Assessments of Health and Environmental Risks of Management Options for Contaminated Land

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Contents

1 Introduction

The purpose of this SAFEGROUNDS paper is to encourage a consistent approach to the assessment of the health and environmental risks associated with land management options. The paper deals with assessments for radioactively contaminated land, land contaminated with non-radioactive contaminants and land with mixed contamination. More detail is provided for radioactively contaminated land because there is little existing guidance. The paper does not deal with assessments for the purpose of finding out whether land is contaminated in the Part IIA sense, because the approach for these is largely described in regulatory guidance.

Within the framework of the SAFEGROUNDS guidance on the management of contaminated land on nuclear and defence sites, the main type of risk assessment required is as part of the detailed characterisation of those management options that are to be compared when identifying the preferred option(s) [Hill et al 2002]. This paper focuses on this type of assessment. The same assessment approach may also be useful for carrying out other types of assessments. Examples are scoping/screening assessments to distinguish options for further consideration from other envisageable options, and assessments made during site characterisation [Hill et al 2002; Baker et al 2000]. The approach is not intended to be used for the safety cases produced to gain regulatory and other approvals for implementation of the option preferred by the site owner/operator. When results will feed into major decisions, it is recommended that stakeholders should either be involved in performing assessments (particularly in setting out the scope, methodology and basic assumptions) or be invited to review assessments before options are compared.

2 Scope of Assessments

The scope of assessments is defined largely by Principle 1 of the guidance, which requires that there be a high level of protection of people and the environment (see Section 2 of Hill et al [2002]). Scoping considerations are as follows.

- In general, assessments should produce estimates of health risks to the public and workers, estimates of risks to organisms other than humans, and estimates of contamination levels in the relevant parts of the environment (air, soil, groundwater, foods, houses etc), in routine and incident/accident situations. The level of detail required depends on the scale of the contaminated land situation (see Section 3) and on how the results are to be used in characterising options on their attributes (see Section 6).

- Estimates of risks during and after implementation of the management option are required, including risks in the long term. If a management option is intended to make the land fit for more than one end use, the assessment should cover all relevant uses.

- If implementation of an option would produce effluent or solid wastes, the assessment should include estimates of risks of management of those wastes (e.g. treatment, storage, transport, and disposal).

- It is generally appropriate to include information on uncertainties in estimated risks and contamination levels. The preferred approach is to use best estimate

assumptions and parameter values in the first instance, then go on to produce a range of results corresponding to different assumptions and parameter values (see Section 3.6).

- Results of assessments are to be used mainly in comparisons of options, so relative values of risks and contamination levels are generally more important than absolute values. This may influence both the methodologies and models used in assessments, and the extent of any sensitivity analyses.

3 Assessments of Options for Radioactively Contaminated Land

3.1 GENERAL APPROACH

The guidance on assessment methods given in this section focuses on assessments for the post-implementation period at the site concerned and its environs. Assessments for disposal of the types of wastes produced in implementing options, for example, for solid waste to be disposed of at a specialist facility for such waste, will have been prepared elsewhere. This does not mean that such assessments are irrelevant to the decision for the site concerned, only that the risk assessment will have been carried out for the purposes of the operation of that other facility. Its results should be used for the contaminated land assessment.

The set of potentially relevant endpoints include: radionuclide contamination levels, people's radionuclide intakes, individual doses and risks associated with those intakes, collective dose and number of health effects, and risks to the health of biota, all as a function of time and space during and after the implementation of the management option. It may be sufficient to assess a subset of these endpoints, depending on the nature of the contamination, the land concerned and the options under consideration (see Section 3.2) and on how the results of the assessment are to be used in characterising options on their attributes (see Section 6).

The timeframe for the assessment will depend on the management option and on the radionuclides involved. It is unlikely to be shorter than a hundred years, because of the radioactive half-lives of most of the radionuclides of concern on nuclear and defence sites. It is also unlikely to be as long as thousands of years, because in most cases none of the management options being compared will leave land in a contaminated state for thousands of years or more.

