DOE APPROACH TO THRESHOLD QUANTITIES

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ABSTRACT

The Department of Energy (DOE) is developing the concept of threshold quantities for use in determining which waste materials must be handled as radioactive waste and which may be disposed of as nonradioactive waste at its sites. Waste above this concentration level would be managed as radioactive or mixed waste (if hazardous chemicals are present); waste below this level would be handled as sanitary waste.

Ideally, the threshold must be set high enough to significantly reduce the amount of waste requiring special handling. It must also be low enough so that waste at the threshold quantity poses a very small health risk and multiple exposures to such waste would still constitute a small health risk. It should also be practical to segregate waste above or below the threshold quantity using available instrumentation. Guidance is being prepared to aid DOE sites in establishing threshold quantity values based on pathways analysis using site-specific parameters (waste stream characteristics, maximum exposed individual, population considerations, and site specific parameters such as rainfall, etc.).

A guidance dose of between 0.001 to 1.0 mSv/yr (0.1 to 100 mrem/yr) was recommended with 0.3 mSv/yr (30 mrem/yr) selected as the guidance dose upon which to base calculations. Several tasks were identified, beginning with the selection of a suitable pathway model for relating dose to the concentration of radioactivity in the waste. Threshold concentrations corresponding to the guidance dose were determined for waste disposal sites at a selected humid and arid site. Finally, cost-benefit considerations at the example sites were addressed. The results of the various tasks are summarized and the relationship of this effort with related developments at other agencies discussed.

INTRODUCTION

Numerous organizations have recognized a need for criteria governing the disposal of extremely low-level radioactive waste by means less restrictive than those in use at conventional low-level waste sites. The Nuclear Regulatory Commission has recognized that there may be potential advantages to establishing a lower limit for the radiation dose of concern in their draft standards for protection against radiation.[1] They have developed an approach to analyzing the impact for disposing of very low-level radioactive waste (de minimis waste) by less restrictive means.[2] In addition, the Environmental Protection Agency has several related efforts in this area[3], and have chosen to identify the concept for a de minimis dose as one of "below regulatory concern". EPA is also developing standards for low-level radioactive waste disposal which will address the question of whether wastes with sufficiently low concentrations of radioactivity can be disposed of with minimal controls.[4]

The Department of Energy (DOE) is developing a similar concept, threshold quantities, for use in determining which waste materials must be handled as radioactive waste at its sites. A threshold dose has been defined as the dose below which radioactive waste would be treated according to its nonradiological characteristics.[5] Waste with radionuclide concentrations resulting in a dose greater than the threshold guidance would be managed as radioactive or mixed waste; waste with concentrations less than the guidance would be handled as sanitary waste. Implicit in the definition is that the materials disposed of to the environment would cause a negligible increase to the total radiological impact to an individual or population.

Several considerations were made before the work to select a threshold was begun. Ideally, the threshold had to be technically sound and defensible; it had to be high enough to significantly reduce the amount of waste requiring special handling, but it also had to be low enough that it posed a very small health risk, even considering continuous exposure. It also had to be practical to segregate waste. Complicating the situation is that current accepted theories of radiation biology do not suggest a unique dose level below which effects are not predicted to occur.

The approach taken to select a threshold dose was to evaluate a risk level, or levels, associated with waste disposal, that were likely to be acceptable to society at large. Then, using radiobiological data regarding dose effects, the selected risk level was expressed in terms of a dose to an individual. Subsequent to selecting a dose, guidance for calculating operational threshold concentrations that correspond to the dose limit was prepared.

