NATIONAL NUCLEAR REGULATOR

For the protection of persons, property and the environment against nuclear damage

INTERIM REGULATORY GUIDE

SITE DECOMMISSIONING FOR PLANNED EXPOSURES AND REMEDIATION OF EXISTING EXPOSURES FOR RELEASE OF LAND FROM REGULATORY CONTROL

RG-0026

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	Name	Designation	Date
Prepared	Dr. A J.oubert	Manager: ERP	**Note: The original, signed document is retained by the Record Management.**
	O.J. Pule	Manager: Contaminated Sites	
Edited	N/A	N/A	
QC Review	F. Malashe	Manager: KQM	
Reviewed or consulted	RG-0026 Team	Email correspondence	
	Management Review	E-mail correspondence	
	Legal Review	E-mail correspondence	
Recommended for approval	L. Mpete	Executive: RITS	
Approved	EXCO	E-mail correspondence	
Issued	**Name**	**Designation**	
	Dr M. B. Tyobeka	Chief Executive Officer	

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DOCUMENT HIERARCHY AND PROCESS MODEL

Figure 1: Location of the Regulatory Guide in the NNR Document Hierarchy

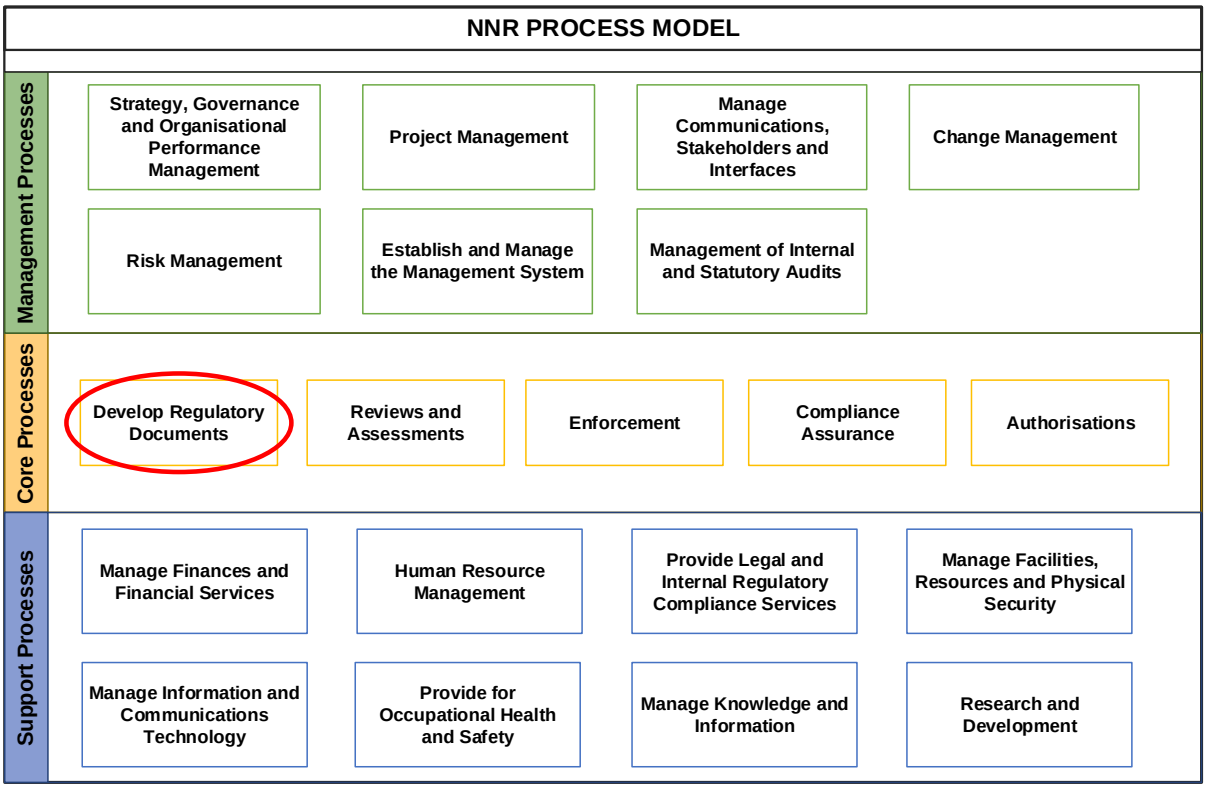

Figure 2: Location of the Regulatory Guide in the Process Model

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FOREWORD

The legal framework applicable to regulation of nuclear industry in South Africa is comprised of law and supporting regulatory documents. Law includes legally enforceable instruments such as Acts, Regulations and Conditions of licences. Regulatory documents comprise of policies, standards, guides, notices, procedures and information documents which support and provide further information on the legally enforceable instruments. Both law and regulatory documents form the framework for regulation of the nuclear industry in South Africa.

Regulatory Guidance documents provide guidance to the licensees and applicants on how to meet requirements of the legally enforceable instruments. This Regulatory Guidance document provides more information about approaches for Site Decommissioning for planned exposures and remediation of existing exposures for release of Land from Regulatory Control.

1. BACKGROUND

South Africa is country rich in minerals. These reserves are being recovered through different mining processes and then further processed on the surface to extract the monetary value of the material. The processes involved result in volumes of mining residue that range from a few to millions of cubic meters mainly in the form of tailings storage facilities. The mineral ore and the resulting tailings material contain some concentrations of a wide variety of radioactive nuclides (radionuclides), each nuclide with a specific half-life and chemical and physical properties. The radionuclide range includes, amongst others, uranium, thorium, protactinium, radium, radon, polonium, lead, bismuth, atrium, etc.

Prior to the establishment of the NNR, naturally occurring radioactive material (NORM) was not regulated in South Africa. The lack of regulatory control has resulted in widespread radiological contamination in former mining areas resulting in the formation of what is referred to as legacy sites or existing exposure situations. This contamination resulted in exposure conditions through various pathways. To protect the members of the public and the environment from radiological damage, remediation of the legacy sites is necessary.

The current NNR regulatory framework does not provide a framework for remediation of legacy sites, however there is provision for release from regulatory control of contaminated land that has been used for an authorised action as per the criteria contained in section 5.4 of the current SSRP [2]. The land release criteria is an exclusion level of 0.5 Bq/g for naturally occurring radioactive nuclides of uranium and thorium and their progeny with the exception of radon.

