demands on the United States (which of course continues to bear the responsibility for the original move) to provide for the people. Looking to the future, very careful planning and plan execution will be required if the people are not to continue as wards of the government.

(3) Another potential problem concerns future relationships between driEnjebi and driEnewetak simply because the former cannot occupy their former island or indeed their traditional section of the atoll. Rather they will find themselves relocated quite close to their neighbors. Although I note that distinctions between the two populations have been reduced to the extent that the 12 man council is now elected at large from all the people, and that the large majority of the population have been brought up as members of a "single community," nonetheless the present plan to relocate the driEnjebi on Medren and Japtan puts them in the relationships of "relocatees" to the driEnewetak "hosts" which raises the possibility of the type of deteriorating relationships which all too frequently characterizes hosts and relocatees in other settlement schemes, especially where the two communities find themselves in competition for scarce resources, resources to which the hosts traditionally held claims.

At this point there is little more that I can say without further knowledge. In conclusion, however, let me say that there are sufficient social and economic problems connected with the entire relocation effort to justify a well-thought out, longterm program for "monitoring" events from this day forward -- in hopes of anticipating problems before they arise and easing those that inevitably do arise. If I can be of further assistance alone such lines, please let me know.

With best wishes.

Yours sincerely,

Thayer Scudder
Professor of Anthropology

gsh
enclosure

P.S. I enclose an article which summarizes the impacts of compulsory relocation of people moved in connection with big dam projects which may be of some use to you. No, I have not seen Tobin's thesis nor do I have easy access to it. If you can get me a copy I would much appreciate it.

Basic Considerations in the Assessment of the Cancer Risks and Standards for Internal Alpha Emitters

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APPENDIX II

1. Introduction: The adequacy of the biomedical basis of standards for occupational and public exposure to plutonium and other internal alpha emitters have been widely discussed[1-5] and seriously questioned[6-8]. The serious uncertainties in the cancer risks attributable to internal alpha emitters must be resolved before we are irretrievably committed to a nuclear energy program. This is a matter of immediate concern in the western suburbs of Denver due to plutonium and americium contamination of surface soils in public areas around the Rocky Flats Plutonium Plant[9]. Many other localities are similarly affected by tranuranium element contamination and its attendant cancer risks.

Recent controversy regarding the adequacy of plutonium standards has centered on several aspects of the problem of the cancer risks attributable to inhaled plutonium oxide particles, including such questions as which organ and how small a tissue volume constitutes the "critical" organ (i.e., that experiencing the highest cancer risk), and whether the average alpha radiation dose to the critical organ or the tumor risk attributed to a given number of individual hot plutonium oxide particles provides the best guidance for the assessment of risks and standards for plutonium. Geesaman[6] has discussed possible mechanisms of cancer induction by hot particles and concludes that the tumorigenic risk may be as high as 1/2000 per particle for submicron particles of plutonium oxide. A recent examination of hot particle risks by Tamplin and Cochran[8], based largely on the Geesaman study, led these authors to recommend that the occupational MPLB (maximum permissible lung burden) be reduced by a factor of 115,000, to a value of 0.14 pCi. A recent study[10] was carried out by Bair, Richmond and Wachholz at the request of the U.S. Atomic Energy Commission with the specific objective of providing an updated review of the evidence bearing on the problem of uniform vs nonuniform alpha radiation dose distribution in the lung. The authors of this study take exception to the conclusions and recommendations of Geesaman, Tamplin and Cochran[6,8] and conclude that

> "the nonuniform dose distribution of plutonium particles in the lung is not more hazardous and may be less hazardous than if the plutonium were uniformly distributed and that the mean dose lung model is a radiobiologically sound basis for establishment of plutonium standards."

Bair et al.[10] fail to take into account the full implications of some of the recent published results: in particular, the observed higher tumor risks for $^{238}PuO_2$ than for $^{239}PuO_2$[11], the apparently limited biological response of mammal lung cells from ^{238}Pu and ^{239}Pu incorporated into ceramic microspheres[12,13] and the tobacco smoke radioactivity results[14]. The latter results imply that as little as a few picocuries of insoluble alpha emitting particles in the lung may give rise to a significant risk of lung cancer and other serious health effects in the chronic exposure case.

On the basis of a brief review of the known effects of alpha interactions with cells (below) it will become evident that alpha radiation induced cancer in mammals and man must be brought about by subjecting a large number of living cells to a limited number of alpha interactions. Thus, in principle, the highest risk would be associated with a uniform distribution of the alpha dose, in accordance with the conclusion of Bair et al. However, in fact, we are almost always concerned with a highly irregular tissue distribution of alpha emitting particles. For hot particles, the tumor incidence must be due to the low dose irradiation of a large number of cells by a very small fraction of the hot particle burden. And for long term exposures, unacceptably high tumor risks appear to be associated with picocurie burdens of internal alpha emitters. This serious possibility calls for a drastic downward revision of permissible exposure standards for inhaled plutonium. It also is possible that the critical health effects for inhaled alpha emitting particles are the incidence of atherosclerosis and other degenerative diseases of the cardiovascular system. The published evidence supporting these conclusions is briefly reviewed below.

2. Tumor Production: The interactions of various types of radiation with living cells and their mutagenic effects have been widely investigated, with results which have been reviewed and summarized by Lea[15], Muller[16] and others. When alphas interact with the chromosome or its genes in the nucleus of a cell, the dense ionization in the track of the alpha particles give rise to closely spaced breaks which bring about a wide variety of irreversible chromosome structural changes, or mutations. X-ray and γ-ray interactions give rise to a diffuse distribution of ions, resulting in widely spaced individual breaks, most of which can undergo repair by recombining without structural change. Thus permanent structural changes for X-rays and γ-rays are proportional to the square of the dose, with greatly reduced incidence at low dose rates. By contrast, structural changes resulting from alpha interactions are directly proportional to the number of interactions and are independent of alpha interaction rates. Thus, with regard to the production of irreversible structural changes in cells the relative biological effectiveness of alpha radiation, compared to X-rays and γ-rays, increases markedly at lower dose rates and over longer periods of exposure.

For alpha interactions with cell nuclei, most of the structural changes are lethal and lead to the mitotic death of the cell at the next or subsequent cell division[17,18]. However, as Lea[15] and others have pointed out, some cell nuclei experience only minor structural changes (chromosome inversions, duplications, translocations, deletions, etc.) and remain viable. However, although only a very small fraction of alpha interactions give rise to viable mutated cells, these survive to proliferate, whereas cells which suffer lethal changes are eliminated from the cell population. Thus in the case of long-term exposure of tissue to internal alpha emitters at low dose rates there is a cumulative increase in the population of cells which have survived one or more chromosome structural changes. However it is equally obvious that a cell whose nucleus is subjected to repeated alpha interactions within the mean life of the cell has only a negligible chance of survival.

It is likely that the production of a radiation-induced tumor begins with the formation of a single malignant cell characterized by a combination of two or more chromosome changes and/or gene mutations. The alpha radiation-induced bone tumor incidence in dogs is observed to be proportional to the square of the alpha dose[19] implying that a sequence of two or more low probability events must be involved. This is consistent with the two-mutation and multiple-mutation theories of cancer[20,21] based on the age distribution of cancer in man. On the basis of these considerations the production of a malignant cell involves a sequence of events, as follows: (1) production of a viable mutated cell; (2) clone growth from the mutated cell; (3) production of a second viable mutation in one or more of the clone; (4) growth of a clone of doubly-mutated cells; etc. Thus, for a two-mutation sequence, the tumor risk would be proportional to the $R^2t^2(t/\tau_c)$, where R is the alpha dose rate, t is the time of exposure, and τ_c is the mean life of the normal cell and singly mutated cell. The term (t/τ_c) represents the influence of the growth of the clone of the singly-mutated cell on the long-term risk.

This tumor risk relationship makes it abundantly clear that a linear extrapolation to low dose rates is not only not conservative for alpha radiation induced tumors, but rather that there is a marked inverse dose-rate vs risk relationship. There is an increasing body of published experimental evidence that reflects this trend.

Speiss and Mays[22] observed that for ^{224}Ra alpha radiation induced bone sarcoma in man, the tumor incidence per rad approximately doubled for a four-fold increase in the spacing of ^{224}Ra injections and that the observed incidence of bone tumors per rad in children was nearly twice that for adults. Upton et al.[23] show a significantly higher incidence of tumors in mice for a given neutron dose at more protracted periods of exposure. Moskalev and Buldakov[24] showed that fractionation of the administered ^{239}Pu dose over larger periods of time increased bone tumor induction. The higher tumor incidence per rad for the smaller lung burdens of crushed $^{238}PuO_2$ microspheres observed by Sanders[11] seems best explained by the limited alpha irradiation of large numbers of cells by numerous very small, mobile particles of low activity per particle (see below). Hamsters subjected to low alpha doses from ^{210}Po distributed quite homogeneously in the bronchiolar-alveolar region show a marked increase in the lung tumor incidence per rad at very low doses and dose rates[25]. And the incidence of bronchial cancer in uranium miners reflects a higher tumor risk per rad at the lower doses[26] for this low dose rate exposure group. The tobacco radioactivity results[14] indicate a significant tumor risk for the cumulative alpha radiation dose from ^{210}Po in insoluble particles in the bronchi of smokers, involving much lower dose rates.

Based on the above considerations it is evident that the tumor risk is optimized when a very large number of cells and their descendants are subjected to only a few widely spaced alpha interactions with the small target afforded by the cell chromosomes. This follows necessarily from the fact that most alpha interactions with cell chromosomes lead to the subsequent mitotic death of the cell, as Barendsen has shown[17,18]. The production of a malignant cell calls for a sequence of two or more low probability events and thus cannot be speeded up by the application of massive alpha doses, but rather only by subjecting a much larger number of cells to a limited number of interactions. Additionally, assuming that the tumor risk to the tissue subjected to alpha irradiation is proportional to $R^2t^2(t/\tau_c)$, explained above, it is apparent that the alpha activity concentration or the activity per particle which is equated to a given tumor risk decreases with increasing time of exposure and also that a given risk can be attributed to smaller cumulative doses when the time of exposure t is appreciably longer than the mean life of the cell, τ_c. Brues[27] and Burch[28] both pointed out that the two-mutation theories of carcinogenesis[20,21] would imply an exceptionally high effectiveness of widely spaced radiation for tumor production. It is proposed that just such a dose rate relationship serves to reconcile the observed significant tumor risk in cigarette smokers with the presence of a persistent lung burden of insoluble smoke particles involving a total of only a few picocuries of ^{210}Po[14].

3. <u>"Hot" PuO_2 Particle Risks</u>: If the above tentative conclusions are correct, then the same considerations must apply in the assessment of tumor risks for hot particles. In this connection a preliminary consideration of the influence of specific alpha activity and particle size of the hot alpha emitting particles is in order.

Raabe et al.[29] report an apparent rate of dissolution of $^{238}PuO_2$ in lung fluid which is two orders of magnitude higher than that observed for $^{239}PuO_2$ particles. Such a dramatic difference in the chemical behavior of two isotopes of plutonium is seriously inconsistent with the negligible influence of isotope effects on the chemical kinetics of heavy elements. Thus it seems necessary to explain this apparent solubility difference on physical grounds. The specific activity of the $^{238}PuO_2$ particles (~80% $^{238}PuO_2$ and ~20% $^{239}PuO_2$) was about 220 times that of $^{239}PuO_2$. In addition the $^{238}PuO_2$ particles exhibited a very significantly lower density than the $^{239}PuO_2$ particles(30), indicating a highly faulted structure and weakened intermolecular bonding for the $^{238}PuO_2$ particles. Fleischer(31) proposes that the apparently higher dissolution rate for $^{238}PuO_2$ may be explained by the alpha recoil nucleus ablation of the surface layers of the particles, with a fragmentation rate proportional to the specific alpha disintegration rate and with variable sizes of fragments ranging up to $\sim 10^4$ atoms. The poorer structural integrity of the $^{238}PuO_2$ particles may give rise to an increase in the size range of the ejected fragments. Such small fragments, ranging up to tens of angstroms in diameter or more, would pass readily through the 0.1 μm diameter pores of the membrane filters used in the dissolution experiments(29). Also, such small ablation fragments may exhibit a much higher mobility in tissue than that of 0.1 to 1.0 μm diameter, the size range of particles used in most animal inhalation experiments. This greater mobility for very small ablation fragments in tissue may explain the observed more rapid rate of translocation for $^{238}PuO_2$ than for $^{239}PuO_2$ from the lung to the liver and bone(32,33).

Another explanation for the apparently higher solubility of $^{239}PuO_2$ than $^{238}PuO_2$ is the possibility that the intense alpha radiolysis of the lung fluid at the surface of the particles leads to the production of chemically active free radicals which in turn react with PuO_2 molecules on the particle surface. This process also would proceed at a rate proportional to specific activity and to particle surface area. In this case the dissolved plutonium would diffuse away from the hot particles. However this dissolved plutonium undoubtedly would be slowly redistributed in the lung in the same fashion as that reported by Moskalev[34] for inhaled soluble compounds of plutonium, resulting in a highly non-uniform distribution, with hot spots located predominantly in the sub-pleural region of the lungs. This gradual conversion of the soluble plutonium compounds to small colloidal size particles at focal points of activity may be the result of the self-chelating properties of tetravalent plutonium in solution.

In recent studies of rat inhalation of $^{238}PuO_2$, Sanders[11] has demonstrated a substantially increased risk per rad for small lung burdens of aged, "crushed" $^{238}PuO_2$ microspheres. In this case the inhaled particles involve smaller particles and a correspondingly larger surface area. The observed more rapid rate of translocation to other organs can be attributed variously to the higher mobility of the smaller particles, or to the higher rate of surface ablation (or dissolution) for the increased surface area, or both. The higher tumor incidence can be attributed to the fact that the greater mobility and wider redistribution of the $^{238}PuO_2$ microspheres and their breakdown products subject a much larger number of cells to a limited number of alpha interactions.

The correctness of the above interpretation is reinforced by the results of the Los Alamos ceramic sphere experiments reported by Richmond et al.[12,13] and further discussed by Bair et al.[10]. In these experiments 2000 zirconium oxide microspheres of 10 μm diameter, each set containing a specified amount of plutonium, were injected into the lungs of groups of experimental animals. The total plutonium per microsphere ranged from 0.07 to 1.6 pCi of ^{239}Pu and from 4.3 to 59.4 pCi of ^{238}Pu, with identical activity for each of the 2000 microspheres in each of eight animal exposure groups of 70 animals per group. The local dose rate, averaged over the small tissue volume within 40 μm from the surface of the ceramic microspheres is ~17,000 rads per year for the 0.07 pCi microspheres, or ~200,000 alpha disintegrations per year within each microgram of irradiated tissue. The dose rate is correspondingly higher around the microspheres of greater activity. Less than one milligram of tissue, only one millionth of the lung, is subjected to these massive radiation doses.

The limited biological response obtained in these experiments is consistent with expectations based on Barendsen's results[17,18]; the small population of cells within the alpha range around the microspheres experience so many alpha interactions that they all receive chromosome structural changes that result in their mitotic death. The 10 μm diameter microspheres are immobile in tissue. Also their specific alpha activity is so low compared to pure PuO_2 that their surface recoil ablation and dissolution rates are negligibly low. Thus in these experiments there is no large population of cells which are subjected to a limited number of alpha interactions, as is the case for Sanders crushed $^{238}PuO_2$ microsphere experiments[11]. Richmond and Voelz[12] observed only two lung tumors (at 9.5 months and 12 months in animals exposed to 2000 ceramic microspheres of 0.42 pCi ^{239}Pu per microsphere) for a total of ~10^6 hot particles. It is proposed that these two tumors may be attributed to secondary protons ejected by alpha interactions with hydrogen atoms. The expected yield is one proton per 10^4 alpha interactions. Such protons have energies of about 100 KeV and a range about 4 times that of the alpha particle. Thus these secondary protons irradiate 63 times as many lung cells at correspondingly much lower doses. It is unlikely that the two tumors observed in these experiments can be attributed to X-rays or γ-rays from plutonium for reasons discussed by Warren and Gates[35,36].

