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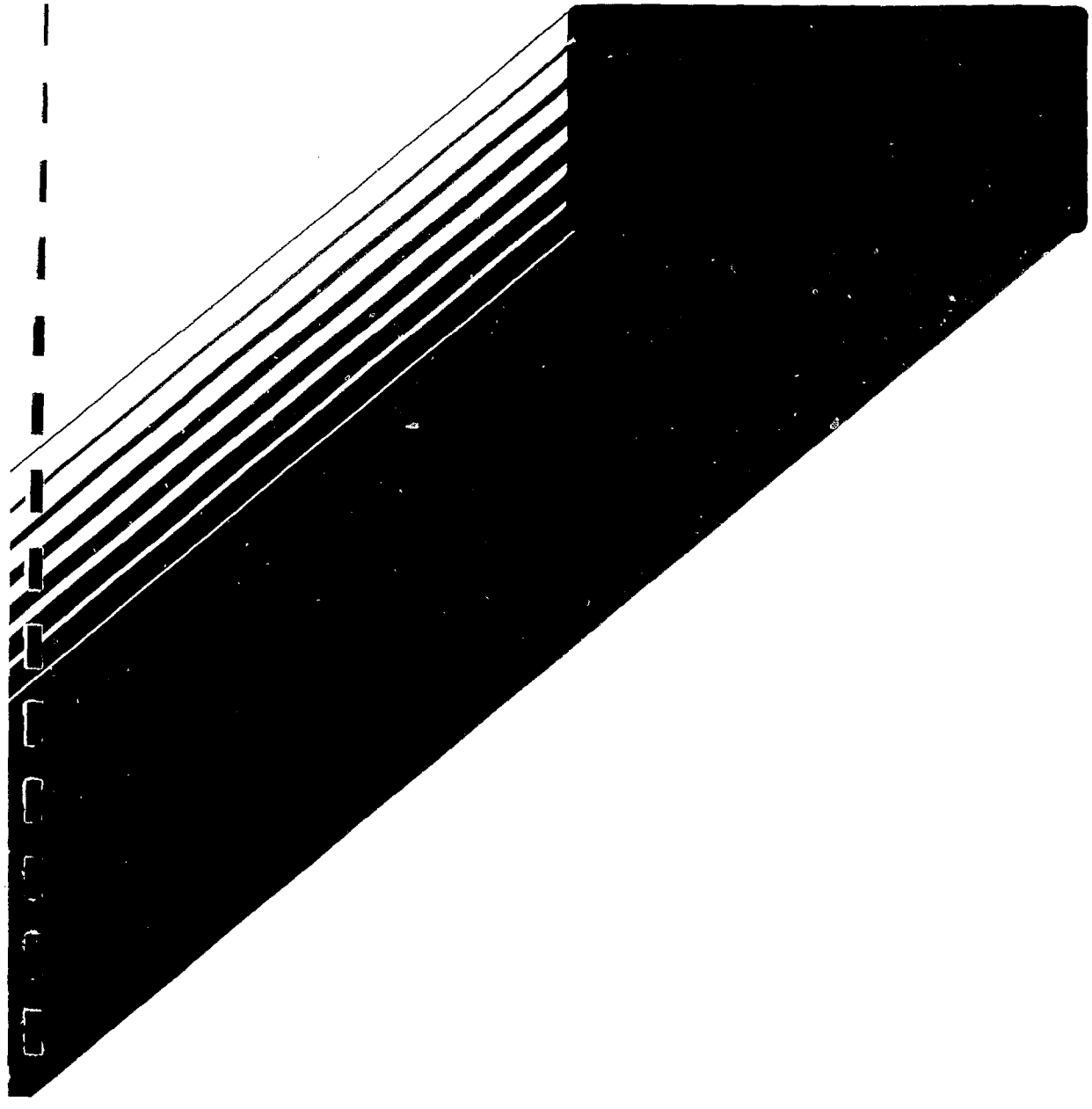