For simplicity, the main calculations are best carried out using currently recommended values of environmental transport parameters for radionuclides, doses per unit intake of radionuclides and risk per unit dose. The references for dose coefficients (relating intake of radionuclides or exposure to external sources to radiation dose) are ICRP Publication 72 [ICRP, 1996] for intake of radionuclides and FGR13 [USEPA, 1998]. The ICRP relationship between radiation dose and health risks to humans is given in Publication 60 [ICRP, 1991]. It should be recognised that some groups of stakeholders do not accept ICRP recommendations. Alternative views should be taken into account when forming a preliminary view on the significance of the source term (see Section 3.2) and should be examined in sensitivity analyses (see Section 3.6).

The following assessment steps are suggested, based on a source, pathway, receptor approach.

3.2 ESTABLISH PRELIMINARY VIEW OF SIGNIFICANCE OF SOURCE TERM

This step begins with identification of the relevant contamination source term in terms of the activity levels of the main radionuclides, their physico-chemical forms, and their spatial distribution over and under the land concerned. This information will be available from site characterisation. These levels are then compared with those published for other purposes, in order to gain a preliminary view of the order of magnitude of potential doses to individual people. Levels that might be used for comparison are given in NRPB [2000], European Commission [2000], Hill et al [1999] and WHO [1993]. If doses seem likely to be of the order of microsieverts then a simple assessment may be sufficient. If doses are of the order of hundreds of microsieverts or more then much more detail will be needed.

It is also necessary in this step to bear in mind scientific uncertainties and stakeholder views. It would be unwise to conclude that levels of a particular radionuclide are of little significance, and to then pay little attention to them in assessments, if recent evidence has called into question the scientific basis for the judgement of significance. Such an approach would be inefficient, because the assessment is likely to have to be repeated at a later stage. Similarly, it is sensible to take into account stakeholder concerns about particular radionuclides, and particular physico-chemical forms of radionuclides, when judging source term significance and establishing assessment methodology, because this could save time later on.

3.3 SYSTEM DESCRIPTION

This step is to determine the features of the site and its environment. Relevant features will include soil type and land cover, surface and subsurface groundwater bodies, and the current land use. The amount of detail required will be influenced by the significance of the source term. Details of potentially relevant system components and how they can be characterised for the purposes of radiological assessment are available in the output from the International Atomic Energy Agency's BIOMASS programme [IAEA 2001a]. Such full details as shown in Table 1 would not normally be required but the table indicates the types of information that could be relevant.

Table 1: Example System Components based on BIOMASS

Principal Component	Definition	Required information
Climate and atmosphere	Climate is the expression of meteorological parameters over an area.	For example, rainfall, temperature, windrose, now and in possible future climate states..
Water bodies	Water bodies (surface and subsurface water masses) and may include near-surface aquifers.	Whether such features are present in the biosphere system.
Human activity	Human activity describes the nature of the communities, their habits, their ways of life.	Nature of the communities, their habits, their ways of life.

Table 1: Example System Components based on BIOMASS

Principal Component	Definition	Required information
Biota	Biota are the terrestrial and aquatic plant and animal life in the biosphere system.	A distinction should be made between domestic and wild flora and fauna and between those in the food chain and those which are not but are used by humans for purposes other than food.
Near surface lithostratig-raphy	Near surface lithostratigraphy describes the general characteristics of soils and sediments including both their composition and structure.	Near surface lithostratigraphy includes all weathered material above the bedrock and associated life forms (excluding those predefined under flora). It can include bedrocks if they contain aquifers which are to be considered within the biosphere.
Topography	Topography is the configuration of the earth's surface including its relief and relative positions of natural and man-made features.	Information should be provided concerning the features of the system under consideration and its relief.
Geographical extent	Geographical extent defines the boundaries and/or spatial domain of the biosphere.	At a minimum, the area over which direct contamination of the biosphere may occur should be considered. It should be recognised that extent may change as a function of time.
Location	Location is the position of the biosphere system on the earth's surface.	Information concerning latitude and longitude should be provided for site-specific contexts. For more generic situations, less specific information might be available e.g. coastal, inland, distance from sea, altitude.

