DEVELOPMENT OF INTERNATIONAL CRITERIA FOR THE CLEANUP OF CONTAMINATED AREAS

P. HEDEMANN-JENSEN
Risø National Laboratory,
Roskilde, Denmark

I. BARRACLOUGH
National Radiation Protection Board,
Chilton, Didcot, United Kingdom

R. MECK, G. GNUGNOLI
U.S. Nuclear Regulatory Commission,
Washington, DC, United States of America

P. STEGNAR
International Atomic Energy Agency,
Vienna, Austria

Abstract

IAEA TECDOC-987, *Application of radiation protection principles to the cleanup of contaminated areas*, provides a coherent framework and consistent guidance needed for approaches to cleanup that encompass the entire range of contamination situations. A major goal of cleanup is usually to re-establish that the environment can acceptably support habitation and use. Difficult situations include chronic exposures due to radioactivity associated with the discovery of contamination from a previously discontinued practice and post-accident situations. and post-accident situations. The concepts of justification, optimization, and limitation can be applied to cleanup from "trivial" to "intolerable" situations by taking into account not only radiological risk, but the entire range of social values including the ability of the society to feed and shelter itself and to sustain a productive economy. TECDOC-987 proposes six ranges, or bands, of doses that correspond to trivial, acceptable, tolerable - clean-up unlikely (unless constrained), tolerable - clean-up likely, unacceptable, and intolerable risks. Remedial actions may vary from "none" to elaborate decontamination or restricted or prohibited use.

Introduction

At the present time there is a gap in the guidance offered by the international agencies concerned with radiation protection in the area of chronic exposure to residual radioactivity. This gap arises from past practices, which may have been discontinued at a particular site, and may have resulted in contamination either routinely from the previous activities or else from an accident, where adequate cleanup had not been undertaken or completed. These are commonly known as "cleanup situations". The term "cleanup" in this context has approximately the same meaning as the words "rehabilitation", "reclamation", and "remediation" used elsewhere. In these situations some remedial actions may be necessary, such as removal, cover and/or mixing of radioactive materials in soil, treatment of ground and surface waters, and the decontamination of structures. Decisions on remedial actions should

be guided by appropriate radiological criteria. Considerations for the development of such criteria are summarized in the following sections [1].

Types of Contamination Situations

Cleanup may be needed when environmental media have been contaminated as a result of a variety of human activities involving radionuclides. The activities past and present that may lead to contaminated areas and eventually to cleanup include amongst others:

- Various phases of nuclear fuel cycle (mining and milling of uranium ore, enrichment and fuel fabrication, energy production and reprocessing);
- Radioactive waste disposal, either on land or in the marine environment;
- Nuclear weapons production;
- Nuclear tests and other detonations;
- Use of radionuclides in medicine and research;
- Use of sealed and unsealed sources in industry;
- Ore processing, mineral extraction of materials containing natural radionuclides, and other activities with may generate enhanced levels of natural radionuclides (radium, thorium, rare earths, phosphates, oil and gas production);
- Misuse of natural or man-made materials containing natural radionuclides, which have been used in construction (e.g., uranium mill tailings used in landfills or in residential construction); and
- Accidents

The type and extent of the contamination will depend on the scale of the operation, the source term, the nature of the radionuclides and the contaminated environmental media involved. This will lead to different contamination situations. They may be confined to the site of the operation or may extend to off-site areas. In the latter case, the contamination situation may be caused by inadequately controlled discharges, either by current operations, or by operations in the past, transportation accidents (including satellites and weapons) and major accidents with nuclear installations, causing large scale off-site contamination. Apart from the terrestrial contamination, such releases may also contaminate off-site groundwater, aquifers and river, lake and estuarine sediments.

Development of Cleanup Criteria

The approach suggested for establishing criteria (action levels) for cleanup operations involves the justification/optimization principles of radiation protection and also defines a maximum generic annual dose level to constrain the residual dose following cleanup operations. This maximum, generic annual dose level is based on a series of international recommendations on intervention and exemption levels and on the perspective supplied by the variation of annual individual doses from natural sources.

Figure 1 displays the range of possible cleanup situations, divided into six sections or "bands", each covering approximately an order of magnitude in dose or risk. For easy reference, these are numbered from 1 (annual doses less than 10 μSv or 1 mrem above background) to 6 (annual doses with the potential to cause serious deterministic effects in less than a year). Each band is categorized into two aspects: the need or for cleanup if this level of exposure would result from the *initial* level of contamination, and the post-cleanup measures that would be implied if the situation were to be used as the end-point, indicating its possible suitability

Band	Risk Index	Actions if this is the initial level	Acceptability status of this level for release as "new background"	Additional annual dose projected, mSv y^{-1}	Additional annual dose projected, rem y^{-1}	Additional annual risk
6	Intolerable	Clean-up or prevent use	Not suitable for release. Restrict use	~ 100	~10	
5	Unacceptable	Clean-up or restrict use		~ 10	~1	~ 10^{-3}
4	Tolerable (if ALARA)	(Clean-up likely) Clean-up decisions based on justification/optimization	Release may be possible subject to regular review of situation	~ 1	~0.1	~ 10^{-4}
3		(Clean-up unlikely unless constrained)	Release possible - situation may need occasional review	~ 0.1	~0.01	~ 10^{-5}
2	Acceptable	Clean-up unlikely to be necessary on the basis of radiological risks	Release likely - review only if a problem becomes apparent	~ 0.01	~0.001	~ 10^{-6}
1	Trivial	No clean-up necessary	Can be released without controls			~ 10^{-7}

Figure 1. Scale of proposed actions for different dose and risk levels

as a release level. The doses are chronic and to be considered additional to the level of doses attributable to the natural environment.