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AN APPROACH TO THE EXEMPTION OF MATERIALS FROM REGULATION AS RADIOACTIVE WASTES

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ABSTRACT

Staff of the Atomic Energy Control Board are proposing to establish a general framework for assessing the radiological impact of radioactive waste management practices. This framework features, in addition to the familiar radiation protection principles concerning dose limits and optimization, the concept of trivial doses that are so low that for practical purposes they may be neglected. The rationale for the derivation of numerical criteria for trivial doses is based primarily on considerations of risks to individuals in small and large populations.

The concept of trivial individual doses has wide application and significant implications for a variety of waste management practices, including the definition of contaminated materials that are exempt from regulation as radioactive wastes. Examples are given of the practical application of this approach to specific waste disposal issues.

RÉSUMÉ

Les spécialistes de la Commission de contrôle de l'énergie atomique proposent de mettre sur pied un plan de travail général dans le but d'évaluer les répercussions d'ordre radiologique des méthodes de gestion des déchets radioactifs. Dans ce plan, figure à côté des principes connus de radioprotection portant sur les limites de doses et l'optimisation, le concept des doses insignifiantes qui, de par leur peu d'intensité, peuvent être négligées à toutes fins pratiques. Le bien-fondé des critères numériques pour les doses insignifiantes tient surtout à des considérations sur le risque qu'encourent des personnes faisant partie de populations à faible et à forte densités.

Le concept des doses individuelles insignifiantes jouit d'un champ d'application très étendu et pourrait avoir des conséquences importantes pour plusieurs méthodes de gestion des déchets, notamment en ce qui a trait à la définition de certaines matières contaminées qui échappent à la réglementation des déchets radioactifs. L'exposé décrit, avec exemples à l'appui, l'application de cette approche à des problèmes précis d'évacuation des déchets.

AN APPROACH TO THE EXEMPTION OF MATERIALS FROM REGULATION AS RADIOACTIVE WASTES

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INTRODUCTION

The Atomic Energy Control Regulations require that any prescribed substance associated with the development, use, application or production of atomic energy shall not be abandoned or disposed of except in accordance with a licence that is in effect or in accordance with the written instructions of the Atomic Energy Control Board (AECB). This requirement implies that a regulatory judgement must be made in every case where it is proposed to dispose of radioactive waste from nuclear fuel cycle operations or the use of radioisotopes no matter how low the concentration or quantity of radionuclide present. Embodied in a working definition of "radioactive waste", however, is the concept that there are some waste materials that have such low radionuclide content that the radiological health risks associated with their disposal in an unrestricted manner are negligible and for which there is consequently no practical requirement for regulatory control.

Various attempts to identify such materials, often referred to as de minimis wastes, in terms of an upper bound concentration or quantity have met with great difficulty, even in the case of a radionuclide which, depending on the practice, may follow different pathways through the environment to humans. The approach being developed at the AECB for the exemption of materials from regulation as radioactive waste requires initially the agreement on a level of radiological health risk which for practical purposes may be neglected. Such a step, though contentious, does not in fact contradict the linear, non-threshold hypothesis for the dose-response relationship. Rather, a judgement is made that such risks below the selected level can be ignored.

The concept that very low doses may be neglected is a particularly significant factor in decisions related to practices for the management of radioactive wastes that extends beyond the mere categorization of de minimis wastes. The concept also provides a fundamental basis for relinquishing regulatory controls over waste disposal practices and offers a pragmatic approach to dealing with some of the otherwise intractable problems associated, in particular, with assessments of the long-term behaviour of long-lived wastes.

In the present paper, a general framework for assessing the radiological impact of waste management practices is outlined which accepts the notion that there are trivial doses that may be ignored. A rationale is also presented for the definition in numerical terms of trivial dose criteria from which de minimis waste concentrations and quantities may be derived. Finally, a number of examples are given of de minimis waste issues that have been satisfactorily resolved through the use of this approach.

