INSIGHTS ON STANDARDS AND CRITERIA FOR WASTE DISPOSAL DERIVED FROM WASTE CLASSIFICATION

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Early in the development of the U.S. Nuclear Regulatory Commission's (NRC) waste management program the need for a waste classification system for the purpose of regulation was recognized. After initial studies, it was decided to base the classification system on the requirements for safe disposal. The ability of various disposal methods to confine waste and the hazards of various waste would be analyzed and the waste would be classified according to "what waste goes where" for their safe disposal.

The purpose of this paper is to present insights on standards and criteria for radioactive waste disposal which have been gained through the development of the Radioactive Waste Disposal Classification System (RWDCS). Waste classification, as such, will not be discussed. The RWDCS has been developed by Ford, Bacon and Davis Utah (FBDU) under the direction of Dr. Vern Rogers and is currently being reviewed by the NRC staff. The RWDCS and the insights being presented do not necessarily reflect the position of NRC. Nor is the RWDCS the only classification system which will be considered by NRC.

At the time the study was initiated there was not a generally accepted definition of safe disposal, nor did it appear there would be such a definition in the near future. Rather than delay the development of the waste classification system until a definition of safe disposal was established, a definition was provided in the form of "study guidelines."

The development of the study guidelines began with the consideration of the system of dose limitation recommended by the International Commission on Radiological Protection (ICRP) as presented in ICRP Publication 26:[1]

(a) no practice shall be adopted unless its introduction produces a positive net benefit;

(b) all exposures shall be kept as low as reasonably achievable; and

(c) the dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission.

Before numerical guidelines could be developed from the ICRP recommendation, the approach to the analyses had to be determined.

Through the use of probabilistic analyses we could attempt to predict the actual risk to man. (Risk = consequences x probability.)

For this type of analyses to be meaningful, a realistic set of probabilities would have to be developed. The difficulties in developing probabilities for the acts of man and nature far into the future for use in a generic study were considered insurmountable. The uncertainties in the probabilities would likely be greater than the refinements in the results which could be achieved with such analyses.

Instead, deterministic analyses which would not explicitly contain probabilities was used. Deterministic or consequence analyses without the use of probabilities would be very conservative; and therefore, the study guidelines to be used with such analyses should not be conservative. With this in mind, the following study guidelines limiting exposures were provided the contractor:

(a) 500 mrem/yr whole body or critical organ equivalent dose rate to few individuals.

(b) 100 mrem/yr whole body or critical organ equivalent dose rate to many individuals.

(c) 1 mrem/yr whole body or critical organ equivalent dose rate to many individuals from the disposal of waste from 1 GWe-yr of energy production.

(d) population doses should not exceed those which could be achieved at a reasonable cost (ALARA).

The next step in developing the RWDCS was to define a reasonably comprehensive and representative set of pathways that could be applied to most waste types and disposal methods. The pathways considered in the RWDCS are of two categories: those in which man comes to the waste and those where the waste moves to man. The first category of pathways, referred to as "on-site reclaimer" events, consists of inhalation, ingestion, and direct exposure events which are postulated to occur when the disposal site is reclaimed for some "reasonable" economic use. The general scenario assumes man will dig basements for homes, grow food and obtain well water on-site.

The second category of pathways, referred to as "off-site transport," consists of groundwater migration of the waste to rivers, erosion of the surface soils from the disposal site and airborne releases off-site.

The on-site reclaimer events are postulated to occur either immediately after disposal or after some period of restricted land use. The first case, no period of restricted land use, is representative of what could happen at an unlicensed disposal facility such as a sanitary landfill. Licensed facilities, such as a shallow land burial ground, are assumed to have some period of administrative control. Restricted land use need not be complete restriction. For example, it may be acceptable or desirable to build warehouses or airfields over burial grounds that are no longer active but are still under administrative control. Such administrative control could be passive in nature.

To determine an appropriate period for restricted land use, the consequences of the on-site reclaimer events were calculated as a function of time using typical low-level waste as the source term. The results for 100, 150, and 200 years after the time of disposal had the ratio of 3.5/1.5/1.0. The reduction of the consequence between 100 and 150 years which resulted mostly from the decay of cesium-137 was judged to be significant. The further decay which occurs between 150 and 200 years was not considered significant. After 200 years the controlling isotope was carbon-14 which has a 5700 year half-life, and further reductions in the consequences from the on-site reclaimer events would require an unacceptably long period of restricted land use.

When different mixtures of isotopes, models, or parameters are used in the calculation, similar results are obtained. A fifth study guideline was provided to contractor: when a period of restricted land use is to be employed, a period of at least 150 years is appropriate.

Using the study guidelines and models for both generic facilities and specific existing facilities, the calculations were made. The results of the calculations are being used to develop the RWDCS. The results also provide for some new insights into the nature of radioactive waste disposal.

