Review of dose criteria for cleanup of contaminated land

S Mobbs, J Cooper and W Oatway

Abstract

Dose criteria for the cleanup of contaminated land have been recently recommended by ICRP in ICRP publication 82. They address both practice situations and intervention situations.

The aim of this poster is to discuss the radiological framework for developing criteria for defining areas of radioactively contaminated land.

The dose criterion can be related to operational quantities such as cleanup values by the use of a methodology to calculate doses. NRPB has developed a methodology which has been used in a number of studies. This methodology is described in a separate paper.

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1 Introduction

Contaminated land can give rise to chronic exposures, in other words exposures that persist in time. Specific examples are the exposure of the public from land that has been contaminated by past practices or previous events: early luminising operations with Ra-226, testing of nuclear weapons, and long term contamination following an accident.

The aim of this poster is to describe international radiological protection principles for contaminated land, particularly the recent International Commission on Radiological Protection (ICRP) recommendations. The ICRP is the primary international body for recommending radiological protection standards. Its latest recommendations for an overall system of protection were issued in 1990 as ICRP publication 60 (ICRP, 1991). Recommendations for prolonged exposure (contaminated land) were issues in ICRP publication 82 (ICRP,1999).

The ICRP system distinguished between two categories of exposure: practices and interventions. Practices are situations which lead to an increase in the exposure of individuals or to new individuals being exposed. Emphasis is on the control of the source of exposure and this can generally be planned for before commencing the practice. Examples of practices are the generation of electricity by nuclear power and the production of radioisotopes for medical or research usage. ICRP's principles of protection for practices are:

i) No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. (The justification of a practice.)

ii) In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account. This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or the risks to individuals in the case of potential exposures (risk constraints), so as to limit any inequity resulting from the inherent economic and social judgements. (The optimisation of protection.)

iii) The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures. These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances. Not all sources are susceptible to control by action at the source and it is necessary to specify the sources to be included as relevant before selecting a dose limit. (Individual dose and risk limits.)

In simpler terms, these principles may be phrased as follows: Radiation can cause harm and therefore any intended use should be worthwhile (Justification) and, this being the case, all <u>reasonable</u> steps should be taken to reduce exposures (Optimisation). Doses and risks from uses of radiation should be kept within pre-defined limits or constraints (dose and risk limitation) - obviously, this principle does not apply to sources which cannot be controlled.

Interventions are situations where the sources, pathways and exposed individuals are already in place when a decision on control has to be taken. In such situations, protection can only be achieved by intervention; that is by removing or modifying existing sources or pathways, reducing the numbers of people exposed or reducing the time for which they are exposed. The system of radiological protection recommended by ICRP for intervention has the following principles:

i) The proposed intervention should do more good than harm, ie, the reduction in radiation detriment resulting from the reduction in dose should be sufficient to justify the harm and the costs, including social costs, of the intervention. (The justification of intervention.)

ii) The form, scale and duration of the intervention should be optimised so that the benefit of the reduction of dose, ie, the benefit of the reduction in radiation detriment, less the detriment associated with the intervention, should be maximised. (The optimisation of intervention.)

In most cases, intervention cannot be applied to the source of the exposure and has to be applied in the environment and, particularly in the case of accidents, to an individual's freedom of action. Thus a programme of intervention will always have some disadvantages but should always be justified in the sense that it does more good than harm. Thus, ICRP recommends that dose limits for practices (and, by inference, dose constraints) do not apply in intervention situations. There will, of course, be some level of dose approaching that which would cause serious deterministic effects, where some form of intervention will be almost always required.

Intervention situations are distinct from practices in that the principles of justification and optimisation apply to the measures taken to reduce doses, termed remedial action, rather than to the exposures. Thus, decisions on intervention involve the consideration of the level of avertable dose judged to offset the costs and other disadvantages of a remedial action. It is simpler, however, in situations involving long-term exposures to specify in advance a level of dose, or directly measurable quantity, above which action should be taken. Such criteria are termed action levels. From the above discussion, it will be clear that in situations where an action level is just exceeded, any measures taken should result in a substantial reduction in doses in order to be justified.