SELECTION OF THRESHOLD DOSE

Risk levels of various events and from various sources were reviewed[6,7,8] and evaluated to determine a risk level that would be acceptable to society, on which to base a threshold dose for the maximally exposed individual. It quickly became evident that acceptable risk, that is, events having a very low probability of occurrence, was very different from accepted risk, that is, risk for which no significant public concern was evident.[9,10,11] Table I gives examples of five categories of "acceptable versus accepted" risk defined by the Commission of European Communities.[11] From the review of this and other risk studies, it was apparent that no single unequivocal risk value for establishing a threshold dose to individuals could be derived. A range of risk values, however, is suggested by the data, extending from a value of 10^{-8} probability of fatal effects per year up to a maximum value of about 10^{-5}. Since for any given source of risk, the number of people exposed is a determinant as to its acceptability, it was deemed reasonable to consider the population exposed in the determination of the acceptable risk, and ultimately, the threshold risk.

TABLE I

Categories and Magnitudes of Selected Risks

Risk	Annual Probability of Death
Unacceptable And Not Accepted	
Death at age 55	9.5×10^{-3}
Death from cancer (average)	10^{-3}
Acceptable But Not Accepted	
Occupational death in coal mining	2.5×10^{-4}
Nuclear Power	5.2×10^{-9}
Unacceptable But Accepted	
Dam Failure	1.8×10^{-2}
Lung cancer to smokers	10^{-3}
Traffic accidents	10^{-3}
Acceptable and Accepted	
Railway accident	10^{-4}
Steam boiler explosions	10^{-7}
Television viewing	10^{-9}
De Facto Accepted	
Natural background radiation	10^{-5}
Earthquakes	10^{-6}
Meteorite impacts	10^{-10}

From CEC [1980][7]

The risk levels were converted to dose levels by applying a risk coefficient for whole-body equivalent dose as suggested by the Committee on Biological Effects of Ionizing Radiation.[6] The coefficient was expressed in terms of the risk of somatic or genetic effects per Sv of radiation dose. The suggested range for threshold risk (10^{-8} - 10^{-5}/yr) was equated to a threshold dose range of 0.001 to 1 mSv/yr (0.1 to 100 mrem/yr). This range of threshold dose values encompasses values previously suggested in other threshold and de minimis studies.

Recognizing that there is a level of subjectivity that has, of necessity, been applied to this and previous efforts to establish individual threshold dose limits, and considering the relevance of incorporating risk and cumulative dose as important factors, a variable threshold dose guidance was proposed dependent on the size of population exposed. The dashed line in Fig. 1 illustrates the concept of a variable threshold guidance as a function of population. The proposed guidance varies from a value of 1 mSv/yr for exposure of a single individual down to the lowest threshold value proposed (0.001 mSv/yr) for exposure of large populations. From a practical or operational standpoint, a threshold dose that varied according to the potential surrounding population was impractical to implement. Hence, a set of operational recommendations, also shown in Fig. 1, was made to the DOE. The values 0.3, 0.03, and 0.003 mSv/yr (30, 3, and 0.3 mrem/yr) represent the threshold dose to the maximum exposed individual for a given affected population size at the sanitary landfill accepting below-threshold waste. Given that the critical population would be small based on the two limiting scenarios (landfill marker and intruder-agriculture scenarios, discussed below), 0.3 mSv/yr was selected as the threshold dose guidance upon which to base calculations. It was felt that basing calculations on a specific value would help focus the discussion and comments about the threshold dose guidance.

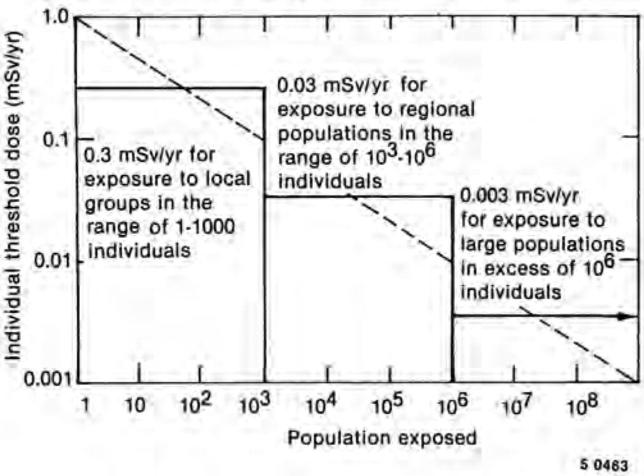

Fig. 1 Proposed variable threshold guidance.