4. Critical Health Effects: It is widely recognized that inhaled insoluble alpha emitting particles deposited in the lung are, in part, translocated via the phagocytic action of macrophages to the lymph nodes and to other sites in the reticuloendothelial system, and also via blood leucocytes to the liver, spleen and bone marrow. Recent experiments with inhaled plutonium make it evident that the pattern and rate of translocation of plutonium from the lung to other sites is highly dependent on particle size and specific activity, with more rapid transport of the smaller and more active particles. Thus, it is far from obvious whether the lung, lymph nodes, liver, bone or other organ, or fraction thereof, should be taken as the critical organ or critical tissue site.

It has long been known that those tissues in which there is more active cell division suffer the earliest and most severe radiation damage effects, and that this includes the blood forming cells in lymphatic glands and in bone marrow[16,37]. Such effects include the destruction of rapidly multiplying cells that produce the blood platelets which assist in the control of blood clotting. Similarly the population of leucocytes is reduced with a corresponding reduction in resistance to disease. These effects plus the accompanying chromosome structural changes can give rise to the earlier incidence not only of cancers, but the whole pattern of diseases of the cardiovascular and renal systems[37,38].

Let us review the mounting evidence which suggests that inhaled insoluble alpha emitting particles may be the agent of atherosclerosis and thus give rise to an increased risk of death by early coronaries and strokes. Atherosclerosis is reported to be present in every instance of partial or complete arterial occlusion and every case of coronary thrombosis[39].

Recently Benditt has shown[40] that the human atherosclerotic plaque is a monoclonal proliferation of a mutated cell of the artery wall, and thus an arterial tumor. Elkeles[41-43] has observed anomalously high concentrations of alpha activity at the calcified plaque sites. In addition atherosclerosis plaques normally occur in the main and abdominal aortas and the coronary arteries, but rarely in the pulmonary arteries[42-44]. This distribution suggests a respiratory origin for the mutagenic agent. Attempts to reproduce arterial lesions in animals by chemical, mechanical and nutritional means have not produced plaques similar to those of atherosclerosis in man[40]. However atherosclerotic plaques have been directly induced in human arteries by intensive irradiation with X-rays and radium[45]. There is a high incidence of early coronaries among cigarette smokers, with a mortality rate for males who smoke two packs or more daily that is 2 to 2.5 times that of non-smokers but at a mean age of death some 10 to 16 years earlier.[46] For all these reasons it is proposed that inhaled insoluble alpha emitting smoke particles are very likely to be the mutagenic agent which gives rise to atherosclerosis in cigarette smokers. If this is the case, similar increased risk of early coronaries are to be expected for other groups of individuals who are occupationally or environmentally exposed to the inhalation of insoluble alpha emitting particles of respirable size. Attention should be addressed to industrial and combustion product aerosols which contain uranium oxide, thorium oxide and lead-210, as well as to plutonium oxide from nuclear industry, nuclear accidents and fallout from atmospheric nuclear tests.

The first and most obvious place to look for such effects is among past and present plutonium workers. Very significant increases in the incidence of early coronaries as well as lung cancers and cancers at other sites is observed among cigarette smokers[46] with insoluble alpha emitting particle burdens of only a few picocuries of ^{210}Po in the lung[14] and similar total alpha activity per 100 grams of arterial wall tissue[41-43]. By comparison, plutonium workers exhibit plutonium organ burdens ranging from a few picocuries to a few manocuries or more[47,48]. And although there has been no epidemiological study of the age-incidence of heart disease and cancer among plutonium workers, the limited published information bearing on this question is more disturbing than reassuring. Most often cited is the medical experience of 26 plutonium workers at Los Alamos[49,50], usually accompanied by a statement to the effect that none of the medical findings for this group can be attributed definitely to internally deposited plutonium. With equal justification one may state that most of the serious medical findings in this group can be attributed to plutonium. One member of the original group died in the early 1950's. Cause of death is not reported. Another died of a coronary at age 38. A third suffered a coronary occlusion but recovered and was well compensated. A fourth developed a hamartoma of the lung and his right lower lobe was surgically removed in May 1971. A fifth had a melanoma of the chest wall. A sixth had a partial gastrectomy for a bleeding ulcer. One subject suffered loss of teeth, apparently due to damage to the lamina dura of the jaws which show the earliest effects in beagles given toxic doses of plutonium. Another subject has gout. The full medical history of this group, now mostly in their fifties, has not yet completely unfolded. Only 12 of these 26 plutonium workers were exposed to plutonium inhalation. Which of the observed effects were experienced by the inhalation exposure group? Regardless of the distribution, the medical experience of this small group thus far provides no basis for complacency about the health consequences of plutonium exposure.

Hanford employees and others whose autopsy tissue samples exhibited plutonium levels in excess of 5 fCi/g died mainly of coronary heart disease and other cardiovascular effects and to a lesser extent of cancer and pulmonary emphysema[47]. Based on evidence reviewed above it appears that atherosclerosis is a cancer of the artery wall and thus that coronary heart disease and other diseases of the cardiovascular and renal system are expected effects of inhaled plutonium and of other insoluble alpha emitting particles. An adequate assessment of the magnitude of these risks can only be obtained by a comprehensive medical follow-up of all past and present plutonium workers. Until the age distribution of these effects among plutonium workers is fully assessed, any claim by the proponents of nuclear energy that there is little risk associated with the MPLB (maximum permissible lung burden), 16 nCi of plutonium, or fractions thereof, is totally unjustified. The growing evidence suggests that as little as a few picocuries of alpha activity in the lung, in arterial tissue, and in other organs gives rise to a significant cancer risk.

5. Discussion: The published evidence, reviewed above, clearly indicates that a linear extrapolation to lower doses and dose rates is not conservative for internal alpha emitters. The initial effects of alpha interactions with cell chromosomes are irreversible and thus will vary linearly with alpha dose rate. However the cumulative effects of internal alpha emitters gives rise to an increase in the populations of mutated cells (cells with viable structural changes in their chromosomes) and in the health consequences of such changes. Therefore the tumor incidence per alpha disintegration must increase with decreasing dose rate. For this reason a given cancer risk is equated with smaller cumulative alpha doses and with much smaller internal alpha emitter burdens as the period of exposure increases.

By contrast, the cellular effects of X-rays and γ-rays are largely repairable at low dose rates. This stems from the fact that the diffuse distribution of ion pairs produced by such radiation results in widely spaced single chromosome breaks which repair themselves readily. For these reasons the relative biological effectiveness of alpha particles, compared to X-rays and γ-rays increases continuously with decreasing dose rate. Thus alpha radiation acquires a greatly increased biological significance relative to soft radiation in the production of tumors and other health consequences of chromosomal structural changes.

There are several other lines of evidence which reinforce the possibility that alpha interactions with cells play a unique role in human cancer production. The distribution of cancer sites in the bronchi, in the lymphatic system, in arterial tissue, in the liver and bone, all involve sites at which insoluble alpha emitters are known to accumulate. Anomalously high concentrations of alpha activity have been observed at the bronchial cancer sites[51], at cancer sites adjoining lymph glands in other organs [52,53] in atherosclerosis plaques[41-43], at liver cancer sites in thorotrast patients[54], at bone tumor sites in the radium dial workers[55], etc. The difficulties of producing lung cancer by external radiation has been pointed out by Warren and Gates[35,36]. The absence of cancers in muscular tissue, except at sites of thorotrast injection or plutonium injection, also is relevant to this issue. All of these observations reinforce the possibility that one or more of the chromosomal structural changes which characterize a malignant cell must be brought about by alpha interactions and not by low intensity X-rays or γ-rays. In this connection, the determination of the nature of the structural differences between the healthy and the malignant cells of each organ could shed some light on this important question.

It also is observed that the relative significance of chemical agents, viruses and radiation in the incidence of human cancer is not known. Details of the mechanisms of cancer induction by chemical agents and viruses also are poorly understood. And the proposed chem: al carcinogens in cigarette smoke and in polluted urban environments have not been demonstrated to be carcinogenic at the low concentrations involved. For all of these reasons it is deemed likely that radiation, and alpha radiation in particular, may be the principal agent of human cancer. In view of such a possibility, it is very disturbing to note that the U.S. National Cancer Institute, now spending about one-half billion dollars per year on cancer research, has completely neglected the field of radiation induced cancer research.

Published evidence[(39-45)] indicates that atherosclerosis is a tumor of the artery wall and that the alpha activity at the calcified plaque site is likely to be the mutagenic agent. If so the major causes of death in the general population - coronary disease, other cancers, and strokes - may in large part be attributable to internal alpha emitters from natural and pollutant sources. If so, fallout plutonium and alpha emitting contaminants must already be contributing to increased health risks and life shortening to the general public. Cigarette smoking causes increased risks of early coronaries, lung cancer, cancers at other sites, and other health effects[(46)], with about 15 years reduction in life expectancy for those who regularly smoke 2 packs of cigarettes per day or more (attributable to lung burdens of only about five picocuries of ^{210}Po in excess of that of nonsmokers). Fallout levels from past atmospheric nuclear tests have given rise to plutonium organ burdens of ~0.5 pCi/kg of lung tissue and ~0.7 pCi/kg of liver tissue in the general public[(56)]. Although these levels are only about 10 percent of the ^{210}Po organ burdens of heavy smokers, the effects may be correspondingly greater because the total population is exposed, and the inhalation exposures begin at birth.

If the health risks attributable to fallout plutonium exceed 10 percent of the risks of heavy smoking, then inhalation exposure at ~20 times fallout (the surface soil concentration of plutonium which corresponds to the interim soil standard adopted by the Colorado Board of Health in 1973) would give rise to organ burdens more than twice that of heavy smokers. Exposing children to such levels would be tantamount to their smoking four packs of cigarettes per day, beginning at birth. This estimate assumes, as I believe to be the case, that the inhaled, insoluble radioactive smoke particles give rise to the serious health effects of smoking.

For the estimation of organ burdens which may result from the inhalation of soil contaminants, it is common practice to attempt to determine the average surface soil concentrations, the applicable resuspension factors, inhalation exposure patterns, particle size distributions, lung retention, clearance and translocation patterns and rates, etc. The large cumulative errors and uncertainties in the prediction of the ultimate organ burdens from long-term exposure to contaminated surface soils and urban dusts by such a long sequence of complex processes serve to make this procedure an almost useless exercise. There is a more direct approach which sould give more reliable estimates. Lewis et al[57] show that the adult lung burden of nitric acid-insoluble particles increases almost linearly with age, with about 1.5 grams per kilogram of lung tissue at age 60. It seems reasonable to assume that individuals chronically exposed to soil dust and urban dusts will acquire just such burdens of the insoluble constituents in the respirable size fraction of dust particles (i.e., particles less than ~5 μm diameter). It should be noted that PuO_2 particles are highly insoluble and friable.

Experiments in the Rocky Flats area also have shown that about one-third of the airborne plutonium which has been resuspended from soil surfaces by wind action falls within the respirable particle size range. However only a very small fraction of the bulk surface soil is made up of insoluble particles of respirable size. For this reason, surface soils with one picocurie of plutonium per gram (the Colorado interim soil standard) should contain an estimated 10 to 100 pCi of plutonium per gram of insoluble soil particles of respirable size. Such a soil level should lead to plutonium lung burdens of 5 to 50 picocuries by age 20, or 15 to 150 picocuries by age 60, with correspondingly higher concentrations in the lymph nodes, liver, and bone. Thus the Colorado interim soil standard is hardly a safe or acceptable standard unless it can be shown that such levels of plutonium have no serious long term health effects.

There are, of course, a number of considerations which make it inappropriate to equate the effects of a given burden of low specific activity alpha emitting cigarette smoke particles with the same amount of alpha activity in hot particles. The Los Alamos experiments[12,13] make it evident that most of the alpha dose from "hot" particles of PuO_2 is wasted in the excessive irradiation of cells within the alpha range of the hot particle surface. Thus the high tumor risk for the hot $^{238}PuO_2$ particles[11] can be variously attributed to (a) the mobility of the smaller particles (b) the recoil ablation and/or dissolution rates which increase with specific activity and with surface area of hot particles and (c) the irradiation of larger numbers of cells with scattered protons (an effect that may be significant for very hot particles).

For these reasons, the insoluble alpha emitting smoke particle, uranium oxide, thorium oxide and other alpha emitting particles of moderate to low specific activity may be expected to give rise to a higher tumor risk per alpha disintegration or for a given cumulative dose. Similarly plutonium-239 in mixed fallout particles may be expected to produce more tumors per disintegration than is the case for pure $^{238}PuO_2$ and $^{239}PuO_2$. However although larger burdens of hot particles will be required for a given tumor risk, such risks can be expected to increase with both alpha specific activity and with particle surface area, and the effects should occur earlier for a given burden of smaller particles of higher specific activity.

The above considerations make it obvious that the present practice of averaging the alpha dose over the whole lung or some arbitrary fraction thereof[10-13] is a highly questionable and grossly misleading procedure at best.

It also should be noted that americium-241 is present in association with plutonium contamination in the Rocky Flats area and in nuclear test areas. In addition, curium isotopes as well as americium-241 will be present in high concentration in the nuclear fuel mixture from fission and breeder reactors which use plutonium fuel. The chemical behavior of americium and curium in the environment will give rise to their substantial uptake in the biosphere and the food chain. Thus the ingestion of americium and curium, their uptake from the gastrointestinal tract, and their accumulation in the liver and skeletal tissue of mammals and man will give rise to additional serious health risks. These contaminants will be relatively more serious than plutonium inhalation in some environments, particularly in vegetated areas of moderate to high rainfall, where soil resuspension processes are not effective.

6. Recommendations: It is urged that the U.S. Environmental Protection Agency consider and act upon each of the following recommendations which are called for (a) in order to provide an improved basis for the assessment of health risks and standards for plutonium and other actinides and (b) to provide a higher degree of protection from the effects of internal alpha emitters for occupational groups and the general public by adopting more conservative interim standards for plutonium exposure.

(1) Initiate a comprehensive interagency research program to assess the health risks of inhaled alpha emitting particles, with special attention to both "hot" particles and insoluble particles of low activity per particle (Some pertinent studies have been proposed to the EPA[53].)

(2) Conduct a comprehensive epidemiological health study of all past and present plutonium workers, and of all other groups which have been exposed to the inhalation of plutonium at levels significantly above fallout plutonium.

(3) Call upon the National Cancer Institute and the National Heart and Lung Institute to apply an appropriate fraction of their resources to assess the role of inhaled alpha emitting particles on the incidence of human cancer and heart disease.

(4) Adopt more conservative occupational standards for plutonium. A reduction of present air concentration and lung burden standards by a factor between 100 and 1000 appears to be in order. Better protection should be provided for younger employees and groups exposed to possible inhalation of finely divided and higher specific activity plutonium.