2 Intervention or practice?

Contaminated land situations may be considered either a practice or intervention depending on the precise circumstances. Where contaminated land is to be subject to change of use leading to greater public access then this would introduce additional or new exposures to the radionuclides and would be considered a practice. Where, however the "current use" of the land is being addressed, the principles of intervention apply. In the UK the "current use" may be taken as '*any use which is currently being made, or is likely to be made, of the land and which is consistent with any existing planning permission…'*

Intervention implies measures to be taken to reduce existing doses. Where contamination is discovered on land currently in use and no change of use is planned or occurs, then measures may be taken to reduce doses. These measures would be classed as intervention. The source, pathways and receptors are already in place and the intervention would seek to reduce or eliminate the received doses (the balance of risks and benefits is optimised).

Some times it is not easy to categorise a particular contaminated land situation into intervention or practice. ICRP 82 (ICRP, 1999) advises that if one can choose *a priori* whether to accept sources and their attendant exposures, then the exposure is due to a practice, and control should be planned in advance (ICRP, 1999). Subsequent steps to reduce doses would be regarded as improvements in the practice. If there is no choice, because the sources already exist, then any action to reduce doses is intervention. Thus, if the practice giving rise to the contamination is still continuing, then action to reduce doses would be regarded as a practice.

3 Advice for practices

ICRP advice on the radiological protection of the public in situations involving prolonged exposures is given in ICRP 82 (ICRP, 1999). In the case of practices, ICRP recommends the use of a dose constraint of a value no more than 300 _Sv y^{-1}. In cases where radionuclides are being released to the environment, ICRP recommends use of a 100 _Sv y^{-1} constraint for the component of dose delivered by long-lived radionuclides in circumstances where it cannot be shown that the build up of doses with time will not exceed 300 _Sv y^{-1} (ICRP, 1999).

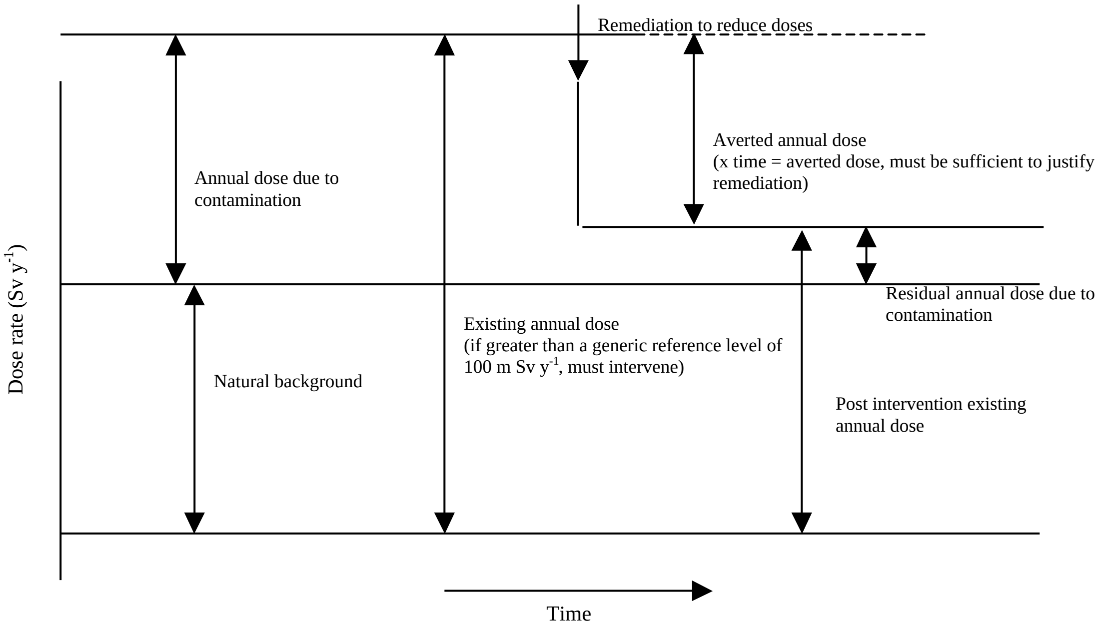
NRPB issued advice on radiological protection objectives for land contaminated with radionuclides (NRPB, 1998). This also addresses both practice and intervention type situations. In order to ensure that doses and risks to the public will not be unacceptable, NRPB recommended that the additional risk to a member of the critical group, attributable to the residual contamination, should not exceed a maximum risk constraint of 10^{-5} y^{-1}. For year on year exposures over a lifetime, this corresponds to the risk associated with an effective dose of about 300 μSv y^{-1}.

