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Approach toward Development of Release Standards for D&D Cleanup

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ABSTRACT

The release of materials containing residual radioactivity from a controlled environment in decontamination and decommissioning (D&D) activities has been problematic. The primary impediment to such a release is the lack of a suitable framework within which release standards can be developed. The concept of clearance for radioactive materials was recently introduced by the International Atomic Energy Agency (IAEA) (1). This concept is being evaluated by the international regulatory communities as a basis for setting standards for releasing from control solid materials containing residual radioactivity. Accordingly, both the IAEA (2) and the European Commission (EC) (3) have recently proposed clearance standards. In the United States, the Nuclear Regulatory Commission (USNRC) has just begun its rule-making process on clearance. The term "clearance" was introduced as a regulatory process for releasing radioactive materials posing negligible risks. A trivial risk level has been determined to be a 10^{-6} to 10^{-7} annual risk to an exposed individual, and a population risk of no more than 0.1 for an annual practice. Under these strict constraints, exposure scenarios would be developed to estimate potential doses to affected individuals. Such scenarios may account for processing, disposal, and product end-use of materials. This paper discusses these scenarios and also describes the technical basis for deriving release levels under the suggested risk-based constraints.

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INTRODUCTION

Large amounts of potentially reusable or recyclable materials are expected to occur in the traditional waste streams in the cleanup activities associated with the decontamination or decommissioning (D&D) of buildings or structures. Recent studies (4,5) have estimated a world-wide stockpile of radioactive scrap metals in the order of 30 million tons, of which approximately 70% is steel and iron. Furthermore, a large majority (over 80%) of these scraps are either merely suspected of contamination or can be decontaminated by using current technology. The traditional disposition approach for these slightly contaminated materials is burial in a licensed facility. This disposition approach, however, carries obvious financial consequences such as the loss of potential resources, which would be valued from 10 to 20 billion dollars at the going market price. This approach would also result in the added financial burden, in the order of 5 billion dollars, of having to dispose of the materials in an ever-scarce and expensive licensed burial facility.

The release of materials is not a common practice because of the lack of consistent, internationally accepted criteria and release levels. Recent guidance from international bodies (1,6) has established a basis for deriving risk-based release criteria for radioactive materials. The criteria provide the basis for developing internationally acceptable standards for release of materials containing residual radioactivity.

CONCEPTUAL FRAMEWORK

Protection Principles

The International Commission on Radiological Protection (ICRP) system of protection for practices is based on three general principles (4), which must be satisfied independently. The first principle is justification of practice. That is, no practice that involves radiation exposure should be adopted unless it produces sufficient benefit to exposed individuals or to society to offset the radiation detriment it produces. The second principle is optimization of protection. This principle specifies that the radiation detriment (usually expressed in terms of collective exposure to the population) from the individual sources be maintained "as low as reasonably achievable," taking economic and social factors into account. The third, and final, principle is limitation of individual risk. The intent of this

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principal is to establish an upper limit to the maximum risk to which individuals would be subjected as a result of the combined exposure from all relevant practices.

The first principle, justification of practice, for the release of slightly contaminated materials can be realized by comparing the risks and benefits of such practice with the existing practice of disposal at a licensed burial facility (4,7). The second principle can be demonstrated by developing constraints on the source of exposure. This principal is accomplished by evaluating the alternatives in reaching an optimal exposure to the population. For the third principle, the ICRP further recommends that upper bounds be established for optimization of exposure from individual practices in terms of constraints that are below the limit on maximum exposure to individuals. The current recommended constraint is 1 mSv/yr for members of the general public.

Risk Levels

The International Atomic Energy (IAEA) has published principles for exempting radiation sources and practices from regulatory control (6). Based on the trivial risk levels, the IAEA provides numerical interpretations for the ICRP protection principles (i.e., the second and third principles).

For the collective dose, it is the IAEA's position (1) that "the use of the IAEA minimum value of the man-sievert suggested . . . lead to a practice related to 'trivial' collective dose for exemption purposes of the order of a few man-sievert. For continuing practices this can be interpreted as a commitment of about 1 man-Sv per year of practice."

For the individual dose, the IAEA states, "Most authors proposing values for trivial individual dose have set a level of annual risk of death which is held to be of no concern to the individual at 10^{-6} to 10^{-7} . Taking a round risk factor of 10^{-2} Sv^{-1} for whole body exposure as a broad average over age and sex, the level of trivial individual effective dose equivalent would be in the range of 10-100 uSv per year." In the IAEA's interim report on clearance levels (2), the clearance level for the individual dose is further interpreted to be 10 uSv/yr.

Alternatives and Scenarios

Unrestricted release of materials containing residual radioactivity may follow basic alternatives. The *reuse alternative* can be applied to facilities, equipment, small tools/motors, or other salvageable materials. Decontamination may be performed before release to satisfy standards. Exposure scenarios related to reuse primarily involve building occupants and people who reuse tools and equipment.

The *recycle alternative* is broader than the reuse alternative. Exposure scenarios involve workers associated with recovery activities, such as metal smelting, and members of the general public who use the products. Analysis of risk requires knowledge of the recycling process for each material, as well as specific end-use potentials identified for the recycled products. Because the products' radioactive contents are usually mixed uniformly following recycling, standards for the recycle alternative should be issued on a volumetric (dispersed) basis.