(5) Maintain public exposure levels of plutonium and other alpha emitters to the practical minimum. In my view this would limit public exposure to airborne dusts not exceeding 0.5 picocuries of alpha activity (About one alpha disintegration per minute) per gram of nitric acid insoluble

particulates of respirable size. This level would result in the accumulation of adult organ burdens about equal to that from fallout plutonium[56]. On this basis the Colorado interim standard may be at least 10 times too high.

(6) Call for a full disclosure of all past plutonium spills and accidental releases and conduct appropriate surveys and cleanup operations.

(7) Develop standards for americium and curium, with particular attention to their distribution in the food chain and their uptake from the gastrointestinal tract.

(8) Give immediate attention to current plans of the U.S. Department of Defense and the U.S. Atomic Energy Commission to resettle Enewetak Atoll. The high levels of plutonium and americium on these islands and in the lagoon sediments are likely to give rise to tragic health effects on this small native population group.

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APPENDIX III

COMMENTS ON THE

DRAFT ENVIRONMENTAL IMPACT STATEMENT

LIQUID METAL FAST BREEDER REACTOR PROGRAM
(WASH-1535)

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PREFACE

Four comments are attached.

Comment #1, ACCIDENTS

Comment #2, ESTIMATION OF THE HEALTH EFFECTS OF PLUTONIUM AND OTHER ALPHA-EMITTING TRANSURANICS

Comment #3, DIVERSION AND SAFEGUARDS OF FISSIONABLE MATERIALS

Comment #4, GENERAL AND IN SUMMARY

With the possible exception of #2, these comments are generic in nature. For a draft statement of this physical extent, detailed comment would be nearly prohibited by personal limitations of time and resources. This dilemma is not encountered here since generic comment seems indicated. Treatment of acne can be sensibly deferred when the patient shows systemic failure.

Comment #2, ESTIMATION OF THE HEALTH EFFECTS OF PLUTONIUM AND OTHER ALPHA-EMITTING TRANSURANICS

The estimate of lung cancer incidence associated with the inhalation of plutonium (or other transuranics) in particulate form is a critical factor, along with source terms and resuspension, in defining the probable impact of the LMFBR's plutonium based fuel-cycle. This subject is discussed in Section 4.G.5 "Particle Lung Dose Effects" of WASH-1535. I quote the first sentence from that section:

> "The estimates of lung cancer incidence associated with the inhalation of transuranics used in this report are based upon a calculation of the average radiation dose delivered to the lung and application of tumor incidence estimates for the uniformly irradiated lung as estimated in the BEIR report."[1]

This cited basis, and hence the derived estimates, are indefensible.

Section 4.G.5 acknowledges "that 'insoluble' particles of radioisotopes, when deposited in tissue, provide focal spots of high radiation dose rates close the the particle," so there is no presumption that the exposure by particulates of plutonium is uniform. The deep respiratory tissue of the lung is made up of 10^8 alveoli. Each aveolus is a complexly organized unit of tissue. If an insoluble alpha-emitting particulate is deposited in this tissue some 10 to 100 alveoli will be exposed. A crude measure of the nonuniformity of this exposure is that at most about one-millionth of the lung's alveoli are affected by a single particulate.

The significance of the preceding is that in the actual lung exposure by an alpha-emitting particulate, the energy of the ionizing radiation is deposited in a very limited volume of tissue, and hence that the actual radiation dose to lung tissue scaled roughly a million times larger than the dose associated with an averaging of the equivalent radiation energy over the entire lung.

A multiplicative difference of a million in a significant physical quantity generally suggests a qualitative difference. Suppose, for example, that the problem were to estimate the effects of small projectiles on human organisms. Suppose that the projectiles weigh 1/2 ounce and have a velocity of 1000 ft/sec. Note that the effect of the projectile depends on the energy, and note that a 6 ton vehicle moving at 1 mile per hour has similar energy. There is experience with humans stopping slow moving vehicles by exerting strenuous counterforces. Using this experience the effect of the projectiles on humans is inferred to be oxidation of the biological fuel necessary to do the work of stopping the vehicle. But this reasoning is manifest nonsense. Even though the energies involved are similar, a fast moving rifle bullet is quite different from a truck weighing a million times more and moving at a one-thousandth the velocity. The former dissipates its energy in the local disruption of tissue, the latter leads to the ordered and non injurious oxidation of biological fuel. The end results become very different as the physical characteristics of the situation change, and a new biological phenomenon intercedes. Obviously the way to estimate the effects of rifle bullets is either from past experience that is explicitly applicable, or alternatively, to calculate the effects considering the physical characteristics of the rifle bullet and knowledge of the biological and physical characteristics of the human organism.

This nonsense example has much the same logical structure as the method of estimating hot particles effects set forth in Section 4.0.5 of

WASH-1535. There, by introducing a fictitiously large mass of exposed tissue, the calculated dose becomes commensurately small. In passing from the real situation in which a hot particle irradiates 10 to 100 alveoli, to the fictional situation in which the ionizing radiation from the hot particle is averaged over 10^8 alveoli, the dose scale has decreased by roughly a factor of a million.

Living tissue shows extensive intra-cellular and inter-cellular organization. Several regimes of biological response would be expected as physical characteristics of exposure are varied. Carcinogenic response to whole organ exposure by non acute doses of radiation will fall in one of these regimes, and this will be a regime in which there is human experience. From the physical characteristics of plutonium aerosols, from the lung deposition experience with aerosols, and from the lung clearance experience with plutonium particulates, it can be inferred that at least one class of particles exist which subject lung tissue to an exposure associated with a different carcinogenic response regime. This is because other biological phenomenon has intervened.

For hot particle exposure that phenomenon is mitotic death of cells, i.e., loss of the cell's ability to divide. There is an extensive literature on the subject. Radiologically induced mitotic death is, in fact, the basis for treating malignant tissue with ionizing radiation, and is the cause of most acute symptoms consequent to radiation exposure. Even though the intercession of extensive mitotic death of cells must inevitably place certain particulate exposures in a different response regime from whole lung, non acute exposures, a compelling argument might be made that the carcinogenic response in the former case is necessarily less than the carcinogenic response in the latter. This argument would appear to have merit since mitotic death of cells, of well as reducing the general viability of the tissue, would also reduce the number of irradiated cells with carcinogenic potential. Usually implicit in this argument is a conceptualization of all radiation carcinogenesis as a single-cell, direct-injury process.

To confirm this argument, there is a respectable literature in which carcinogenesis is described as occurring after doses of radiation that are sufficiently local as to not be organism lethal, and that are sufficiently high for the fraction of mitotically competent cells to be greatly reduced, i.e., to 1% or less. Unfortunately, in at least some of these experiments, carcinogenesis is inversely related to the fraction of mitotically competent cells, i.e., cancer induction in the regime where mitotic competence is greater than 1% is small compared with the cancer induction in the regime where mitotic competence is much less than 1%.

There are several points to be made here. Loss of mitotic competence and carcinogenesis are two indices of radiation effect in tissue. They cannot be independent, and their relationship can tell us something about some radiation carcinogenesis.

Mitotic competence is not generally related in a linear way to carcinogenic response. Moreover, it is a major anomaly that an increased carcinogenic response is observed in dose regimes associated with greatly reduced mitotic competence. It is difficult to reconcile this result with any single-cell, direct-effect origin for radiation induced cancer.

Mitotic competence of a cell population decreases exponentially with increasing alpha-radiation dose and is a fairly general index of radiation effect in tissue. If radiation carcinogenesis universally decreased with mitotic competence, then estimates of carcinogenesis based on a fictitious averaging of a local inhomogeneous dose over a much larger volume would be necessarily conservative. Since radiation carcinogensis can, and in fact, does increase to anomalously large values while the mitotic competence becomes vanishlingly small, the fictitious averaging of dose over larger volumes is not necessarily conservative. Instead it would appear that an intense local dose of ionizing radiation can be a more efficient carcinogen than a diffuse tissue exposure with the same type of ionizing radiation and the same total energy. The above then implies that averaging of dose over larger volumes may be far from conservative.

It is obvious that as a local exposure becomes more intense, a stage must finally be reached where the carcinogenic efficiency of the exposure (on a per unit energy basis) is reduced. This is not pertinent to previous arguments. It would, however, be important to know the characteristics of the most carcinogenicly efficient exposures.

The following excerpt taken from the BEIR report (p. 95) summarizes the state of knowledge concerning the causation of cancer (emphasis added):

> "Although the mechanisms of carcinogenesis, or of radiation carcinogenesis in particular, are not fully known, available information implies that most, if not all, types of cancer develop as a result of the combined effects of multiple factors. These causative factors may include: prezygotic (inherited) mutations of chromosomal aberrations, which can spread during development to many kinds of cells; somatic cell mutations or chromosomal aberrations, which can be acquired at any time after conception; changes resulting from the action of viruses; and changes in systemic growth factors (e.g., depressed immune competence, hormonal imbalance) and in local tissue regulation (disorganization, damage), such as may result from diseases other than cancer or from advancing age (1).
>
> "Although point mutations, chromosomal abberations, and other changes at the cellular and molecular level may require only small doses, tissue disorganization and

gross disturbances in physiology are unlikely without larger doses (2).

"Of the many types of changes which radiation can cause in cells or tissues, none is considered to be unique for radiation. Many, if not all, such changes can presumably result from a variety of other agents."

This summary view on carcinogenesis is compatible with the ideas leading to the conclusion reached earlier, that fictitious dose averaging to larger tissue masses need not be conservative. The possibility of various modes of carcinogenesis is acknowledged, and in particular, mention is made of a pathway mediated by tissue disruption.

Disease profiles are highly species specific. Cancer is no exception. Gross characteristics are obviously highly species specific also. A rat and a mouse are distinct and yet incredibly similar. The gross tissue differences are articulated out through subtly different informational resonances amongst cell populations, - the collective behavior being phased ultimately, though perhaps remotely, by the genetic controls of the cells. Not to belabor this point unnecessarily, - cancer profiles are species specific; gross characteristics and, of course, genetic material are also species specific. Collective detuning of tissue, by tissue disruption seem as acceptable an origin for the tissue instabilities of cancer as does an isolated single cell event.

Return now to the problem of risk estimates associated with radioactive particulates in human lungs. Most of what has been said earlier in this comment has been general, and has been aimed at showing that there was no inherent conservatism in the method of estimating cancer risks set forth in the first sentence of 4.G.5, and that moreover the method could be far from conservative. The conclusion could as well be applied to lymphatic tissue or to bronchial tissue.

Having this background notice that human lung tissue has a well known carcinogenic potential under a number of situations, including exposure to ionizing radiations; and that in the Hanford dog study induction of lung cancer was observed after exposure to plutonium aerosols. These are a sufficient basis to establish plutonium induced lung cancer as a legitimate concern for humans.

The following is a review of the official guidance for estimating the carcinogenic effects from exposure to radioactive particulates.

I. "(210) The NCRP has arbitrarily used 10% of the volume of the organ as the significant volume for irradiation of the gonads. There are some cases in which choice of a significant volume or area is virtually meaningless. For example, if a single particle of radioactive material fixed in either lung or lymph node may be carcinogenic, the averaging of dose either over the lung, or one cubic centimeter may have little to do with the case. Use of significant volumes or areas must be looked on as one of the round off devices which in special cases must give way to detailed study."

NCRP Report #39
Basic Radiation Protection Criteria
January 15, 1971.
(emphasis added)

II.

40. The problems of high local concentration of dose are at their most severe with radioactive particulate material in the tissue, especially with α-emitters. Here the local dose can reach very high values even though the mean tissue dose may be very low. Certainly it cannot be assumed that linearity of dose and effect will hold at these high doses and dose rates. On the other hand, there may be a great deal of cell death, and particularly with α-emission, with its short and well-defined range, the number of affected but viable cells may be small compared with the number of killed cells. However, this ratio will depend on the size and activity of the particles, the extent to which they aggregate, and their movement within the tissue, and the movement of the cells past them.

41. On the basis of general considerations and of some experimental data and clinical experience the Task Group were of the opinion that, for late effects, the same radiation energy absorption might well be less effective when distributed as a series of "hot spots" than when uniformly distributed. Thus, with particulate radioactive sources within a tissue, a mean tissue dose would probably introduce a factor of safety. However, a severe practical problem has now been recognized in connection with the inhalation of plutonium particulates, and is now being considered in detail by a Task Group of Committee 1 of ICRP.

42. From dog experiments being carried out in the United States and from limited studies in human subjects it has become clear that inhalation of plutonium particulates can lead to high concentrations of the particulate material in the pulmonary lymph nodes, and that the mean radiation dose to the pulmonary lymph nodes and indeed to lymphoid tissue as a whole is likely to be greatly in excess of that to the lung, which is at present regarded as the critical organ for inhaled particulate matter.

43. The actual dose ratios are not yet known with any precision but the Task Group understood that the mean dose to lymphoid tissue as a whole might exceed that to the lung by a factor of 10 or more, and, if the respiratory lymph nodes were alone taken into consideration, the factor could be 100 or perhaps much greater. The problem is whether lymphoid tissue as a whole or respiratory lymph node tissue in particular should be taken as the critical organ, and, if so, whether the dose limit (MPC_a) for plutonium in particulate form should be substantially reduced below the current value.

44. One is concerned here with the relative risks of particulate material (mainly α-emitting, but with some soft x-ray emission) deposited in lung and in lymph nodes, and any analysis based on dose determination encounters profound difficulties. Considering only the lymphoid tissue, there is first the problem of lack of knowledge of the sensitivity to radiation-induced malignant change of the reticulum cells present, and possibly also of lymphocytes themselves. Also any calculation of dosage distribution to the various elements of the lymphoid tissue would require information, at present unavailable, on such subjects as the degree of aggregation of the particulate material within the lymph nodes, its change with time and the movement of the particles within the lymph nodes. In addition there is very little reported work on the distribution of the material within the nodes, which could be obtained by autoradiographic study, or on the degree of fibrosis and other histological changes produced. Better data are also required on the residence times of the particulate material in the lymph nodes and the solubility of the particulate material over many years. Another factor to be taken into consideration, common to all particulate deposition and especially to those involving α-emitters, is that the number of cells irradiated is, for the same mean tissue dose, very dependent on the particle size. Finally, lymphocyte migration is a factor that should be taken into consideration.

45. In so far as mean dose calculations can be made the Task Group considered that they should, for consistency within the recommendations, refer to the whole lymph tissue and not only to the respiratory lymph nodes. However, until more information becomes available on some of the subjects mentioned above, little weight can be put on dose calculations. Data on tumour production from animal experiments are of more significance, and the results of present work with dogs, particularly those with lower amounts of plutonium, are awaited with interest. In the meantime, the Task Group are of the opinion that any immediate change in the dose limit for plutonium on the basis of risk to lymphoid tissue is not warranted.

ICRP Publication 14
Radiation Sensitivity and
Spatial Distribution of Dose
(Publication 14 appears as a
report of two Task Groups,
and not as the official
recommendations of the ICRP.)

(23) Within the range of the Maximum Permissible Doses (see paragraph 37) specified for occupational exposure, when it is assumed that there is no threshold and that effects are linearly related to dose, it is justifiable to consider the average dose to the whole organ or tissue, although it is recognized that when more information is available, it will be more appropriate to use the mean dose for cells of any given type, as is already done when the bronchial mucosa is irradiated by daughter products of radon and thoron. The use of the mean dose has practical advantages in that the significant volume can be taken as that of the organ or tissue under consideration. In fact, this principle has necessarily been used already in calculating maximum permissible burdens of radionuclides in tissues. However, with extreme inhomogeneity of dose (for example, with particulate radioactive material of high specific activity) such a procedure may be inappropriate. This is a matter upon which further work is needed. Also, for external exposure of the skin, especially when the distance to the source is very short or when the exposed area is very small, it would not be appropriate to average the dose over the entire skin. Instead, it is recommended that the dose be averaged over an area of a square centimetre in the region receiving the highest dose; however, with very narrow beams of extremely high intensity, such as those used for X-ray analysis, the value of such an average dose may be misleading, and protection measures have to be based on qualitative considerations.