The NNR has proposed new draft General Nuclear Safety Regulations (dGNSR) [3] and section 6(1) (d) stipulates the requirements for remediation of areas with residual radioactive material. The regulations provide overarching requirements that must be complied with and may not be sufficiently detailed and comprehensive to enable authorisation holders and applicants to easily and fully meet the requirements. Therefore, regulatory guidance is necessary so that some level of consistency can be achieved and maintained amongst all holders and applicants in complying with the requirements.

2. PURPOSE

The purpose of this guidance document is to assist applicants, and authorisation holders on the NNR expectations in order to meet the general requirements for the release of land after decommissioning of planned exposure situations and the remediation of existing exposure situations. The document provides recommendations on the content, and methodology to be used as well as considerations for safety assessment in order to comply with NNR criteria and requirements.

3. SCOPE

This document provides guidance on the criteria applicable to the release of land after decommissioning of planned exposure (authorised actions) situations. Furthermore, it deals extensively with the remediation of existing exposure situations (never authorised), which are areas containing residual contamination from activities that were never subject to regulatory control or that were subject to regulatory control but not in accordance with current requirements. Such activities may have involved the industrial processing of radioactive material, the mining and processing of uranium or thorium ores, and the management of residual materials, including radioactive waste. The safety assessment process applicable to remediation can be applied to planned exposure situations for clean-up of land in preparation for the release of that land from regulatory control. Exposures from accidents and malicious acts are excluded.

4. DEFINITIONS AND ABBREVIATIONS

4.1 Definitions

In this RG any word or expression to which a meaning has been assigned in the NNRA or the Regulations promulgated in terms of the NNRA, or in the draft Regulations on General Nuclear Safety (dGNSR), shall have the meaning so assigned. The definitions included are limited to the most important issues.

Action: (a) the use, possession, production, storage, enrichment, processing, reprocessing, conveying or disposal of, or causing to be conveyed, radioactive material;
(b) any action, the performance of which may result in persons accumulating a radiation dose resulting from exposure to ionizing radiation; or
(c) any other action involving radioactive material;

Existing exposure situation: a situation of exposure that already exists when a decision on the need for control needs to be taken. Existing exposure situations include exposure to natural background radiation that is amenable to control; exposure due to residual radioactive material that arose from past practices that were never subject to regulatory control or exposure due to residual radioactive material arising from a nuclear or radiation emergency after an emergency exposure situation has been declared to be ended;

Planned exposure situation: situations involving the planned introduction and operation of sources (This type of exposure situation includes situations that were previously categorized as practices.)

Reference levels: for an existing exposure situation, the level of dose, risk or activity concentration above which it is not appropriate to plan to allow exposures to occur and below which optimization of protection and safety would continue to be implemented;

4.2 Abbreviations

DGNSR	Draft General Nuclear Safety Regulations
DWS	Department of Water and Sanitation
IAEA	International Atomic Energy Agency
ICRP	International Commission on Radiation Protection
NNR	National Nuclear Regulator
NNRA	National Nuclear Regulator Act, Act 47 of 1999
NORM	Naturally Occurring Radioactive Material
RG	Regulatory Guidance Document
SSRP	Regulation on Safety Standards and Regulatory Practices

5. REGULATORY FRAMEWORK FOR RELEASE OF LAND AFTER DECOMMISSIONING IN PLANNED EXPOSURE SITUATIONS

The current NNR's regulatory scope is limited to planned exposure situations according to the NNRA. Section 2 (c) of the NNRA [1] is applicable to any "action" which is capable of causing nuclear damage. An "action" is defined in the NNRA, Section 1 (i) [1] and in Section 4.1 of this document. The SSRP in Section 5.4 is concerned with release of land from regulatory control, after decommissioning in planned exposure situations (currently authorised actions).

5.1 Decommissioning and release of land under regulatory control

The NNR standards, as captured in section 5.4 of the SSRP [2], makes provision for the release of land from regulatory control as follows:

5.4.1 A site used in the conduct of an authorized action may be released for unrestricted use provided that it is demonstrated; -

5.4.1.1 that radioactive contamination and radioactive materials which can reasonably be attributed to the authorized action have been removed from the site or, in the case of naturally occurring radioactive nuclides, have activity concentrations below the levels for exclusion specified in section 2.1.1.1 (b), (c) and (d); or

5.4.1.2 that radioactive contamination and radioactive materials which can reasonably be attributed to the authorized action have been removed from the site or, in the case of naturally occurring radioactive nuclides, have activity concentrations below the levels for exclusion specified in section 2.1.1.1 (b), (c) and (d); or

5.4.2 In the event that the release of a site in accordance with the conditions in section 5.4.1.2 can only be reasonably achieved by imposing restrictions on the use of the site, the Regulator may, subject to the conditions in section 5.4.1.2 being met, approve the release of that site for restricted use.

5.2 Criteria applicable to release of land under regulatory control [2]

In terms of the provisions of section 2 (2) (b) of the Act, the Act does not apply to any action where the radioactivity concentrations of individual radioactive nuclides, or the total radioactivity content, are below the exclusion levels provided for in the safety standards contemplated in section 36. The exclusion level, as defined in Section 2.1.1.1 of the SSRP is where the level of radioactivity concentration of each radioactive nuclide in materials is below:

i. 0.5 Bq per gram for naturally occurring radioactive nuclides of uranium and thorium and their progeny except for radon;
ii. 10 Bq per gram for potassium-40 in materials that are used in building construction or disposed of;
iii. 50 Bq per gram for potassium-40 in all other materials.

The above criteria and requirements will be used in instances where land is to be released from regulatory control following decommissioning in planned exposure situations. All related clean-up activities will have to satisfy these criteria as prescribed in the current SSRP. Where the above requirements cannot be fully met, the regulator can impose restrictions on the subsequent possible uses of the land. If the criteria cannot be satisfied fully, the authorisation holder may propose to the NNR based on a safety assessment outcome what the site will be earmarked for or used for. The NNR will then conduct a regulatory review of the outcome and make a determination on the restrictions that will be imposed on the site.

