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402980

SEP 25 1973

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DRAFT MATERIAL FOR REPORT BY AEC TASK GROUP ON RECOMMENDATION FOR CLEANUP OF ENIWETOK ATOLL

The drafting group of the Task Group (McCraw, Nervik, Wilson, and Schroebel) met at LLL August 20-21, 1973 to review the current status of the radiological survey, to discuss a tentative outline for the document which will contain the AEC recommendations for cleanup of Eniwetok Atoll, and to prepare a schedule for preparation of that document.

As now envisioned, the Task Group document will consist of the following three sections:

1. <u>Summary of the Radiological Survey Findings, including:</u>

   a. Description of the current radiological status of the atoll.

   b. Description of the population living patterns and diets used in assessing population doses.

   c. Results of dose assessments for living patterns and diets used in 1, b.

d. Discussion of results of available corrective action on doses shown in 1, c.

2. Radiological Implications of Data Obtained from the Survey

a. Presentation and discussion of the radiation exposure criteria against which survey findings will be compared.

b. Comparison of survey findings with radiation exposure criteria.

c. Identification of specific areas where the comparison of survey findings with radiation exposure criteria suggest a need for corrective action, and assessment of the effectiveness of proposed corrective action in reducing exposures.

3. Judgments and Recommended Actions

It is planned that the final chapter of the Radiological Survey Report be written in such a way that it can be used, with only minor modification, as Section 1 of the Task Group document. Similarly, Section 3 of the Task Group document is to be written in such a form that it can be used directly as part of a Commission document recommending action to be taken by DNA.

Since it is expected that the survey findings will be available to the Drafting Group on October 1, we propose to have a draft copy of the Task Group document ready for distribution on October 15. Allowing two weeks for distribution and for receipt of comments, the Drafting Group will meet in Germantown on October 29 to prepare the final document for distribution on November 1.

One of the key actions that must be taken if the above schedule is to be met is to obtain an early agreement on the approach to be used in development of recommendations and specifically on the use to be made of current guidance on radiation protection. The Drafting Group discussed this, and agreed that Section 2. a of the report, dealing with criteria for cleanup, should be drafted and circulated immediately for review and comment. This has been done, and a draft of that section is enclosed for your consideration.

In order to meet the tight schedule for the Task Group report, it is requested that you provide telephone comments to me during the period October 4-5, 1973, at Walter Nervik's office, LLL, (415-447-1100, ext. 8711) where the drafting group will be working on the report. Please send followup written comments to the Division of Operational Safety, U. S. Atomic Energy Commission, Washington, D. C., 20545.

T. F. McCraw

Tommy F. McCraw
Chairman
Task Group on Recommendations
for Cleanup of Eniwetok Atoll

Enclosures:
Section 2a (Draft) -
Criteria for Cleanup

DRAFT

Sept. 26, 1973

2. Radiological Implications of Data Obtained from the Survey

a. Guidelines against which Survey Findings will be Compared

The radiological survey of Enewetak Atoll provides a comprehensive data base needed to derive judgments and recommendations relative to the radiologically safe return of the Enewetak people. These judgments are based on an evaluation of the significance of all radioactivity on the Atoll in terms of the total exposure to be expected in the returning population, and recommendations as to reasonable actions and constraints which, where made, will result in minimum exposures.

The guidelines used in deriving these recommendations can be summarized as two interdependent considerations:

1. Expected exposures should be minimized and should fall in a range consistent with guidance put forward by the International Commission on Radiological Protection (ICRP) (see Table 1 and Appendix I for summaries of these radiation protection standards and for planned application).

2. Actions taken to reduce exposures should be those which show promise of significant exposure reduction when weighed against total expected exposures and the "costs" of the actions.

"Costs", in this context, are measured primarily in terms of costs to the Enewetak people as constraints on their activities or as dollar costs for cleanup or remedial action.

In these evaluations, it should be emphasized that dosages through various pathways are estimated on the basis of environmental data and considerations of expected living patterns and dietary habits. While "radiation standards" do not exist for environmental contamination levels in substances such as soil and foodstuffs, there is general agreement in terms of conservative models of these pathways and the relationships between a certain level in the environment and the likely dose to result from the pathway exposure.