CALCULATION OF THRESHOLD CONCENTRATIONS

Threshold concentrations corresponding to the threshold dose of 0.3 mSv/yr were claculated using selected exposure scenarios and a computer pathways model. Two DOE sites were used in the analyses, the Idaho National Engineering Laboratory (INEL) and the Savannah River Plant (SRP). These sites were selected as examples of disposal operations in arid and humid climates, respectively. The same computer site performance model, DOSTOMAN,[12] was readily available for use at each site.

Site specific data pertaining to environmental conditions and waste disposal (both radioactive and sanitary landfill) operations were collected from INEL and SRP. In addition, information on each site's waste streams was collected so that isotopic waste stream concentrations could be compared with the respective threshold concentrations.

The exposure scenarios considered in the analysis included a landfill worker, reuse of materials, intruder-construction, intruder-agriculture, offsite maximally exposed individual, and offsite maximally exposed population.[5] The landfill worker scenario addressed exposure pathways to occupational personnel during the operational period of the landfill facility. During the operational phase, workers (waste collection and transport personnel) would be exposed to direct radiation from contained and buried waste, and to inhalation and ingestion of contaminated soil. The reuse scenario dealt with radiation exposure resulting from reuse by the public of such items as tools, building materials, scrap metal, and instrumentation.

For the intruder-construction scenario, an individual constructs a house, including excavation of a basement, on the landfill site following a site surveillance period of 100 years. (Although no environmental monitoring or institutional control period would be formally required of a sanitary landfill, it was assumed that the entire DOE site, of which the landfill was a part, would have limited public access for some period of time after all the facilities on the site were no longer being used.) The intruder-agriculture scenario assumed that a family of four occupied and farmed the above homestead, and derived food from produce and animals raised within the landfill boundaries. Exposure pathways include inhalation and ingestion of contaminated soil particles, external radiation, and for the latter scenario, ingestion of contaminated foodstuffs and water.

The offsite exposure scenarios were concerned with exposure pathways and consequent doses to the maximally exposed individual and population located offsite. The principal modes of exposure include inhalation and ingestion of radioactivity transported by air and water vectors, respectively.

Transport of radionuclides from the buried waste through the environment to locations accessed by man was modeled using the DOSTOMAN computer code. Abiotic and biotic access locations included air, ground and surface waters, soil and biota (plants and animals). Calculated doses were 50-year effective whole-body dose equivalents as defined in the International Commission of Radiological Protection (ICRP, publication 26).[13]

MODELING RESULTS

The intruder-agriculture and the landfill worker scenarios proved most limiting and were used in determining the threshold concentrations for both INEL and SRP. The resulting threshold concentrations were compared with the radionuclide concentrations in individual waste streams to assess each waste streams compatibility for disposal in a sanitary landfill. Of the 38 INEL waste streams considered, only one was within the threshold concentrations for INEL. Examination of SRP's 52 waste streams showed a total of 22 that fell within threshold concentration guidelines for the years 1983 and/or 1984, representing approximately 13% and 17% of the total waste volumes disposed of at SRP for 1983 and 1984, respectively. Seven waste streams complied for both 1983 and 1984.

DISCUSSION

Three points were identified for further investigation: the degree of conservatism incorporated into the modeling analysis, variability of the waste streams, and the affects of waste processing. The degree of conservatism incorporated may be addressed using a sensitivity analysis of nuclide transport processes. This analysis would allow the identification of processes important in affecting nuclide migration within the disposal sites and outside site boundaries. Upon identifying important processes, further analysis could be performed to define the input parameters that control these processes. Those identified may, subsequently, be examined to ensure realistic values were inputed for model use.

