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NEW IAEA GUIDELINES ON ENVIRONMENTAL REMEDIATION

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INTRODUCTION

There are many areas around the world contaminated with radioactive substances which may require remediation. The source of contamination with radionuclides varies; the most important sources include nuclear testing, radiation accidents and inadequate waste disposal practices. Contamination at such sites may present a risk to humans and the environment. Therefore, issues related to remediation of such sites are potentially of concern for both the general public and a wide variety of stakeholders. In response to the needs of its Member States, the International Atomic Energy Agency (IAEA) has published many documents covering different aspects of remediation of contaminated environments. These documents range from safety fundamentals and safety requirements to technical documents describing remedial technologies for legacy sites, former uranium mining areas and territories affected by radiation and nuclear accidents (IAEA, 1994, 2003, 2007).

In recent decades,many various options for remediation have been developed, tested and implemented in contaminated areas. As a result, a large amount of data on the effectiveness of management options has been generated, together with information on ancillary factors such as the required resources and costs. In response, the IAEA initiated the development of a new document, which incorporated new knowledge obtained during last 20 years, lessons learned and subsequent changes in the regulatory framework. The new IAEA document (IAEA, 2012) covers all aspects related to the environmental remediation from site characterisation to a description of individual remedial actions and decision making frameworks, covering urban, agricultural, forest and freshwater environments.

The primary objective of the new technical report is to provide Member States and responsible organizations with information on available management options for remediation of terrestrial and freshwater ecosystems contaminated with radioactive substances. An associated objective is to provide guidelines on formulation of sustainable remediation strategies based on the experience and lessons learned following previous severe radiation

accidents and other existing situations. The report also guides readers to relevant IAEA documents providing detailed information on different aspects of remediation.

CHARACTERISING THE CONTAMINATED ENVIRONMENT FOR REMEDIATION PURPOSES

Decisions taken to commence remediation need to be based on an accurate assessment of the amount and extent of contamination in relevant environmental compartments and how they vary with time. Therefore, a comprehensive evaluation of the site is an essential first step in application of remediation of contaminated environments. The IAEA has previously published many documents on characterization of contaminated environments and associated environmental monitoring as a tool for underpinning remediation strategies and evaluating the effectiveness of implemented remedial actions (IAEA, 1998). The current document outlines key stages in characterizing the contaminated environment including: an initial survey, monitoring during implementation of remediation programme and a final survey (compliance monitoring). Both *in situ* and sampling-based techniques are described along with basic concepts used for sampling of major environmental compartments such as soil, plant animals and foodstuff.

EVALUATING REMEDIAL OPTIONS

Management options used in a remediation strategy should also be part of a sustainable approach which will allow either regular agricultural use or other use of contaminated areas, as well as commercial trading and social and cultural activities to continue. Such positive social and economic consequences can act as important additional benefits of remediation, in addition to dose reduction. Remedial actions aiming at the reduction of exposures to the public are subject to the application of the three radiation protection principles: justification of practice, optimization of protection and limitation of individual doses. One challenge, therefore, is to identify features of different potential management options which allow a remediation strategy to be derived that complies with each of these three criteria.

Remediation strategies need to take account of variation in radionuclide activity concentrations with time in different environmental compartments, in food and in feed for animals. Changes with time in these compartments may differ between different types of ecosystem and are particularly affected by soil type for some radionuclides, such as radiocaesium, in the longer term. The document provides comprehensive description of basic criteria used for evaluating management options. These criteria were grouped as follows: effectiveness and feasibility, economic cost, remediation waste, side effects and constraints. Attention was also given to social and ethical issues.

MANAGEMENT OPTIONS FOR REMEDIATION

The new IAEA document focuses on the management options which have been identified to be suitable for consideration in a remediation strategy. Many of them are similar to those

given in the previous international reviews such as (IAEA, 1994, Howard *et al.*, 2005; Nisbet, 2009), but there are some differences in the options considered and their content. The descriptions of the various management options given in the document address key issues that are relevant to their implementation based on practical experience, and provide some guidance regarding their usefulness as part of a remediation strategy.

The management options presented in the documents are subdivided into four groups, namely, those for agricultural and non-agricultural systems, generally applicable options and food processing management. The agricultural options include soil-based management options, management options for fodder production, crop-based options, animal-based management options, whilst non-agricultural options describes actions applicable for freshwater and forest environments. Generally applicable options cover different exposure pathways and consider: selection of alternative land use, topsoil removal or replacement, attenuation of external dose from contaminated soil and prevention of fire. Finally, food processing options describe processing of crops, vegetables, milk, meat and fish.

Some management options were not recommended to be considered in a remediation strategy for a variety of reasons, as being: (i) not sustainable, in that they do not sustain normal socio-economic activities; (ii) largely relevant only as countermeasures for the emergency situation and would preferably be avoided if a subsequent remediation strategy is functioning effectively; (iii) technically effective, but with significant disadvantages such as high cost currently inadequately supported by scientific evidence of cost-effectiveness; (iv) not likely to be technically effective and (v) associated with significant adverse side effects. Food bans, dilution of food, decontamination techniques for milk, phytoremediation, administration to animals of stable analogues for radiocaesium, *in-situ* leaching of soil to remove radionuclides are examples of the options which can be excluded from remediation strategy due to above reasons.

REMEDIATION PLANNING, OPTIMISATION AND DECISION AIDING TECHNOLOGIES

There are many technical and non-technical factors that need to be taken into account as part of the process of preparing an adequately justified remediation strategy. Therefore, generalised recommendations which do not take the diversity of local site-specific conditions into account can result in inadequate decision-making and may not be feasible to implement. The document describes basic concepts and technologies to be used to optimize decisions on remediation of areas affected by radionuclides. A review of the existing Environmental Decision Support Systems is also provided along with practical examples.

The effective response to contamination of the environment should be based on a multidisciplinary approach. Because of this, the selection of management options based only on the advice of radiation protection or other experts may lead to inadequate decisions. On the other hand, the examples presented demonstrate that the remediation strategies which give a priority to social factors are often less cost-effective and requires larger resources for

remediation compared with strategies based only on radiological criteria. The document demonstrates examples for selection of optimal management strategies based not only on specific information on individual management options, but also on the use of multi-attribute utility analysis which considers the involvement of stakeholders as one of the key components.

CASE STUDIES

The new IAEA technical report provides many examples of successful remediation experiences in agricultural, forest and aquatic environments contaminated with radionuclides. Areas affected by the major radiation accidents (Kyshtym and Chernobyl accidents) and nuclear tests (Bikini atoll and Maralinga) were considered as case studies. Special attention was given to evaluating experience in identification of a remediation strategy in different periods after depositions, remediation criteria used to assess a need in remediation and effectiveness of corresponding options. Overall, the selected case studies provide good illustrations of the concepts, data and decision making methods suggested by the new IAEA guidelines for remediation strategies to reduce the radiological consequences of environmental contamination.

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