REGULATORY AND INSTITUTIONAL ISSUES FOR DEVELOPMENT OF REMEDIAL ACTION STRATEGIES AT ORNL*

D. C. Kocher
Health and Safety Research Division
Oak Ridge National Laboratory
P.o. Box X
Oak Ridge, TN 37831-6383

ABSTRACT

This paper discusses a number of unresolved regulatory and institutional issues of fundamental importance to the development of strategies for cleanup of sites contaminated by radioactive materials at Oak Ridge National Laboratory. These issues include [a] the development of criteria for limiting radiation exposures of the public from remedial action sites, [b] the time period to be assumed for active institutional controls over contaminated sites and the location at which such controls will be maintained, and [c] the applicability of current standards for radioactivity in drinking water to surface waters and ground waters on the Oak Ridge Reservation. Proposals for resolution of these issues emphasize the need to protect public health, but in a cost-effective manner.

INTRODUCTION

Important aspects of the Remedial Action Program at Oak Ridge National Laboratory (ORNL) include, first, the development of methods for identifying those existing sites of contamination by radioactive materials that are in greatest need of remedial action and, second, the development of appropriate strategies for those sites requiring remediation. Two types of remedial actions can be considered: [A] use of institutional controls to prevent public access to contaminated sites or unacceptable radiation exposures of the public beyond site boundaries and [b] cleanup and closure of contaminated sites to an extent sufficient to ensure protection of public health in the absence of institutional controls.

This paper discusses a number of unresolved regulatory and institutional issues of fundamental importance to site prioritization and the development of remedial action strategies for radioactively contaminated sites at ORNL. These issues include [a] the development of criteria for limiting radiation exposures of the public from remedial action sites, including exposures of inadvertent intruders onto contaminated sites following loss of institutional controls, [b] the time period to be assumed for active institutional controls over contaminated sites, the location at which such controls will be maintained, and the use of passive barriers to prevent inadvertent intrusion, and [c] the applicability of current standards for radioactivity in community drinking systems to surface waters and ground waters on the Oak Ridge Reservation (ORR). The importance of the latter two issues is related to current levels of radioactivity at contaminated sites and beyond the boundaries of the ORR. Thus, information is presented on levels of radioactivity in the environment and potential radiation doses to the public, including inadvertent intruders, associated with these levels. Finally, needs for additional data and modeling activities in developing remedial action strategies are discussed.

This paper presents proposals for resolution of the issues outlined above which are not in accord with all aspects of current regulations applicable to radioactive waste disposal. Thus, these proposals represent the viewpoint of the author but have not been endorsed by the Remedial Action Program at ORNL or the U. S. Department of Energy (DOE).

PROPOSED RADIOLOGICAL CRITERIA FOR LIMITING PUBLIC EXPOSURES

According to current DOE policy (1), cleanup and closure of sites contaminated by radioactive materials at ORNL will be based on regulations developed by the U. S. Environmental Response, Compensation, and Liability Act (CERCLA). These regulations focus on prioritization of sites for remedial action primarily on the basis of assessments of potential hazards to the public beyond site boundaries (2).

The DOE's and CERCLA Order (1) specifies use of the modified Hazard Ranking System (mHRS) (3) to prioritize radioactively contaminated sites. The mHRS has been applied to remedial action sites at ORNL (4), but the resulting migration scores for all sites were well below the

* Research sponsored by the U.S. Department of Energy under contract DE-AC05-84OR21400 with Martin Marietta Energy Systems, Inc.

minimum that would result in automatic inclusion on the EPA's National Priorities List, primarily because the sites are far from uncontrolled areas. More importantly, there was considerable ambiguity in interpretation of the scoring system, due to the high sensitivity of the results to minor changes in some of the assumptions. Thus, the mHRS was judged inappropriate for site prioritization at ORNL (4).

More sophisticated methodologies for site prioritization, such as the Remedial Action Priority System (RAPS) (5), could be used to overcome many of the limitations of the mHRS. However, such methodologies may be unsuitable for use at ORNL at the present time, because the required data on waste characteristics and site performance currently are unavailable.