The area of plutonium in soils, however, is one for which there is no general agreement as to the quantitative relationship between levels in soils and dosages to be expected through the inhalation pathway, ~~the pri-~~ mary one through which man can receive a significant dose from plutonium. The ICRP recommends a maximum permissible average concentration (MCP) of 1 picocurie per cubic meter (pCi/m^3) of air for "insoluble" plutonium -239 and 0.06 pCi/m^3 for "soluble" plutonium for unrestricted areas. While the plutonium in the soil at Enewetak is thought to be typical of world-wide fallout, and therefore insoluble, we will use the 0.06 pCi/m^3 value for the sake of conservatism.

A guide for assessing the importance of a certain soil level of Pu on Enewetak can be arrived at by a set of conservative assumptions regarding the resuspension pathway. This is the "critical" pathway since the inhalation route to man is more hazardous than the soil-root pathway for ingestion of plants by man. These assumptions are:

1. Plutonium in soil is resuspended at rates similar to the soil material, e.g., the specific activity of soil equals the specific activity of air particulates.

2. All particles in air originate from local soil.

3. Plutonium in air is all in the respirable range of particle size and is soluble in lung fluids.

Appendix II develops average lifetime exposure to particulates in air by the returning population, combining the ~~arguments~~ assumptions outlined above with an analysis of air concentrations and time-of-exposure weightings to be expected for the mix of environmental conditions associated with routine activities (ambient) and under special conditions which stir up the soil.

In Table II are reproduced airborne particulate concentration data published by the U. S. Dept. of Health, Education, and Welfare* for the

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*Air Quality Data, 1966 Edition, APTD 68-9 year 1966 for thirty non-urban locations in the United States. No similar data are available for Enewetak or an equivalent south sea atoll location. The average mean value for the 30 locations in Table II is 38 micrograms per cubic meter (microgram/m^3). Assuming, to be conservative, that the average airborne particulate concentration level at Enewetak is 150 microgram/m^3, and further assuming that all of this particulate matter consists of local soil (i.e., no salt spray from the ocean), one obtains a value of 400 pCi/gm as an average surface soil concentration which corresponds to the ICRP guide for maximum permissible average airborne concentration of plutonium.

In the evaluation of the radiological condition of Enewetak, we will apply the criteria that areas in which any soil samples show concentrations greater than 400 pCi/gm should receive corrective action, areas which show soil concentrations between 40 and 400 pCi/gm may receive corrective action, depending on other radiological conditions present, and areas showing less than 40 pCi/gm do not require corrective action because of the presence of plutonium 239 alone.

TABLE I

ICRP DOSE LIMITS

	Individuals	Population
Gonads, red bone-marrow	0.5 rem/yr	
Skin, bone, thyroid	3.0 rems/yr	
Hands and forearms; feet and ankles	7.5 rems/yr	
Other single organs	1.5 rems/yr	
Genetic dose		5.0 rems/30 yrs

TABLE II: SUSPENDED PARTICULATES, NONURBAN FREQUENCY DISTRIBUTIONS

Location: Region, State or Station	Micrograms Per Cubic Meter: Max	Arith Mean	Geo Mean	Std Geo Dev
ARIZONA GRAND CANYON PK	98	33	27	2.17
ARKANSAS MONTGOMERY CO	246	50	38	1.98
CALIFORNIA HUMBOLDT COUNTY	158	43	35	1.82
COLORADO MONTEZUMA COUNTY	75	19	14	2.17
DELAWARE KENT COUNTY	116	64	59	1.52
INDIANA MONROE COUNTY	83	48	46	1.32
PARKE COUNTY	171	46	40	1.62
IOWA DELAWARE COUNTY	110	40	35	1.73
MAINE ACADIA NAT PARK	57	25	22	1.64
MARYLAND CALVERT COUNTY	72	40	38	1.38
MISSISSIPPI JACKSON COUNTY	213	37	31	1.73
MISSOURI SHANNON COUNTY	62	32	30	1.52
MONTANA GLACIER NAT PARK	54	16	12	2.25
NEBRASKA THOMAS COUNTY	66	27	22	1.99
NEVADA WHITE PINE CO	28	9	6	2.80
NEW HAMPSHIRE COOS COUNTY	81	28	23	1.94
NEW MEXICO RIO ARRIBA COUNTY	54	26	25	1.67
NEW YORK CAPE VINCENT	88	31	25	2.06
NORTH CAROLINA CAPE HATTERAS	122	68	59	1.76
NORTH DAKOTA WARD COUNTY	141	45	32	2.39
OKLAHOMA CHEROKEE COUNTY	287	53	45	1.62
OREGON CURRY COUNTY	133	79	73	1.49
PENNSYLVANIA CLARION COUNTY	97	41	37	1.56
RHODE ISLAND WASHINGTON CO	114	46	40	1.73
SOUTH CAROLINA RICHLAND COUNTY	80	38	35	1.53
SOUTH DAKOTA BLACK HILLS	48	20	14	2.64
TEXAS MATAGORDA COUNTY	280	38	29	1.79
VERMONT ORANGE COUNTY	117	45	41	1.54
VIRGINIA SHENANDOAH PARK	75	34	30	1.68
WYOMING YELLOWSTONE PARK	30	11	8	2.74

"URBAN" LOCATION

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judgements made as to exposure levels that are justifiable under the circumstances.

