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Approach and Issues Toward Development of Risk-Based Release Standards for Radioactive Scrap Metal Recycle and Reuse[1]

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INTRODUCTION

The decontamination and decommissioning of nuclear facilities is expected to generate large amounts of slightly radioactive scrap metal (RSM). It is likely that some of these materials will be suitable for recycling and reuse. The amount of scrap steel from DOE facilities, for instance, is estimated to be more than one million tons (Hertzler 1993). However, under current practice and without the establishment of acceptable recycling standards, the RSM would be disposed of primarily as radioactive low-level waste (LLW). In the United States, no specific standards have been developed for the unrestricted release of bulk contaminated materials. Although standards for unrestricted release of radioactive surface contamination (NRC 1974) have existed for about 20 years, the release of materials is not commonly practiced because of the lack of risk-based justifications. Recent guidance from international bodies (IAEA 1988) has established a basis for deriving risk-based release limits for radioactive materials. It is important, therefore, to evaluate the feasibility of recycling and associated issues necessary for the establishment of risk-based release limits for the radioactive scrap metals.

EXEMPTION LEVELS

The International Atomic Energy Agency with the Organization for Economic Cooperation and Development/Nuclear Energy Agency, has published principles for the exemption of radiation sources and practices from regulatory control (IAEA 1988). Two basic radiation protection criteria have been prescribed:

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- Individual risks must be low enough to not warrant regulatory concern, and

- Radiation protection, including the cost of regulatory control, must be optimized.

The first criterion is aimed at the protection of individuals while the second meets the as low as reasonably achievable (ALARA) principal for controlling the collective exposure to society. The numerical guidance recommended by IAEA includes:

- 10 μSv/yr dose limit per practice to an average member of the "critical group," and

- 1 person-Sv collective dose commitment from an annual practice.

Using the health risk conversion factor of $5x10^{-2}$ cancer fatality per person-Sv of exposure, recommended by the International Commission on Radiological Protection (ICRP 1991), the annual limit of 10 μSv exposure corresponds to an individual's lifetime risk in the range of 10^{-6} to 10^{-7}. The population dose of 1 person-Sv corresponds to a risk level of 10^{-2} to 10^{-1} annually.

RELEASE ALTERNATIVES AND SCENARIOS

Unrestricted release of radioactive scrap metals results in three major alternatives: reuse, recycle, and disposal. A discussion of each follows.

The *reuse alternative* applies to a surface contamination situation. Reuse includes facility, equipment, small tools/motors, or other salvageable materials. Decontamination may be performed prior to release, to satisfy the standards. Scenarios related to the reuse alternative primarily include building occupancy and tool/equipment reuse. Pathways considered for the reuse scenarios are inhalation, ingestion, external exposure, and exposure to radon and its decay progeny.

The *recycle alternative* is broader than the reuse alternative. The exposure scenarios include activities associated with smelting RSM for workers and the use of metal and products for the general public. Analysis of risk requires knowledge of the recycling process for each material (e.g., different metal types), as well as the specific end-use potentials identified for the recycled products. Because the radioactive contents are usually mixed uniformly following recycling, standards for the recycle alternative should be issued on a volumetric (dispersed) basis. The external exposure pathway is the primary concern, although other potential pathways (such as ingestion via erosion of frying pans [O'Donnell 1978; IAEA 1992]) should also be considered.

The *disposal alternative* regarding unrestricted release specifically applies to disposal at public landfills or by incineration. Scenarios for the disposal alternative involve numerous environmental pathways that are associated with the transport of contaminants at the disposal sites. These pathways include air (inhalation), surface or groundwater (ingestion), ground (external), food crops and animals (food ingestion). Scenarios for incineration would include air emission and transport in the environment. Scenarios would likely include the residential scenario, which usually assumes an on-site resident who maintains a drinking water well and a farm or garden for personal food consumption. For reasons stated previously, disposal of RSM is not a preferred alternative to recycling. However, limits derived from such a practice can be used for evaluating the potential long-term radioactivity reconcentration issue discussed below.

ASSESSMENT METHODOLOGY

Several risk assessments for the release of radioactively contaminated materials have been published (CEC 1988; IAEA 1987; 1992; O'Donnell 1978), including NUREG/CR-5512 issued by the U.S. Nuclear Regulatory Commission (NRC 1992). In all these assessments, pathway analysis has been used to assess risks to potentially exposed individuals. The pathways analyzed include inhalation, ingestion, and external radiation exposure. As stated in NUREG/CR-5512, the existing methods are designed to serve as a "screening model" and are not intended for a "site-specific" analysis. The screening model used conservative parameters that yield overestimated risk values. Another approach, RESRAD-BUILD, currently under development at Argonne National Laboratory, is designed to place emphasis on the "site-specific" issues by using a room compartmental model. The RESRAD-BUILD approach also considers pathways of radon (Rn-222 and Rn-220), which have been determined as important to doses from parent nuclides of radon. Assessment of doses from incineration can be performed by codes such as CAP88 (EPA 1992). For assessment of risk from disposal, a multi-media pathway analysis code such as RESRAD (Yu et al., 1993) should be used.