Thus, the DOe policy of focusing primarily on releases of radioactivity and exposures of the public beyond site boundaries apparently does not provide a suitable basis for site prioritization or development of remedial action strategies at ORNL. Not only are there the considerable difficulties described above in using existing hazard ranking systems for site prioritization, but in addition as discussed in the next section, past releases of radioactivity from the ORR have resulted in estimated radiation doses to the public that are far below levels that would pose a significant threat to public health and, thus, cannot be used to determine needs for remedial action.

The current DOE policy on cleanup and closure of radioactively contaminated sites does not take into account that release of sites for unrestricted use by the public, following loss of active institutional controls, is a viable goal of remedial actions. Site prioritization and the development of remedial action strategies should be based on potential exposures of inadvertent intruders onto contaminated sites following loss of institutional controls, as well as potential exposures of the public beyond site boundaries, as any time in the future.

It seems reasonable that radiological criteria for limiting exposures of the public from remedial action sites at ORNL can be established on the basis of criteria applicable to new low-level radioactive waste disposal facilities at DOE sites, essentially because both cases involve similar wastes. Thus, on the basis of impending revisions of DOE Orders on radiation protection (6) and management of low-level wastes (7), the following criteria are proposed to define the need for and acceptability of remedial actions at radioactively contaminated sites:

- for off-site individuals beyond any boundary at which institutional controls are maintained, a limit on annual effective dose equivalent from all exposure pathways of 0.25 mSv (25 mrem);
- for inadvertent intruders onto contaminated sites following loss of institutional controls, limits on annual effective dose equivalent from all exposure pathways of 1 mSv (0.1 rem) for continuous exposure and 5 mSv (0.5 rem) for occasional exposure; and
- for community drinking water systems, limits on concentrations of radionuclides or annual dose equivalent as specified in current EPA standards (8) or their future revisions (9).

The dose limit for off-site individuals from all exposure pathways and the EPA standards for radioactivity in community drinking water systems are based primarily on judgments regarding levels of protection that are reasonably achievable using best-available control technologies, rather than the need for limitation of risks to the public per se. The concept of reasonable achievability for these criteria has important implications, discussed later in this paper, for the role of institutional controls at remedial action sites and the applicability of standards for radioactivity in drinking water to any potential sources on the ORR.

POTENTIAL RADIATION DOSES TO THE PUBLIC ASSOCIATED WITH CURRENT LEVELS OF RADIOACTIVITY AT REMEDIAL ACTION SITES

A useful perspective on the development of remedial action strategies at ORNL can be obtained from estimates of doses that could be received at the present time by off-site individuals, and by inadvertent intruders if there were no restrictions on access to contaminated sites.

Doses to Off-Site Individuals

The most important pathway for release of radioactivity from remedial action sites to locations beyond the boundaries of the ORR is believed to be discharge into the Clinch River from White Oak Dam (10). Estimated doses to the public at the present time (11) may be summarized as follows.

- The annual effective dose equivalent due to ingestion of drinking water from DOE or public water systems supplied by the Clinch River is 1 μ Sv (0.1 mrem) or less.
- For a hypothetical exposure time of 250 h per year to contaminated shorelines along the Clinch River, the annual dose equivalent from external exposure would be less than 0.1 mSv (10 mrem).
- The annual effective dose equivalent from ingestion of contaminated fish from the Clinch River is less than 0.01 mSv (1 mrem).

In addition, discharges of radionuclides from White Oak Dam have decreased substantially over the last three decades (10, 11).

These results show that, at present, doses to the public are far below limits in impending DOE standards on

radiation protection (6), proposed standards for new DOE low-level waste disposal facilities (7), and the EPA standards for drinking water (8). Thus, ad indicated in the previous
section, current levels of radioactivity beyond the boundaries of the ORR, and their decreases over time, do not provide a suitable basis for site prioritization and the development of remedial action strategies.

Doses to Inadvertent Intruders at Contaminated Sites

Data are available at a few remedial action sites which can be used to estimate doses that would be received by inadvertent intruders at the present time. It must be emphasized, however, that active institutional controls over contaminated sites are being maintained to prevent such exposures. Hypothetical doses to inadvertent intruders at some remedial action sites may be summarized as follows.