Guidance

RADIATION PROTECTION ~~STANDARDS~~ RELEVANT TO ENIWETOK ~~GUIDANCE~~

Within the United States essentially all radiation protection activity is based on issuances of the:

Federal Radiation Council (FRC)

National Council on Radiation Protection and Measurements (NCRP)

International Commission on Radiological Protection (ICRP)

International Atomic Energy Agency (IAEA)

~~Standards~~ Recommendations or guidance adopted and published by these bodies are in regular, day-to-day use; they provide the bases for judgements and recommendations pertaining to radiation protection at Eniwetok Atoll in the years ahead as it relates to cleanup, potential or possible rehabilitation and reoccupation of the islands by the Eniwetok Atoll people. The material which follows is based on the philosophy and numerical values contained in ICRP, NCRP and FRC publications, with the most extensive use being made of the first. Some details of ICRP, NCRP and FRC guidance are provided in a concluding section. Readers are referred to the various reports, listed as references, for complete guidance issued by the councils and commission.

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RADIOLOGICAL CONSIDERATIONS FOR REOCCUPATION OF ENIWETOK ATOLL

Insert A → See Suvie version

~~ICRP, NCRP and FRC recommendations must be applied to Eniwetok in manner different from that used for a proposed nuclear facility or at a laboratory where radioisotopes or ionizing radiation generating machines are to be used. At Eniwetok radioactive contamination is distributed in~~

the environment and the owners of the atoll are absent at a radiologically safe location. The problem is finding the procedure, assuming one exists, through which all or part of the atoll can be made safe as the permanent home for the Eniwetok Atoll people.

The basic principles of radiation protection are applicable everywhere. In the case of Eniwetok, fundamental decisions relate to the exposure standards to be used in the evaluation of the radiological survey and the cleanup and rehabilitation options. Benefits for the returning people must be identified. The objectives, drawn from ICRP, are:

1. to prevent acute radiation effects, and
2. to limit the risks of late effects to an acceptable level.

~~Implementation of the plans for~~ Successful recovery of Eniwetok Atoll will require: ~~for their success:~~

1. Cleanup of radiological contamination
2. ~~1.~~ Periodic assessments of environmental radioactivity.
3. ~~2.~~ Measurements of humans by dosimeters and whole body counter.
4. ~~3.~~ Forthright attention by Trust Territory officials and by island residents to the procedures which will keep exposures as low as practicable.
5. ~~4.~~ The most critical element of the population receiving the highest exposure will be used in applying numerical criteria.
6. ~~5.~~ Use of dynamic life style and diet adapted to radiological conditions during the lifetime of returnees and later generations.
7. ~~6.~~ Data on total annual exposures for those receiving highest exposures.

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Risks and Benefits

Risks associated with radiation exposures during a life ~~at~~ time on Eniwetok should ~~are assumed to~~ be equal to or less than those risks from exposures arising from ~~others involving comparable quantities of radioactivity in~~ conventional technological situations as treated by ICRP, NCRP and FRC. ~~Radionuclides in the land, lagoon and sea environment are predicted to pass through various pathways to man. To the extent that practical measures can reduce exposures, there is a degree of control available to inhabitants.~~

Benefits associated with the return to Eniwetok Atoll have been stated by the Eniwetok people. Recovery of property, use of land, lagoon and sea resources with minimal restrictions, obtaining new housing and community facilities, and acquiring structures, etc., left behind by the U.S.A. qualify as benefits from their viewpoint. In this case, unlike some nuclear technology applications, risks and benefits apply to the same persons; nevertheless there may be some variation in exposures among Eniwetok families because of ~~variations~~ differences in conditions between the family-owned land holdings.

Steps taken to reduce exposures may have undesirable consequences. Actions causing soil disturbance may reduce food crop production; inability to construct a permanent home on an island for a period of years would inconvenience the owners. The concept of net benefit must be kept in mind.