3.4 SCENARIO CONSTRUCTION

This step is to construct scenarios, i.e. simple descriptions, for the evolution of the source term within the described system according to the assumed future land use associated with each option under evaluation. These descriptions should include:

- controls over land use
- assumptions for land use
- processes likely to results in migration and accumulation of radionuclides
- processes likely to give rise to radiation exposure of people and non-human biota as a results of the presence, or migration and accumulation of radionuclides.

Modes of radiation exposure considered should include ingestion and inhalation of radioactively contaminated materials, including dust, aerosols, soil and foodstuffs,

as well as external irradiation from contaminated soils and other materials. Not least since local people may be aware of local conditions, such possibilities should take into account local advice.

The key issue is to identify the more significant mechanisms by which people and other biota could come into contact with the more significant levels of radionuclides. Scenarios should include likely as well as unlikely events and processes.

3.5 DEVELOP/ACQUIRE AND APPLY ASSESSMENT MODELS AND DATA

An assessment model is no more than a set of assumptions on which a calculation can be based, in this case concerning the risks to people and the environment. It is recommended that the simplest models be used that meet the purpose of the assessment. That purpose is to be able to distinguish effectively between the options under consideration, taking account of the factors discussed in Section 2. Based on the output from the steps in Sections 3.2-3.4 above, a set of assessment endpoints should be chosen from those mentioned in Section 3.1.

The models are normally developed in stages, including a conceptual description, a mathematical representation of that description and then the selection of data for the mathematical models. In general, new models will not be required; rather, based on the output of previous steps and the choice of endpoints, models can be chosen from the literature. Furthermore, many of these models can be implemented on spreadsheets and do not require sophisticated techniques or software. Useful examples, including some generic example results, are described in Hill et al [1999], NRPB [2000], FSA [2002] and IAEA [2001b]. These documents focus on impacts on people. The Environment Agency R & D Report 128 [EA, 2001] provides methods and data, as well as a CD for implementation of models, to assess the impacts on non-human biota.

In the case of more significant contamination it may be appropriate to apply more sophisticated models, e.g. for the long-term migration of contamination through the ground. A comparatively simple approach is presented by the IAEA's ISAM methodology [IAEA, 1997]. Site specific information on the near-surface hydrology may be required, or other detailed site investigation necessary, in order to provide suitable site specific input.

The assessment process typically involves some iteration. For example, suitable data may not be available for the initial choice of model, or some variant exposure pathway which is locally relevant may have been identified, and so a variation in the model may be appropriate. Any such developments should be transparently documented and justified. Preliminary results may be used to identify the more significant impacts and hence guide assessment iterations.

3.6 SENSITIVITY ANALYSIS

In most cases a sensitivity analysis should be carried out to address variations in assumptions and parameter values, and perhaps models. The analysis could be quantitative or semi-quantitative, and need not involve complex calculations. The aim is to produce a range of results so that it can be seen whether the comparison

of options has a different outcome if very different assumptions and parameter values are used in estimating risks.

The analysis could include, for example, different assumptions about people's habits and about the likelihood that their radiation exposure will lead to health effects, and different values for environmental transport parameters. In designing the analysis it is important to bear in mind that the results of the assessments are to be used in comparing options. Thus it is not necessary to vary an assumption or parameter value that will affect the estimated risks from all options in exactly the same way.

4 Assessments of Options for Non-Radioactively Contaminated Land

Guidance on risk assessments for non-radioactively contaminated land is available in a number of publications (see, for example, Environment Agency [1999], SNIFFER [1999], CIRIA [1995], Welsh Development Agency [1993], Scottish Enterprise [1994]). The most recent guidance on human health risk assessments was published this year [Environment Agency 2002].