NRPB recognised that it is also useful to provide guidance on a level of future risk below which the optimisation requirement can be relaxed. Therefore, NRPB recommended that it is unlikely that significant expenditure to reduce the excess risk to a member of the critical group of site occupants below about 10^{-6} y^{-1} would be warranted on radiological protection grounds. Risks below 10^{-6} y^{-1} are generally considered to be 'broadly acceptable', and correspond to a dose of about 20 μSv y^{-1}.

4 Advice for intervention

ICRP 82 defines a number of quantities: the existing annual dose, the averted dose, and the post intervention existing annual dose. The existing annual dose is the total dose being received by the individual, including natural background. The intervention is carried out to reduce the existing annual dose; the dose saved is called the averted dose and the remaining residual dose is called the post intervention existing dose. This is illustrated in Figure 1.

Figure 1 Intervention



Intervention is required to reduce the existing annual dose if a de facto exposure situation is judged to be unsatisfactory from the point of view of radiological protection. In other words, intervention must be justified. Justification of intervention should consider the following factors: the existing individual and collective annual doses; the anxieties they cause; the political pressures to remedy the situation; the reassurance produced by the intervention; the costs, harm and inconvenience introduced by the protective action; the social disruption; and the occupational doses incurred by those implementing the intervention.

Optimisation is the process of deciding on the form, scale and duration of the protective actions. This involves assessing a range of justified intervention options. The optimum solution may not necessarily be that which delivers the lowest residual dose. Intervention may take the form of a single set of protective actions that achieve a permanent reduction of components of the existing annual dose: eg, cleaning up residues. Alternatively it may reduce the dose by requiring continuing protective action eg, relocating people.

ICRP introduces the concept of an upper and lower bound, or two extremes. One extreme is where the existing annual dose is so high as to justify intervention under almost any circumstances. The other extreme is where the existing annual dose is low enough to make intervention unlikely to be justified. Justification and optimisation of protective actions are crucial between these two extremes. However, generic approaches may be more appropriate at the extremes and ICRP introduces the concepts of specific and generic reference levels. These are discussed below.

Specific reference levels are expressed in terms of the averted dose, or avertable dose. ICRP recommends that they should be developed for particular exposure situations and has suggested the following specific reference levels:

TABLE 1 ICRP Specific reference levels

Situation	Specific Reference level
Relocation after accident	5-15 mSv/month averted
Permanent resettlement	1000 mSv averted lifetime dose (~15-20 mSv y^{-1})
Restriction of foodstuff	10 mSv y^{-1} averted
Radon action level	3-10 mSv y^{-1}

Generic reference levels are expressed in terms of the existing annual dose and ICRP recommends that these can be used to establish whether intervention is likely to be justified or not. However, they caution that the existing annual dose is made up of many different components and hence it is not easy

to measure or to assess. The components may include: external exposure to nuclides in soils and building materials, exposure to radon, and internal exposure due to inhaled or ingested radionuclides. Some of these radionuclides may be at naturally occurring levels while others may be at enhanced levels or artificially produced radionuclides. As a result, the intervention option may differ for areas of the same existing annual dose, depending upon the composition of the different components and the degree to which their doses can be reduced. Hence a low level of existing annual dose does not necessarily imply intervention is not applied; conversely a high level of existing dose does not necessarily require intervention.
The identification of generic reference levels is not straightforward and ICRP considered naturally occurring annual doses, other situations where they have given advice and the need to avoid deterministic effects. Taking all these considerations into account, ICRP recommends the following generic reference levels for intervention:

TABLE 2 ICRP generic reference levels

Natural background	Existing annual dose (including background), mSv	Generic intervention levels
Very high	100	Intervention almost always justifiable
Typically elevated	10	Intervention may be necessary
		Intervention unlikely to be justifiable
Global average	2.4	

Therefore an existing annual dose approaching about 10 mSv may be used as a generic reference level below which intervention is not likely to be justifiable for some prolonged exposure situations. It should be remembered that below this level, protective actions to reduce a dominant component of the existing annual dose are still optional and may be justifiable. These values are upper bounds of generic reference levels; they are not restrictions, limiting values or acceptable levels.