Remedial measures

Engineering and advisory actions are the two categories of remedial measures considered in this report.

1. Engineering actions taken during cleanup and rehabilitation operations provide a basis for measurement or other determination of effectiveness and adverse impact. Good initial assurance of satisfactory completion can be given.

2. Advisory actions cover those activities of the returning people and their professional counselors in response to instructions and technical advice on land use, housing sites, dietary usages, etc. Results will be achieved over a long period and depend on the conscientious use of advice and counsel and require continuing exchange of information between inhabitants and technical sources. Because of time, human factors, pressures and qualifications, less than optimum effectiveness may be [illegible] expected, despite a strong initial will by the Enewetak people to cooperate at the outset.

Engineering actions are those upon which the U.S. parties to cleanup and rehabilitation should place the greatest reliance for assuring continuing "as low as practicable exposures." If the U.S. leaves the atoll in nominally safe condition, it can put the control in the hands of the people with a high degree of confidence that predicted exposures will not be exceeded to any significant degree. Disposal of contaminated scrap, construction of permanent housing, selecting sites for any planting of delayed yielding food sources such as coconut and pandanus, and drilling and locating pumps at wells in uncontaminated ground water, are typical engineering actions. Decisions having the approval and cooperation of the Eniwetok people will be necessary for some of these. Advisory actions should be considered as a bonus in the exposure reduction planning. Restrictions on visits to certain islands, restrictions on use of specific animal or vegetable foods, and use of dietary supplements are advisory actions.

Considering the exposure reduction achieved by engineering actions, it must be possible to maintain exposures of people below recommended levels; otherwise the U.S. parties must deliberate whether cleanup and rehabilitation of the atoll should be initiated now or at some later time. The application of the array of actions to the situation at Eniwetok Atoll as portrayed in the report of the radiological survey must lead to positive findings if the people are to be given clearance for safe return to their traditional home.

Insert 1

Recommended guides

The dose limits issued by ICRP ~~is~~ are recommended as the basic ~~standard~~ guidance for control of exposures to individuals at Eniwetok. This is recommended with ~~the~~ provisos that: 1. The full amount of the numerical values should not be used for ~~an~~ allowable exposures from a single man-made source, in this case radioactivity from weapons tests. This ~~proviso~~ is ~~made~~ applied so that the Eniwetok people will not be denied benefits of future nuclear technology because they are receiving exposures from man-made radiation to ~~the~~ levels of acceptable standards. 2. Environmental and medical followup surveys and studies are performed such that the full range of radiation exposures of individual members of the Eniwetok population will be known. (ICRP has not routinely [illegible] measurement of individual exposures).

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Survey, Cleanup and Rehabilitation Evaluation

It is recommended in this context that:

1. A limit of 50 percent of the ICRP dose limits for individuals (because of the small population size and the planned medical and environmental followup) be used. This assumes that the range of annual exposure levels for persons receiving the higher exposures will be known. The following values apply:

Gonads, red bone marrow	0.25 rem/yr
Skin, bone, thyroid	1.50 rem/yr (0.75 rem/yr, childrens thyroid)
Hand, and forearms; feet and ankles	3.75 rem/yr
Other single organs	0.75 rem/yr

2. A limit for gonadal exposure of the population be 5 rems in 30 years. This is based on the genetic dose coming primarily from ^{137}Cesium, that has a ~~the~~ radiological half-life of ~~which is~~ 30 years.

REVIEW AND SUMMARY OF STANDARDS

REVIEW AND SUMMARY OF STANDARDS

A. The International Commission on Radiological Protection (ICRP)

The ICRP originated in the Second International Congress of Radiology in 1928. It has been looked to as the appropriate body to give general guidance on widespread use of radiation sources caused by rapid developments in the field of nuclear energy. ICRP recommendations deal with the basic principles of radiation protection. To the various national protection ~~councils~~ bodies is left the responsibility for introducing the detailed technical regulations, recommendations, or codes of practice best suited to their countries. Recommendations are intended to guide the experts responsible for radiation protection practice.

ICRP states that the objectives of radiation protection are to prevent acute radiation effects and to limit the risks of late effects to an acceptable level. It holds that it is unknown whether a threshold exists, and it is assumed that even the smallest doses involve a proportionately small risk. No practical alternative was found to assuming a linear relationship between dose and effect. This implies that there is no wholly "safe" dose of radiation.

