APPLICATION OF EXEMPTION PRINCIPLES TO LOW-LEVEL WASTE DISPOSAL AND RECYCLE OF WASTES FROM NUCLEAR FACILITIES[a]

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INTRODUCTION

The International Atomic Energy Agency (IAEA) and other international groups for the past several years have been investigating the possibility of exempting from regulatory control certain radiation sources and practices, initially under the general heading of de minimis. Much of the interest in this topic arises from the recognition that a significant fraction of the wastes from industry, research, medicine, and the nuclear fuel cycle are contaminated to such low levels that the associated risks to health are trivial. Therefore, the application of regulatory processes seems to be unwarranted. Recently, the IAEA work has been conducted by Advisory Groups on two interrelated levels: to establish principles for exemption, and to apply the principles to various areas of waste management. In the second area, the main objectives have been: 1) to illustrate a methodology for developing practical radiological criteria through the application of the IAEA preliminary exemption principles, 2) to establish generic criteria, and 3) to determine the practicability of the preliminary exemption principles. The method used by the IAEA Advisory Groups to develop the criteria relies on a modeling assessment of the potential radiation exposure pathways and scenarios for individuals and population groups following the unrestricted release of materials. The scenarios and models used are necessarily generic; however, an attempt was made by the Advisory Groups to identify the most important pathways based on available literature. The generic scenarios and methods are intended to provide the basic framework for the numerical derivation of generic exempt quantities that would be adequately conservative in most situations. This paper describes the IAEA's assessment methodology and presents the generic results expressed in terms of the limiting activity concentrations in municipal waste and in low-activity materials for recycle and reuse.

PRELIMINARY EXEMPTION PRINCIPLES

As the result of recent IAEA Advisory Group efforts on the subject of exemption, the IAEA published interim general principles for exemption of sources and practices that result in both individual and collective doses of very low significance (IAEA 1987a). The principles are intended to be quite general and applicable to any type of manmade radiation source that gives rise to trivial risks; they do not, however, apply to natural sources of radiation. These interim exemption principles provide a safety margin to account for selected individuals who may be exposed to radiation from several exempted sources and

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to account for the uncertainty of future human activities. With this safety margin in mind, an Advisory Group to the IAEA recommended that the individual doses from a single exempted source or practice should not exceed 1% of the existing individual dose limit for members of the public, or 10 μSv. This dose equivalent is less than 0.5% of the annual effective dose equivalent from natural background radiation and is small compared with the natural variation in background radiation. For skin doses, the IAEA Advisory Group also recommended a dose limit of 1% of the existing limit, or 500 μSv (IAEA 1987a).

The IAEA Advisory Group also recommended that consideration be given to controlling the collective dose to provide additional assurance that many small doses will not add to a significant total and to guard against the possibility that this could occur without the knowledge of controlling authorities for sources which are exempt and, therefore, not subject to notification and registration. The Advisory Group recommended that as part of the "basic case" for exemption, the collective effective dose equivalent commitment from the exempted source or practice should be about 1 person-Sv or less (IAEA 1987a). This does not preclude national authorities from exempting sources that give rise to larger collective doses, but merely establishes a condition below which no further consideration needs to be given on the radiological basis for exempting a source. The Advisory Group considered that sources and practices which comply with the conditions relating to individual and collective dose may be exempted from the normal regulatory requirements of registration and notification, and treated just as if no radiation exposures were involved.

DESCRIPTION OF GENERIC METHODS

Exempt quantities, expressed in units that relate to radiation-detecting instruments, are a more practical expression of the general exemption principles. The steps used by the IAEA Advisory Groups in deriving exempt quantities for a defined source or practice involve: 1) establishing a series of radiation exposure scenarios that account for various exposure pathways and conditions, 2) estimating the resulting radiation doses to individuals and population groups for these scenarios, 3) determining the limiting (highest dose) scenario for each radionuclide, and 4) determining the concentration of individual radionuclides that would result in the exemption criteria (dose limits). In assessing the radiation doses, the IAEA Advisory Group advised that care must be taken in the selection of parameters, assumptions, and data (IAEA 1987b). For their assessments, the IAEA Advisory Group judged scenarios on the likelihood of their occurrence leading to human exposure and the likely magnitude of those exposures. In addition, the potential exposure of a critical population group was necessary.