- Average concentrations of radionuclides, principally ^{90}Sr and ^{3}H, in ground water near some sites (11) could result in an annual effective dose equivalent from ingestion of drinking water in excess of 10 mSv (1 rem).
- Large areas of surface soils in Solid Waste Storage Area (SWSA) four have been contaminated with ^{90}Sr and ^{137}Cs due to leakage from burial trenches (12). For ^{90}Sr, the annual effective dose equivalent from the vegetable pathway (13) could exceed 5 mSv (0.5 rem) over large areas and could be as high as 0.2 Sv (20 rem) at some locations. For ^{137}Cs, the annual effective dose equivalent from continuous external exposure (12) could exceed 5 mSv (0.5 rem) over large areas and could be as high as 0.5 Sv (50 rem) at some locations.
- Annual effective dose equivalents from exposure to waste trenches in SWSA 6, based on average concentrations of radionuclides (14) and an intruder-homesteader scenario (13), could be about 0.1 Sv (10 rem), due primarily to ^{90}Sr and ^{137}Cs. In addition, average concentrations of long-lived ^{99}Tc, ^{232}Th, and ^{238}U could result in annual effective dose equivalents that exceed 1 mSv (0.1 rem).

Thus, inadvertent intrusion at some remedial action sites at the present time could result in radiation doses that would be unacceptable, and remediation clearly will be required at some sites. However, appropriate strategies for remedial action may vary greatly from one site to another, due to the wide variations in radionuclide constituents and their present concentrations.

ROLE OF INSTITUTIONAL CONTROLS

If permanent institutional controls over contaminated sites are presumed not to be feasible, then the assumed time period for active institutional controls and the locations at which such controls will be maintained are issues of great importance to the development of appropriate strategies for remedial action. A finite control period could allow significant reductions in concentrations of radionuclides at disposal sites and, thus, future doses to inadvertent intruders, either via radioactive decay for shorter-lived radionuclides (e.g., ^{90}Sr and ^{137}Cs) or via mobilization and transport in water for longer-lived and mobile radionuclides (e.g., ^{99}Tc).

For new DOE low-level waste disposal facilities, a time period of 100 years for active institutional controls has been proposed (7), in agreement with the current assumption for commercial low-level waste disposal facilities (15) and deep geologic repositories for high-level wastes (16). A control period of 100 years presumably will be assumed for remedial action sites, particularly since remedial action sites and new low-level waste disposal facilities at ORNL will be located within the present boundaries of the ORR.

However, there are two factors regarding the time period for active institutional controls that warrant further scrutiny. First, the assumption of a particular time period (e.g., 100 years) does not have a firm technical basis, but represents a largely arbitrary judgment on the length of time that present governmental institutions and their responsibilities will be perpetuated (7, 15, 16). Second, the role of an assumed time period for active institutional controls is quite different for remedial action sites than for new disposal facilities. For new facilities, the assumed control period provides an important basis for waste acceptance criteria for many radionuclides, and wastes with concentrations of radionuclides exceeding limits that would provide protection of future inadvertent intruders must be disposed of elsewhere. At remedial action sites, however, waste disposal occurred without regard for future doses to inadvertent intruders. Thus, the assumed control period may be very important in determining the extent to which cleanup of remedial action sites will be required to protect future intruders. This distinction is important because the costs of cleanup and re-disposal of wastes at previously contaminated sites are likely to be much greater, on a per unit volume basis, than even the costs of off-site shipment and disposal of future wastes.

At many remedial action sites, the principal radionuclides of concern for limiting future doses to inadvertent intruders are ^{90}Sr and ^{137}Cs. Radioactive decay reduces the inventories of these radionuclides by about an order of magnitude every 100 years. On the basis of the intruder dose analyses summarized in the previous section, an institutional control period of 100 years probably will not suffice to reduce the concentrations of ^{90}Sr and ^{137}Cs to acceptable levels at many sites, but a longer control period (e.g., 200-300 years) would eliminate the need for extensive cleanup and re-disposal at a majority of sites. Thus, an important issue for remedial action planning is to establish a reasonable time period for active institutional controls by evaluating the trade-offs between assuming [a] a shorter control period with its lower maintenance costs and institutional impacts but potentially high costs of cleanup and re-disposal of wastes versus [b] a longer control period with its increased maintenance costs and institutional impacts but reduced costs of cleanup and re-disposal. In this manner, a time period for active institutional controls could be established on the basis of technical, social, and economic analyses related specifically to remedial actions at ORNL.