Exposure to natural background radiation carries a probability of causing some somatic or hereditary injury. However, the Commission believes that the risk resulting from exposures received from natural background should not affect the justification of an additional risk from man-made exposures. Accordingly, any dose limitations recommended by the Commission refer only to exposure resulting from technical practices that add to natural background radiation. These dose limitations exclude exposures received in the course of medical procedures. (These same qualifications with regard to natural background and medical procedures are applied to NCRP and FRC recommendations.)

ICRP developed the concept of "acceptable risk." Unless man wishes to dispense with activities involving exposures to ionizing radiation, he must recognize that there is a degree of risk and must limit the radiation dose to a level at which the assumed risk is deemed to be acceptable to the individual and to society ~~because~~ in view of the benefits derived from such activities.

For planned controlled exposures of individuals and populations, the ICRP has recommended the term "dose limit." For unplanned exposures from uncontrolled sources the term "action level" is recommended. In general it will be appropriate to institute countermeasures only when their social cost and risk will be less than those resulting from the exposure. Setting of action levels is the responsibility of national authorities.

It is not desirable to expose members of the public to doses as high as those considered to be acceptable for radiation workers because children are involved, members of the public do not make the choice to be exposed, and members of the public are not subject to selection, supervision and monitoring, and are exposed to the risks of their own occupations. For planning purposes, dose limits for members of the public are set a factor of ten below those for radiation workers. The dose limits for members of the public are a somewhat theoretical concept intended for planning purposes. It will seldom be possible to ensure that no single individual exceeds this dose limit. Even when individual exposures are sufficiently low so that the risk to the individual is acceptable small, the sum of these risks may justify the effort required to achieve further limitation.

Where the source of exposure is subject to control, it is desirable and reasonable to set specific dose limitations. In this manner the associated risk is judged to be appropriately small in relation to the resulting benefits. The limitation must be set at a sufficiently low level so that any further reduction in risk would not justify the effort required to accomplish it. Such risks to members of the public from man-made sources of radiation should be less than or equal to other risks regularly accepted in everyday life. They should also be justifiable in terms of benefits that would not otherwise be received. ICRP has stated that when dose limits have been exceeded by a small amount, it is generally more significant that there has been a failure of control than that one or more individuals have slightly exceeded the limits.

"Dose limits" for members of the public are intended to provide standards for design and operation of radiation sources so that it is unlikely that individuals in the public will receive more than a specified dose. The effectiveness is appraised by assessments through sampling procedures in the environment, by statistical calculations, and by a control of the sources from which the exposure is expected to arise. Measurement of individual doses is not contemplated.

Actual doses received by individuals will vary according to age, size, metabolism, and customs, as well as variations in their environment. These variations are said to make it impossible to determine the maximum individual doses. In practice it is feasible to take account of these sources of variability by the selection of appropriate critical groups within the population, provided the critical group is small enough to be homogeneous with respect to age, diet and those aspects of behavior that affect the doses received. Such a group should be representative of those individuals in the population expected to receive the highest dose. ICRP believes that it will be reasonable to apply the appropriate dose limit for members of the public to the mean dose of this group.

The inate variability within an apparently homogeneous group means that some members of the critical group will receive doses somewhat higher than the dose limit. At the very low levels of risk implied, the health consequence is likely to be minor whether the dose limit is marginally or substantially exceeded.

Limitation of exposure of whole populations is achieved partly by limiting the individual doses and partly by limiting the number of persons exposed. It is of the utmost importance to avoid actions that may prove to be a serious hazard later, when correction may be impossible or costly.

The ICRP dose limits for individual members of the public are in Table I. No maximum "somatically significant" dose for a population is given. Using the linear dose-effect relationship and assuming no threshold, the ICRP indicates that an annual exposure of active red marrow, averaged over each individual in the population, of 0.5 rem (corresponding to the annual dose limit for members of the public) might at equilibrium lead to an increased incidence of leukemia, at most, of about ten cases per year per million persons exposed.

The genetic dose to the population should be kept to the minimum amount consistent with necessity and should certainly not exceed 5 rems in 30 years from all sources other than natural background and medical procedures. No single type of population exposure should take up a disproportionate share of the total of the recommended dose limit.

For exposures from uncontrolled sources, e.g., following an accident, ICRP identifies the term "action levels." The setting of action levels for particular circumstances is considered to be the responsibility of national authorities.

B. <u>National Council on Radiation Protection and Measurements* (NCRP)</u>

The NCRP was chartered by Congress in 1964 to collect, analyze, develop, and disseminate information and recommendations about protection against radiation, radiation protection measurements and units, and to provide a means for cooperation between organizations concerned with radiation protection.