The activity limit that is protective of workers or the public can be derived for a particular radionuclide from unit dose factors according to the following equation:

$$L = \frac{D_0}{D}, \quad (Bq/cm^2 \text{ or } Bq/g)$$

where D_0 (in μSv/yr) is the dose limit to an individual (e.g., 10 μSv/yr) for the release, and D (in μSv/yr per Bq/cm^2 or μSv/yr per Bq/g) is the worker or public dose per unit activity concentration (e.g., 1 Bq/cm^2 or 1 Bq/g). Limits based on individual doses should be evaluated against the potential population dose commitment in meeting the criterion of 1 person-Sv annually.

KEY PARAMETERS

Conservative assumptions are typically employed in various dose assessment steps because of uncertainty regarding appropriate parameter values. Such conservatism has been consistently assumed in the literature and is acknowledged in the Safety Series No. 111 report (IAEA 1992). A discussion follows of the sensitivity of dose estimates to the parameter assumptions and the ramifications for release standards.

Key parameters affecting dose estimates include: metal dilution factor, nuclide partitioning factors, dust loading rate, ingestion rate, nuclide emission rate, and radon enamation factor. The parameters vary in importance, from those that substantially affect multiple scenarios (e.g., the dilution and partitioning factors) to those that only affect one exposure pathway for one scenario.

LONG TERM CONSIDERATIONS

A discussion of issues resulting from the long-term practice of RSM releases follows.

Proliferation of RSM in the Metal Supply. Continued recycling of RSM gradually increases the percentage of RSM in the common metal scrap returned to smelters, which effectively decreases the dilution rate for RSM. In the Safety Series No. 111 report (IAEA 1992), the resulting buildup of radioactivity in a typical consumer product for a recycling practice is estimated to be about 25% over 40 years. Considering the level of uncertainty in estimated doses and the very low doses associated with undiluted RSM, this increase is insignificant.

Decay Product Ingrowth. For some nuclides, such as radon parents, the potential buildup by ingrowth continues over time. Because radon buildup can be substantial, the release limits for such nuclides should take daughter ingrowth into consideration. That is, maximum doses should be identified and calculated for a specified time duration (e.g., 30 years for building occupancy).

Reconcentration of Radioactivity. Currently, obsolete scrap constitutes about 20 to 25% (IAEA 1992) of the inputs to iron and steel production in the United States each year implying that 75 to 80% is eventually discarded to landfills, where RSM activity could be reconcentrated. Therefore, derived limits should be further evaluated against this potential.

Multiple Exposures. Doses to an average member of the "critical group" are the primary concern (IAEA 1988) for deriving release limits. The "critical group" is defined as a group of individuals who are "representative of individuals receiving the highest levels of dose from a particular practice, and defined so that it is reasonably homogeneous with respect to factors that affect the dose received" (IAEA 1988). Generally, the "critical group" may represent a group of professionals (e.g., taxi drivers exposed to automobiles) and end-use products (e.g., residents exposed to rebars). The potential of multiple exposures (e.g., taxi drivers exposed to automobiles and rebars, etc.) exists if the recycling practice continues for a long period of time. Such exposures would present further constraints on the release limits. Currently, RSM represents a small fraction (less than 1%) of the entire scrap metal inventory. Thus, the issue of multiple exposure may not be a concern. However, a long-term practice should carefully evaluate this potential.

Population Dose Buildup. Population dose commitment from a particular metal release should be assessed for the useful lives of the metal end products. For example, if 10 years is the assumed life of an automobile, exposure to the population should account for that time duration, plus the potential of exposure from future recycling activities. Thus, in calculating the population doses, the long-term exposure potentials should also be considered.

CONCLUSIONS

Recycling and reusing radioactively contaminated metals could be a viable alternative to their disposal as low-level waste. Release of such metals under the current international dose guideline would result in annual public risk levels of less than 10^{-6} for an individual and 10^{-2} for the society. Methodology and data are available to strongly support a conservative yet practical analysis. It is feasible, therefore, to address the issues and to derive risk-based standards for unrestricted release of radioactive scrap metals that are designed to prevent undue risk to the public.

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