BURIAL LIMITS FOR RADIOACTIVE WASTE

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INTRODUCTION

Although the title of this paper indicates a general topic for all radioactive waste, we will discuss only the burial of low-level solid waste. The disposal of solid wastes by shallow earth burial has long been an easy and economical method of disposal of such wastes - some say, "out of sight, out of mind". Thus when the Manhattan District began generating radioactive materials in unprecedented quantities, it was only natural to consider the burial of wastes contaminated with relatively small quantities of radioactive materials as a method of disposal. However, another factor was involved in the decision - security. Even the mention of the words "radiation" or "radioactive" was forbidden because of the clear clue that they would give to the nature of the project.[b] As a result, the burial grounds for these wastes were established on the lands controlled for the project so that the radioactive materials could be guarded. This practice has continued in all of the Government facilities where land is available in order to eliminate any possible exposure to the public resulting from contact with these wastes.

These early disposal methods were predicated upon the permanent government dedication of the lands used for this purpose. In recent years, this thinking has changed drastically

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b Incidentally, security was also responsible for the coining of the name "health physics" in order to avoid the use of terms such as "radiation protection".

as the expanding population requires more room and as a part of the environmental ethic.

The first serious attempt to limit the quantities of radioactive materials being placed into burial grounds was taken by the AEC in 1970 when they required that their own laboratories place into "20 year retrievable" storage those solid wastes that contained more than 10 nCi/g of transuranium elements so that it could later be taken to a repository. The 10 nCi/g value was derived by a Task Force reporting to the General Manager of the AEC[1] and represented a high value for the natural alpha-emitting radionuclides in the earth's crust. Harvey Soule has generally been credited with the derivation of this number within the Task Force. This action by the AEC was an indication of the changing attitudes of the public and the government toward the burial of radioactive materials. In more recent years, the publicity on sites containing hazardous chemicals has heightened the public concern for all types of wastes, making it imperative that sites be selected on a rational basis and the quantities of radionuclides that we place in them be limited so that the public can have assurance that their health will not be damaged.

Many of the ideas in this paper arose from a study of the limits for transuranium elements on or in wastes disposed of in DOE burial grounds. The study started in 1976, before the NRC and the EPA programs were underway. A Task Group was assembled to advise in the preparation. The members of the Task Group were:

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William Reinig, Savannah River.
Roy Thompson, Battelle-Pacific Northwest Laboratories.
Bruce Owen, Dow Chemical USA.
Bruce Wachholz, Department of Energy.

The assistance and advice of this group was invaluable, however the author takes full responsibility for all discussions in this paper. We will not discuss numerical limits because the study involved only a limited number of nuclides. Rather we will review some of the problems and the concepts that we feel should be included in any study of the hazards of low-level waste burial grounds.

DOSE LIMITS

Any limitation placed upon wastes to protect health must consider the radiation exposure or the risk assumed to result from this exposure to the public. Historically, such limitations were defined by radiation dose limits derived by the National Council on Radiation Protection and Measurements (NCRP),[2] or the International Commission on Radiological Protection (ICRP).[3] In 1959, the Federal Radiation Council (FRC) was formed in the U.S. to provide Federal Policy on human radiation exposure and to advise the President on guidance to be applied by all Federal Agencies. In fact, the general guidance now in effect for limiting radiation exposure in the U.S. was devised by the FRC in 1960.[4] Upon formation of the Environmental Protection Agency (EPA) in 1970, the functions of the FRC were transferred to this Agency.

The FRC guidance approach to providing guidance was to provide a "Radiation Protection Guide" that was to be interpreted by the Agencies according to their need and could be exceeded if justified. However, the FRC also required the Agencies to carry out their work so that the dose was minimized to the extent practicable.

The EPA, in their role of providing general guidance, is using a different method and is estimating the minimum practicable level as a basis for their standards in each potential standards areas. Thus, they consider costs and risks and balance these to a level they consider to be appropriate, even for new procedures where experience is not available. This results in numbers lower than the FRC guidance with considerable variation depending upon the project and the judgements used by the EPA. For example, their proposed limits for transuranics in the environment are 1 mrad/y to lung and 3 mrad to bone and, for the nuclear fuel cycle, a limit of 25 mrem/yr is set for any individual.