The NCRP position is that the rational use of radiation should conform to levels of safety to users and the public which are at least as stringent as those achieved for other powerful agents. Continuing and chronic exposure attributable to peaceful uses of ionizing radiation are assumed.

The NCRP has adopted the assumption of no-threshold dose-effects relations and uses the term "dose limits" in providing guidance on population exposures. Radiation exposure is to be kept as low as practicable. The numerical values of exposure as presented are to be interpreted as recommendations not regulations. Use of the no-threshold concept involves the thesis that there is no exposure limit free from some degree of risk.

To establish criteria, NCRP uses the concept of "acceptable risk" (where the risk is compensated by a demonstrable benefit) broken down to fit classes of individuals or population groups exposed for various purposes to different quantities of radiation. Numerical

*This was formerly the National Committee on Radiation Protection and Measurements.

recommendations for dose limits are necessarily arbitrary because of their mixed technical and value judgement foundation. The dose limits for individual members of the public and for the average population recommended by NCRP represent a level of risk considered to be so small compared with other hazards of life, and so well offset by perceptible benefits when used as intended, that public approbation will be achieved when the informed public review process is completed.

For peaceful uses of radiation NCRP provides yearly numerical dose limits for individual members of the public, considering possible somatic effects, and strongly advocates maintenance of lowest practicable exposure levels especially for infants and the unborn. NCRP also recommends yearly dose limits for the average population based upon somatic and genetic considerations and ~~promulgates~~ recommends the same value as ICRP ~~limit~~ of 5 rems in 30 years for gonadal exposure of the U.S. population. Table II contains a summary of recommended values. NCRP Report No. 39 entitled, "Basic Radiation Protection Criteria," dated January 15, 1971, contains the most recent updating of NCRP recommendations for protection of the public.

C. <u>Federal Radiation Council (FRC)</u>

In 1959 by Executive Order and PL 86-373, the FRC was established to advise the President and to provide guidance for Federal agencies. The responsibility for establishing generally applicable environmental standards was assigned to the Environmental Protection Agency in 1970.

Basic FRC numerical ~~standards~~ guidance and health protection philosophy are similar to those of the ICRP and NCRP. Numerical criteria and supporting material are provided in (1) Radiation Protection Guides (RPG's) which deal with exposures of individuals and of population groups where actions are directed primarily at control of the source of radioactivity, and (2) Protective Action Guides (PAG) that deal with exposures of individuals and population groups to radioactivity from an unplanned release where action is taken in the production and use of foods.

<u>RPG</u>, Radiation Protection Guides, express the dose that should not be exceeded without careful consideration of the reasons for doing so. Every effort should be made to encourage the maintenance of radiation doses as far below this guide as practicable. The RPG's are intended for use with normal peacetime operations, and there should be no man-made radiation exposure without expectation of benefits from such exposure. Considering such benefits, exposure

at the level of the RPG is considered as an acceptable risk for a lifetime. The RPG's for the population are expressed in terms of annual exposure except for the gonads where the ICRP recommended value of 5 rems in 30 years is used. FRC states that the operational mechanism described for application of criteria to limit the whole body dose for individuals to 0.5 rem per year and to limit exposure of a suitable sample of the population to 0.17 rem per year is likely to assure that the gonadal exposure guide will not be exceeded.

Environmental radiation monitoring is a necessary part of complying with the RPG guidance. The intensity and frequency of measurements is to be determined by the need to be able to detect sharply rising trends and to provide prompt and reliable information on the effectiveness of control actions. Radioactive source control actions and monitoring efforts are to increase as predicted exposures move upward through a range of values and approach the numerical value of the RPG. A sharply rising trend approaching the RPG would suggest strong and prompt action. The magnitude of the action should be related to the degree of likelihood that the RPG would be exceeded.

The child, infant, and unborn infant are identified as being more sensitive to radiation than the adult. Exposures to be compared with the guidance are to be derived for the most sensitive members in the population. The guide for the individual applies when individual exposures are known; otherwise, the guide for a suitable sample (one-third the guide for the individual) is to be used. This operational technique may be modified to meet special situations.

The FRC primary numerical guides, expressed in rem, are provided in two reports, FRC Nos. 1 and 2, summarized in Table III. Secondary numerical guides developed by FRC are expressed in terms of daily intake of specific radionuclides corresponding to the annual RPG's. Consideration is given to all radionuclides through all pathways to derive a total annual exposure for comparison with FRC guides. However, for many practical situations a relatively few radionuclides yield the major contribution to total exposure; by comparison, exposures from others are very small.