NRPB advice given in 1998 states that intervention will almost certainly be justified on health grounds if the projected lifetime dose to an individual member of the critical group is likely to exceed 1 Sv. This equates to an annual dose of the order of 10 mSv y^{-1} for long lived radionuclides. This value is consistent with the dose criterion for considering the more resource intensive and disruptive countermeasures after an accident (NRPB, 1997).

The International Atomic Energy Agency (IAEA, 1998) has offered dose criteria for cleanup or intervention in contaminated land situations.

TABLE 3

Band no	Range of annual doses attributable to the contamination, mSv y^{-1}	Is cleanup needed?
6	>100	Always
5	10-100	Almost always
4	1-10	Usually
3	0.1-1	Sometimes
2	0.01-0.1	Rarely
1	<0.01	Almost never

5 Choice of dose criterion for intervention

Obviously, when trying to decide whether some land should be defined as contaminated, it is more practical to consider the existing annual dose or the dose attributable to the contamination. The development of a screening level for the identification of radioactively contaminated land will need to take account of a number of issues, including the relevant national and international radiological advice and recommendations, corresponding issues from the non-radioactively contaminated land regulations and natural background levels.

The implication from ICRP, IAEA and NRPB advice is that an annual projected (total) dose of 10 mSv is an appropriate threshold above which intervention may be justified in a majority of cases. This can be thought of as an upper bound for the dose criterion.

Considering the lower bound, IAEA suggests that below an incremental dose of 0.1 mSv y^{-1} intervention would rarely be justified on radiological protection terms alone; below 1 mSv y^{-1} they suggest that intervention may sometimes be justified. Furthermore, natural background radiation gives average annual doses of a few mSv y^{-1}. The values given in ICRP 82, based on UNSCEAR (2000), and the UK average values (Hughes, 1999) are given in Table 4.

TABLE 4

Source of exposure	Global average (mSv y^{-1})	Elevated areas (Sv y^{-1})	UK average
Cosmic rays	0.39	2.0	0.26
Terrestrial gamma	0.46	4.3	0.35
Radionuclides in the body	0.23	0.6	0.30
Radon	1.3	10	1.3*
Total	2.4		2.2

* including 0.1 mSv from thoron

ICRP reports that the majority of the world population experiences natural background doses between 2.2 mSv y^{-1} and 2.4 mSv y^{-1}, with 98% below 5 mSv y^{-1} and about 99% below 7 mSv y^{-1}. However, some areas experience levels significantly above 10 mSv y^{-1}. In the UK, the majority of areas experience less than 10 mSv y^{-1} with a maximum of about 100 mSv y^{-1} at some particular locations. Intervention to reduce components of background dose at average levels would not normally be justified.

Taking all this together, it would appear that an appropriate choice of dose criterion for screening would be of the order of a few mSv y^{-1}. It should be remembered that the dose criterion refers to the mean dose to a member of the critical group. Since the habits of the critical group are chosen such that they receive the highest doses, it follows that the dose to an average individual will be less. Experience has shown that the dose to a typical individual is a factor of 2 or more less than that to a member of the critical group.

The screening dose criterion could be used to mark the dividing line between land which is not deemed to be radioactively contaminated and that which is defined as radioactively contaminated. In circumstances where assessed doses are greater than the dose criterion, the land would be designated as radioactively contaminated and intervention to reduce doses would be considered but not necessarily undertaken. Where assessed doses are less than the dose criterion, the land would not be categorised as radioactively contaminated but this would not preclude the use of simple measures to reduce doses where appropriate.

6 Hotspots

Radioactive contamination is often patchy and therefore it is necessary to consider realistic assessments of the pattern of exposure. ICRP recommends that the probability of exposure should be considered, along with the probability that the exposure causes fatal stochastic effects. This means, in effect, that the dose from the exposure multiplied by the probability of receiving that dose can be compared with the dose criterion. This is valid for doses, should they occur, that are within the range where the dose response relationship is assumed to be linear. However, more information can be obtained for the decision-making processes by presenting probabilities and the corresponding doses separately.

7 Conclusions

This paper describes the international advice on radiological protection criteria for contaminated land and explores how it can be used to develop criteria for the designation of contaminated land.

The NRPB has developed a methodology for the assessment of doses from contaminated land (Oatway and Mobbs, 2003) which can be used to estimate doses or cleanup levels.

8 References

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