The criteria for the release of land in planned exposure situations is based on a public dose limit of 1 mSv/a. When considering release of land from regulatory control, optimisation of dose to members of the public needs to be demonstrated.

6. REGULATORY CONTROL OF EXISTING EXPOSURE SITUATIONS

The remediation criteria for existing exposure situations is as per the revised draft regulations, called the “General Nuclear Safety Regulations” [3], which are based on the IAEA GSR Part 3 [4] requirements and ICRP 103 [5] recommendations. The dGNSR [3] have included under Part Six: Radiation Protection, Waste Management and Decommissioning, the remediation requirements for existing exposure situations in section 6(1)(a) to (d) of dGNSR as follows:

(1) Public exposure

Justification for protective actions and optimisation of protection and safety

(a) Any person or organization responsible for the planning, implementation and verification of remedial actions shall, as appropriate, ensure that:

i A protection strategy, which is commensurate with the radiation risks associated with the existing exposure situation is established for the management of existing exposure situations;

ii Remedial actions or protective actions which are expected to yield sufficient benefits to outweigh the detriments associated with taking them, including detriments in the form of radiation risks are established; and

iii The form, scale and duration of remedial actions or protective actions shall be optimised.

(b) While this optimisation process is intended to provide optimised protection for all individuals subject to exposure, priority shall be given to those groups for whom residual dose exceeds the reference level.

(c) Reference levels

i. Reference levels shall typically be expressed as an annual effective dose to the representative person in the range 1 - 20 mSv or other equivalent quantity, the actual value depending on the feasibility of controlling the situation and experience in managing similar situations in the past.

ii. All reasonable steps shall be taken to prevent doses remaining above the reference levels.

(d) Remediation of areas with residual radioactive material

i. Persons and organisations responsible for remediation shall ensure that a remedial action plan for an area with residual radioactive material, supported by a safety assessment, aimed at the timely and progressive reduction of the radiation risks and eventually the removal of restrictions on use of or access to the area is prepared and submitted to the Regulator for approval.

ii. A remedial action plan referred to in (i) above shall provide for a system for

(aa) maintaining, retrieval and amendment of records that cover the nature and the extent of contamination;

(bb) the decisions made before, during and after remediation, and

(cc) information on verification of the results of remedial actions, including the results of all monitoring and surveillance programmes after completion of the remedial actions.

iii. Measures for radioactive waste management shall be put in place to deal with any waste arising from the remedial actions

iv. Radiological, environmental and public exposure monitoring and surveillance programmes shall be established and implemented.

v. Procedures shall be in place for reporting to the Regulator on any abnormal conditions relevant to protection and safety.

vi. A final remediation report shall be prepared and retained which shall be submitted to the Regulator or other relevant authority involved in the process.

vii. For post-remediation control measures, an appropriate programme shall be established and maintained for as long as required including any necessary provisions for monitoring and surveillance, to verify the long term effectiveness of the completed remedial actions for areas in which controls are required after remediation has been completed.

viii. The conditions prevailing after the completion of remedial actions, if the Regulator or other relevant authority has imposed no restrictions or controls, shall be considered to constitute the background conditions for any new facilities and activities or for habitation of the land.

(2) Occupational exposure

i. Persons and organisations responsible for remediation shall ensure that exposure of workers undertaking remedial actions shall be controlled in accordance with the relevant requirements for occupational exposure in planned exposure situations established in Annexure 3.

7. DETERMINATION AND APPLICATION OF REFERENCE LEVELS FOR EXISTING EXPOSURE SITUATIONS

1) A safety assessment should be prepared to determine the effective dose from all exposure pathways.
2) The safety assessment should consider reference levels, together with the principles of justification and optimisation.
3) Only if it cannot be demonstrated that the 1 mSv/a public dose limit for planned situations cannot be met after optimisation has been applied, further consideration should be given establish a reference level between 1 and 20 mSv/a.
4) Remediation should always be considered for all activities where the annual effective dose to the critical group (reference person) exceeds the public dose limit of 1 mSv/a.
5) Peak dose, which is the maximum dose from a specific exposure scenario at any given time, now and in the future, should be determined and considered.
6) The end use of land released from existing exposure situations exceeding the 1 mSv/a public dose limit should be submitted for regulatory approval if it can be demonstrated that all remedial activities were optimised and an appropriate justification is provided.
7) The restrictions on land use should be documented and included on the land deed.
8) Land for which a release from regulatory control is being considered, the safety assessment should be performed for the following scenarios (Detail in Section 10.1):
   i. Subsistence farmer;
   ii. Residential; and
   iii. Industrial.
9) Specific reference levels should be derived for commodities, including food, feed, drinking water and construction materials, on a case by case basis, considering effective dose from all pathways.
10) These levels should be optimized and periodically reviewed to be reduced as far as reasonably possible.

The application for a nuclear authorisation for a remediation action should be in accordance with Guideline Document for Applying for a Nuclear Authorisation, Revision 9, July 2009 [9].

8. DEFINING END POINTS FOR REMEDIATION

1) The end point of remediation (the dose value that would satisfy the NNR that remedial actions have been optimised) should be radiation exposure based.
2) Radiation dose to people should be kept as low as reasonably achievable, taking social and economic factors into consideration.
3) Remediation should be considered when the exclusion level of 0.5 Bq/g per natural occurring nuclide is exceeded, by optimising exposure through a process of safety assessment.
4) Various remediation options should be considered, and the most effective remediation option should be chosen, considering radiological dose, economic and social factors, and the optimum end point.

9. DETAILED SAFETY ASSESSMENTS FOR REMEDIATION

Public safety assessments and worker safety assessments should be performed for existing exposure situations.

9.1 Public safety assessments

1) Public safety assessments should be performed, at minimum, prior to decision making of whether remediation is required and after remediation has been completed.
2) The latter process should be a repetition of the initial assessment, just using the results of the radionuclide distribution after remediation as input to the assessment.
3) The last assessment should be performed to demonstrate that the remediation was successful and that the site can be cleared of radioactive contamination. This exclude any in-between safety assessments that may be required.
4) A comprehensive site characterisation should be performed through sampling and analysis.
5) All sources of radiological contamination and all pathways of exposure should be identified.
6) The reference person should be identified for any relevant end use scenario such as a subsistence farmer exposure situation [6].
7) A land-use survey should be performed to determine the habitat, agricultural and social activities that could impact on radiation doses.
8) The subsistence farmer scenario should include an analysis of the following exposures, as applicable to the site [11]:

a. External gamma exposure;
b. Inhalation;
c. Plant ingestion;
d. Meat ingestion;
e. Milk ingestion;
f. Aquatic foods;
g. Drinking water; and

h. Soil ingestion.