III. (20) In the case of non-homogeneous distribution of absorbed dose in the lung, an estimate of the Dose Equivalent to the whole lung, determined merely by the product of QF and the mean absorbed dose, may be greatly in error, but our full understanding of this problem must await further experimental evidence. In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung. When irradiation results from the inhalation of thoron or radon and daughter products, the relevant Dose Equivalent is that in the bronchial mucosa which is the tissue considered to be most heavily irradiated. Here the use of the whole lung would be an inadequate substitute for that of the irradiated tissue.

ICRP Publication 9
Recommendations of the
International Committee
on Radiological Protection
(adopted September 17, 1965).

The recommendations of the National Council on Radiation Protection and Measurement set forth in I, and the recommendations of the International Commission on Radiological Protection set forth in III, are explicit in offering no guidance.

II is a discussion of the hot particle problem taken from the report of an ICRP Task Group. It is not intended to give dispositive official guidance. The discussion is useful commentary, but inconclusive. The very conditional statement made in the first and second sentence of II (41) is not generally convincing.

With regard to the previously cited method of risk estimation described in the first sentence of 4.G.5, that section continues with the following supportive references:

> "This approach has been used by the Environmental Protection Agency in recent reports on the potential health consequences of the nuclear fuel cycle.[2-5] The approach leads to estimates comparable to those of Gavankar[6] following Thompson et al[7] based on linear non-threshold extrapolation of observations on beagle dogs administered $^{239}PuO_2$ aerosols."

As to the first, consensus in error may provide amiable agreement amongst federal agencies, but seems hardly a desirable basis for decisions involving the public health and safety. The observations on beagle dogs are discussed further on 4.G-117 and deserves separate consideration.

It requires pathological optimism to find reassurance in the results of the now completed Hanford beagle experiment. Dogs were given initial aerosol burdens of approximately 1-10 microcuries of $Pu^{239}O_2$. By nine years post-exposure the lung cancer response was virtually saturated and multicentric origins were noted in some dogs. Those receiving larger lung burdens greater than 10 microcuries died of pulmonary insufficiency within 4-1/2 years. Twenty-one dogs survived for more than 4-1/2 years, and only one of these did not exhibit lung cancer at death. A relationship observed between initial lung burden and time to death with cancer has been often used to infer a threshold burden below which no life shortening of dogs would be expected. This is shown in Figure 4.G.10 on 4-G 118. Note that the fibrotic deaths there have no bearing on cancer incidence and inclusion of those points in the constructing extrapolated curves is a senseless exercise. Note also that the results are exhibited on a log-log graph which virtually obscures all differential detail. Most important, recognize the nature of the experiment, i.e., the lung burdens were large, the results were saturated, and the number of animals was small. The crude relationship observed between initial lung burden and time to death with lung cancer does not necessarily imply that a threshold burden exists for beagles. Quite to the contrary, the range of exposures above the inferred threshold burden may be interpreted as a region of saturated carcinogenic response, that is a burden regime in which lung cancer induction in a beagle population approaches 100% during a normal life span. The point is that the observed time to death is more likely related to the burden, through a population depletion effect, rather than through a burden dependent latent period. In the former interpretation appreciable cancer would be anticipated at lower burdens. This is again consistent with extensive observations of radioisotope-induced bone tumors in mice, which support the interpretation that "latent period is constant and that the apparent relationship between increasing dose and decreasing time to death with tumor is due to the effects of dose-level on survival and on tumor expectancy." (See Toxicity of Ra-226 in Mice," M. Finkel et al, in Radiation-Induced Cancer, IAEA, Vienna, 1969.)

The domain of this comment is broadened here in order to summarize a specific concern with plutonium, and, to a lesser extent, other transuranics. Under a number of circumstances plutonium forms aerosols. The physical character of these aerosols is such that on inhalation by humans they are preferentially deposited in respiratory tissue. Because of slow clearance and because of their insoluble character, particles may experience long residence times in tissue. An appreciable mass fraction of the aerosol is usually associated with particles sufficiently large that small but physiologically significant volumes of tissue will be exposed to intense (i.e., organism lethal or greater) radiation doses within a meaningful physiological time. Studies of the effects of intense local radiation to skin and kidney tissue indicate that despite the near mitotic sterilization of the involved tissue, an enhanced carcinogenic response may occur, in the sense that energy dissipated in a limited volume may be far more carcinogenic than if the same type of radiation were to dissipate its energy over a much larger tissue mass. The question is then: do particulates of plutonium lead to exposures that have enhanced carcinogenic potential? If they do, then present standards can be in error by orders of magnitude.

Notice that the emphasis here is on the anomalous hazard associated with a single particle; and that if any threshold is relevant, it is not a dose threshold since local exposures are large, but rather a possible volumetric threshold that must be exceeded by the physical extent of the exposure. Plutonium, as an insoluble aerosol-forming, long-lived alpha-emitter, constitutes a very special case of the low exposure problem.

In conclusion, it is indefensible to base estimates of cancer risk on the method of dose averaging over fictitiously large volumes. Similarly, estimates based on non conservative interpretations of the Hanford beagle results are highly suspect.

PLUTONIUM AND PUBLIC HEALTH

by Donald P. Geesaman

A talk given at the University of Colorado on April 19, 1970.

Printed with references added in Underground Uses of Nuclear Energy, Part 2. Hearings before the Subcommittee on Air and Water Pollution of the Committee of Public Works, United States Senate, August 5, 1970.

Printed with Author's Note added in Electric Power Consumption and Human Welfare, AAAS Committee on Environmental Alterations, August 11, 1974.

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PLUTONIUM AND PUBLIC HEALTH

Donald P. Geesaman, 1972

AUTHOR'S NOTE--JUNE 1972

On May 11, 1969, a major fire occurred at the large Rocky Flats plutonium facility located northwest of Denver, Colorado, and operated for the Atomic Energy Commission by the Dow Chemical Company.

Consequent to this fire E. A. Martell and S. E. Poet conducted a pilot study on the plutonium contamination of surface soils in the Rocky Flats environs. Their results suggested an off-site contamination orders of magnitude larger than that which would have been expected from the measured plutonium releases in the air effluent of the facility.

In a letter of January 13, 1973, to Glenn Seaborg, then chairman of the Atomic Energy Commission, and in a press release of February 24, 1970, by the Colorado Committee on Environmental Information, Martell and co-workers called attention to this anomalous contamination and expressed concern over its uncertain origin and over its significance to public health. In response the Atomic Energy Commission fixed the probable origin of the off-site contamination as wind dispersal of plutonium leaking from rusted barrels of contaminated cutting oil, and denied that cause existed for concern over hazards to public health.

It was my conviction that the Atomic Energy Commission response provided a distorted and inadequate representation of the possible hazards associated with the observed off site contamination, and that the imminent large-scale commercial introduction of plutonium gave this situation a precedential significance much greater than the already considerable significance of the situation itself.

Dr. Donald P. Geesaman is an associate professor in the School of Public Affairs of the University of Minnesota, Minneapolis, Minnesota. His professional interest is in the relationship between technology and political institutions. He spent thirteen years in the Theoretical Physics Division and the Biomedical Division of the Lawrence Radiation Laboratory, University of California, where much of his research was concerned with nuclear technologies and their implications concerning society.

From Underground Uses of Nuclear Energy, Part 2, Hearings before the Subcommittee on Public Works, United States Senate, August 5, 1970, and subsequently submitted as a working paper to the AAAS/CEA Electric Power Study Group (1972). Reprinted by permission of the author.

In April 1970 a representative of the Division of Biology and Medicine of the Atomic Energy Commission and I were invited to present our views at the University of Colorado.

Attachment #1 to Comment #2

"Plutonium and Public Health," in Electric Power Consumption and Human Welfare, AAAS Committee on Environmental Alterations, August 11, 1972 (non-copyrighted).

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PLUTONIUM AND PUBLIC HEALTH

Donald P. Geesaman

Author's Note--June 1972.

On May 11, 1969 a major fire occurred at the large Rocky Flats plutonium facility located northwest of Denver, Colorado, and operated for the AEC by the Dow Chemical Company. For description of this fire see AEC press releases M-121, May 20, 1969, and M-257, November 18, 1969.

Consequent to this fire E.A. Martell and S.E. Poet conducted a pilot study on the plutonium contamination of surface soils in the Rocky Flats environs. Their results suggested an off site contamination that was orders of magnitude larger than that which would have been expected from the measured plutonium releases in the air effluent of the facility.

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It was my conviction that the AEC response provided a distorted and inadequate representation of the possible hazards associated with the observed off site contamination, and that the imminent large-scale commercial introduction of plutonium gave this situation a precedential significance much greater than the already considerable significance of the situation itself.

In April 1970 a representative of the AEC's Division of Biology and Medicine and myself were invited to present our views at the University of Colorado. "Plutonium and Public Health" derives from the preceding history and should be so interpreted. The presentation was to a lay audience and was made with that expectation. Adequate referencing was added to the written text prior to its inclusion in Underground Uses of Nuclear Energy, Part 2, Hearings before the Subcommittee on Air and Water Pollution of the Committee on Public Works United States Senate, August 5, 1970.

As it stands the paper still represents a legitimate critique, and the recent emphasis on plutonium as a major energy source increases the relevance of the discussion. An updating would involve only incremental changes, and would generally supplement rather than disturb the substantive arguments of the original paper. Hence while such an updating is desirable, it is also of sufficient marginal value that it can be properly deferred at my discretion.

For those who are interested in reading the traditional AEC position on the subject I would suggest "Appendix 24 - Safety Considerations in the Operations of the Rocky Flats Plutonium Processing Plant", from AEC Authorizing Legislation Fiscal Year 1971 - Hearings before the Joint

Committee on Atomic Energy, Part 4, March 19, 1970.

Times have changed since May 1969. Then plutonium was regarded as a military substance and was accordingly given little public attention. Now it is much publicized as the energy source of the not too distant future. April 1970 was a time of transition, and I felt the strong presence of the earlier tradition, and the decision to speak was not an easy one for me. I have had no regrets.

D. P. G.

Plutonium and Public Health

For the sake of completeness let me give you some background on plutonium. It is an element that is virtually non-existent in the earth's natural crust. In the early 1940's it was first produced and isolated by Dr. Seaborg and colleagues; --Dr. Seaborg is presently Chairman of the Atomic Energy Commission. Plutonium has several isotopes, the most important being plutonium-239, which, because of its fissionable properties and its ease of production, is potentially the best of the three fission fuels. That is why it is of interest. Aside from its fissionable properties, plutonium-239 is a radioactive isotope of relatively long half-life (24,000 years), hence its radioactivity is undiminished within human time scales. When it decays, it emits a helium nucleus of substantial energy. Because of its physical characteristics, a helium nucleus interacts strongly with the material along its path; and as a consequence deposits its energy in a relatively short distance, --about four-hundredths of a millimeter in solid tissue. For comparison, a typical cell dimension is about 1/4 to

1/10 of that. A cell whose nucleus is intercepted by the path of such a particle suffers sufficient injury that its capacity for cell division is usually lost (Barendson, A.W., 1962 and Bloom, W., 1959).

The cancer inducing potential of plutonium is well known. One millionth of a gram injected intradermally in mice has caused cancer (lisco, H., et al., 1947); a similar amount injected into the blood system of dogs has induced a substantial incidence of bone cancer (Mays, C.W., et al., 1947), because of plutonium's tendency to seek bone tissue. Fortunately the body maintains a relatively effective barrier against the entry of plutonium into the blood system. Also, because of the short range of the emitted helium nuclei, the radiation from plutonium deposited on the surface of human skin does not usually reach any relevant tissue. Unfortunately the lung is more vulnerable.

Before I describe why this is, I'd like to say something about the characteristics of an aerosol. An aerosol is physically like cigarette smoke, or fog, or cement dust. Because of their small size, the particles comprising an aerosol remain suspended in air for long periods of time. If an aerosol is inhaled, then, depending on its physical characteristics, it may be deposited at different sites in the respiratory tree (Health Physics, 1966). Larger aerosol sizes are usually removed by turbulence in the nose, particles deposited in the bronchial tree are cleared upward in hours by the ciliated mucus blanket that covers the structure. This clearance system does not penetrate into the deep respiratory structures, the alveoli, where the basic oxygen-carbon dioxide exchange of the lung takes place. Smaller particles tend to be deposited here by gravitational settling, and if they are insoluble they may reside in the alveoli for a considerable time. The problem is that, under a number of conditions (Anderson, B.V., et al., 1967; Fraser, D.C., 1967; Kirchner, R.A., 1966; Mann, J.R., et al., 1967; Stewart, K., 1963; Wilson, R.H. et al., 1967) plutonium tends to form aerosols of a size that are preferentially deposited in deep lung tissue. Plutonium dioxide, which is a principal offender, is insoluble and may be immobilized in the lung for hundreds of days before being cleared to the throat or to the lymph nodes around the lungs (Health Physics, 1966).

An aerosol is comprised of particles of many different sizes, and their radioactivity may differ by factors of thousands or even more. I will simplify the argument and say that there is a class of these particles, the largest ones deposited in the deep lung tissue, that can be expected to have a different potential of cancer induction than the particles of the smaller class. This is because they are sufficiently radioactive to disrupt cell populations in the volume of cell tissue which they expose (Geesaman, D.P., 1968a). An example might be a particle that emits 5000 helium nuclei per day. It would subject between 1 and 20 alveoli to intense radiation, sufficient to inflict substantial cell death and tissue disruption. For reference, the alveoli are the basic structural units of the deep lung. They are shaped and bunched roughly like hollow grapes 0.3 millimeter in diameter. Their walls are thin, a few thousandths of a millimeter, and they are a highly structured tissue with many cell types. Intense exposure of local tissue by a radioactive particle is referred to as the hot particle problem. The question is: does such a particle have an enhanced potential for cancer? No one knows. One can argue that cancer cannot evolve from dead cells, hence a depleted cell population must be less carcinogenic. This is believeable, and must be true on occasion. The facts are, though, that intense, local doses of radiation are extremely effective carcinogens, much more so than if the energy were averaged over a larger tissue mass (Geesaman, D.P., 1968b). Furthermore, this can take place at high doses of radiation where only one cell in ten thousand has retained its capacity to divide. The cancer susceptibility of lung tissue to radiation has been demonstrated in many species; one can say in general that the lung is more susceptible to inhomogeneous exposures from particles and implants than it is to diffuse uniform radiation. Some very careful skin experiments of Dr. Albert have indicated that tissue disruption is a very likely pathway of radioactive induction of cancer after intense exposure (Albert, R.E., et al., 1967a, 1967b, 1967c, 1969). The experiments show that the most severe tissue injury is not necessary, nor even optimal, for the induction of cancer. When these notions are applied to a hot particle in the lung, the possibility of one cancer from 10,000 disruptive particles is realistic. This is disturbing because an appreciable portion of the total radioactivity in a plutonium aerosol is usually in the large particle component.

Let me demonstrate what I mean. Suppose a man received a maximum permissible lung burden for plutonium, and suppose roughly [illegible]% of the mass of the burden was associated with the most active class of particles deposited (that is those emitting several thousand helium nuclei per day). This is reasonable. There would be something like a thousand of these particles and each would chronically expose 1 to 20 alveoli to intense radiation. If the risk of cancer is like 1 in 10,000 for one disruptive particle, then the total risk in this situation is one in ten, i.e., one man in ten would develop lung cancer.