In their evaluations to date, the IAEA Advisory Groups have considered: 1) disposal of exempt wastes in a sanitary landfill (IAEA 1987b); 2) disposal of exempt wastes by incineration (IAEA 1987b); 3) recycle of contaminated steel, aluminium, or concrete;(a) and 4) reuse of concrete buildings, tools, or equipment.(a) The radiation exposure pathways included external exposure to penetrating radiation, inhalation of airborne material, and ingestion of contaminated food crops or removable surface contamination (through secondary transfer from hands to the mouth). A variety of representative radionuclides were considered to fully explore the radionuclide-dependence of the resulting exemption limits. These radionuclides were chosen to represent alpha emitters (^{239}Pu and ^{241}Am),

(a) As described in a draft working document on "The Application of Exemption Principles to Wastes from Decommissioning and Recycle of Materials from Nuclear Facilities."

high-energy photon emitters (^{60}Co), low-energy photon emitters (^{55}Fe), and pure beta emitters (^{90}Sr and ^{99}Tc).

The potential radiation exposures resulting from different scenarios that may be envisaged have a probability of occurrence that may range from zero to one. Thus, judgment is necessary when including scenarios for the derivation of exempt quantities. As a result, most attention was paid to those scenarios where individuals could have direct contact with the radioactive materials. These scenarios included workers at landfills, incinerators, smelters or recycle centers, and consumers who may use materials made from recycled materials or who reuse released buildings, tools, or equipment. Additional scenarios, such as use of ground water near a landfill or release of volatilized material through the stack at a smelter, were also included to provide an estimate of the likely collective dose.

RESULTS AND DISCUSSION

Example results for the groupings of reference radionuclides and the various types of exemption considered by the IAEA Advisory Group are summarized in Table 1. The results are presented in terms of reasonably expected ranges, based on the various radionuclides in each group, and the expected variation among exposure scenarios. Control of the future fate of exempted materials through unrestricted release is lost; thus, material exempted for recycle or reuse could be disposed of in a landfill, or material exempted to a landfill could be recycled or reused. Because of the lack of future control, the proposal has been made that a single exempt quantity should be established which would cover all alternative future conditions, without placing specific limitations for landfill disposal, incineration, recycle, or reuse. This appears to be possible because of a close grouping of the results shown in Table 1 across most radionuclide and unrestricted-release categories.

TABLE 1. Example Exempt Quantities for Various Exemption Categories

Exemption Category	Alpha Emitters	High-Energy Photon Emitters	Low-Energy Photon Emitters	Pure Beta Emitters
Sanitary Landfill (Bq g^{-1})	1 - 10	0.1 - 10	(a)	300 - 600
Incineration (Bq g^{-1})	0.1 - 100	0.5 - 10	(a)	10^2 - 10^3
Recycle(b) (Bq g^{-1})	1 - 10	1 - 10	10^4 - 10^5	40 - 300
Building Reuse (Bq cm^{-2})	1 - 5	0.004 - 1	10 - 100	60 - 500
Reuse of Tools and Equipment (Bq cm^{-2})	10 - 100	10 - 100	60 - 500	10^2 - 10^3

(a) No radionuclides were considered for the scenarios shown.
(b) For recycle of steel, aluminium, or concrete rubble.

Three potential groupings of released material are: 1) mass concentrations (in units of Bq g^{-1}), 2) surface contamination in buildings (in units of Bq cm^{-2}), and 3) surface contamination on reused tools and equipment (in units of Bq cm^{-2}). Further, it appears that a set of radionuclide groupings could be made by combining the high-energy photon emitters and alpha emitters into a single grouping across all categories. The resulting overall exemption limits are summarized in Table 2.

TABLE 2. Preliminary Exemption Limits for all Release Categories

Limit Category	High-Energy Photon and Alpha Emitters	Low-Energy Photon and Pure Beta Emitters
Mass Concentration (Bq g^{-1})	1 - 10	10^2 - 10^3
Building Surfaces (Bq cm^{-2})	0.1 - 1.0	10^2 - 10^3
Reuse of Tools and Equipment (Bq cm^{-2})	10^1 - 10^2	10^2 - 10^3

Again, ranges of values are shown to denote the potential variations of radionuclides and exposure conditions. For mixtures, the sum of the fractions rule could be applied. The net result for mixtures is that the limit is controlled by the most restrictive radionuclides present. It may be noted that for all scenarios considered, the individual dose criterion is limiting in relation to the exempt mass concentration and surface contamination limits; the collective dose criterion is the determining factor, however, in assessing the total quantity of material that may be buried, incinerated, or recycled. The IAEA work will continue, because further studies are needed to determine if additional practical considerations (including costs and detectability) will change the results or the basic conclusions. At the same time, the preliminary exemption principles will be reviewed again, taking due account of the experience gained through these applications.

REFERENCES

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