9) If compliance with non-restricted remediation release criteria cannot be demonstrated, the applicant can motivate for an alternative land use scenario with restrictions on land use, supported by a safety assessment report.

10) These scenarios could impose restrictions on the use of the land and the time that can be spent on the premises.

11) In an urban resident scenario the following should be considered:

a. External gamma exposure from the soil and water;
b. Inhalation of dust and radon;
c. Ingestion of some fruit and vegetables produced on the land;
d. Ingestion of the soil; and
e. 8 760 hours per annum exposure time, minus the time spent indoors.

12) If the urban resident scenario cannot be demonstrated an industrial exposure scenario should be considered, and the following exposure pathways and exposure conditions should be used:

a. External gamma exposure from the soil, with a surface cover over it;
b. Inhalation of dust and radon; and
c. 2 000 hours per annum exposure time.

9.2 Worker safety assessments

1) The worker safety assessments, should be performed to determine the type and extent of protective action required to ensure that exposure from remediation activities are minimised.
2) The worker safety assessment should be applicable to the period of authorisation during which remediation activities will be applied.
3) The worker safety assessment should identify and quantify sources of potential exposure.
4) Efforts should be focused on eliminating or at least reducing exposure to potential radioactive material to minimise exposure during remediation.
5) Workers should be registered as radiation workers and a radiation worker protection programme should be implemented.
6) This programme should consist of a workplace surveillance programme, a worker surveillance programme and a medical surveillance programme.
7) The prior safety assessment should determine the average and maximum annual effective occupational dose from normal operations and anticipated operational occurrences.
8) The safety assessment should demonstrate that adequate measures, including design provisions where required, are in place to control the radiation exposure of workers within the occupational dose limits of 20 mSv per annum.
9) Protection should be optimised and the magnitude of individual doses, the number of people exposed and the likelihood of exposures being incurred have all been kept ALARA, economic and social factors taken into account.

Note: worker safety assessment falls beyond the scope of this guidance. However, this section is included to remind the user of this guide that the worker safety assessment is required and should not be neglected.

9.3 Remediation criteria

1) Remediation should always be considered for all the sites where the annual effective dose to the representative person exceeds the public dose limit of 1 mSv/a.
2) Each situation should be evaluated on a case-by-case basis based on the results of a safety assessment, considering all relevant scenarios including the subsistence farmer scenario [6].
3) The safety assessment should identify the peak dose and should be performed over an extended period of up to 1 000 years [12].
4) Evaluation of the need for remediation should be based on the principles of justification, optimisation and reference levels.
5) Reference levels between 1 and 20 mSv should be complied with [6] and the acceptability of level will be evaluated on a case-by-case basis. Where the public dose limit (1 mSv/a) is still exceeded after remediation, land use scenarios should be motivated for by the applicant for consideration by the NNR, and where restrictions are imposed, the public will be informed accordingly.

9.4 Remediation strategies

1) In order to develop technical solutions for the remediation of dispersed environmental contamination, input from various scientific and engineering disciplines, including health sciences, chemistry, physics, geology, microbiology and environmental engineering should be used.
2) Information on the political, social and economic context should be included.
3) While attempting to reduce residual contamination over large areas, factors such as dose, cost, public perception and anxiety, and minimal disturbance to the environment should be taken into account [13].
4) The overarching objective of the operation should be to remove or reduce the source term, or prevent the likelihood of exposure in excess of allowed dose.
5) A generic process map for decision making and technology assessment in Figure 10-1 [7] should be followed.