GENERAL FRAMEWORK FOR ASSESSING THE RADIOLOGICAL IMPACT OF WASTE MANAGEMENT PRACTICES

The general framework by which the AECB is proposing to assess the radiological impact of any waste management practice comprises the following three statements of principle:

(i) the dose limits specified in the Atomic Energy Control Regulations shall be observed;

(ii) all doses arising from a radioactive waste management practice shall be kept as low as reasonably achievable, economic and social factors being taken into account;

(iii) there are some doses arising from radioactive waste management practices which are so small that, for practical purposes, they may be neglected.

Notably absent from these three principles is the justification principle recommended by the International Commission on Radiological Protection (ICRP) in its system of dose limitation. This principle has been omitted here since the production of radioactive wastes is an inevitable consequence of nuclear fuel cycle operations and the uses of radioisotopes. Any justification of waste management practices must therefore be examined in the context of the net benefits derived from nuclear power production and the use of radioisotopes in industry, medicine and research.

In the application of these principles to waste management practices, it is recognized that there are uncertainties associated with predicting the doses likely to be received by individuals. These uncertainties arise in the assumptions, data and models that are employed in predictive analysis and, as a result, there is no absolute assurance that any specified dose will not be exceeded. However, the probability of exceeding a prescribed dose will be required to be appropriately small. An examination of the uncertainties in dose calculations must therefore be conducted in order to understand the relationship between a prescribed dose and the probability of exceeding that dose. Obviously, the rigour and comprehensiveness of an uncertainty analysis should be commensurate with those of the overall predictive analysis, which are in turn determined by the scale of the potential radiological impact of the practice. Regardless of the magnitude of the practice and in keeping with the differences in the intent of the dose limits and trivial dose criteria, the allowable probability of exceeding the dose limits will be smaller than that associated with the criteria that determine whether a dose may be neglected.

Notwithstanding the probabilistic nature of dose estimates, the interrelationship of the three principles may be schematically represented in simplified form as shown in Figure 1. This diagram displays the dose limits as a boundary between acceptability and unacceptability and the trivial dose criteria as annual individual dose levels below which no further optimization of radiation protection is necessary. It must be emphasized here that the trivial dose criteria are neither regulatory limits that must be observed nor criteria that determine the acceptability of a waste management practice. Rather, they define an upper bound of annual individual doses that may be neglected for practical purposes. Thus, for waste management practices for which the predicted doses received by individuals are unlikely to exceed the trivial dose criteria, no further expenditure of resources for additional analysis and precautionary measures is necessary to reduce the collective dose commitment.

It must be emphasized also that the establishment of trivial dose criteria must not be interpreted as a licence to disperse and dilute in the environment large quantities of diffuse wastes or small quantities of highly concentrated wastes. Dispersion and dilution as a method of disposal is considered acceptable only for limited amounts of radioactive wastes. Furthermore, while it might be quite possible to design containment and isolation

practices for the disposal of all wastes such that doses received by members of the public are below the trivial dose criteria, other factors, such as radiological health hazards to workers, may be such that nuclear regulatory controls are retained during the operational period. Nonetheless, the achievement of trivial levels of individual dose in any post-operational period would, by definition, be sufficient technical reason to relinquish nuclear regulatory controls over the practice.

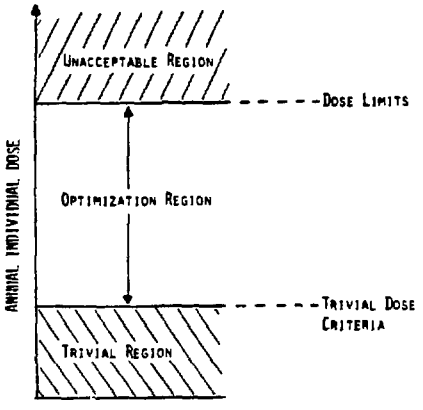

FIGURE 1. ILLUSTRATION OF RADIATION PROTECTION PRINCIPLES FOR WASTE MANAGEMENT.