Put another way, about 1 cubic centimeter of the lung is receiving high doses of radiation. It would not be surprising if intense exposure of such a localized volume led to a cancer one time in ten. The question is: if the individual volumes are separated from each other, is substantial protection afforded? No one knows. It is much easier to find two cancers using 50 exposures of 1 cubic centimeter each, than it is to find a couple of cancers in 50,000 single particle exposures. Certainly the length scales of injury are long enough that a disruptive carcinogenic pathway cannot be disregarded for isolated hot particles (Geesaman, D.P., 1968b).

One can look to the relevant experience for reassurance. In an experiment done at Hanford by Dr. Bair and his colleagues, beagle dogs were given $Pu^{239}O_2$ lung burdens of a few hundred thousandths of a gram (Bair, W.J., et al., 1966; Ross, D.M., 1967). At 9 years post exposure, or after roughly half of an adult beagle life span, 22 of 24 deaths involved lung cancer, usually of multiple origin. Five dogs remain alive. For comparison, these exposures are about 100 times larger than the present maximum permissible burdens in man.

There are two unsatisfactory aspects of this experiment. First, because all of the dogs are developing cancer, it is impossible to infer what would happen at lower exposures: simple proportionality does, however, suggest that present human standards are too lax by at least a factor of ten. Second, because the radiation dose is large, with tissue injury almost killing the dogs; and because large numbers of particles are involved, often acting in conjunction; it is improbable that the risk from disruptive particles can be inferred. And after all, this is what we need to know, since almost all human exposures will involve hot particles acting independently, and if there is a risk from these particles, it will be additive throughout the population; --there will be no question of a threshold burden; and there will be a possibility that a man with an undetectable burden of a few particles will develop a cancer as a consequence. For the exposures of concern, 1000 people with 100 disruptive particles each will suffer as many total cancers as 10,000 people with 10 particles each, or as 100 people with 1000 particles each.

Human experience does not give us the answer either. Plutonium has been around for 25 years, and people have been exposed. In 1964 through 1966 contractors indicated an average total of 21 people per year with over 25% of a maximum permissible burden of plutonium (Ross, D.M., 1968). Three out of four of these exposures derived from inhalation. To be reasonably useful, the documentation of exposure must go back more than 15 years, because of the latent period for radiation induced cancer. In recent years documentation has improved greatly, but from early days there is pitifully little of relevance to the hot particle problem in the lung.

Since I have mentioned maximum permissible lung burdens, you are aware that there is official guidance. I would like to comment on it. The maximum permissible lung burden is established by equilibrating the exposure from the deposited radioactive aerosol with that of an acceptable uniform dose of x-rays. The International Commission on Radiological Protection indicates this may be greatly in error, and specifically states in its publication 9, "In the meantime there is no clear evidence to show whether, with a given mean absorbed dose, the biological risk associated with a non-homogeneous distribution is greater or less than the risk resulting from a more diffuse distribution of that dose in the lung." (ICRP, 1966). They are effectively saying that there is no guidance as to the risk for non-homogeneous exposure in the lung, hence the maximum permissible lung burden is meaningless for plutonium particles, as are the maximum permissible air concentrations which derive from it.

So there is a hot particle problem with plutonium in the lung, and the hot particle problem is not understood, and there is no guidance as to the risk. I don't think there is any controversy about that. Let me quote to you from Dr. K. Z. Morgan's testimony in January of this year before the Joint Committee on Atomic Energy, U.S. Congress (Morgan, K.Z., 1960). Dr. K.Z. Morgan is one of the United States' two members to the main Committee of the International Commission on Radiological Protection; he has been a member of the committee longer than anyone; and he is director of Health Physics Division at Oak Ridge National Laboratory. I quote: "There are many things about radiation exposure we do not understand, and there will continue to be uncertainties until health physics can provide a coherent theory of radiation damage. This is why some of the basic research studies of the USAEC are so important. D.P. Geesaman and Tamplin have pointed out recently the problems of plutonium-239 particles and the uncertainty of the risk to a man who carries such a particle of high specific activity in his lungs." At the same hearing, in response to the committee's inquiry about priorities in basic research on the biological effects of radiation, Dr. M. Eisenbud, then Director of the New York City Environmental Protection Administration, in part replied, "For some reason or other the particle problem has not come upon us in quite a little while, but it probably will one of these days. We are not much further along on the basic question of whether a given amount of energy delivered to a progressively smaller and smaller volume of tissue is better or worse for the recipient. This is another way of asking the question of how you calculate the dose when you inhale a single particle." (Eisenbud, M., 1970). He was correct; the problem has come up again.

In the context of his comment it is interesting to refer to the National Academy of Sciences, National Research Council report of 1961 on the Effects of Inhaled Radioactive Particles (U.S. NAS.NRC.1961). The first sentence reads, "The potential hazard due to airborne radioactive particulates is probably the least understood of the hazards associated with atomic weapons tests, production of radioelements, and the expanding use of nuclear energy for power production." A decade later that statement is still valid. Finally let me quote Drs. Sanders, Thompson, and

Bair from a paper given by them last October (Sanders, C.L., 1970). Dr. Bair and his colleagues have done the most relevant plutonium oxide inhalation experiments. "Nonuniform irradiation of the lung from deposited radioactive particulates is clearly more carcinogenic than uniform exposure (on a total-lung dose basis), and alpha-irradiation is more carcinogenic than beta-irradiation. The doses required for a substantial tumor incidence, are very high, however, if measured in proximity to the particle; and, again, there are no data to establish the low-incidence end of a dose-effect curve. And there is no general theory, or data on which to base a theory, which would permit extrapolation of the high incidence portion of the curve into the low incidence region." I agree and I suggest that in such a circumstance it is appropriate to view the standards with extreme caution.

There is another hazardous aspect of the particulate problem in which substantial uncertainty exists. In case of an aerosol depositing on a surface, the material may be resuspended in the air. This process is crudely described by a quantity called a resuspension factor which is remarkable in that it seems generally known only to within a factor of billions (Kathren, R.L. 1968). Undoubtedly it can be pinpointed somewhat better than this for plutonium oxide, but the handiest way to dispatch the problem is to say there is some evidence that plutonium particles become attached to larger particles and are therefore no longer potential aerosols. Unfortunately there is also evidence that large particles generate aerodynamic turbulence, and are hence blown about more readily, and on being redeposited tend to knock small particles free. In relation to this, I'd like to give you a little subjective feeling for the hazard. There is no official guidance on surface contamination by plutonium. Two years ago, in an effort to determine some indication of the opinions of knowledgeable persons with respect to environmental contamination by plutonium, a brief questionaire was administered to 38 selected LRL employees (Kathren, R.L., private communication). All were persons who were well acquainted with the hazards of plutonium. The group consisted of 16 Hazards Control personnel, primarily health physicists and senior radiation monitors. The remainder were professional personnel from Biomedical Division, Chemistry, and Military Applications, who had extensive experience with plutonium. I had nothing to do with the survey, nor was I one of the members who was queried. The conjectured situation was that their neighborhood had been contaminated by plutonium oxide to levels of 0.4 microcuries per square meter. For reference, this value is roughly ten times the highest concentration Dr. Martell found east of the Rocky Flast Dow Chemical facility (Martell, E.A., 1970), --and bear in mind that a factor of ten is a small difference relative to the large uncertainties associated with the hazards from plutonium contamination. Several questions were asked. One was, would you allow your children to play in it? 86% said No. Should these levels be decontaminated? 89% said Yes. And to what level should the area be cleaned? 50% said to background, zero, minimum, or by a reduction of at least a factor of 40. This has no profound scientific significance, but indicates that many people conversant of the hazard are not blase about the levels of contamination encountered east of Rocky Flats.

Finally I would like to describe the problem in a larger context. By the year 2000, plutonium-239 has been conjectured to be a major energy source. Commercial production is projected at 30 tons per year by 1980, in excess of 100 tons per year by 2000. Plutonium contamination is not an academic question. Unless fusion reactor feasibility is demonstrated in the near future, the commitment will be made to liquid metal fast breeder reactors fueled by plutonium. Since fusion reactors are presently speculative, the decision for liquid metal fast breeders should be anticipated and plutonium should be considered as a major pollutant of remarkable toxicity and persistence. Considering the enormous economic inertia involved in the commitment it is imperative that public health aspects be carefully and honestly defined prior to active promotion of the industry. To live sanely with plutonium one must appreciate the potential magnitude of the risk, and be able to monitor against all significant hazards.

An indeterminate amount of plutonium has gone off site at a major facility 10 miles upwind from a metropolitan area. The loss was unnoticed. The origin is somewhat speculative as is the ultimate deposition.

The health and safety of public and workers are protected by a set of standards for plutonium acknowledged to be meaningless.

Such things make a travesty of public health, and raise serious questions about a hurried acceptance of nuclear energy.

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Advisory Council
On Historic Preservation
1522 K Street N.W. Suite 430
Washington D.C. 20005

Lt.General Warren D. Johnson, USAF
Defense Nuclear Agency
Department of Defense
Washington, D. C. 20305

Dear General Johnson:

This is in response to your request of September 3, 1974 for comments on the draft environmental statement for Clean Up, Rehabilitation, Resettlement of Enewetak Atoll, Marshall Islands. Pursuant to its responsibilities under Section 102(2)(C) of the National Environmental Policy Act of 1969, the Advisory Council on Historic Preservation has determined that while you have discussed the historical, architectural and archeological aspects related to the undertaking, the Advisory Council needs additional information to adequately evaluate the effects on these cultural resources. Please furnish additional data indicating:

I. Compliance with Section 106 of the National Historic Preservation Act of 1966 (16 U.S.C. 470[f]). The Council must have evidence that the most recent listing of the National Register of Historic Places has been consulted (see Federal Register, February 19, 1974 and monthly supplements each first Tuesday thereafter) and that either of the following conditions is satisfied:

A. If no National Register property is affected by the project, a section detailing this determination must appear in the environmental statement.

B. If a National Register property is affected by the project, the environmental statament must contain an account of steps taken in compliance with Section 106 and a comprehensive discussion of the contemplated effects on the National Register property. (Procedures for compliance with Section 106 are detailed in the Federal Register of January 25, 1974.)

II. Compliance with Executive Order 11593, "Protection and Enhancement of the Cultural Environment" of May 13, 1971.

A. Under Section 2(a) of the Executive Order, Federal agencies are required to locate, inventory, and nominate eligible historic, architectural and archeological properties under their control or jurisdiction to the National Register of Historic Places. The results of this survey should be included in the environmental statement as evidence of compliance with Section 2(a).

B. Until the inventory required by Section 2(a) is complete, Federal agencies are required by Section 2(b) of the Order to submit proposals for the transfer, sale, demolition, or substantial alteration of federally owned properties eligible for inclusion in the National Register to the Council for review and comment. Federal agencies must continue to comply with Section 2(b) review requirements even after the initial inventory is complete, when they obtain jurisdiction or control over additional properties which are eligible for inclusion in the National Register or when properties under their jurisdiction or control are found to be eligible for inclusion in the National Register subsequent to the initial inventory.

The environmental statement should contain a determination as to whether or not the proposed undertaking will result in the transfer, sale, demolition or substantial alteration of eligible National Register properties under Federal jurisdiction. If such is the case, the nature of the effect should be clearly indicated as well as an account of the steps taken in compliance with Section 2(b). (Procedures for compliance with the Executive Order are detailed in the Federal Register of January 25, 1974, "Procedures for the Protection of Historic and Cultural Properties," pp. 3366-3370.)

C. Under Section 1(3), Federal agencies are required to establish procedures regarding the preservation and enhancement of non-federally owned historic, architectural, and archeological properties in the execution of their plans and programs.

The environmental statement should contain a determination as to whether or not the proposed undertaking will contribute to the preservation and enhancement of non-federally owned districts, sites, buildings, structures and objects of historical, architectural or archeological significance.

III. The procedures for compliance with Section 106 of the National Historic Preservation Act of 1966 and the Executive Order 11593 require the Federal agency to consult with the appropriate

State Historic Preservation Officer. The State Historic Preservation Officer for the Trust Territory is Mr. Neil Chase, Chief, Land Resources, Department of Resources and Development, Trust Territory of the Pacific Islands, Saipan, Marianas Islands 96950.

Should you have any questions or require additional assistance, please contact Brit Allan Storey of the Advisory Council staff at P.O. Box 25085, Denver, Colorado 80225, telephone number (303) 234-4946.

Sincerely yours,

John D. McDermott

John D. McDermott
Director, Office of Review
and Compliance

TAB 10 - SUMMARY OF COMMENTS ON DEIS

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1.	Environmental Protection Board, Department of Health Services, TTPI	10-1
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SUMMARY OF COMMENTS ON DEIS

1. ENVIRONMENTAL PROTECTION BOARD, DEPARTMENT OF HEALTH SERVICES, TRUST TERRITORY OF THE PACIFIC ISLANDS (TTPI) (KUMANGAI, OCTOBER 15, 1974)

Comment	Reply to Comment
Pg 1, Par. 2	
a. The DEIS satisfactorily addresses most of the various environmental, social, and cultural aspects of the problem.	a. None required.
Pg 1, Par. 3	
b. The DEIS represents the most practical and realistic approach to the problem.	b. None required.
Pg 1, Sect. 1	
c. An environmental/health education program is required.	c. See below.
(1) The Enewetak people require a thorough education and understanding of the concept of radiation poisoning and the consequences of long-term exposure to excessive radiation levels.	(1) The ERDA has informally agreed to prepare educational documents for the Enewetak people pointing out the radiation hazards. These will include graphic illustrations of the types of radiological exposures that may be encountered and the possible effects that could result. Graphics are based on those presented to Enewetak people in September 1974.
(2) The adequacy of the translation of the summary to explain potential hazards is questionable.	(2) The summary was written in terms which the Enewetak people can comprehend. Criticism of the content was provided by English speaking Marshallese people. The documents mentioned in (1) above will be a supplement to the summary. The level of residual radiation on Enewetak Atoll should not be thought of as excessive when other situations are considered, but can be classified as low level long-term ionizing radiation. The summary was not intended to provide a comprehensive discussion of potential hazards but rather an overview.
(3) A comprehensive training program for Enewetak people, their legal counsel, and TTPI governmental officials is required to ensure cooperation with the program.	(3) Such a program is being planned by DOI and should be included in the school curriculum for the Enewetak people. Indoctrination of the counsel for the people and the TTPI officials should be a continuing program of employee development by the organizations concerned. See Sect. 7.4.
Pg 2, Sect. 2; 1a	Sect. 5.4.3.1, Pg 5-33, EIS
d. Ashes resulting from burning of combustible nonradioactive debris recommended for use as soil conditioner.	d. Ashes will be stockpiled for agricultural use in accordance with Case 3.
Pg 3, Sect. 2; 1b	Sect. 5.4.3.1, Pg 5-33, EIS
e. Nonradioactive, noncombustible debris recommended to form artificial reefs in lagoon for development of a new reef environment for associated flora and fauna.	e. Location of reefs to be determined. Information would be collected during cleanup operation.