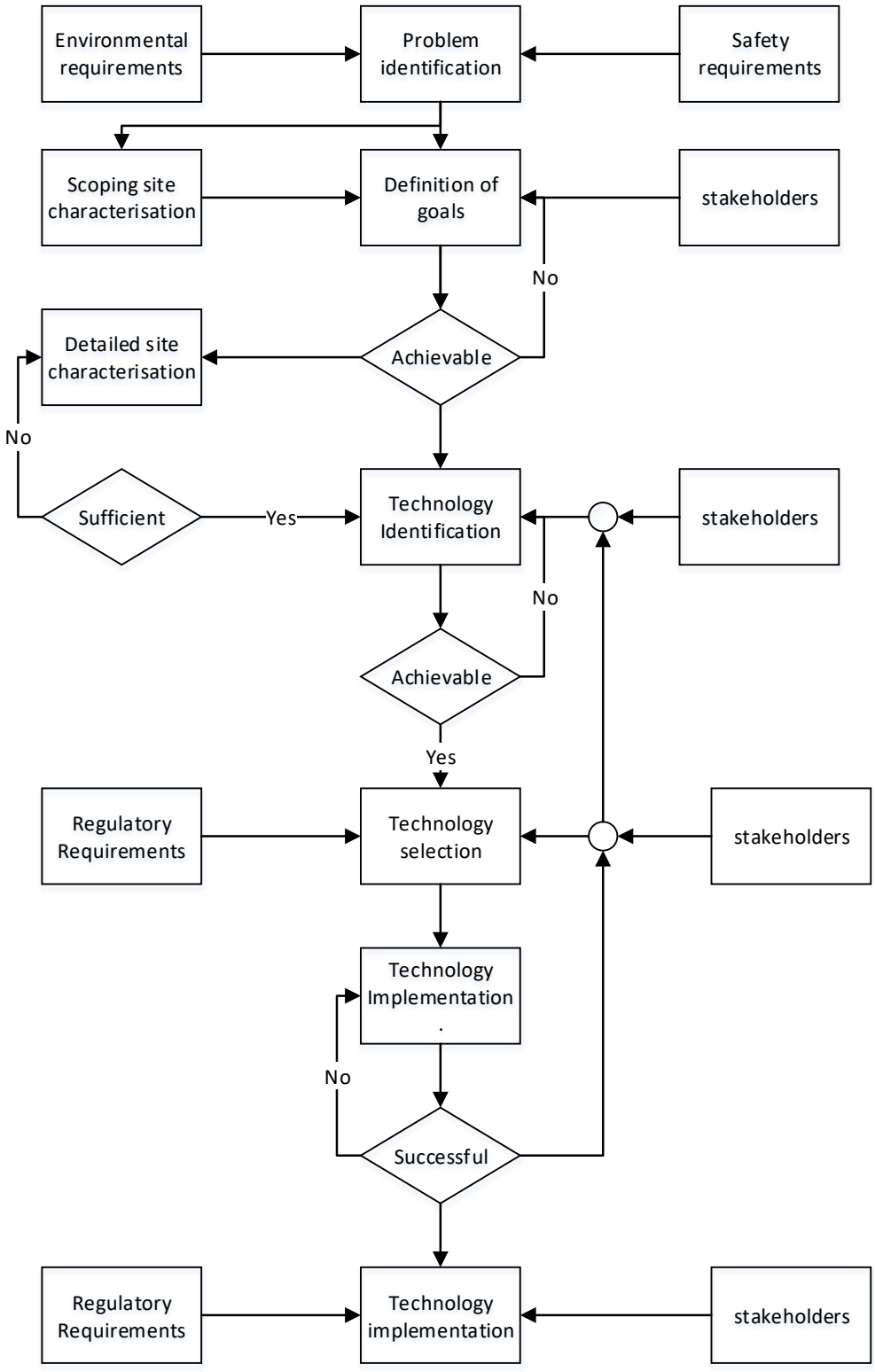

Figure 10-1: Process Map for Decision Making

The following steps should be followed, as depicted in Figure 10-1, in establishing a process when remediation and specifically the technology applied to remediate is to be considered [6]:

1) Problem Identification - a site should be identified as a potential existing exposure scenario because the in-situ conditions seem to be in conflict with regulatory safety requirements and environmental laws;
2) Definition of Goals - the site should be radiologically characterised, using a screening analysis. During this process, all stakeholders should be afforded the opportunity to comment on the process. If the site requires remediation, a detailed safety assessment should be prepared;
3) Technology Identification - remediation goals should be identified and Nuclide Specific Guidelines derived. Technologies applicable to the situation should be evaluated;
4) Technology Selection - The best available technology should be identified for the task at hand. Different technologies, should be analysed to determine the most effective application. This should form part of the site safety assessment required for submission to the NNR to obtain an authorisation to remediate;
5) Technology Implementation - the technology should be applied to the contaminants, while the efficiency is continuously measured. If the technology does not comply with efficiency requirements, a re-assessment should be performed.
6) Monitoring for Compliance - before the site can be released from regulatory control, the holder should compile a completion of remediation report for submission to the NNR. This report should include a detailed monitoring to demonstrate compliance with the Nuclide Specific Guidelines, developed prior to commencement with remediation.

9.5 Remediation technologies

The following remediation technologies should be considered [13]:

1) Excavation and Landfills - removal of the top layer of soil. The thickness is determined through sampling and analysis. The use must be justified from a radiological safety perspective, in terms of the dose to the representative person;
2) Chemical Extraction (Ex situ) - disposal of contaminated soil is the option that has been most widely used to date. This involves the separation or extraction of contaminants. It would rely on the required substitution of the removed material with clean top soil. It may not be viable in the case of large volumes of contaminated soil;
3) Surface and Ground Waters: Pump and Treat - large quantities of ground water are pumped and stored in a suitable nearby location. Sediment is then removed and similarly heavy metals can be separated or extracted by chemical processes;
4) Natural Attenuation - this method relies on the capacity of natural media (rocks, soils, sediment and ground water) to retard contaminant migration. This however will require adequate monitoring owing to the evolution of natural systems with time and our incomplete understanding of natural processes at a site;
5) Alternative Land Uses - when extensive areas have been contaminated, many of the discussed remediation methods may be too expensive to carry out or too intrusive. Alternative uses of the land may need to be considered (for example if the land was used

for agricultural purposes). These may range from considering uses such as a parkland or eco-tourism;

6) Phytostabilisation - involves the development of a stable and permanent vegetation cover that reduces the risk of erosion of contaminated soil and thus reducing waterborne and dust-borne exposure pathways. This technique may also change the mobility of toxic elements by reducing concentration in the soil matrix;
7) Phytoextraction - the use of plants to remove contaminants from the environment and concentrate them in above ground plant tissue. It requires that the target radioelement be available to the plant root, absorbed by the root and trans-located from the root to the stem. For uranium removal, free $UO_2(2+)$ is the uranium species most readily taken up and translocated by plants. It may require soil amendments that increase the availability of uranium complexation;
8) Chemical Processes: Co-Precipitation - radionuclides present at very low mass concentrations can nevertheless form solid phases by co-precipitation in mineral lattices. A useful example for NORM materials is the high selectivity shown by radium for barite. This may however involve establishing geochemical controls for the migration of radioelements in the field;
9) In Situ Soil Vapour Extraction Treatment - the physical removal of volatile compounds from the unsaturated zone through vapour extraction boreholes or air injection boreholes. Vacuum blowers produce a motive force to induce airflow through the soil. Volatiles are typically adsorbed on to activated carbon; and
10) Reactive Barriers - a passive, in situ technology that emplaces the reactive media in the subsurface designed to intercept a contaminant plume, provide a flow path through the reactive media, and transform the contaminant(s) into environmentally acceptable forms to attain remediation concentration goals down-gradient of the barrier.

9.6 Prioritisation of remediation

1) Priority should be given to those groups for whom residual dose exceeds the reference level.
2) The groups should be relocated to a site, which complies with free living requirements.
3) The site of relocation should be declared as contamination free to be considered as a site for relocation.
4) Interim safety measures should be considered to render the site safe until remediation activities are to be implemented [6].
5) Sites that are considered for remediation should be characterised prior to decision making.
6) The characterisation should be used as input into a screening safety assessment.
7) Radiological prioritisation should be determined in accordance with the results of the screening as given in the Table 9-1.
8) Category A should receive priority consideration for remediation [6].