Active institutional controls may be maintained either at the boundary of the ORR, as at present, or at the boundaries of contaminated sites. The latter choice agrees with the proposed DIE policy for new low-level waste disposal facilities (7) and, thus, may be appropriate for remedial action sites. However, the choice should depend, in part, on whether the proposed dose limit for off-site individuals is reasonably achievable at the boundaries of contaminated sites at any time following cessation of operations at ORNL. As in the case of the future protection of inadvertent intruders discussed above, previous waste disposal practices did not take into account the proposed dose limit for off-site individuals. Thus, a determination of the most appropriate locations for maintaining active institutional controls over remedial action sites should involve a balancing of [a] the economic costs and possible lack of acceptance by the public of extensive land-use restrictions in maintaining controlled areas well beyond the boundaries of contaminated sites with [b] the increased costs of cleanup and re-disposal of wastes that may be required to meet the dose limit for off-site individuals at site boundaries that are close to the original locations of wastes.

An alternative to active institutional controls or cleanup of contaminated sites for protecting inadvertent intruders is the use of such passive intruder barriers as in situ vitrification of wastes, grouting or cobbling of waste sites, and marker systems at site boundaries. However, there are difficulties with the use of passive intruder barriers, including [a] the need to demonstrate their effectiveness over the long time periods that may be required for reduction of radionuclide concentrations to acceptable levels and [b] the need to consider reasonable scenarios by which as inadvertent intruder still could contact the waste. Nevertheless, the cost-effectiveness of passive intruder barriers should be considered in developing remedial action strategies.

APPLICABILITY OF DRINKING WATER STANDARDS

Current EPA standards for radioactivity in drinking water apply only to community water systems and only at the point of use (8). However, these standards are potentially quite important for the development of remedial action strategies, because similar requirements are increasingly being applied to any potential sources of drinking water and without regard for the number of potential users. For example: [A] the Superfund Amendments and Reauthorization Act of 1986 has established that drinking water standards are relevant and appropriate for cleanup of ground water at remedial action regulated under CERCLA (17); [b] EPA standards for inactive uranium and thorium processing sites (18) specify the same limits on concentrations of alpha-emitting radionuclides in ground water as in the drinking water standards (8); [c] EPA standards for disposal of high-level wastes (16) contain ground-water protection requirements for 1,000 years after disposal that are similar to the drinking water standards (8); [d] the impending revision of the DOE Order on radiation protection (6) applies the drinking water standards to any public or private water system downstream of a facility discharge; and [e] the EPA's proposed standards for low-level waste disposal (19) contain ground-water protection requirements at disposal sites that could be more restrictive than current drinking water standards (8).

Thus, requirements consistent with current drinking water standards (8) or their future revisions (9) may be applied to potential sources on the ORR, including surface waters and ground waters at contaminated sites, following loss of active institutional controls. This approach could impose severe requirements on cleanup of sites, given expected hydrologic conditions [e.g., see refs. (14) and (20)] and the stringent limits on radionuclide concentrations in water specified by the standards.

Similar to the case of institutional controls discussed in the previous section, application of the drinking water standards to sources at previously contaminated sites has quite different implications from their application to sources at new disposal sites, since current standards affect past disposal practices only in regard to limiting contamination of existing drinking water systems beyond the boundaries of the ORR. Thus, although the current standards are reasonably achievable by off-site water systems and could be used to establish waste acceptance criteria for new facilities, there is a need to determine whether the standards are reasonably achievable for all potential sources of drinking water on the ORR that may be contaminated by remedial action sites, i.e., to evaluate the costs of possibly extensive cleanup and re-disposal of wastes in meeting the drinking water standards in relation to the reductions in health risk to the public that would be achieved.

Although the cost-benefit analysis described above has not been performed, it probably would be reasonable to apply current drinking water standards to sources that are potentially usable by community water standards to sources that are potentially usable by community water systems (8) at any location outside the boundaries of contaminated sites, but doses from drinking water for sources usable by only a few individuals at such locations, which are not covered by the EPA standards, probably should be limited only by the proposed dose limit for off-site individuals from all exposure pathways. However, it probably would not be reasonable to apply current drinking water standards to potential sources within the boundaries of contaminated sites. Rather, doses from drinking water for inadvertent intruders onto contaminated sites should by limited only by the proposed dose limits for intruders from all exposure pathways.