1. EPB TTPI (Continued)

Comment	Reply to Comment
f. Discusses disposal alternatives.	f. See below.
(1) Shipment to CONUS would not result in a delay not in the best interests of the people.	(1) Considered impractical. See discussion Sect. 5.4.3, Vol. I.
(2) Deep ocean dumping could result in unpredictable ecological consequences.	(2) Deep ocean dumping rejected. See discussion Sect. 5.4.3, Vol. I.
(3) Disposal by burial in the craters on Runit requires additional supportive data in the form of a feasibility study.	(3) Investigations by the U.S. Army Corps of Engineers show that the geological and physical conditions of the craters are compatible with this method of disposal and that this concept is feasible. (Tab H, Vol. II). The EPA position on crater burial is favorable and is shown in the EPA comments found later in this summary.

2. OFFICE OF ENVIRONMENTAL AFFAIRS, DEPARTMENT OF HEALTH, EDUCATION AND WELFARE (HEW) (CUSTARD, NOVEMBER 15, 1974)

Comment	Reply to Comment
a. Sect. 5.3.3.1 Control of Food Sources. The comment summarizes the radiological findings and recommendations concerning radiological dose levels, the problems of external and internal dose levels particularly the problems of internal exposures from food grown in radioactive soil and the problems associated with corrective action.	a. None required.
b. Sect. 5.6.1 Dose Estimates. Clarification required on inclusion of ground water in dose estimates.	b. Dose estimates do not include the contribution from ground water. Table 5-12 indicates this omission. This omission is recognized in Sections 5.4.1.3, 5.4.3.1.2 and 8.23.6. Studies of the ground water system, particularly the fresh water lens have been undertaken as a part of the long range follow-up program by ERDA.
c. 5.6.1 Dose Estimates. Clarification required regarding mortality rates of Table 5-14 (pg 5-60) as the rate may be effected by the dose to bone marrow.	c. As mentioned in the response to the AEC comments, the bone marrow dose is traditionally accepted to be one-third the bone dose for ^{90}Sr bone deposition. The exposure standards for these two target organs are also different by a factor of three. Consequently when ^{90}Sr is the principal source of bone and bone marrow exposure, as is the case at Enewetak, it essentially does not make any difference relative to the normally accepted exposure standards which organ is used for the hazards analysis. (Table 5-12). The contributions due to sources other than ^{90}Sr are not sufficient to significantly affect the analysis of any of the cases presented, as shown by the AEC data. (Sect. 5.6.1)
d. Sect. 6.1 Selection of Case 3. Statement required on control and/or quarantine measures to be implemented and enforced over a specified number of years.	d. Necessary quarantine measures will be enforced by the people and the TTPI as a matter of their law enforcement agency. (Sect. 7.1.3 and 7.4, Vol. I). An educational program by the TTPI will be used to indoctrinate the people to the dangers of radiation. The long-term follow on health program should detect undue exposure and the effectiveness of the quarantine measures.
e. Sect. 7.2.4 Community Center Development. Since there are significant shortages of health services manpower, additional information is required on the long-term health services to be provided to the people at remote locations.	e. The TTPI intends to man a dispensary with a health aid or nurse as is the case with other outer islands. A medical officer and dentist generally will accompany a field trip vessel which will call approximately once a month. ERDA will provide periodic monitoring of the health status of the resettled people to insure that the dose rates do not exceed FRC radiation protection guides. Follow on studies of the radio decay processes and the potential food chain to man will be conducted. See Sect. 7.2.4.
f. Sect. 7.2.4 Community Center Development. A recommended generalized method of providing health care is described.	f. The method described is that generally intended by the TTPI. See Sect. 7.2.4.
g. Sect. 7.2.4 Community Center Development. Recommends physical examinations, immunizations and preparation of individual health records prior to relocation.	g. TTPI medical authorities will institute such measures in conjunction with the follow on program to be conducted by ERDA. See Sect. 7.1.1.3 and 7.4.

2. HEW (Continued)

Comment	Reply to Comment
h. Sect. 7.2.4 Community Center Development. Are the hospitals at Majuro and Kwajalein equipped to handle cases of radiation sickness?	h. Hospitals at Ebye and Majuro do not have that capability. Kwajalein has the personnel but not the equipment. Radiation sickness cases would have to be evacuated for treatment at Tripler in Honolulu or specialist centers on the mainland. (Sect. 7.2.4, Vol. I)
i. Sect. 7.2.4 Community Center Development. Clarification on location of dispensaries should be given.	i. These locations are clearly indicated in Master Plan (Tab D, Vol. 2 EIS, Plates 33 & 34, Pgs 4-31 & 4-32).
j. Sect. 7.2.5 Utilities. What means of augmenting the potable water supply other than the existing ground water lens can be used? Can the 43,000 gpd distillation plant be used? The feasibility of other techniques for augmenting the water supply should be investigated.	j. While a power plant exists on Enewetak Atoll only 2 small KVA generators will be available for use at selected locations. The TTPI does not have the resources, the capability or the expertise to maintain and operate sufficient power sources on Enewetak Atoll to provide electric power for a supplemental water supply at this point in time. The study of this problem and the application of other techniques are factors which must be considered by responsible staff elements of the TTPI in the long range development of the atoll. Emergency water supplies can always be provided by ship in the event of a severe water famine. (Sect. 7.2.5, Vol. I).
k. Sect. 7.2.5 Utilities. Effluents from septic tank drain fields may contaminate the fresh water lens.	k. This is a very real concern in that the fresh water lens has a stay time of a considerable period and once it becomes contaminated, decontamination will be difficult. The migration of water appears at this time to be from the ocean toward the lagoon. However, it should be noted that ground water is very sparse and may not be of sufficient quantity to provide any reliable potable supply except in emergencies. Drain fields will be located carefully along the lagoon shore to take advantage of the hydraulic gradient of the ground water and other natural features to obtain the most acceptable solution. (Tab G, Vol. II).
l. Sect. 7.2.5 Utilities. Suggests definitive sanitation program be implemented for continual monitoring of usable water supplies.	l. Wells and cisterns will be monitored by the health aid at frequently scheduled intervals. See Sect. 7.1.3, Vol. I.
m. Sect. 7.2.5 Utilities. Recently developed small scale aerobic digestion unit should be considered as an alternative to septic tanks.	m. Limited resources for the generation of power do not permit the use of such equipment. Consideration of this method of sewage disposal will be included in future development studies. See Sect. 7.2.5, Vol. I.
n. Sect. 8.6 Base Camp Sewage Disposal. Existing sewage outfall lines should be relocated to flow into ocean rather than the lagoon.	n. A brief study of the base camp sewage disposal problem is attached at Tab G, Vol. II. Large populations have used the existing system for 25 years with little or no reported adverse effects.
o. Sect. 8.11 Impact of Pesticides. A concern is expressed for toxic effects to workers applying pesticides for insect and rodent control and to people working in general areas.	o. Pest control operations will comply with OSHA Standards, Part 1910, Sub Part G, Sect. 1910.63, Table G-1 and Sect. 1926.55. (Sect. 8.11.1, Vol. I).

2. HEW (Continued)

Comment	Reply to Comment
p. Sect. 8.16 Impact of Blasting. Recommends extensive sampling for fission and activation materials before harvesting shellfish.	p. This comment seems to have confused nuclear explosions with minor high explosive blasting which may be required to provide shallow channels from the lagoon to the shore of a few of the northern islands to provide access. This blasting is not expected to cause significant disturbances of bottom sediments. The controls recommended could be implemented and integrated into the long-term follow up studies by ERDA.
q. Sect. 8.22 Impact of Toxic Materials. Safeguards for workers conducting cleanup of toxic materials (beryllium) not mentioned.	q. The residual levels of beryllium have been reported to be very small. A cleanup operation by the USAF has already been conducted and natural processes have been working to further reduce the problem. Protective clothing and breathing equipment will be required to protect workers in accordance with OSHA Standards, Part 1910, Sub Part G, Table G-2.
r. Sect. 9.26 Impact of Noise. No mention made of the impact of noise levels which may affect workers and people residing on the atoll.	r. OSHA Standards for noise control and protection of personnel will be observed, Sub Part D, Sect. 1926.52.

3. DEPARTMENT OF TRANSPORTATION, U.S. COAST GUARD (CALDWELL, DECEMBER 13, 1974)

Comment	Reply to Comment
12/13/74, Par. 3	
a. Concern over termination of DNA Contractor support services for LORAN Station to December 31, 1977.	a. DNA will operate Enewetak as Host-Manager until cleanup is completed and approved. Support for the LORAN Station will be available until the cleanup operation is completed, now estimated to be about mid-1979. (Sect. 3.3.4.1, Vol. I).
12/13/74. Par. 4	
b. LORAN Station on Enewetak Island should be mentioned on text and in summary.	b. See Par. 3.3.4.1, Vol. I, EIS. Mention of USCG LORAN Station in Summary is not considered necessary.
12/13/74. Par. 5	
c. Should review basis for calling atoll and island "Enewetak" versus "Eniwetok".	c. It was a DNA decision to use Marshallese names so the Enewetak people would understand them.
12/13/74, Pg 2, Par. 1	
d. In Vol. 3, "Phase 3 - Resettlement" use of "that the living patterns of the people conform to the limitations recommended" could be offensive if taken out of context.	d. Have prefaced sentence with "For the safety of the people concerned . . . ". (Pg 3, Vol. III).
12/13/74, Pg 2, Par. 2	
e. The elements of sewage disposal and ocean-lagoon water quality should be commented on by EPA.	e. EPA was given opportunity to comment on entire DEIS. See No. 6 following.
12/13/74, Pg 2, Par. 3	
f. Should mention that transport of radioactive material by vessel will be done in compliance with current regulations.	f. Normal transport of radiological material expected to be within the confines of Enewetak lagoon. In the event that radioactive material would require transport to the U.S. by vessel, 46CFR 146.19 will be used. Sects. 5.4.3.2.1, 5.4.3.2.4, 8.23.4, Vol. I).

4. U.S. ATOMIC ENERGY COMMISSION BIOMEDICAL AND ENVIRONMENTAL RESEARCH AND SAFETY PROGRAM (LIVERMAN, DECEMBER 9, 1974)

Comment	Reply to Comment
Pg 1, Par. 1, Comments	
a. DEIS presents a careful and thorough study of problem. Agree that Case 3 is reasonable, feasible and assures the health and safety of the people insofar as is practical.	a. None required.
Pg 1, Par. 2, Comments	
b. Presentation of AEC radiation exposure criteria is satisfactory, but the word "standards" should be replaced by "guidelines". Those criteria are based on current, recognized national and international standards.	b. The term "standards" has been replaced by the term "guidelines" in EIS. (Sects. 5 and 6, Vol. I).
Pg 2, Par. 1, Comments	
c. Estimates for maximum annual exposures for individuals considering the most sensitive members of the population presented in the Task Group Report should be used rather than material fron NVO-140.	c. The AEC Task Group Report (Tab B, Vol. 2 of the EIS) shows that calculations based on the most sensitive individual do not result in dose estimates significantly different than those for adults, especially when reporting doses to one significant number only. (Sect. 5.6.1)
Pg 2, Par. 1	
d. Tables 5-11, 5-12 and 5-13 should be deleted.	d. Table 5-11 is a simplification of Table 240 in Appendix II of the Task Group Report. As noted on page II-1 of the AEC Task Group Report, Tab B, all three methods of measuring external gamma doses, including the method referenced in Table 5-12, agree within 10%. Also, Table 5-12 is retained as it provides a basis for estimating relative amounts of land areas involved in various cleanup actions. (Table 5-11 now 5-9, 5-12 now 5-10) Table 5-13 provides full disclosure of the methods used to develop maximum annual doses from 30-year integrated doses. These methods are consistent with 30-year and annual dose relations in the AEC Task Group Report and are completely satisfactory when considering doses to one significant number. (Table 5-13 now 5-11)
Pg 2, Par. 1	
e. Sects. 5.6.1.1, 5.6.1.2 and 5.6.1.3 and Tables 5-8, 5-9 and 5-10 should be revised using information from Appendix 4, Task Group Report (Tab B, Vol. II, EIS).	e. Sects. 5.6.1.1, 5.6.1.2 and 5.6.1.3 and Tables 5-8 and 5-9 were developed from the AEC Task Group Report using adaptations of Task Group Report results which are appropriate to habitation plans and cleanup actions in the EIS. Use of Appendix 4 of the Task Group Report to obtain bone marrow dose would not change conclusions with regard to acceptability of any plan of action since guideline-to-dose estimate ratios for bone and bone marrow are the same on Enewetak. New Tables 5-6, 5-7, 5-8, Vol. I, EIS. (See Sect. 5.6.1 also)
Pg 2, Par. 1	
f. Doses for bone marrow, not bone, should be used in all tables presenting maximum annual marrow criteria.	f. See Item e.

4. AEC (Continued)

Comment	Reply to Comment
Pg 2, Par. 1	
g. AEC estimates of 30 years and maximum annual doses for Belle, the island with the highest predicted doses, be used for Case 1 wherever appearing instead of exposure estimates for an average individual for the entire atoll. Estimates of averaged exposures over the entire atoll are meaningless and should be deleted.	g. The Belle Island case is considered an extremely remote possibility in view of historic living patterns and stated preferences of Enewetak people for return atoll. Furthermore, the doses as calculated for Case 1 are already so high that this case is unacceptable. Thus, use of Belle Island would only make an already unacceptable situation even more unacceptable.
Pg 2, Par. 1, Lines 3-5	
h. Recommend revising Table 5-14 to present estimated risks as upper limits and add footnote to show that at low dose rates, risk may be zero.	h. These comments have been incorporated by revising table and text to reflect range of risk. (Table 5-12, Sect. 5.6.2, Vol. I).
Pg 2, Par. 2, Lines 6, 7	
i. Risk estimates should be recalculated to account for revisions needed for estimates presented in Table 5-8 in calculation of 30-year dose.	i. No recalculation is required since as noted in Item g - unacceptable cases become more unacceptable. Furthermore, acceptable cases would remain acceptable.
Pg 2, Par. 2, Lines 8-10	
j. Based on suggested revisions to 30-year and maximum annual dose estimates, revise Table 5-16 to reflect these changes.	j. No change required. See Item i.
Pg 2, Par. 3	
k. Further discussions of the reasons for rejecting ocean dumping means of disposal is necessary.	k. Sect. 5.4.3.2.1, Vol. I, EIS, includes these discussions.
Pg 3, Par. 1, Lines 1-8	
l. Ocean dumping option is believed to be the least costly method of disposal, the safest, and hence this option should be left open.	l. Ocean dumping and the reasons for its rejection are discussed in detail in Sect. 5.4.3.2.1, Vol. I, EIS. Federal law requires a complete study of the ocean community around the proposed dump site, and that does not guarantee approval after that requirement has been satisfied. Costs and delay incurred would probably lead to abandonment of the entire program.
Pg 3, Par. 1, Lines 8-9	
m. Return of Pu contaminated soil to CONUS for burial would be unacceptable.	m. This is recognized as discussed in Sect. 5.4.3.2.4, Vol. I, EIS.
Pg 3, Par. 1, Lines 9-11	
n. Burial of material on an island would required periodic follow up.	n. This is recognized in Sect. 5.4.3.2.3, Vol. I, EIS.
Pg 3, Par 2	
o. Clarify the requirement for blasting operations in Sect. 8.16.	o. Blasting operations are required to clear channels of coral heads so that marine craft can land equipment and personnel to conduct cleanup operations on some northern islands. Channels are for approach from the lagoon side only and will not be cut through the reef to the ocean in any instance. Sect. 8.16, Vol. I, EIS, revised to clarify this.