Annual Effective Dose	Site Categorization
> 20 mSv/a	A
5 - 20 mSv/a	B
1 - 5 mSv/a	C
250 µSv/a - 1 mSv/a	D

Table 10-1: Site Categorisation

9) Other factors that should be considered for further prioritisation include the following [6]:
   i. Socio-economic considerations;
   ii. Deployment of available remediation techniques;
   iii. Availability of scientific data required for the site characterisation;
   iv. Potential impacts of adjoining properties and protection of the environment;
   v. Availability of funds; and
   vi. Inputs from interested and affected parties including affected communities.

9.7 Environmental sampling and analysis

1) Sampling programmes should be conducted with the following objectives [6]:
   i. To characterise the source term by sampling and analysis of releases and environmental media;
   ii. To provide input for validation of transport models;
   iii. To identify unexpected environmental contamination, transfer routes and pathways;
   iv. Depending on the results obtained and the requirements of the transport models used, the consideration of the amendment of the monitoring programmes from time to time;
   v. To consider a background or reference site when historical practices have been performed in the area that may have contributed to the increase in radionuclides in the environment;
   vi. To assure the quality of the sampling programme;
   vii. To utilise an analytical method capable of performing the measurement at the required sensitivity (usually background level) and accuracy;
   viii. To analyse the main radionuclides such as long lived alpha emitters: 238U, 234U, 230Th, 226Ra, 210Po; 232Th, 228Th, 224Ra; Beta emitters: 210Pb, 228Ra; and 222Rn and 220Rn (and their progeny)
   ix. To justify the exclusion of radionuclides from analysis programmes and modelling assessments;
   x. To perform a screening analysis where limited information is required; or for a detailed safety assessment where nuclide specific data is required;
   xi. To define an appropriate subsistence farmer scenario for the representative person;

xii. To provide information during the different stages of remediation regarding the efficiency of the remediation technologies applied; and

xiii. To verify efficiency of the applied remediation technologies at the end of remediation and to verify compliance with release criteria.

9.8 The Public Safety Assessment Methodology for Remediation

1) The safety assessment methodology applied for remediation, should follow the same basic principles as followed in the safety assessment methodology for planned situations.
2) The safety assessment methodology for remediation, should be an iterative process, being a repeat of the initial safety assessment after the remediation activities have been completed (see Figure 10.2).
3) The revised final safety assessments should use the radionuclide activity concentrations, obtained from the post-remediation surveys.

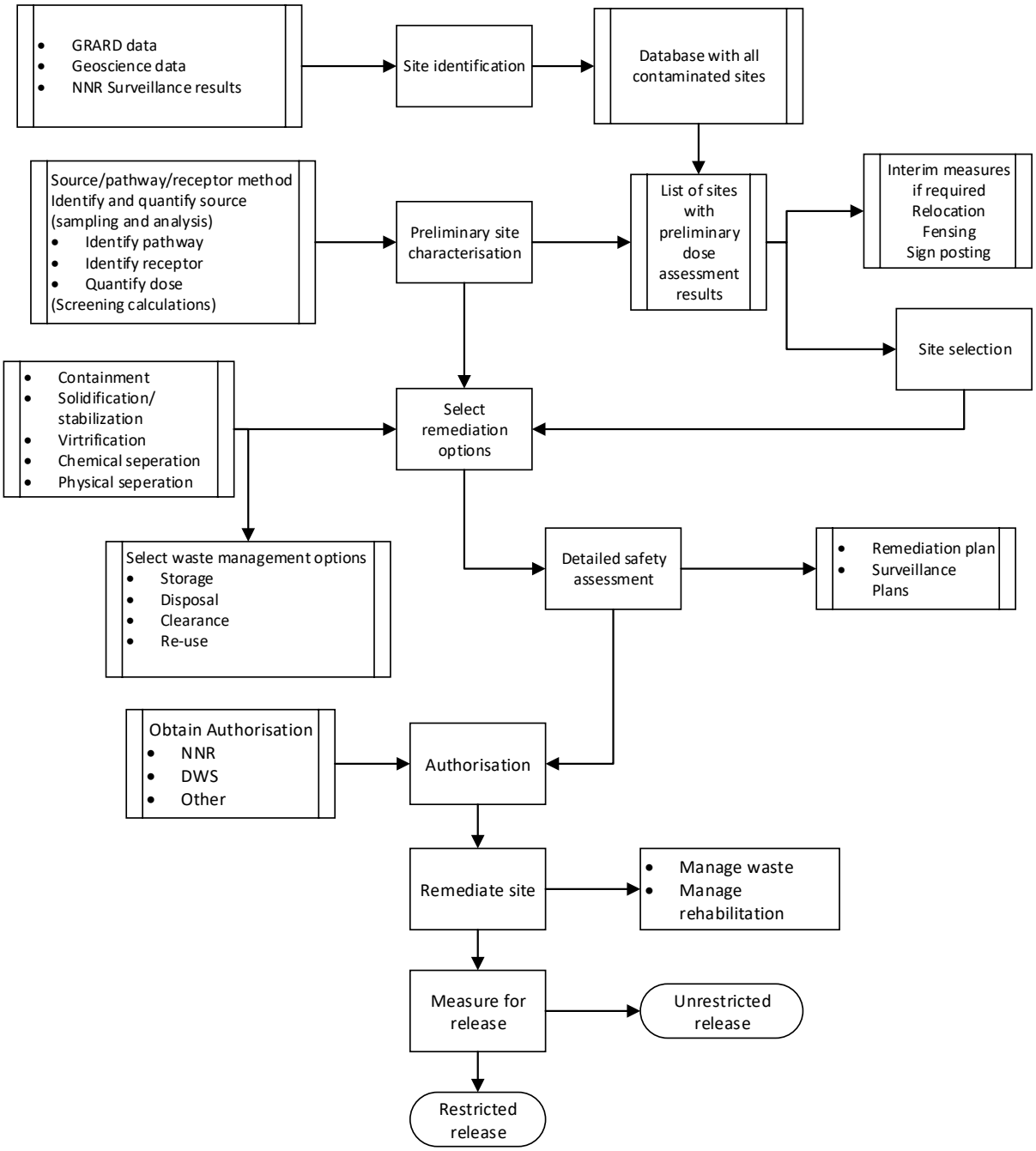

Figure 10-2: Public Safety Assessment Methodology for Remediation

9.8.1 Safety assessment process description

9.8.1.1 Site identification

The identification of sites should be based but not limited to the following sources of information;

1) Relevant database of radiologically contaminated sites

2) Information from the public, operators, other national authorities involved in the process and any other source of information.