OTHER ISSUES FOR DEVELOPMENT OF REMEDIAL ACTION STRATEGIES

There are a number of additional technical issues that must be addressed in developing appropriate remedial action strategies at ORNL. These include the need for [a] measurements of concentrations of radionuclides at contaminated sites, particularly the long-lived and immobile radionuclides for which institutional controls or passive intruder barriers may not be effective in limiting doses to inadvertent intruders at times far into the future and for which the limits on acceptable concentrations for protection of intruders may be quite low, [b] a better understanding of radionuclide mobilization and transport in water and a better characterization of potential ground-water flow paths, in order to predict future doses to off-site individuals and inadvertent intruders, [c] knowledge of the distributions of individual radionuclides within each remedial action site, rather than average radionuclide concentrations over entire sites, and [d] development of models for estimating exposures at inadvertent intruders for such situations as placement of wastes in auger holes, in situ vitrification of wastes, or use of passive intruder barriers.

CONCLUSIONS

Site prioritization and the development of remedial action strategies for sites at ORNL that have been contaminated with radioactive materials must be based on the need to protect public health, both for off-site individuals and potential inadvertent intruders. This paper has proposed that protection of public health from remedial action sites be defined by radiological criteria which are consistent with those that will be applied by the DOE to new low-level waste disposal facilities.

Given the proposed radiological criteria for remedial action sites, considerations on the role of active institutional controls and the applicability of current standards for radioactivity in community drinking water systems in limiting future radiological impacts on the public are of paramount importance in developing remedial action strategies. Although regulatory precedents exist for specifying active institutional controls and the applicability current of drinking water standards to new low-level waste disposal facilities, it may not be reasonably cost-effective to apply these precedents to previously contaminated sites. Rather, given that completion of remedial measures at ORNL could cost more than one billion dollars (21), it seems essential to develop policies regarding use of institutional controls and the applicability of drinking water standards that take into account these costs in relation to the associated benefits in reducing health risks to the public.

REFERENCES

1. U. S. DEPARTMENT OF ENERGY, "Comprehensive Environmental Response, Compensation, and Liability Act," Order 5480.14 (February 26, 1985).
2. U. S. ENVIRONMENTAL PROTECTION AGENCY, "40 CFR Part 300 - National Oil and Hazardous Substances Contingency Plan," Final Rule, Fed. Registr. 47, 31180 (1982).
3. K. A. HAWLEY AND B. A. NAPIER, "A Ranking System for Mixed Radioactive and Hazardous Waste Sites," Proc. Fifth DOE Environmental Protection Information Meeting, CONF-841187, Vol. 1, p. 33, U. S. Department of Energy (1984).
4. C. E. NIX, F. K. EDWARDS, T. E. MYRICK, J. R. TRABALKA, and J. B. CANNON, "CERCLA Phase I Report: Identification and Preliminary Assessment of Inactive Hazardous Waste Disposal Sites and Other Contaminated Areas at ORNL," ORNL/TM-9989, Oak Ridge National Laboratory (1986).
5. G. WHELAN, D. L. STRENGE, J. G. DROPPO, Jr., B. L. STEELMAN, and J. W. BUCK, "The Remedial Action Priority System (RAPS): Mathematical Formulations," DOE/RL/87-09, PNL-6200, Pacific Northwest Laboratory (1987).
6. U. S. DEPARTMENT OF ENERGY, "Radiation Protection of the Public and the Environment," draft Oder 5400.3 (March 31, 1987).
7. U. S. DEPARTMENT OF ENERGY, "Prospective Revision of DOE Order 5820.2, Chapter III, Management of Low-Level Waste" (April 17, 1987).
8. U. S. ENVIRONMENTAL PROTECTION AGENCY, "Part 141 - National Interim Primary Drinking Water Regulations," Code of Federal Regulations, Title 40, Parts 100 to 149, p. 520, U. S. Government Printing Office (1986).
9. U. S. ENVIRONMENTAL PROTECTION AGENCY, "40 CFR Part 141 - Water Pollution Control; National Primary Drinking Water Regulations; Radionuclides," Advance Notice of Proposed Rulemaking, Fed. Registr. 51, 34836 (1986).
10. T. W. OAKES, W. F. OHNESORGE, J. S. ELDRIDGE, T. G. SCOTT, D. W. PARSONS, H. M. HUBBARD, O. M. SEALAND, K. E. SHANK, and