The most restricting pathways are the on-site reclaimer events. If the on-site reclaimer exposures are restricted to 500 mrem/yr, then the exposure of individuals off-site will be much less than 100 mrem/yr specified for many individuals and the population doses will be very small. Consider the example of groundwater migration. The individuals on or near the site can obtain well water before there has been significant decay or dilution of the wastes. However, movement of most of the isotopes will be slow and they will decay prior to reaching the more distant surface water and the resulting population dose will be comparatively small. Isotopes which are highly mobile in groundwater and are long-lived, such as iodine-129 or tectium-99, are exceptions. These isotopes are not normally present in large quantities. In general, groundwater migration of the waste is not a restrictive pathway.

Both groundwater migration and surface erosion rates are highly site specific. The impacts of groundwater migration of the wastes depends on the rate of groundwater movement, and for some sites there may not be any groundwater movement; the degree of waste retardation which is both waste and soil specific; the distance to surface water and the demography. Similar variations can be found for surface erosion.

The on-site reclaimer events are not nearly as site specific. Dust resuspension rates can vary, but not nearly as much as groundwater migration rates. Crops can be made to grow in nearly any location and the uptake of the waste by the plants will not vary greatly. The on-site pathway with the greatest variance is well water consumption. For some sites, at least initially, there may not be any well water.

The exposures resulting from on-site events are largely dependent on the concentration of the wastes. The consequences of the off-site migration depends on the total site inventory and site specific parameters. Therefore, it is logical to use waste classification to control the most restricting pathways (on-site reclaimer events) by defining allowable concentrations in the waste to be disposed of by a given disposal method. The licensing process can be used to reduce off-site exposures through proper site selection.

Two of the on-site reclaimer events can be eliminated by burying the waste sufficiently deep to preclude reasonable men from digging into the waste during site reclamation and to avoid plant roots from reaching the waste. For such deeper burial the controlling pathway would be well water consumption. Eliminating the inhalation and food pathways allows substantially higher concentrations of most isotopes to be safely buried. However, because well water can be obtained near the site boundary, deeper burial or a period of restricted land use does not necessarily reduce the consequences of the well water pathway.

On the other hand, if there is not a groundwater system present which is capable of moving the waste or providing well water, even greater concentrations and inventories of waste could be safely buried at the deeper depths. In fact, if man was never to dig into the waste, if roots and animals could never reach the waste, if there never was any groundwater flow, and if natural events did not uncover the waste, then there would not be any limitation on what could be safely buried. However, except for deep geologic repositories, there is little confidence that these conditions will prevail for any given site over a long period of time. It is reasonable to assume that these conditions can persist for at least the 150 years suggested earlier as a period for restrictive land use. The RWDCS does consider deeper burial of waste both without decay if groundwater is present and with 150 years decay if groundwater is not present.

Waste which exceeds the concentrations allowed for deeper burial with 150 years decay should be disposed of in a repository or other disposal facility which provides a high degree of isolation.

The following is a summary of insights which have been discussed:

- Potential exposures from on-site events are usually directly proportional to the concentration of the waste.
- Potential exposure rates from on-site events are much higher than the exposure rates which would result from off-site migration of the wastes.
- Potential exposures from inhalation of the waste or ingestion through the consumption of food grown on site can be reduced by providing for a period of restricted land use of a few hundreds of years and/or deeper burial.
- Deep burial of the waste significantly reduces the consequences of reasonable site reclamation and allows waste of higher concentration to be safely disposed of as compared to shallow burial. However, there may be an increase in population dose commitment if the waste is buried near or in an aquifer.
- The consequence of on-site exposure events are not highly site specific and can be controlled through the choice of appropriate concentration limits.
- Population doses resulting from off-site migration of wastes are directly proportional to the total inventory of waste.
- The use of administrative controls, including restricted land use, has no effect on exposures from the consumption off-site well or surface waters unless such controls are used to keep the place of burial dry.
- The rate and consequence of off-site migration of waste is highly site specific. Limitation

of off-site exposures are best accomplished through proper site selection and inventory limitations rather than concentration limitations.

Some additional insights are:

- Given numerous pathways (i.e., inhalation of dust, food, well water, and direct exposure), a single pathway will completely dominate for any given isotope.

- If the allowed concentrations of individual isotopes are restricted according to their controlling pathways, then the addition of exposures from multiple pathways will not normally increase the total exposure. The existence of multiple pathways would be expected to reduce the total exposure since an atom of waste cannot be present in all pathways at the same time and some of the waste will be in less important pathways.

- The controlling pathway for fission products is usually the food pathway.

- The controlling pathway for alpha-emitters is usually the inhalation pathway.

- Typically, the allowable concentrations of transuranics are about the same as for the more important nontransuranic isotopes.

- Limiting allowable concentrations of waste according to controlling on-site events is expected to reduce population dose to levels below those which would be considered for further reduction using the ALARA philosophy.

This discussion of the insights on standards and criteria for waste disposal derived from waste classification is brief and does not present the numerous qualifications and caveats. A better understanding of the insights can be obtained from NUREG-0456[2] and future reports on the RWDCS.

REFERENCES

1. ICRP, "Recommendations of the International Commission Radiological Protection, ICRP No. 26, Pergamon Press, Adopted January 17, 1977.

2. Adam, J. A. and Rogers, V. L., "A Classification System for Radioactive Waste Disposal--What Waste Goes Where?", NUREG-0456, U.S. Nuclear Regulatory Commission, June 1978.