9.8.1.2 Preliminary site characterisation

1) A survey should be performed to obtain the required site and area information.
2) The site characterisation should identify and quantify the nature of the contamination as an input to the selection of the appropriate remediation technology.
3) A public safety assessment should be performed.
4) The source-pathway-receptor method should be used to model the dose to the representative person using various relevant scenarios and a subsistence farmer scenario.
5) The dose assessment should be performed to establish the maximum exposure for a year at the time of assessment as well as the peak dose.
6) The results of the safety assessment should be evaluated against the 1 - 20 mSv/a criteria.
7) Nuclide specific reference levels should be determined in aid of the choice of remediation technology [6].

9.8.1.3 Select site remediation option

1) A team of experts of a wide range of areas should be used to define a remedial plan.
2) The remediation technology should be defined and the efficiency of the process should be modelled to determine whether the site would comply with release criteria after completion of remediation.
3) Final sampling and analysis should verify the efficiency of the claimed technology before the land is released from regulatory control [6].

9.8.1.4 Authorisation of remedial activities

1) The application for remediation of radiologically contaminated sites should be made to the NNR.
2) The other applications may need to be made to the Department of Mineral Resources (DMR), Department of Environmental Affairs (DEA) and Department of Water and Sanitation (DWS) as applicable.

9.8.1.5 Remediate site

1) Once the remediation activities have been authorised, the specified remediation technology or combination of technologies should be applied.

9.8.1.6 Measure for release

1) A detailed site survey should be prepared at the end of the remediation actions [7].
2) This survey should be nuclide specific, to verify compliance with the nuclides specific release criteria that has been identified in the initial remediation safety assessment.

3) Release criteria should be expressed in terms of nuclide activity concentrations in media, for example the uranium-238 concentration (Bq/g) in soil.

9.8.1.7 Release site

The final step in the remediation process should be to release the site from regulatory control.

1) The applicant should apply for release of site from regulatory control.
2) If the site can comply with the release criteria for a subsistence farmer scenario, an application for unrestricted use should be made.
3) If the site cannot comply with the unrestricted release criteria, the applicant should apply for the less stringent land use scenarios on the basis of a safety assessment or should consider further removal of the contaminants until the unrestricted release criteria is achieved.

10. REMEDIATION PLAN

1) A site specific remediation plan may be submitted to the NNR, prior to commencement of the remediation activities. The following aspects should be considered when the plan is prepared [9]:
   i. Development of a site-specific remedial action plan taking into account of the site-specific remediation strategy.
   ii. Design and implementation of an action plan and associated monitoring arrangements to identify possible adverse health, safety and environmental impacts of the contaminants and to optimize protection related to workers performing the remediation, the public and the environment.
   iii. Clearly stipulating the remediation objectives, taking cognisance of justification and optimisation.
   iv. Developing plans for both the remediation work and the necessary actions for post-remediation, such as maintenance, monitoring and institutional controls to enforce restrictions on land use and buildings, if applicable.
   v. Update of the plan as the remediation progresses, to reflect any changes or provisions relating to the conduct and progress of the remediation.
2) The site-specific remedial action plan should include, but not be limited to, consideration of the following aspects:
   i. The overall safety objective of protecting people and the environment, now and in the future, from the harmful effects of radiation;
   ii. The importance of assigning responsibilities for all aspects of the remediation process;
   iii. The basic principle that remedial actions be justified and optimized;
   iv. The consideration of non-radiological hazards and the implication of the competent authorities for these hazards;

v. The importance of selecting and achieving a remediation end state that provides long term protection and sustainability with consideration of short term benefits versus adverse impacts;
vi. The need for a formal process including means of engagement with all relevant interested parties to identify areas that may need to be remediated, evaluate the risks, assign priorities, and adopt a graded approach such that level of effort and oversight is commensurate with risk, taking into account the possible levels of exposure in comparison with the applicable reference levels and the need to avoid any deterministic effects on humans and reduce the risk of stochastic effects;
vii. A means for evaluating a range of possible remediation and waste minimization technologies that may be applied, as appropriate;
viii. The identification of the basic approach to dose reduction, i.e., the choice between actions to remove contaminated material and actions to modify the exposure pathways to humans, taking into account factors, such as worker dose, short term impacts relative to long term benefits, volume of radioactive waste generated, and others;
ix. The need for urgent protective actions (such as access controls) to prevent further exposure in the area to be remediated and to prevent the spread of contamination into other areas (outside of the remediation area);
x. Any arrangements necessary, in the interests of public safety, for obtaining access to or use of private property;
xi. Communication with and involvement of interested parties in decisions regarding the development and implementation of protection and remediation strategies, as appropriate;
xii. The availability of adequate funding for the remediation, including funding of the management of the waste, media and/or debris generated;
xiii. Minimizing the generation of radioactive waste and managing such waste in accordance with the national framework of safety (including policy and strategy) for radioactive waste management;
xiv. Employing clearance, reuse, and recycling to the extent practicable;
xv. The need for any post-remediation monitoring, surveillance and institutional controls (such as access restrictions);
xvi. Ensuring formal arrangements for record keeping and communication during all stages of remediation, specifying who is responsible to perform these functions at each stage, which records should be kept, to whom they should be submitted and communicated, and for how long they should be retained.
xvii. Analysis and interpretation of historical records from past activities, including records of inspection, incidents, as well as site physical and environmental data.
xviii. The need to impose institutional controls or restrictions on land use during or after remediation.
xix. Monitoring the efficacy of the remedial action plan through evaluation of environmental monitoring data and contaminant transport modelling.
xx. Mechanism ensuring that formal approval by the regulatory body is performed prior to the implementation of each step of the remedial action plan and that the verification of a previous step is done. This mechanism should provide a step-wise

process for approval, verification and financing of the remediation, with the adequate flexibility to review past decisions and to adjust the remedial action plan, as appropriate. Financial control of the program could be coupled with this procedure.