Band 1 represents annual doses less than 10 μSv (1 mrem) above background, and represents risks that would be regarded as trivial in the vast majority of situations. Criteria for triviality of risks have been published in the context of exemption of practices and sources and clearance of materials from practices. The Basic Safety Standards [2] specifies criteria for exemption and clearance, when the effective dose expected to be incurred by any member of the public is on the order of 10 μSv or less in a year, and the collective dose committed by one year of performance of the practice is no more than about 1 man-Sv.

Band 2 represents annual doses (typically tens of μSv y^{-1} above background) in the range that would be considered acceptable, as additional exposures imposed on members of the public as a result of a set of planned actions with an overall net benefit to society (i.e., a justified practice, such as the use of smoke detectors).

Band 3 represents risks that might be considered tolerable as additional risks from a justified practice, provided that they were as low as reasonably achievable; the upper bound of Band 3 corresponds approximately to the ICRP [3] dose limit for members of the public (1 mSv y^{-1} or 100 mrem y^{-1} above background). Also, many national authorities have adopted dose constraints, typically between a hundred to some hundreds of μSv y^{-1} to apply to new and/or existing practices, and international recommendations have been made about rationales for choosing constraints [4, 5]. However, these levels of risk are low enough that they would be considered acceptable in many other situations.

Examples of situations involving decisions for Bands 1-3 involve the presence of natural radionuclides (e.g., ^{226}Ra) in construction fill material. Depending on the levels of radium, and hence radon, and the resultant radon daughter concentrations, decisions would need to be made based on the cost of repair and on the benefit thereof.

Band 4 represents risks corresponding to doses of the order of mSv y^{-1} (up to a few times average background). These would *not* normally be considered acceptable if they were deliberately imposed on the public, but are low enough that they would be acceptable in other situations, such as:

- If the individuals are exposed voluntarily and receive a direct compensating benefit; e.g., radiation workers or people receiving medical x-rays, then risks of this magnitude would be acceptable if they were as low as reasonably achievable; or

- Radiation risks of this magnitude are routinely accepted from natural sources, and variations of this magnitude in levels of background radiation do not appear to influence people's behavior.

Band 5 (doses of tens of mSv y^{-1}) represents risks that would generally be regarded as unacceptable from any source (with the exception of necessary medical treatment) because the stochastic risks associated with exposures in this band are too high to be tolerated under normal circumstances.

Band 6 represents risks (whether in terms of serious deterministic effects or a high probability of stochastic risk) that are clearly intolerable in all but the most exceptional circumstances (e.g.; radiation therapy to treat cancer). Both the risk of serious deterministic effects and stochastic risks would always be so high as not to be tolerated under any circumstances.

It is clear that the annual doses dividing the bands can only be approximations in view of the uncertainties involved. Nevertheless it is convenient to have single numbers to represent criteria, and considerable presentational problems may be expected if slightly different numbers are quoted in different situations.

In this case, the most significant criterion that cannot readily be linked to existing criteria is probably that dividing Bands 4 and 5. This represents a point above which cleanup would normally be expected to be undertaken in unconstrained situations, and therefore also represents the maximum level of residual risk that (apart from exceptional circumstances) might be considered acceptable as a "new background" level. Therefore, situations with annual individual doses *above* this level would never be considered as normal, whereas situations with annual doses *below* this level would in most cases - but not always – would be considered normal.

The choice of 10 mSv y^{-1} (or 1 rem y^{-1}) for this boundary is necessarily a judgement, but is felt to be robust in the face of a number of considerations, including:

- Worldwide variation in natural background dose;
- Action levels recommended by ICRP and IAEA for radon in dwellings and workplaces;
- Doses implied by interdiction levels of activity in foodstuffs; and
- IAEA recommendations on criteria for resettlement of populations.

Real Example Situations

An example of a challenging clean-up situation is the former nuclear weapons testing site, Semipalatinsk, in the Republic of Kazakhstan. Initial findings of dose assessments indicate annual exposures in the region of 10 mSv (1 rem) predominately due to external exposure. If these areas were permanently settled in the future, estimated exposures could be up to 140 mSv (14 rem) per year. Remedial action is considered necessary for these localized elevated areas. However, due to budgetary and other constraints, the most appropriate remedial action at this time may be to restrict access to these areas [6].

Another example is the Bikini nuclear weapons testing area in the Republic of the Marshall Islands in the Pacific Ocean. The annual background (excluding the effects of the nuclear weapons testing) is 2.4 mSv (0.2 rem). Without any intervention, the total effective dose could have been about 15 mSv (1.5 rem). Following an optimized remediation strategy, the estimated effective dose is reduced to 2.8 mSv (0.3 rem). This effective dose rate (which includes the contribution from the natural environment) becomes the "new background" level [7].

The above examples are consistent with a generic criterion in the region of *10 mSv y^{-1} or 1 rem y^{-1}* as a level above which some form of cleanup would normally be expected.

References

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[4] INTERNATIONAL ATOMIC ENERGY AGENCY, Principles for the Establishment of Upper Bounds to Doses to Individuals from Global and Regional Sources, Safety Series No. 92, IAEA, Vienna (1989).

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