Consistent compliance of waste streams with threshold concentrations, over time is not a foregone conclusion as shown by the SRP waste streams. Consequently, determination of waste stream radionuclide concentrations may be necessary on a regular basis. The type and frequency of analysis necessary may have a major impact on cost considerations of disposal.

Many waste streams at both sites had only one or two radionuclides that did not fall below the threshold concentrations. Segregation of the waste at its point of origin before it is mixed with other waste generated within the same building, or the ability to segregate specific radionuclides out of a particular process could increase the number of waste streams ultimately being considered as candidates for sanitary landfill disposal.

Two relatively simple methods of processing waste to reduce nuclide concentrations are dilution and incineration. Dilution would reduce concentrations uniformly to the extent that nonradioactive, or extremely low-level radioactive wastes are mixed into the offending waste stream. The volume of the waste stream being diluted would be increased, thereby requiring greater disposal capacity at the disposal site.

For certain nuclides, most notably H-3 and C-14, significant reductions in absolute levels could be realized, given combustible waste streams. However, as this reduction is accompanied by a concomitant reduction in waste volume, concentrations may not be similarly reduced. In this situation, dilution may be required following incineration. With this processing procedure, as with all others, impact analysis must be performed prior to implementation.

Waste processing, with the intent of bringing waste streams into compliance with concentration limits, must be cost-effective. It is generally inadvisable to treat those streams in which the majority of radionuclides present exceed threshold concentrations. Rather, those waste streams exhibiting only a few outliers should be considered for treatment initially.

Other considerations in waste stream processing include waste stream generation rates and isotopic content. The benefit of investing in waste processing options should be proportional to the volume of waste generated.

Large, initial expenditures may, over time, be expected to pay off if waste volumes are large. In contrast, expensive processing procedures would likely be prohibitive for low-volume waste streams.

Based on a consideration of the operational costs of shallow-land burial and sanitary landfill disposal, implementation of the threshold guidance concept is highly cost-effective at a generic level. The cost advantage of sanitary landfill could be eroded, however, by any additional costs associated with waste stream analysis and/or processing. Clearly, if the costs of analysis or processing reach or exceed the cost advantage value, it would not be cost-effective to proceed with sanitary landfill disposal for those wastes.

SUMMARY AND CONCLUSIONS

Completion of the work outlined above, culminating in the definition of threshold limit dose and concentration levels for each site, provides a method by which very low activity waste may be screened and considered for alternative disposal. In approaching this work it was found that it would be appropriate to incorporate the following ideas:

- Due to the element of subjectivity in the establishment of risk or safety standards, no single value of threshold or de minimis risk or dose would be appropriate for all situations
- The range of previously determined threshold dose recommendations included values of individual annual dose ranging from 0.001 to 1 mSv/yr (0.1 to 100 mrem/yr)
- The inclusion of the size of the population at risk.

The concept of threshold dose guidance varying with the size of the potentially affected population is shown in Fig. 1. Given that the critical population would be small based on the limiting scenarios, 0.3 mSv/yr was selected as the threshold dose guidance upon which calculations were based. If for some reason the controlling scenario changed such that if the affected population significantly increased, the conceptual model for deriving a new threshold dose guidance is in place.

It must be emphasized that application of threshold guidance is intended for waste disposed of on DOE facilities only. Implicit in the assumptions used in exposure scenarios and calculations was controlled access to the DOE facility for a period of time. Evaluations were not made to determine if these assumptions could be applied to a site in the public sector.

A computer model was used to calculate threshold concentrations corresponding to the threshold dose guidance recommended. The INEL and SRP were modeled using site specific data to provide examples of how threshold concentrations could be derived. Both sites, however, will need to carefully reevaluate the input parameters when the threshold guidance is adopted. Other DOE site, in turn, will have to determine the radionuclide concentrations in their waste that correspond to the threshold guidance of 0.3 mSv/yr, using site-specific performance assessment procedures. This allows increased flexibility at the DOE field office level to account for special site conditions.

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