The *disposal alternative* 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. For reasons stated previously, disposal of radioactive scrap materials usually is not a preferred alternative to recycling.

Exposure Considerations

Doses to an average member of the critical group are the primary concern (1) 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" (1). 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 rebar). In such cases, the potential of multiple exposures exists if the recycling practice continues for a long period of time. Such exposures would present further constraints on the release limits. Currently, radioactive scrap materials represent a small fraction (less than 1%) of

the entire scrap metal inventory. Thus, the issue of multiple exposure may be a concern. However, long-term exposure potentials should also be considered.

APPROACH AND METHOD

Several risk assessments for the release of radioactively contaminated materials have been published, including NUREG/CR-5512 issued by the U.S. Nuclear Regulatory Commission (8). In all these assessments, pathway analysis has been used to assess risks to potentially exposed individuals. RESRAD-BUILD, a recently published approach developed by Argonne National Laboratory, is designed to emphasize "site-specific" issues by using a room compartmental model (9). For recycling of metals, the RESRAD-RECYCLE code, currently under development at Argonne National Laboratory, is suitable for use. Assessment of doses from incineration can be performed by codes such as CAP88 (10). For assessment of risk from disposal, a multimedia pathway analysis code such as RESRAD should be used (11).

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:

$$L = D_0/D \text{ (Bq/cm}^2 \text{ or Bq/g)} \quad (\text{Eq. 1})$$

where D_0 (in $\mu\text{Sv/yr}$) is the dose limit to an individual for the release, and D (in $\mu\text{Sv/yr per Bq/cm}^2$, or $\mu\text{Sv/yr per Bq/g}$) 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, as discussed earlier.

SUMMARY OF RECENT DEVELOPMENTS

In the absence of consistent international release criteria, several nations have independently established release criteria suited for various purposes and conditions. Such national criteria are limited and somewhat simplistic. For instance, only a few nations (such as the United States and some European nations) have existing release levels. For the United States, release levels for volumetric contamination do not exist. In most cases, release of materials is, in large measure, still performed on a case-by-case basis.

Recognizing a need for establishing consistent international release standards, some international agencies, including the IAEA (2) and the European Commission (EC), (3) have proposed clearance criteria. Such a need is exemplified by a compelling trend in the increased international trades, where consistent standard is an absolute necessity. The Organization for Economic Cooperation and Development (OECD) (12) recently also issued a report evaluating the potential criteria for reuse and recycling of metals. All the evaluations are based on the general risk-based approach discussed in previous sections. Further, a rather constraining individual dose level of 10 $\mu\text{Sv/yr}$ has been used for deriving the proposed release criteria. A comparison of the derived release levels is shown in Tables 1 and 11 for a number of representative radionuclides.

It can be seen in Tables 1 and 11 that all the derived criteria are strikingly similar, except for a few cases where the basic assumptions and considerations vary. For instance, if radon and its progeny are considered in the dose analysis, the resulting criteria are much more restrictive compared to the ones derived without that dose component. Also, the derived criteria seem to indicate the general conservative nature of the existing national criteria.

DISCUSSIONS AND CONCLUSIONS

An enormous amount of materials is expected to be released from nuclear installations through the cleanup process. The lack of consistent international and national standards impedes the process of releasing materials containing residual activity. Such a release is analogous to discharging radioactive gaseous effluents through the stacks to the atmosphere or liquid effluents through the water treatment system. In these cases, contaminants are removed so the underlying potential risks would become trivial, thus making further efforts to reduce potential risk levels unwarranted or economically unacceptable. The international radiation protection bodies have prescribed principles

Table I. Summary of Existing Release Criteria in Various Countries

Country	Surface Contamination for Beta-Gamma Emitters (Bq/cm ²)	Volumetric Contamination for all Types of Radionuclides (Bq/g)
United States	0.83 ^a	-
Germany	0.37	1.0
Sweden	4.00	0.1
Great Britain	-	0.4
Belgium	0.40	-
Finland	0.40	-

^aPer U.S. NRC Regulatory Guide 1.86 (13).

Table II. Summary of Proposed International Release Criteria for Some Sample Radionuclides

		Proposed		Release Criteria	
		Surface Contamination (Bq/cm ²)		Volumetric Contamination (Bq/g)	
Nuclide Category	Sample Nuclide	IAEA ^a (2)	Ec ^b (3)	IAEA (2)	EC (3)
Alpha	U-238	0.3	1	0.3	1
	Pu-239	0.3	0.1	0.3	0.1
	Am-241	0.3	0.1	0.3	0.1
Beta	Sr-90	3	10	3	10
	Tc-99	300	1,000	300	1,000
Gamma	Co-60	0.3	1	0.3	1
	Cs-137	0.3	10	0.3	1
Volatile	H-3	3,000	10,000	3,000	1,000
Nuclides	I-129	30	10	30	1
Radium ^c	Ra-226	0.3	0.1	0.3	1
Thorium	Th-232	-	0.1	-	1

^aInternational Atomic Energy Agency (IAEA).

^bEuropean Commission (EC).

^cDoses considered include radon and its progeny.

and criteria under which such releases would satisfy all principles of radiation protection. Additionally, assessment methods and scenarios have sufficiently matured to perform a risk-based analysis from which release levels can be derived. Efforts remain in the areas of effective regulatory control and implementation. Furthermore, extensive communication with the public and stakeholders is necessary in order to reach an acceptable scheme for the release of materials.

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