11. POST REMEDIATION REPORT TO THE NNR

1) The post remediation report should be a summary of the history of the facility and process followed during remediation and how the remediation end goals were met.
2) The following items should be included:
   i. Facility history – use and dates of all phases
   ii. The authorisation process
   iii. Overview of initial radiological characterisation results
   iv. Remediation techniques applied
   v. Results of remediation process versus initial goals
   vi. Efficiency of remediation technologies
   vii. Dose report of accrued dose by workers - Radiological data including survey results, personnel doses, radioactive waste quantities, disposal/interim storage locations, and declassification/clearance surveillance data and similar information for chemical facilities as appropriate.
   viii. Waste report – quantities, classification and methods of disposal
   ix. Costing of remediation – comparison of initial costing versus final costing
   x. Remediation outcomes
   xi. Post remediation plan
   xii. Lessons learnt
   xiii. Deed inscription details as applicable
   xiv. NNR release certificate.

12. POST REMEDIATION CONTROL

1) If post–remediation control is needed, a plan should be prepared and submitted to the NNR is accordance with the requirements of the dGNSR**.**
2) When preparing for post-closure remedial activities, the following should be kept in mind:
   i. Planning for post-remediation management should be initiated at the commencement of planning of the remediation itself.
   ii. Once the remediation is complete, post-remediation management should be initiated. The post-remediation phase should address how the remediated area should be managed once the remediation has been completed for an area. The complexity of this phase should depend on whether restrictions on use or access need to be imposed, and what those restrictions are. Even where there are no restrictions in place, some level of surveillance, monitoring, and engagement of interested parties should be considered.

iii. Post remediation management should include the justification and implementation of any institutional controls, and the periodic re-evaluation of the effectiveness and robustness of the remedial actions taken. If a determination is made during re-evaluation, in consultation with the relevant parties that the action is less effective than anticipated, additional actions should be considered.

iv. Institutional controls should be implemented, where appropriate, to verify effectiveness of remediation over time. A qualified person should routinely inspect and sign off on the integrity of engineered structures. Future monitoring and surveillance should be appropriate to future land use.

13. FORMAT AND CONTENT FOR A SITE SPECIFIC REMEDIAL ACTION PLAN

1) A remedial action plan, supported by a safety assessment, should be prepared and submitted to the NNR for approval [8].
2) The remedial action plan should aim at the timely and progressive reduction of the radiation risks and eventually, if possible, at the removal of restrictions on the use of or access to the area”
3) A typical Table of Contents for a remedial action plan should include the aspects below.

Executive Summary

1. Introduction
    - 1.1. Scope of remediation
    - 1.2. Remediation objectives
    - 1.3. Organisation and management
        - 1.3.1. Staffing resources
        - 1.3.2. Roles and responsibilities
        - 1.3.3. Time schedule
        - 1.3.4. Coordination expectations with other organizations
2. Regulatory control
3. Site history
    - 3.1. Past operations
    - 3.2. Ownership records
    - 3.3. Production records
4. Site characteristics
    - 4.1. Location and key features, including man made features such as existing above ground and below ground utilities
    - 4.2. Local and regional demographics, current and future land uses, current and future land users
    - 4.3. Geology, seismicity and hydrogeology of site
    - 4.4. Surface water, wetlands, streams, rivers, lakes, ponds, etc.
    - 4.5. Groundwater
    - 4.6. Type of climate, weather patterns, seasonal characteristics, rainfall
    - 4.7. Maps and plans (may need multiple maps and plans at various scales and aerial photos)

5. Area investigation activities
    - 5.1. Detailed description of the area(s) investigated
    - 5.2. Previous analytical data
    - 5.3. Initial evaluation of data and identification of hazards
    - 5.4. Assessment of radiological exposures relative to the historic and newly collected data
    - 5.5. Evaluation of uncertainties
    - 5.6. Identification of data gaps and investigative strategy to fill gaps, as necessary
6. Site and area contamination survey
    - 6.1. Simple site and area survey and sampling methods
    - 6.2. Survey strategy
    - 6.3. Sample analysis
    - 6.4. Radionuclides of interest
    - 6.5. Non-radiological contaminants of interest
    - 6.6. Presentation of data
7. Dose assessment
    - 7.1. Doses received by members of the public
    - 7.2. Doses received by remediation workers
    - 7.3. Radiation protection programme
        - 7.3.1. Protection of the public during remediation activities
        - 7.3.2. Health and safety of workers
    - 7.4. Prioritisation of areas for remediation and public risks
8. Risk assessment
    - 8.1. Table of site components with issues and risks itemized
    - 8.2. Evaluation of risks and consequences
    - 8.3. Risk rankings
    - 8.4. Risk management strategies
    - 8.5. Residual risk after implementation of management strategies
9. Assessment of environmental impacts
10. Development of remedial action options
    - 10.1. General approach to investigating and evaluating options
    - 10.2. Overall objectives of the options analysis
    - 10.3. Preliminary identification of general response actions and available remediation technologies
    - 10.4. Development and screening of options
    - 10.5. Detailed analysis of options
    - 10.5.1. Threshold criteria
    - 10.5.2. Balancing criteria
    - 10.5.3. Modifying criteria
    - 10.6. Identification of potential remedial actions (including interim actions)
    - 10.7. Development of specific site work plans, including possible arrangements for incidents and accidents during remediation
11. Post-remediation planning

- 11.1. Long term care and maintenance
- 11.2. Monitoring and surveillance
- 11.3. Monitoring schedule
- 11.4. Monitoring of performance criteria
- 11.5. Responsibilities for assessing monitoring data
- 11.6. Costs of remediation and post-remediation activities

12. Residue management plan
    - 12.1. Opportunities for minimization of residues
    - 12.2. Identification and characterization of residues
    - 12.3. Residues to be cleared from regulatory control
13. Residues to be recycled or used as by-products
14. Residues to be managed as radioactive waste
    - 14.1. Predisposal (pre-treatment, treatment, conditioning)
    - 14.2. Storage
    - 14.3. Transport
    - 14.4. Disposal
15. Communication with interested parties
    - 15.1. List of parties identified
    - 15.2. Engagement, consultation and communication plan.
    - 15.3. Issues and concerns raised
    - 15.4. Record of consultations

14. REFERENCES

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