4. AEC (Continued)

Comment	Reply to Comment
Pg 3, Par. 3	
p. Delineation of responsibilities for future studies is not germane and should be deleted.	p. Statement has been deleted. However, responsibilities for various aspects of the operations have been rewritten. DNA has always considered that ERDA, as the certifying agency, must monitor such actions to insure that acceptable procedures were followed and that guidelines have reasonably been achieved. The ERDA has accepted full responsibility, including funding, for future periodic follow up radiological surveys as necessary; and the maintenance of periodic monitoring of the health status of the resettled people and of the radioactivity in the environment subsequent to rehabilitation. (Sect. 1.4, Vol. I; Tab K1, Vol. II.)
Pg 3, Par. 4	
q. Confusion over temporary storage of contaminated material on Runit as an intermediate stop pending additional study by AEC. Disposal is DNA responsibility. AEC not committed to provide additional recommendations except possibility of reduction in volume of plutonium contaminated material.	q. This alternative was shown to comply with the requirements of the CEQ guidelines. The intent was to provide temporary storage during the period of time required for ERDA/AEC to perform the necessary research on processing the contaminated soil in order to separate and/or recover the plutonium to reduce the volume of contaminated material. This alternative has been deleted as crater entombment is considered to provide retrievability of the material.
Pg 4	
r. A discussion of the views of AEC and others concerning the early return to Japtan Island should be included.	r. A more complete discussion of early return is given in Sect. 7.1.1.1, Vol. I, EIS. (Tabs E and J, Vol. II also.)
Letter 12/23/74, Pg 1	
s. The disposal of alpha activity into the oceans under the management of the European Nuclear Energy Agency has totalled 3633 Ci during the period 1967-1974. It is evident that the disposal of a few hundred grams of Pu from Enewetak Atoll would not materially add to the existing burden.	s. This is recognized. However, U.S. law demands compliance with more stringent requirements than those of the international body. See Sect. 5.4.3.2.1, Vol. I, EIS.
Staff, Pgs 2 & 3, 5-11, 12, 13, 5-54, 57, 59, Par. 1	
t. The use of isopleths as defined by the EG&G aerial survey as an approach to radiological cleanup alternatives is deficient in that it does not treat the more significant exposures from internal emitters in the food chain.	t. The use of isopleths was only intended as an engineering means of determining the cost effectiveness of the various cleanup alternatives for the external radiation exposure pathway. (Table 5-4, Vol. I).
Staff, Pg 3, Sect. 2 , Par. 1	
u. No mention of environmental impacts of alternate methods for contaminated debris and soil disposal. It is not clear which disposal method is recommended for specific wastes.	u. Impacts of disposal of contaminated material by crater entombment are discussed in Sect. 8.19 as a part of of the proposed cleanup plan. Impacts of alternate methods are not included since they are not pertinent to the program. Discussions of various disposal methods are in Sect. 5.4.3.2. Nonradioactive debris disposal is discussed in Sect. 5.2.2, Vol. I, EIS.

4. AEC (Continued)

Comment	Reply to Comment
Staff, Pg 3, Sect. 2, Par. 2	
v. There are two radioactive waste disposal areas near Richland, WA. Should differentiate between them as one is privately owned.	v. AEC letter of December 23, 1974, clarified disposal sites. See Sect. 5.4.3.2.4, Vol. I, EIS.
Staff, Pg 3, Sect. 2, Par. 3, Lines 1, 2, 3, 4, 5 & 6	
w. Conflict between rejection of ocean dumping in Sect. 5.5.2.1 and Sect. 11.	w. Ocean dumping has been rejected. Statement in Sect. 11 was in error. (Sect. 5.2.2.3, Vol. I, EIS).
Staff, Pg 3, Sect. 2, Par. 3, Lines 6, 7, 8, 9, 10 & 11	
x. Radioactive sea dumping not discussed in Environmental Impact Section (8) while disposal of non-contaminated debris at seas was included (8.18).	x. Radioactive waste disposal by dumping at sea was not adopted as part of plan. Therefore it had no impact as part of the plan. Disposal of nonradioactive debris at sea had been the planned method for that type of waste. (Sects. 5.2.2.3 and 8.18.1)
Staff, Pg 3, Sect. 1, Par. 4	
y. What agency will be responsible for long-term surveillance and maintenance of the craters containing radioactive material?	y. ERDA as part of follow up responsibilities. See Sect. 1.4, Vol. I, EIS.
Staff, Pg 3, Sect. 2, Par. 5	
z. Proposed method of disposal of Pu contaminated material assumes that Lacrosse Crater can be pumped out. DNA should establish whether craters require pumping for this operation and if so whether it can be done.	z. Crater feasibility study (Tab H, Vol. II, EIS) shows it feasible to conduct operation without pumping. (Also see Sect. 5.4.3.2.3, Vol. I, EIS.)
Staff, Pg 4, Sect. 2, Par. 1	
aa. Suggest removal and disposal of all Pu bearing soil in excess of 400 pCi/g at all locations and 40 pCi/g on islands where housing may someday be located.	aa. Cleanup and disposal of Pu bearing soil will be in accordance with AEC guidelines. Housing planned only for Enewetak, Medren and Japtan islands. Any additional cleanup of Pu contamination would be on a speculative basis for future housing and could increase costs to a point where the program would be economically unfeasible. (Sect. 5, 7 Vol. I; also Tab D, Vol. II)
Staff, Pg 4, Sect. 2, Par. 2, 3, & 4	
bb. Recommend deletion of crater entombment and substitution of storage for eventual disposal in its place as regards treatment of radioactive debris and Pu bearing soil.	bb. Crater entombment is method selected by DNA for disposal of those materials. See Sect. 5.4.3.2.3, Vol. I, EIS, also Tab H, Vol. II, EIS.
Staff, Pg 4, Sect. 3, Par. 6, 3-49	
cc. Change "patrilineal" to "matrilineal" in reference to succession to Iroij. (chief).	cc. See "Resettlement of Enewetak People: A Study of a Displaced Community in the Marshall Islands", pgs 125-126, Tobin, 1967. (Sect. 3.5.1, Vol. I).
Staff, Pg 5, Sect. 3, Par. 3, 3-63	
dd. DEIS minimized danger from ingestion of Pu.	dd. Sect. 3.8.1.1.3, Vol. I, EIS, revised.

4. AEC (Continued)

Comment	Reply to Comment
Staff, Pg 5, Sect. 3, Par. 4, 3-63	
ee. DEIS does not consider airborne concentrations of Pu as a result of resident activities.	ee. Sect. 3.8.1.2, Vol. I, EIS, revised.
Staff, Pg 5, Sect. 3, Par. 5, 3-84	
ff. Locations of beryllium contaminated areas not clear.	ff. Sect. 3.8.2, Vol. I, EIS, revised to specifically show the location of beryllium contamination.
Staff, Pg. 5, Sect. 3, Par. 7, 5-13	
gg. Text and Table 5-6 inconsistent as to food growing restrictions on Enjebi.	gg. Table 5-6 deleted. Data now contained in Table 5-5, Vol. I, EIS.
Staff, Pg 5, Sect. 3, Par. 9 & 10, 5-25 & 5-32	
hh. Figures 5-2 and 5-3 inconsistent with text on limits of southern islands.	hh. Figures 5-2 and 5-3, Vol. I, EIS, revised.

5. ASSISTANT SECRETARY OF DEFENSE FOR HEALTH & ENVIRONMENT CATEGORICAL PROGRAMS (MEADE, NOVEMBER 13, 1974)

Comment	Reply to Comment
11/13/74, Pg 1, Par. 2, #1	
a. Estimated time frame of phases of operation should be specified; especially completion of Phases 3 and 4.	a. While inclusion of the specific times for the phases would be desirable, it must be remembered that this is a continuing program and appropriations authorized and appropriated by Congress will govern the specific time phasing of the operation.
11/13/74, Pg 1, Par. 3, #2	
b. Relative hazard level to personnel relocated to islands should be tabulated instead of generalized.	b. Terms used in describing risks from radiation are not translatable into Marshallese language in understandable form. A primer is being prepared by ERDA to provide a better understanding of the health hazards. (Sect. 7.4, Vol. I).
11/13/74, Pg 1, Par. 4, #3	
c. Enforcement of Runit quarantine must be enlarged upon. Educational program required to insure understanding of risks to Enewetak people.	c. See Sect. 7.4, Vol. I, EIS. Long-term monitoring program to be conducted by ERDA will assist in determining effectiveness of quarantine enforcement. Data produced by this program would show degree of exposure to radioactivity for individuals.
11/13/74, Pg 1, Par. 5, #4	
d. Long-term continuous monitoring program required until hazard is removed.	d. ERDA is responsible for conduct of monitoring program for inhabitants' health status and atoll environment (See Sect. 1.4, Vol. I, EIS).
11/13/74, Pg 1, Par. 6, #5	
e. Consideration should be given to the possibility of more adequate disposal techniques becoming available in the future.	e. Some means is required to remove plutonium from being immediately available to the biosphere. If the plutonium were stockpiled and left in the open policing would be difficult and costly and the hazard would remain. Crater burial renders the plutonium inaccessible but retrievable in accordance with the concept considered viable by EPA. Minute amounts of Pu are expected to be released through the geological formation. These, however, will be small and insignificant compared to the amounts already in the lagoon. The concrete matrix, surrounding coral and the concrete cap will provide a shield from external exposure. Monitoring can be accomplished. If more adequate disposal techniques become available in the future and further action is determined necessary, the material could be retrieved and the techniques applied. (Sect. 5.4.3.2.3, Vol. I, EIS.)

6. U. S. ENVIRONMENTAL PROTECTION AGENCY, REGION IX, SAN FRANCISCO, CALIFORNIA (FALCO, DECEMBER 12, 1974)

Comment	Reply to Comment
	(See ERDA letter of February 6, 1975, Tab K1, Vol. II, for amplification).
Pg 1, Sect. 1, Par. a	
a. Radiological, bacteriological and chemical quality tests should be conducted for a minimum of 12 months to determine water quality of brackish water lens.	a. A ground water sampling program has been initiated under ERDA which includes 15 drilled wells on 7 major islands in the atoll. Program objectives are the determination of radionuclides and stable element concentrations, cycling mechanisms, recharge rates, etc. (See Sect. 5.5.3.3, Vol I, EIS).
Pg 1, Sect. 1, Par. b	
b. There is a need for a 12-month, minimum, air sampling program on all islands to be inhabited, on heavily contaminated islands after cleanup and before lifting of quarantine. Actual conditions should be determined, not calculated.	b. Item #11, Sects. 5.5.3.3 and 5.7, Vol. I, EIS, comment on air sampling program. It should be performed by those providing health physics support for cleanup and be under direction of agency responsible for cleanup (pgs 27 and 31, Tab B, Vol II, EIS). Results of air sampling would be documented in final report of cleanup agency and samples could be analyzed for all radionuclides including uranium.
c. Were air samples taken during AEC survey analyzed for uranium?	c. Apparently samples were not analyzed for uranium.
Pg 1, Sect. 2, Par. 1	
d. Follow on monitoring of air, water, food and body burdens of Enewetak people is needed. This requires some agency to be responsible for implementation and funding.	d. ERDA will be responsible for implementation and funding (Sect. 1.4, Vol I, EIS).
Pg 2, Sect. 3, Par. 1	
e. Application of Pu cleanup criteria too uncertain. Criteria given should be considered upper limits and cleanup levels and population doses should be maintained as low as practicable.	e. We believe that recommendation Nos. 6, 7, & 8, pages 27-29, Tab B, Vol. II, EIS and associated material in Appendix 3, Tab B, Vol. II, EIS are specific enough to guide the actions and decisions of a qualified group who are tasked with carrying out cleanup actions at Enewetak Atoll.
Pg 2, Sect. 3, Par. 2, Lines 1, 2, & 3	
f. Crater entombment should be recognized as a semi-permanent solution.	f. It is, as solidified material is retrievable (Sect. 5.4.3.2.3, Vol. I, EIS). However, we believe that crater entombment will be a permanent solution.
Pg 2, Sect. 3, Par. 2, Item 1	
g. Discussion of ocean disposal should contain technical advantages and disadvantages and not be rejected on only legal and international problem basis.	g. See Sect. 5.4.3.2.1, Vol. I, EIS.
Pg 2, Sect. 3, Par. 2, Item 2	
h. If volume of two craters is insufficient to contain all contaminated soil, what remedial action will be taken?	h. Calculations indicate more than sufficient volume in both craters to contain all contaminated soil collected in Case 3. (Sect. 5.4.3.2.3, Vol. I; Tab G, Vol. II, EIS.)

6. EPA (Continued)

Comment	Reply to Comment
Pg 2, Sect. 3, Par. 2, Item 3	
i. What action will be taken if people of Enewetak reject entombment option?	i. Crater disposal is considered permanent. However, if other more suitable disposal methods were found and the need for redisposal was determined, the contaminated soil and debris could be recovered from the crater. This is not anticipated.
Pg 2, Sect. 4, Par. 2	
j. The decision to permit subsistence coconut production in northeastern islands not justified in DEIS. Virtually all predicted dose received by the Enewetak people under this proposed plan is due to this decision. Use of "as low as practicable" dose concept should be deferred unless it can be shown there is no practicable alternative for an adequate diet or that radionuclide contamination is much lower than predicted.	j. Justification for recommended actions is in Tab B, Vol. II, EIS. Use of northeast islands was recommended for growing coconuts as a cash crop (copra) not as food source. Coconuts grown in southern islands will provide ample food source. It is recognized that wherever coconuts are grown, regardless of purpose, some will be eaten. Also northeast islands' use increases agricultural land areas by about 50% (Table 3-1, Vol. I, EIS), a large factor where usable land is at a premium. Review of predicted doses does not support EPA comment that virtually all of predicted dose received by Enewetak people is due to this decision. Comparisons of 30-year doses can be made using Living patterns A&B, Table 1-4, Tab B, Vol. II, EIS. Maximum annual dose comparisons are made using Tables 3, 4, 5, 8, 9, & 10, Appendix IV, Tab B, Vol. II, EIS. Predicted doses assumed all coconuts for food came from northeast islands, Mijikaidrek-Billae (Kate-Wilma), while it is expected that coconuts eaten by southern island inhabitants will be a mixture with the majority coming from southern village islands. Expected doses will fall between Living Patterns A&B, and Patterns 1 & 2. (See Tab K1, Vol. II, EIS)
Pg, Sect. 4, Par. 1	
k. Marketing of copra should be on "as low as practicable" basis to determine if the economic benefits to Enewetak people outweigh radiological cost of population dose to off-island people.	k. This concept would not guarantee acceptability of product outside atoll. AEC Task Group could not determine unquestionably acceptable level of radioactivity. Detectable levels of radionuclides from nuclear testing will be found in copra from other atolls too. (See Section 8.36, Vol. I, also Tab K, Vol. II, EIS)
Pg 3, Sect. 4, Par. 2	
l. No discussion in DEIS of short and long range implications of radionuclides in lagoon sediments. No indication in DEIS of feasibility of minimizing future radiation dose from seafood pathway.	l. Dose estimates in EIS include contributions of ^{239}Pu and ^{90}Sr coming through seafood pathway and thus are directly related to radioactivity in lagoon sediments. Evaluation efforts were directed to reasonable number of options for exposure reduction and control against primary pathways for radiological doses to humans. (See Sect. 5.3.1, Vol. I, EIS).
Pg 3, Sect. 4, Par. 3	
m. No discussion of decision to permit unrestricted fishing in lagoon.	m. Seafood at Enewetak is among lowest of all contributors to radiation dose to inhabitants. Both annual and up to 70-year doses are presented in EIS. (See reply above.)