<u>PAG</u>: The term "Protective Action Guide" has been defined as the projected absorbed dose to individuals in the general population which warrants protective action following a contaminating event. In setting these numerical guides the FRC was concerned with a balance between the risk of radiation exposure and the impact on public well-being associated with alterations of the normal production, processing, distribution and use of food.

A protective action is described as an action or measure taken to avoid most of the exposure to radiation that would occur from future ingestion of foods contaminated with radioactive materials. An action is appropriate when the health benefits associated with the reduction in exposure to be achieved are sufficient to offset undesirable features of the protective action. An event requiring protective action should not be expected to occur frequently.

The numerical guides are related to three types of actions, (1) altering production, processing, or distribution practices, (2) diverting affected products to other than human consumption, and (3) condemning affected foods. An additional category involves long-term, low level exposure for which numerical guides are not provided; the need for action is determined on a case-by-case basis.

The FRC identifies the critical segment of the population for which dose projections are to be made for comparison with the guides. For instance, for ^{131}I in milk, the critical segment is children one year of age.

In cases where it is not practical to estimate individual doses, action will be based on average values of radiation exposure. Guides for both individuals and a suitable sample are provided. For ^{131}I in milk, the suitable sample is to consist of children approximately one year of age using milk from a reasonably homogeneous supply.

Numerical guidance for PAG's is provided in two reports, FRC Nos. 5 and 7 summarized in Table IV.

Draft 1 of Appendix II

L. Anspaugh

D. Wilson

Lawrence Livermore Laboratory

September 14, 1973

"Relationship between Resuspended Plutonium

in Air and Plutonium in Soils"

There is no general model that can be used with confidence to predict the resuspended air activity in the vicinity of a soil burden of Pu. Two approximate approaches can be used to give an indication of the activity. These are the use of the resuspension factor and an argument based on average dust loading assuming the dust is derived from the contaminated surface.

Resuspension Factor Approach

The resuspension factor, K, is defined as the ratio of air activity/m^3 divided by the surface activity/m^2, and thus has units of m^{-1}. Stewart[1] and Mishima[2] have tabulated values of K from many experiments. The total range is from 10^{-2} to 10^{-13}/m. Most of the high values, however, are derived from experiments with laboratory floor surfaces and with artifical disturbance.

For outdoor situations Stewart[1] suggests a value of 10^{-6}/m "under quiescent conditions, or after administrative control has been established in the case of an accident." A value of 10^{-5}/m is suggested under conditions of moderate activity.

After reviewing the literature, Kathren[3] recommended the use of 10^{-4}/m as a conservative value.

These values, however, address the situation following a fresh deposit of activity. Several studies have demonstrated that the amount of material moving in resuspension decreases with time following its initial deposition[4,5]. Observed half-times of this decrease are 35 to 70 days. The mechanism causing this decrease is apparently the weathering of the surface deposited debris into the soil, and not the loss of the deposited material from the initial area[2]. Kathren's model[3] includes this effect by multiplying his chosen resuspension factor by the exponential function: exp (- 0.693 t/45 days). There are major uncertainties in such a formulation, however. The longest such study extended to only eleven months following the initial deposition[5], which is very short compared to the half-life of a radionuclide such as ^{239}Pu. My own belief is that this half-time increases with the passage of time. Otherwise, after fifteen years following deposition, a 45 day half-life would reduce the resuspension factor by 10^{-37}. Data will be presented below which clearly indicate that this is not true.

There are some values in the literature for resuspenion factors of aged material. Mishima[2] quotes values of 6.2×10^{-10} to 10^{-13}/m for aged plutonium deposits at NTS. These measurements were apparently made 16 months after the initial deposition[6].

Perhaps the most relevant data, however, are unpublished results from the resuspension experiments at the GMX site in Area 5 of NTS. The ^{239}Pu at this location was deposited following 22 high-explosive detonations from December, 1954, to February, 1956. Measurements of resuspended air activity levels at this site during 1971 — 1973 appear to the only available data concerning resuspension of ^{239}Pu from a source of this advanced age.