This procedure, applied to the setting of general standards, not only reduces the flexibility that can be applied by the using Agency but also is a system for providing the standards in which the outcome cannot be predicted before the standard is available. Thus, we find ourselves in the position of having no general guidance for the Agencies to follow so that they must wait until the more specific standard covering a proposed action is issued before they can take action or run the risk of having the action taken on the wrong basis. This has led, further, to the situation where individuals propose interim guidance at as low a level as they can conceive of (and often, perhaps, below a level at which the job can be done) in order to obtain levels they believe will be compatible with any forthcoming EPA standard. As a final problem with this method, the public believes that a standard of this nature is an absolute number; that is, it represents a precipice between life and death. Thus, when the standards are exceeded, the public believes that they have been exposed to a dangerous situation and react accordingly.

From this it can be seen that establishing a basic dose limit for the disposal of radioactive wastes, runs a serious risk of eventually being too high if one relies on the general guidance now available. However, we felt that attempting to outguess, or even go through the analyses that the EPA would use, gives no assurance that the value arrived at will be appropriate. We concluded, therefore, that the proper approach was to use the current FRC guidance, signed by the President, as a basis. This guidance calls for a maximum whole body dose to an individual of 0.5 rems/yr or 0.17 rems/yr to a critical group in the population. However, for simplicity we used 0.5 rems/yr to any organ of the individual who is likely to be the highest exposed. The limit was then applied at the year for which the maximum dose is received - 70 years in the case of long-lived, well-retained nuclides.

EXPOSURE TO MAN

Once the wastes are emplaced there are various methods whereby they can be released to expose man. Table I presents the major release mechanisms and pathways to man that can occur over time. Additional release mechanisms exist but analysis indicates that, when carried to an extreme, conditions approaching those given in the Table will be present. It is our purpose here to discuss certain of the pathways that are somewhat unusual in such analyses. Note that many of these release mechanisms result from the long-lives of the radionuclides and the consequent need to consider what could happen over long periods of time.

TABLE I. Major Exposure Pathways

Release Mechanism	Pathway to Man
Erosion and Transport to streams	Drinking Uptake in Fish Irrigation
Leaching to Aquifer	Drinking Irrigation
Aquifer to Stream	Drinking Irrigation Fish
Intrusion	Resuspension
Exposure of Wastes	Resuspension Ingestion of Foods

Each of the pathways were analyzed using available data although in some cases the data were very sparse. A model burial ground 1000 m on a side and 10 m deep with the bottom immediately above an aquifer with a velocity of 30 cm/day was used for the calculation. This is conservative for most, but not all, sites. Where appropriate, allowance was made for the dilution of the highest level wastes at the limit by the large quantity of non-contaminated or low-contaminated wastes found in most wastes. This is difficult to define because measurements of waste are not usually made. However, data for the levels of plutonium in trash from the LASL Plutonium Research Facility indicated dilution factors of 20-60 at a limit of 10 nCi/g and 80-110 at 100 nCi/g. We have no way of knowing how representative these values are but an estimated overall dilution factor of 20 was considered to be reasonable. However, such dilution was not included for incinerator ash and similar materials where blending and averaging are important.

The intrusion pathway is probably the most controversial and provides some problems of interest. Some feel that it should not be included because we can place markers that will warn of the dangers and anyone penetrating in spite of this warning will be accepting the risk himself. On the other hand, providing markers that will withstand vandals and the ravages of time is difficult. In addition, if archaeologists or treasure hunters are as persistent in the future as they are now, old burial grounds will act as a magnet because of historical interest and the presence of valuable materials and items.

Once this hurdle is crossed and it is agreed that intrusion should be considered, several problems appear in the analysis. The first is the possible condition of the waste. The usual analysis considers the waste to be degenerated to a soil-like mass and soil resuspension relations are applied to obtain the inhalation dose to the intruder. Upon further consideration, however, there are several reasons to question this method of calculation based upon the type of material buried. Most trash types of wastes are contained in plastic to minimize contamination during transport and placement. Some evidence indicates that a tightly sealed plastic bag may preserve the contents for an uncertain but perhaps considerable time. For example, Horton[5] has exhumed wastes buried at Savannah River for 14 years and found the paper and other combustibles contained in plastic to be well preserved. A report prepared by the Union Carbide Company for the EPA,[6] indicates that the current, high-volume, high-molecular weight packaging plastics are not biodegradable at practical rates. It is true that many of the bags will be ruptured when placed into the burial grounds and others may be penetrated by burrowing insects or animals. However, if some survive we are faced with a problem of individuals possibly recovering and handling actual wastes. For this reason, we believe that limits for wastes disposed of in this manner should be lower, to control intruder doses, than for limits in which degradation and mixing with the soil can be expected. Note that the present regulatory trend of requiring containers as long-term barriers will accentuate this problem.