The diagram in Figure 1 also shows that the dose limits and trivial dose criteria define the optimization region in which all doses must be kept as low as reasonably achievable, economic and social factors being taken into account. Any practice for which the predicted doses lie in the optimization region may also be judged acceptable provided the costs and benefits are rationalized, although there are, of course, various other driving forces to keep doses as far below the dose limits as possible. In a quantitative analysis to determine the optimized level of radiation protection, the trivial dose criteria find further application since, by definition, all annual individual doses below the criteria need not be taken into account. Thus, the criteria may be used as annual individual dose cut-offs in both space and time in the calculation of collective dose commitments.

DEFINITION OF TRIVIAL DOSE CRITERIA

Of the various methods that may be used to determine the level of annual dose that would be considered insignificant by individuals, AECB staff have chosen risk as the appropriate reference. This approach was decided on the basis that risk is ultimately the common denominator in all methods that may be used and the conversion from risk to dose is sufficiently well understood even though there may be limitations in extrapolating from mortality risk factors determined at high doses to effects that may occur at very low doses.

Risk is a factor present in all human activities. There is always some chance of serious injury or death, even if the chances are very small. Attitudes towards risks vary from person to person and can be influenced by such factors as whether the risks are voluntary or involuntary, whether they are unusual or not and whether they are likely to occur soon or far in the future. Aversion to an elevated risk is sometimes overcome if the person, or persons, involved perceive that there are adequate compensatory benefits.

It is apparent that individuals generally accept occupational risks in the range 10^{-5} - 10^{-3} fatalities per year (1 ~ 100 deaths per year for every 100,000 workers). Indeed some individuals accept voluntary risks associated with their occupations or recreational pursuits that are even greater than 10^{-3} per year. This wide range may reflect the degree of influence that those who accept the risks feel they have over the situation that affects them. Risks over which people feel they have some control tend to be accepted more readily than risks that they feel are beyond their control.

From information reviewed by the ICRP concerning risks that are regularly encountered by members of the public in every day life, it seems that individuals are likely to accept risks of fatalities in the range 10^{-6} - 10^{-5} per year. Furthermore, surveys of risks associated with various activities have indicated that risks of 10^{-6} per year may be the threshold for risks that are considered insignificant by individuals. For

example, the risk of being struck by lightning, which is about 10^{-7} per year, appears to be ignored by most individuals.

A risk of 10^{-7} per year has been selected as the basis for setting a level of annual dose below which individual doses may be neglected. This is one order of magnitude lower than the level which appears to be the threshold delineating insignificant risk. Selecting the lower level is a conservative move intended to allow for uncertainties in the number of sources to which an individual may be exposed and to ensure that doses corresponding to this magnitude of risk will indeed be regarded by most as trivial. Since the mortality risk factor for radiation-induced cancers is generally accepted as being approximately 10^{-2} per sievert, as an average for both sexes and all ages (ICRP-26), the statistical individual risk of 10^{-7} per year can be expressed as an annual individual effective dose of 10 microsieverts. This level of dose then becomes the upper bound for individual doses which may be regarded as trivial.

A dose rate that may be ignored on the basis of individual risk may not necessarily be ignored by society if large populations are affected. In such cases, the individual dose rate would need to be lower and thus a further stipulation is made that all individual doses below 1 microsievert in any year may be regarded as trivial irrespective of population size. The theoretical implication of this proposal is that if large numbers of people were exposed to annual individual doses of 1 microsievert, a significant collective dose could be ignored. In practice, it is unlikely that large populations would be uniformly exposed to the same annual dose, however small, and so the actual collective dose ignored would be less than the theoretically-implied value.