The approaches recommended in these publications are not dissimilar to that for radioactively contaminated land outlined in Section 4 but tend to be described in different terms. The endpoints of the assessments will also be different. For non-radioactively contaminated land they could be: contamination levels, intakes, health risks, fractions/multiples of maximum tolerable intakes, fractions/multiples of environmental quality standards (EQSs) or environmental assessment levels, (EALs) or threshold limit values (TLVs). For the reasons given in Sections 2 and 3, it is recommended that assessments for non-radioactively contaminated land include sensitivity analyses.

5 Assessments of Options for Land with Mixed Contamination

The recommended approach is to do two separate assessments: one for radioactive and one for non-radioactive contamination. The radioactive assessment should take account of any likely effects of non-radioactive contamination on radionuclide movement through the environment and uptake by organisms. The opposite influence is unlikely since the radionuclide contamination is only likely to be present at very low levels in terms of chemical concentration and so is unlikely to affect the behaviour of other chemicals. As yet, it is not possible to deal with potential synergistic health effects.

Depending on the nature of the contaminants and the land management options that are to be compared, it can be important that the methodologies used for the radiological and non-radiological assessments are consistent in key respects. One particular issue is the time frame considered. Non-radiological assessments tend to consider shorter time frames than radiological assessments. If the non-radioactive contaminants are ones that are persistent in the environment, and the radioactive contaminants have long half-lives, then it may be necessary to extend the non-radiological assessment to longer times. This can be done by bringing elements of

the radiological assessment methodology into the non-radiological assessment, for example by including the same long-term scenarios.

6 Use of Results in Characterisation of Options on Attributes

The results of the health and environmental risk assessments covered in this paper are to be used in characterising options on attributes related to impacts on human health and to impacts on the environment (see Hill et [2002]). They may also be used for attributes of a social nature. For example, it is clear that contamination levels in various environmental media may affect matters such as property prices, inability to sell land that has residual contamination, and reluctance to use groundwater that has residual contamination and foods and natural materials that are contaminated. Even if health risks are thought to be low, the existence of contamination levels that appear to be high (e.g. large Bq/g values) can have a real adverse impact that should be considered in comparing options.

For all these attributes it may be possible to use assessment results as they stand to rank or score options (see Hill et al [2002]). For example, in the case of radioactively contaminated land, sub-attributes for impacts on human health could be defined to be maximum individual risk and collective dose, and for impacts on the environment the sub-attributes could be doses to various species. Non-health impacts could be dealt with by attributes that are simply contamination levels in particular media.

Alternatively, sub-attributes could be defined in terms of fractions/multiples of reference levels. For humans these reference levels could be those related to regulatory effort (e.g. an individual risk of one in a million per year, a collective dose of 1 man sievert). For organisms other than humans they could be the levels at which damage to populations of that species is believed to occur. This latter approach is easier to use for non-radioactive contamination, where the endpoints of assessments are more likely to be in the form of fractions/multiples of reference levels (see Section 4). For mixed contamination it is usual to have separate sub-attributes for radiological and non-radiological impacts, since this provides the opportunity to wait these impacts differently, if required.

It will often be the case that some assessment work is carried out before attributes and sub-attributes have been fully defined. This does not necessarily mean that assessments have to be repeated when the definitions are available. It will frequently be possible to convert existing results to the required form. If repetition is necessary this will be easier if simple assessment methodologies and models have been used.

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*Other publications in this series are:
CLR 8 Potential contaminants for the assessment of land

CLR 9 Contaminants in soil: collation of toxicological data and intake values for humans

CLR 10 The contaminated land exposure and assessment model (CLEA). Technical basis and algorithms.

SGV 1, 3, 4, 5, 7, 9, 10. Soil guideline values for arsenic, cadmium, chromium, inorganic mercury, nickel, selenium, lead

TOX 1, 2, 3, 4, 5, 6, 7 8, 10. Contaminants in soil, collation of toxicological data and intake values for humans for arsenic, benzo(a)pyrene, cadmium, chromium, inorganic cyanide, lead, mercury, nickel, selenium.