6. EPA (Continued)

Comment	Reply to Comment
Pg 3, Sect. 4, Par. 4	
n. Can restrictions on coconut crabs on northern islands be enforced? Also, no samples from northern islands taken to back up decision on restriction.	n. An effort was made to sample crabs throughout the atoll. Samples only found on Ananij (Bruce), Ikuren (Glenn), Ribewon (James), Kidrenen (Keith), and Biken (Leroy). Environment on Northern islands does not now support this form of terrestrial fauna. (Enewetak Radiological Survey, Vol. I, NVO-140; also Tab K, Vol. II, EIS.)
Pg 3, Sect. 5, Par. 1	
o. Constant health physics support required to monitor possible inhalation exposure to workers and transport of radioactive material from greater to lesser contaminated areas.	o. See Sect. 5.7, Item 7a; also Sect. 6.2.4, Vol. I, EIS.
Pg 4, Sewage Disposal during Cleanup	
p. Recommends that some form of sewage treatment be provided for waste waters generated by cleanup personnel and subsequent visitors.	p. Historically there has been no treatment of sanitary waste at Enewetak, even during nuclear testing when the atoll population was in the thousands. There is no recorded evidence of ill effects from discharging raw sewage into the lagoon during that period, or since. For the short period of camp operation and relatively small population in residence, DNA will utilize the existing system. (Sect. 6.2.2, Vol. I; Tab G, Vol. II.)
Pg 4, Garbage and Trash Disposal during Cleanup	
q. Garbage and trash residue should not be dumped into the lagoon. Burial or some other disposal method should be used.	q. Edible garbage will be dumped from the garbage pier on Enewetak for the benefit of the fish. Combustible trash will be burned in the island burn pit (near the garbage pier) and the ashes stockpiled for soil conditioner, noncombustible trash will be compacted and buried in the vicinity of the garbage pier. It should be noted that the available land for this type of disposal is limited. (Sect. 8.5.1, Vol. I).
Pg 4, Water Supply and Waste Disposal	
r. A careful evaluation of plans to use septic tanks, leach fields and burial of garbage as they may affect the possible contamination of the supplemental water supply for the community.	r. Ground water lens is supplemental water supply for emergency use only. Quality and quantity of lens water restricts use to this category only. Waste water study (Tab G, Vol. II, EIS) indicates that locating the septic tanks, leach fields and garbage pits along the lagoon shore will take advantage of the ocean-to-lagoon migration of ground water flow and the natural hydraulic gradient. Also this location would remove the potential source of contamination from proximity to the center of any water lens.
Pg 4, Water Supply and Waste Disposal	
s. A discussion of the potential problem should be presented with evidence that the supplemental water supply will not be degraded.	s. This is discussed in Sect. 8.29.6, 8.30.1 and 8.30.6, Vol. I, EIS.
Pg 4, Water Supply and Waste Disposal	
t. The TTPI Department of Environmental Health should have a fundamental role in the decision process on the selection of water supply and waste disposal system.	t. The Master Plan for Enewetak Atoll (Tab D, Vol. II, EIS) was commissioned by the TTPI Government and approved by the TTPI Government.

7. NATURAL RESOURCES DEFENSE COUNCIL, INC. (NRDC) (THOMAS B. COCHRAN, SEPTEMBER 24, 1974)

Comment	Reply to Comment
a. DEIS fails to address hot particle theory as proposed in "Radiation Standards for Hot Particles", A. R. Tamplin, T. B. Cochran, February 14, 1974.	a. Until this theory is substantiated and accepted by national authorities we have no recourse but to comply with the radiation standards promulgated by the Federal Radiation Council. Discussion of the problem is included in Sect. 5.8, Vol. I, EIS. A letter from the Energy Research and Development Administration, dated January 29, 1975, with attachments, WASH-1320, and LA 5810-MS, are included in Tab I, Vol. II, EIS. Further information is contained in the "The Toxicity of Plutonium", The Medical Research Council, published by Her Majesty's Stationery Office, London, 1975. Acceptance of the standards proposed by Tamplin and Cochran would result in either the prevention of the Enewetak people from returning to their atoll, or make the cost of the project so prohibitive that it could not be accomplished.

8. MICRONESIAN LEGAL SERVICES CORPORATION (MLSC) (THEODORE R. MITCHELL, FEBRUARY 1, 1975)

Comment

a. General. The people left the atoll in a radiological safe state, it should be returned to them in the same state. The U.S., as trustee, has a humanitarian obligation due to the dangerous materials left from the nuclear weapons testing on the atoll. Such responsibility exists both to return the people to their home and to eliminate the likelihood of so much as a single radiation induced illness or anomaly without respect to cost or consequences.

b. Social and Economic Problems

(1) More attention is needed for adequate plans to meet the future needs of the people so economic self sufficiency can be achieved.

(2) The Enewetak Planning Council must be relied upon to make plans with more assistance from government provided specialists.

Reply to Comment

a. General. From a technical point of view, the concept that is presented is not considered to be a feasible solution within the lifetime of the people, their grandchildren or their grandchildren's grandchildren. If this proposed program is to be done now, the monetary and other costs for the solution proposed by the counsel for the Enewetak people are estimated to be prohibitively high. The commitment of such large quantities of the national economic resources to the solution of this one problem may be considered unreasonable by prudent men when due account is taken of other national priorities. The accomplishment of the goal stated by the counsel for the people when compared to the given goal for the proposed project is idealistic to the extreme and could be considered technically, ecologically, and economically infeasible. For example, background radiation alone on Enewetak and in most other parts of the world contributes to risks of induced cancers which are indistinguishable from those occurring naturally. If the counsel for the Enewetak people persists in the most ideal solution, the DNA position will be to recommend that the proposed project be abandoned or postponed.

b. See below.

(1) While the EIS outlines several proposed methods of economic development for Enewetak Atoll, it will be the responsibility of the TTPI and the Enewetak people themselves to see that one or more of these is implemented. Sufficient technical specialists are available in the TTPI staff or could be obtained on a consulting basis to provide the degree of technical advice required. It is acknowledged that some copra producing land had been lost due to residual radiation, but this does not restrict the people in initiating some of the other means of strengthening their economy, such as drying fish, shark fins and promoting handicrafts for sale elsewhere in the Marshalls. See Sects. 7.2 and 7.3, Vol. I, EIS.

(2) The TTPI government has worked and will continue to work with the Enewetak Planning Council. It is recognized that the council would have the last word in selecting the method best suited to the people for enhancing the economy of the atoll. Specialists in these fields selected by the council could be provided by the TTPI. See Tab D, Vol. II, EIS.

8. MLSC (Continued)

Comment	Reply to Comment
(3) The physical and emotional stresses caused by the relocation and resettlement of the people which affect the individual and group processes are not addressed in the DEIS. The objective of such a study would be to make the people aware of these stresses and how to adjust to them and survive with their society intact. Drs. Scudder and Kiste should participate in this study.	(3) It is expected that the entire Ujelang population will have lived for a period of time on Japtan Island starting with the early return program and the anticipated periodic rotation of families. This will give the people an opportunity to gradually acclimate themselves to Enewetak, as well as an opportunity to advance their economic status by working on the Japtan temporary camp and through the other occupations contained in the Early Return Operational Plan (Tab E, Vol. II, EIS). The U.S. Department of Interior has ample resources and will adequately handle any problems arising from the Ujelang-Enewetak transition. See Sect. 8.35.1, Vol. I, EIS.
(4) The Planning Council, its advisors and government decision makers should work together in a more formal manner.	(4) If the TTPI considers it to be a requirement in the interest of obtaining the proper planning decisions, the technical advisors would be organized into an advisory council. However, the procedures required to accomplish a formalized council should be worked out between the Distad and the council.
c. Radiological Considerations	c. Radiological Considerations
(1) More survey work is required to provide follow-up data and assessment of the data for all long life radionuclides, especially the alpha emitting radionuclides known as hot particles. Experimental plantings and other long range research on the marine and terrestrial pathways to man should be conducted to ensure scientific advancements and new remedial measures are applied on Enewetak. The governmental task group which directs such follow-up studies should be enlarged to include scientific personnel known to take the most conservative approach to radiation protection. Messrs. Martell, Tamplin, and Geesaman are recommended.	(1) The AEC Radiological Survey is the most extensive compilation of data known to exist on the radiological conditions of the atoll. An additional program is now in progress to provide added information on the chemical, bacteriological and other natural processes which quicken the reduction of radioactivity, the processes by which plants assimilate radionuclides and other related processes. Practical and cost effective scientific methods which appear in the future will be applied to the solution of acute problems of radioactive contamination on Enewetak. The Ad Hoc Task Group for establishment of guidelines has been disbanded and the necessary research programs to accomplish the objectives of the Task Group recommendations will be pursued by the established ERDA staff organization. See Sects. 1.4, 5.5.3.3 and 7.4, Vol. I; Tab K2, Vol. II, EIS.
(2) A basic inadequacy exists in that the DEIS does not address the hot particle theory and other associated risks of uptake of alpha emitting radionuclides through the foodchain into organs other than the lungs. All the questions raised by Tamplin, Cochran, Geesaman, and Martell should be answered.	(2) It is recognized that the DEIS did not address the hot particle theory espoused by Tamplin, Cochran and others. This problem is a relatively controversial subject at present. Adequate material explaining the pros and cons of the theory is now included and referenced in the EIS. Since this theory has not yet been accepted in the national or international standards for radiation protection, only existing guidance from the FRC, NRPC, and ICRP were considered. National authorities and scientific bodies are now considering the proposals made by Tamplin, Cochran, and others. A resolution of the controversy cannot be expected for several years. It is interesting to note that this proposed standard is so restrictive that the effects of worldwide fallout would be found unacceptable over extensive areas. See Sect. 5.8, Vol. I; Tab K2, Vol. II. Also WASH-1535.

8. MLSC (Continued)

Comment	Reply to Comment
(3) The AEC guidelines for ^{239}Pu and their application to the specific Enewetak problem are questionable in light of the hot particle theory and standards set by the State of Colorado. Before final guideline for Enewetak are adopted, international and national bodies should review, hold public hearings and establish numerical standards for allowable concentrations of $^{239+240}Pu$ and other transuranic wastes in soil, air, water and food. Once such standards are set they should govern the planning and cleanup activities on Enewetak.	(3) The current status of consideration of the hot particle theory is given in ERDA letters of January 29, 1975 (Tab I, Vol. II, EIS, The research on other aspects of this problem particularly the food pathways to man and the potential problem concerning other organs will require many years of research. Accordingly, if one subscribes to the theory, the people of Enewetak should not be permitted to return to any part of the atoll until the results of the research are known and necessary cleanup activities accomplished. (Also Tab K2, Vol. II.)
(4) The objective of the program, regardless of other consequences, requires the complete removal and off-island disposal of all contaminated soil.	(4) To disregard all consequences and make a clean sweep type of operation, subsequently disposing of contaminated soil in an off-atoll location would be irresponsible. This would result in many delays and long-term damage to the land and completely defeat the purpose of returning the Enewetak people to their atoll where they could benefit from the present resources (Tab K2, Vol. II).
(5) Studies must be made of the relationships between soil removal and dose reduction (including risk from airborne hot particles) and the ecological effects of soil removal and replacement.	(5) The ERDA plans to conduct these studies as a part of their follow on program. See Sects. 1.4, 5.5.3.3, and 7.4, Vol. I, EIS.
(6) A team of experts must be formed to monitor the cleanup and disposal of all radioactive materials and soil. This team should include scientific personnel known to have the most conservative approach to radiological problems (see para. (1) above).	(6) The cleanup operation will be conducted in accordance with the established ERDA guidelines. When required, a team of experts will be selected; however it is too early to determine the staffing. Consideration will be given to the recommended persons at that time.
(7) Studies of test plantings, lens water and air sampling should be undertaken immediately and should include the best scientists and technicians available. The work would be under the overall guidance of the enlarged task group.	(7) Studies of test plantings and lens water are currently in progress on Enewetak Atoll under the sponsorship of the ERDA. (Sect. 5.5.3.3, Vol. I). Air sampling studies are planned by ERDA when the cleanup operation commences, as the conditions at that time would be more representative of an inhabited atoll. To pursue an air sampling program at present would produce results comparable to an uninhabited atoll.
(8) A full radiological health follow-up program must be instituted. It should include the Bikini people, the Enewetak people and the Rangelap and Utirik peoples as well.	(8) The ERDA accepts the responsibility for the conduct of a follow on radiobiological health program for the Enewetak people (see Sect. 1.4, Vol. I, EIS). Whether this is done in conjunction with the people from other atolls will be determined by the ERDA. This latter problem is not a subject of this EIS. (See Tab K1, Vol. II, EIS.)
(9) Since all of the problems cannot be anticipated, the U.S. Government should be prepared to give its best and careful attention to all situations which may occur in the future.	(9) The intent of this comment appears to be a catch-all or "hold harmless" clause bound in many contracts. It is intended that this project be accomplished to provide a reasonable degree of safety from both radiological and physical hazards and to resettle the people in adequate homes and to provide stimulation for the future

8. MLSC (Continued)

Comment | **Reply to Comment**

development of the islands. Should acute situations as a result of use of the atoll by the United States be found to exist after the completion of cleanup, such conditions will most certainly be dealt with when the situation is fully known and a reasonable cost effective solution is available.

d. Considerations Relating to Cost

d. See below.

(1) Since the nuclear testing program resulted in significant benefits to the U. S. defense posture, the cost of this program represents a small fraction of the estimated testing cost.

(1) DNA plans to use this approach in the hearings before the congressional committees.

(2) The U.S. has an obligation under the UN trusteeship to protect the people, their health, and promote the economic and social advancement of the Enewetak people. In determining what must be done, the cost of the program should not be a consideration.

(2) It is agreed that the U.S. has an obligation toward the people of Enewetak under the terms of the U.S. trusteeship. However, when the judgment of prudent officials indicates that actions proposed would be uncertain of achieving the stated goals or that such actions would result in more harm than good, the trustee would be derelict in permitting those actions to be accomplished. In the situation under consideration, the idealistic solution proposed is not only uncertain of success but if accomplished could most certainly devastate the meager land resources available to the people.

9. ADVISORY COUNCIL ON HISTORIC PRESERVATION (MC DERMOTT, 19 NOVEMBER 1974)

Comment	Reply to Comment (Sect. 3.6, Vo. I, EIS)
a. Show evidence that the most recent listing of the National Register of Historic Places has been consulted and that either of the following conditions are satisfied.	a. The latest edition of the National Register of Historic Places published in the Federal Register of Tuesday, 4 February 1975 (Vol. 40, No. 24, Part II) has been consulted. No properties or other facilities are shown on Enewetak Atoll, Marshall Islands.
(1) No National Register property is affected.	(1) The above review indicates that no National Register property is affected by the proposed property.
(2) If National Register property is affected show compliance with Sect. 106 of National Historic Preservation Act of 1966.	(2) None required in view of (1) above.
b. Executive Order 11593 Protection and Enhancement of The Cultural Environment requires:	b. The DNA Engineering Survey while not done specifically in compliance with Executive Order 11593 shows the major features of the atoll.
(1) Conduct survey of atoll and report results in EIS.	(1) The survey shows no features which fall within the criteria established for the National Register.
(2) Review of properties is continuous procedure to propose properties for inclusion in the National Register. EIS should contain a determination whether the proposed action will result in the transfer sale, demolition or alteration of properties.	(2) No significant property meeting the criteria exists.
(3) EIS should contain a determination whether or not the project will contribute to the preservation and enhancement of nonfederally owned facilities of significance.	(3) Not applicable.
c. Consultation with the appropriate State historic preservation officer is required.	c. The TTPI Historic Preservation Officer was contacted for assistance.