A second problem with the intruder scenario is the burial of solid contaminated objects, such as discarded equipment. If, as is usually the case, the contamination is on the surface of the object, then limits expressed in mass or volume units are not applicable because of the high surface contamination. For example a sheet of plastic 1 cm thick and having a contamination level of 10 nCi/g would have on the order of 10,000 pCi/cm^2 if the contamination is on one side only. If, then, we visualize recovery of such objects by an individual some years later, the potential problem of exposure to an individual who recovers the pieces and to others who handle them is apparent. It is for this reason, that we believe that a separate limit should be applied to surface contamination of massive objects.

For releases to a stream, it was considered that the radionuclides were in the form of particulates from direct erosion to the stream,or the radionuclides were rapidly adsorbed on sediments if released in ionic form. This results in shifting of the interest from dilution in the water flow of the stream and a transitory passage for each release time, to a problem of contamination of sediments and movement of these sediments. While sediment transport depends strongly upon the character of a given stream, our interest focused on the possible increase in concentration of radionuclides in bottom sediments at low-flow regions, such as dams, or in estuaries where fresh water meets the salt water. This increase results from preferential adsorption of the radionuclide on small particles and sorting of the sediments by changes in velocity of the water resulting in different sizes of particles carried by the stream.

The limiting release mechanism, or the one giving the highest doses, was determined to be the future exposure of wastes in the burial ground with people living on the area. Exposure of the waste by erosion was estimated to take 2000 - 13 000 years by sheet erosion although gully erosion could decrease this time as could human action in the area.

In Table II, we present the limiting concentrations for shallow earth burial of one of the long-lived nuclides, ^{239}Pu, as derived in this study. The importance of the dilution factor and the intrusion considerations can be seen from this Table.

CONCLUSIONS

Some of the release pathways from the shallow burial of long-lived radionuclides have been discussed. The intrusion considerations, particularly the possible preservation of artifacts, clearly points out the need for careful consideration of all factors before decisions are made upon burial conditions. The proposal to require increased reliability of containment over long periods of time is based upon the possibility of leaching of radionuclides from the wastes. However, our study includes that doses to individuals from the leaching pathway are lower than could result from preservation of the wastes in their original concentrated form if intrusion occurs. It may be true that a larger population will be exposed to radionuclides leached to a

TABLE II. Illustrative Limits for ^{239}Pu to Show the Differences for Various Types of Waste

Type of Waste	Method of Exposure	Limit
Normal trash with dilution by non-contaminated waste	Living on exposed wastes	50 nCi/g
Contamination uniform through waste - i.e. Incinerator ash	Living on exposed wastes	2 nCi/g
Normal trash - nondegradable Packages	Intrusion	3 nCi/g
Artifacts	Intrusion	60 pCi/cm^2

stream, but limitations based upon this alone could result in possibly high doses to individuals.

During this study we considered what seems to be the present policy on radioactive waste - the waste either goes to cheap burial or a very expensive repository. It seems that this could be modified to allow an intermediate level of disposal where intrusion or erosion or other method of exposure of the wastes is essentially impossible. Under these conditions the leaching to ground water becomes controlling and the levels, under the limits derived here could be at least one order of magnitude greater. This could be accomplished by deeper burial, perhaps in a mined cavity at depths of 10-100 meters. Such a move would allow the surface to be used by people and, if well-designed, could eliminate much of the technical objection to burial grounds.

We advance this proposal in the belief that shallow earth burial will eventually be limited to those nuclides that will decay to very low levels within the time allowed for institutional control. If this is, indeed, the case, the provision of a third method to take care of all others except the high-level waste will be needed.

REFERENCES

1. U.S. Atomic Energy Commission, "Sorting of Solid Radioactive Wastes, A Report to the General Manager's Task Force on AEC Operational Radioactive Waste Management," June 1970.

2. National Council on Radiation Protection and Measurements, "Basic Radiation Protection Criteria," NCRP Report No. 39, NCRP Publications, Washington, D.C., January 1971.

3. International Commission on Radiological Protection, "ICRP Publication 26, Recommendations of the International Commission on Radiological Protection," Annals of the ICRP 1, 3, 1977.

4. Federal Radiation Council, "Background Material for the Development of Radiation Protection Standards," Report No. 1, Supt. of Documents, U.S. Government Printing Office, Washington, D.C., May 13, 1960.

5. J. H. Horton, "Exhumation of Radioactive Solid Waste Burial for Fourteen Years," Savannah River Laboratory Report DP-1450, March 1977.

6. J. E. Potts, R. A. Gandinning and W. B. Ackart, "An Investigation of the Biodegradability of Packaging Plastics," Environmental Protection Agency Report EPA-R2-72-046, August 1972.