L. D. EYMAN, "Technical Background Information for the Environmental and Safety Report, Vol. 5: The 1977 Clinch River Sediment Survey - Data Presentation," ORNL-5878, Oak Ridge National Laboratory (1982).

11. T. W. OAKES, C. W. KIMBROUGH, S. F. HUANG, P. M. PRITZ, C. S. GIST, S. T. GOODPASTURE, C. W. WEBER, and F. M. O'HARA, "Environmental Surveillance of the U. S. Department of Energy Oak Ridge Reservation and Surrounding Environs During 1986. Volume 2: Data Presentation," ES/ESH-1/V2, Martin Marietta Energy Systems, Inc. (1987).

12. L. A. MELROY, D. D. HUFF, and N. D. FARROW, "Characterization of the Near-Surface Contamination Associated with the Bathtub Effect at Solid Waste Storage Area 4, Oak Ridge National Laboratory, Tennessee," ORNL/TM-10043, Oak Ridge National Laboratory (1986).

13. D. C. KOCHER and F. R. O'DONNELL, "Considerations on a De Minimis Doese and Disposal of Exempt Concentrations of Radioactive Wastes," ORNL/TM-10338, Oak Ridge National Laboratory (1987).

14. W. J. BOEGLY, Jr., R. B. DRIER, D. D. HUFF, A. D. KELMERS, D. C. KOCHER, S. Y. LEE, F. R. O'DONNELL, F. G. PIN, and E. D. SMITH, "Characterization Plan for Solid Waste Storage Area 6," ORNL/TM-9877, Oak National Laboratory (1985).

15. U. S. NUCLEAR REGULATORY COMMISSION, "10 CFR Parts 2, 19, 20, 21, 30, 40, 51, 61, 70, 73, and 170 - Licensing Requirements for Land Disposal of Radioactive Waste," Final Rule, FEd. Registr. 47, 57446 (1982).

16. U. S. ENVIRONMENTAL PROTECTION AGENCY, "40 CFR Part 191 - Environmental Stanards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes," *Final* Rule, Fed. Registr. 50, 38066 (1985).

17. J. R. TRABALKA, "Developing a Strategy and Closure Criteria for Radioactive and Mixed Waste Sites in the ORNL Remedial Action Program: Regulatory Interface," ORNL/TM-10228, Oak Ridge National Laboratory (1987).

18. U. S. ENVIRONMENTAL PROTECTION AGENCY, "Part 192 - Health and Environmental Protection Standards for Uranium and Thorium Mill Tailings," Code of Federal Regulations, Title 40, Parts 190 to 399, p. 16, U. S. Government Printing Office (1986).

19. U. S. ENVIRONMENTAL PROTECTION AGENCY, "40 CFR Parts 193 and 764 - Environmental Standards for the Management, Storage and Land Disposal of Low-Level Radioactive Waste and Naturally Occurring and Accelerator Produced Radioactive Waste," draft Proposed Rule (September 9, 1987).

20. E. C. DAVIS and R. R. SHOUN, "Environmental Data Package for ORNL Solid Waste Storage Area Four, the Adjacent Intermediate-Level Liquid Waste Transfer Line, and the Liquid Waste Pilot Pit Area," ORNL/TM-10155, Oak Ridge National Laboratory (1986).

21. J. B. BERRY, L. G. HILL, P. E. HOLLENBECK, L. E. MCNEESE, T. E. MYRICK, R. E. PUDELEK, P. S. ROHWER, J. H. SMITH, H. R. YOOK, and E. L. YOUNGBLOOD, "Environmental Restoration and Facilities Upgrade: Preliminary ORNL Long-Range Environmental Management Plan and Budget Document," ORNL-6345, Oak Ridge National Laboratory (1987).