When populations of only a small size are affected an alternative approach is proposed. In such cases, annual individual doses in the range 1 - 10 microsieverts may also be disregarded. A small population is arbitrarily defined as being no greater than 100,000 persons, as this is considered to be a reasonable size of local population that might be so affected as a result of a practice that gives rise to a maximum annual individual dose of 10 microsieverts. Under these circumstances, the additional collective dose to be neglected, as a result of 100,000 persons receiving annual doses in the range 1 - 10 microsieverts, likely represents only a small increment on the collective dose already ignored as a result of not including annual individual doses below 1 microsievert from the same practice. At the same time, the maximum individual risk of fatality is maintained at the trivial level of 10^{-7} per year.

In rigorous terms, the trivial doses that may be ignored are expressed in the following ways:

(a) the effective dose received by any person in any year which does not exceed 1 microsievert, irrespective of the size of the exposed population, and

(b) the effective dose received by any person in any year provided that the maximum effective dose in any year as a result of the practice does not exceed 10 microsieverts and that the population receiving doses in the range 1 - 10 microsieverts, in the same year, does not exceed 100,000 persons.

COMPARISON WITH NATURAL BACKGROUND RADIATION

To provide further perspective on these numerical criteria, it is instructive to make a comparison with natural background radiation. The dose received in a year from natural background radiation varies significantly from place to place depending on a number of factors such as elevation above sea-level and the amount and type of radionuclides in the soil. In Canada, individual doses from all natural sources lie in the range 1 - 2 millisieverts per year and variations of 0.1 - 0.2 millisieverts per year in a geographical region are common. A dose of 1 microsievert in any year received by any individual is a factor of 10^3 less than the lower end of the range of annual natural background dose and is also well within the range of variation in natural background radiation normally encountered. If such a dose rate represents a sufficiently small fraction of the annual dose from natural background radiation or its variation that it may be considered trivial, then the collective dose rate arising from large populations receiving annual individual doses at this level should also be considered trivial. This judgement seems reasonable since the collective dose rate derived from individual doses of 1 microsievert per year will amount to an insignificantly small proportion of the collective dose rate from natural

background radiation that humans have endured throughout their evolution.

APPLICATION OF TRIVIAL DOSE CRITERIA TO DE MINIMIS WASTE DISPOSAL PRACTICES

In the exemption of materials from regulation as radioactive wastes, it is important to recognise that whether or not trivial doses are received by members of the public is the outcome of considering the nature of the wastes, the practices and the pathways. Since trivial doses resulting from the release of radioactive materials to the environment are unlikely to be measured directly, they must be calculated using mathematical models that are formulated from experimental data and from realistically conservative assumptions which characterise the materials, the transport pathways, the exposure pathways and the metabolism of the radionuclides involved. While judgement will clearly be needed when selecting the models and the input data and when examining the certainty with which trivial doses can be predicted, it should be possible to derive concentrations and quantities of radionuclides that describe de minimis wastes.

When speaking of de minimis wastes it is implied that the wastes themselves present negligible radiological hazards and could be re-used or otherwise disposed of in an indiscriminate or unrestricted way. This really means that the wastes will be handled and disposed of in a manner dictated exclusively by the properties of the host material.

On the other hand, wastes of somewhat higher concentration or quantity of radionuclides may also be exempt from further regulatory control provided that adequate restrictions are incorporated into the disposal practices such that the resultant doses to members of the public are below the trivial dose criteria. These wastes would essentially be conditionally exempt from regulation as radioactive waste and could be re-used or disposed of using only those options which ensure that subsequent misuse of the materials is highly unlikely. In this case, it is expected that administrative controls other than those of the AECB would be in place to ensure that the materials are properly contained and isolated from the environment. When considering the wide spectrum of radioactive wastes that are generated at all major steps in the nuclear fuel cycle and from the use of radioisotopes, judgement will again be necessary in determining those waste types and streams that lend themselves to exemption from regulation by the above approaches.