Two kinds of measurements are available which can be used to derive time-integrated averages of resuspension factors. First, five Andersen hi-volume cascade impactors were set up within the most highly contaminated area, and were run for 36 days, from July 7 to August 12, 1972[7]. The collected ^{239}Pu was lognormally distributed with particle size with a geometric mean of 3.2 ± 13 μm. The ^{239}Pu concentration varied from 0.023 tp 0.087 dpm/m^3 with an average of 0.052 dpm/m^3 for the five samplers. At the present time only limited data is available regarding the soil activity in the area. Four samples of soil of depth 0 — 3 cm were taken in the approximate area and give values of 2900, 3550, 2060, and 2290 dpm/g[8]; mean = 2700 dpm/g. No profile data are available, so in order to calculate the total deposition we make the conservative assumption that no additional ^{239}Pu is below 3 cm. A measured value of soil density in the area is 1.8 g/cm^3 [7]. Therefore, the deposition is 1.5×10^8 dpm/m^2 and the resuspension factor is

$$\frac{0.052 \text{ dpm}}{m^3} \times \frac{m^2}{1.5 \times 10^8 \text{ dpm}} = 3 \times 10^{-10}/m$$

Additional data were taken by REECo on the edge of the contaminated area during the period of February, 1971, to July, 1972, with a sample period of approximately 48 hours[9]. Measurements were made at four sites, but the site of most interest is the one in the prevailing direction of the strong winds. Here, 254 measurements were made of which 236 gave detectable results. Values range from 0.000077 to 1.4 dpm/m^3, with arithmetic and geometric means of 0.014 and 0.0018 dpm/m^3, and a median of 0.0014 dpm/m^3. Four soil activity values in the general vicinity are 128, 142, 172, and 202 dpm/g. The average deposition level, calculated as before is therefore 8.7×10^6 dpm/m^2. As most of the air activity samples were made over equal time periods, the arithmetic mean would be appropriate for deriving a resuspension factor:

$$\frac{0.014 \text{ dpm}}{m^3} \times \frac{m^2}{8.7 \times 10^6 \text{ dpm}} = 2 \times 10^{-9}/m$$

The fact that the latter value is higher than the former may reflect one of the inherent difficulties in the resuspension factor approach; i.e., that no allowance is made of the geometrical configuration of the source and that higher ground activities are present at upwind locations.

Even though the analysis given above is subject to considerable uncertainties, there is no question but that resuspension is occurring from this aged source and at levels far in excess of what would occur if the decline in resuspended air activity indifinitely followed a 45-day half-time.

Mass Loading Approach

The other approximate prediction method is based upon measured or assumed levels of particulate matter in the atmosphere with the assumption that this material is derived from the contaminated soil. For fresh deposits this approach is not a very good one because we can expect that the freshly deposited material is much more likely to be resuspended. After many years of weathering, however, one would anticipate that the material is sufficiently mixed with the soil that the specific activity in airborne particulate matter should approximate that in the soil. A major difficulty could arise, however, if ^{239}Pu and mass were distributed differently as a function of aerodynamically equivalent particle size of the soil material.

The data derived from the Andersen cascade impactor study at NTS can be examined with this in mind. The mass collected during this experiment was also lognormally distributed with particle size with a geometric mean of 2.0 ± 10 μm.

The specific activity values as a function of particle size were:

Size (μm)	^{239}Pu (dpm/g)
> 7	960
3.3 to 7	740
2.0 to 3.3	980
1.1 to 2.0	1200

Size (μm) cont.	^{239}Pu (dpm/g)
.01 to 1.1	490
Total	730
Soil	2700

The average mass loading during this experiment was 70 μg/m^3. While there is some spread in the data, there is no indication of a preferential association of ^{239}Pu with a particular particle size, and as would be expected due to dilution by inert aerosol, the activity is lower than that in the soil.

If we assume that this is generally true, a method of predicting resuspended air activity of ^{239}Pu would be to simply multiply the ambient mass loading by the soil activity. For small islands like the Eniwetok group, the ambient mass loading would be expected to be very low. Minimum values of mass loading are believed to be of the order of 10 μg/m^3 [10]. The National Air Pollution Central Administration has reported measurements of mass loading at nonurban U.S. locations for the 1966 calendar year[11]. Arithmetic mean values range from 9 to 79 μg/m^3; the average of all locations was 38 μg/m^3. The arithmetic mean of the measurements at urban Honolulu, Hawaii, was 35 μg/m^3.

Some potential problems in using this approach should be mentioned. Although the data from NTS support the premise that the activity per gram of material collected by air sampling is lower than that in the soil in the area, this could perhaps be fortuitous due to dilution with inert aerosol. There is no way of determining the origin of the material collected by the sampler, and it would seem unlikely that a major fraction of the collected mass actually originated from the soil surface within even a few hundred meters of the sampler.