CASE STUDIES

To date, decisions to exempt materials from regulation as radioactive wastes have been made on a case-by-case basis. The following summaries of case studies are provided to illustrate the application of the trivial dose criteria to de minimis waste disposal practices.

Incineration of Liquid Scintillation Fluids

A number of universities, hospitals and other institutions are licensed to use ^{3}H, ^{14}C, ^{32}P, ^{35}S and ^{125}I for biomedical research purposes. These research activities generate substantial quantities of radioactive wastes including contaminated liquid scintillation fluids containing microcurie per litre concentrations of these radioisotopes. The principal techniques for the management of the waste scintillation fluids are immobilization followed by storage at licensed facilities and incineration at both licensed and unlicensed facilities. Regulatory decisions to permit unlicensed incineration at several locations in Canada were based on simple and conservative estimates of the average annual dose received by members of the public being approximately 0.05 microsieverts. In addition, the concentration of radioisotopes in the waste scintillation fluids are such that no special transportation and handling procedures are necessary beyond those normally required for the unused organic solvents.

Incineration and Landfill Disposal of Ionization-Chamber Smoke Detectors

Domestic ionization-chamber smoke detectors, (ICSDs), generally contain microcurie quantities of ^{241}Am in the form of a sealed source where the radioisotope is sandwiched between two layers of inactive material. In 1978, the AECB relaxed its requirements on the management of spent ICSDs used in private residences thereby permitting the disposal

of these devices with municipal garbage. Generic assessments by the OECD-Nuclear Energy Agency and by USNRC of the radiological impact of this practice have predicted that doses to members of the public from deposition of ICSDs in landfill sites and from waste incineration are small fractions of the trivial dose criteria presented here. However, the assessments necessarily made assumptions regarding the annual rate of disposal of ICSDs to a landfill site or municipal incinerator and hence there remains an obligation on the AECB to maintain general surveillance over such practices to ensure that the cumulative impact is indeed insignificant.

Use of Contaminated Ammonium Salt Solutions as Fertilizer

By-products of the uranium mining, milling and refining industry include solutions of ammonium nitrate and sulphate that are contaminated with low levels of natural uranium and ^{226}Ra. Conservative assessments of the usage of these solutions in agricultural fertilizer applications over a 100 year period showed that the concentrations of natural uranium and ^{226}Ra in the soils thus treated were increased by 5% and 0.02% respectively. Considerations of the corresponding chemical toxicity and radiological health implications via the edible plant pathway revealed that any effects on members of the public would be insignificant. Authorized concentration levels for the disposal of contaminated ammonium salts as fertilizer were consequently established. It should be noted that the authorized ^{226}Ra level is within the range normally found in commercial fertilizers.

SUMMARY

The approach being developed by the AECB for the exemption of materials from regulation as radioactive waste is based on a definition of annual individual doses that may be considered as negligible. Numerical criteria for such trivial doses have been derived from considerations of risks that are believed to be ignored by individual members of the public and of the collective risk if large populations are exposed to trivial doses. These trivial dose criteria form one component of a general framework for assessing the radiological impact of waste management practices and as such find applications that extend beyond the basis for deriving concentrations and quantities of radionuclides that describe de minimis wastes. Thus, the criteria may also be used (a) for truncating collective dose commitment calculations in quantitative optimization analyses; (b) for determining whether an optimization analysis and any further radiation protection are necessary and (c) as a reference point for the relinquishing of regulatory controls over a waste management practice.

As an illustration of the practical application of the trivial dose criteria to the exemption of materials from regulation as radioactive wastes, examples have been given of several cases that have been successfully resolved. Until further experience is gained with the application of the criteria to other waste types and waste streams from nuclear fuel cycle operations and the use of radioisotopes, regulatory decisions on this subject will continue to be made on a case-by-case basis.

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