Statens strålevern
Norwegian Radiation Protection Authority

StrålevernRapport 2018:4

Regulatory Supervision of Legacy Sites: The Process from Recognition to Resolution

Report of an international workshop Lillehammer, 21-23 November 2017

Reference:
Sneve M K, Popic J M, Siegien-Iwaniuk K. Regulatory Supervision of Legacy Sites:
The Process from Recognition to Resolution. Report of an international workshop, Lillehammer, 21-23 November 2017
StrålevernRapport 2018:4. Østerås: Statens strålevern, 2018.

Key words:
Radiation protection, nuclear legacy, international recommendations and guidance, spent nuclear fuel, radioactive waste, contaminated land, emergency preparedness and response, environmental monitoring, existing exposure situations, radiological environmental impact assessment, worker protection, public protection, protection of the environment, regulatory compliance.

Abstract:
This report describes the presentations and discussions from the workshop, which also resulted in the identification of further research and cooperation needs. The workshop was organized by the NRPA, with the official support of the IAEA, NEA and ICRP. The objective of the workshop was to promote the sharing of experience on practical regulation of a wide range of nuclear and radiation legacies, from initial recognition through to full resolution.

Referanse:
Sneve M K, Popic J M, Siegien-Iwaniuk K. Regulatory Supervision of Legacy Sites:
The Process from Recognition to Resolution. Report of an international workshop, Lillehammer, 21-23 November 2017
StrålevernRapport 2018:4. Østerås: Norwegian Radiation Protection Authority, 2018.
Language: Norwgian.
Language: English.

Emneord:
Strålevern, kjernesikkerhet, atomarv, internasjonale anbefalinger, brukt brensel, radioaktivt avfall, kontaminert land, beredskap, miljøovervåking, miljøkonsekvensutredning, eksisterende eksponeringssituasjoner strålevern av befolkning og arbeidstakere, beskyttelse av miljø, tilsyn og kontroll.

Resymé:
Denne rapporten beskriver alle presentasjoner og diskusjoner fra en workshop, som også resulterte i å identifisere videre forskning og samarbeidsbehov. Workshopen ble arrangert av Statens Strålevern, med offisiell støtte fra IAEA, NEA og ICRP . Målet med seminaret var å dele erfaringer om praktisk regulering av et bredt spekter av atomarv, fra første anerkjennelse gjennom til full oppløsning.

Head of project: Malgorzata K. Sneve
Approved:

Per Strand

Per Strand, director, Department of Nuclear Safety and Environmental Radioactivity

114 pages.
Published 2018-04-09.
Cover design: 07 Media.

Norwegian Radiation Protection Authority, P.O. Box 55, N-1332 Østerås, Norway.
Telephone +47 67 16 25 00, fax + 47 67 14 74 07.
E-mail: nrpa@nrpa.no
www.nrpa.no

ISSN 0804-4910 (print)
ISSN 1891-5205 (online)

StrålevernRapport 2018:4

Regulatory Supervision of Legacy Sites: The Process from Recognition to Resolution

Report of an international workshop
Lillehammer, 21-23 November 2017

Workshop Coordinator:

Malgorzata K. Sneve

Statens strålevern

Norwegian Radiation Protection Authority
Østerås, 2018

Preface

The following welcoming words set the scene for this report of a workshop hosted by the NRPA in Lillehammer, 21 - 23 November 2017, on the subject of Regulatory Supervision of Legacy Sites: The Process from Recognition to Resolution:

> *"Dear colleagues,*
>
> *I am delighted to welcome you all to Lillehammer for this workshop on "Regulatory Supervision of Legacy Sites: The Process from Recognition to Resolution".*
>
> *It is very gratifying to see many familiar faces and participation from organizations that attended the previous workshop hosted by NRPA in Oslo in 2015.*
>
> *The workshop concluded that strategically, there is a need to link national strategies for legacy management and site remediation with radioactive waste management.*
>
> *This time, the broad focus is much the same, but I would like to highlight that we can now more clearly recognize the links between decommissioning of major nuclear installations, especially old ones, management of contaminated areas and management of radioactive waste that comes from these activities. All of them present many common challenges that are best addressed in a coordinated manner, and this in turn reflects that we now focus on design of an effective process that leads to successful resolution.*
>
> *Norwegian efforts on legacy problems started for more than 20 years ago, and this year was a special one in relation the results of our bilateral cooperation with Russia – 15 years of preparatory work start to give practical results with the first shipment of spent fuel from the Andreeva site of temporary storage in the Kola peninsula to Mayak.*
>
> *In NRPA's view, an important contribution to development of such a process will be provided by involvement of international organizations. We noted in the conclusions from the previous workshop that there is a substantial gap between theory and practice, and that international guidance on practical application would be valuable. It is therefore a particular pleasure to say that this workshop is organized with the official support of the International Atomic Energy Agency, the Nuclear Energy Agency and the International Commission on Radiological Protection. Their direct involvement contributes not only to coordination of improved international guidance, but has also promoted wider participation and networking.*
>
> *A related important international development connected with legacy management is the setting up of a new European – Central Asian network (EuCAS) as part of the IAEA's Global Nuclear Safety and Security Network. I am happy to say that Norway provides the first chair of EuCAS.*
>
> *So welcome also to the new faces; we hope to share all our wider inputs and experience to mutual benefit. At the workshop in 2015 we had about 45 participants from 11 countries and this time we have 63 from 20.*
>
> *Some key points from the previous workshop included the following:*
>
> - *Every legacy is different*
> - *The results of optimization may lead to different solutions at different sites, according to the prevailing circumstances*

- *Effective risk communication is a very important part of the stakeholder engagement process*
- *The concept of emergency, existing and planned exposure situations needs further international guidance on its practical application*
- *Need to apply the protection objectives and standards with a holistic approach to proportionate management of different risks in different contexts*
- *Need to improve prognostic assessment methods and support the consistent application of the principle of optimization*

With these reminders in front of us, I am confident that our workshop will lead to closer cooperation at the international level, and support the continuing development of practical guidance on application of nuclear safety and radiation protection at legacy sites based on very practical experience".

Malgorzata Karpow Sneve, Director for Regulatory Cooperation Program, NRPA

Presentations given at the workshop, conclusions and recommendations are summarized in the current report. The NRPA is very grateful for the support of the participants and the NEA, IAEA, ICRP and IUR at the workshop, and for their review of the draft of this report.

The opinions and other material presented in the report may not be taken to represent the views of the organizations involved. However, it is hoped that the results will support the further development and application of international recommendations and standards in the regulatory supervision of legacy sites.

Executive Summary

International events in recent years that focused on regulatory supervision of legacy sites have highlighted the need for improved collaboration and mutual support in order to develop, implement and maintain efficient and effective measures for supervision and management of different sites worldwide. Concluding remarks from a previous workshop on processes from recognition to resolution of legacy sites, hosted by the Norwegian Radiation Protection Authority (NRPA) in Oslo, 2015, emphasized the gap between theory and good practice and the need for international guidance for various situations. The current workshop, as a continuation, follows up the ideas developed during this previous workshop, with the main objective being to promote sharing of experience on practical issues in regulation of a wide range of radiation legacies in an international arena.

A workshop was therefore organized by the NRPA, with the official support of the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA), the International Commission on Radiological Protection (ICRP) and International Union of Radioecology (IUR). The workshop was attended by 63 representatives of 32 organizations from 18 countries, as well as representatives from international organizations, including the IAEA, NEA and ICRP.

The objective was to promote the sharing of experience on practical regulation of a wide range of nuclear and radiation legacies, from initial recognition through to full resolution.

The scope of the workshop included the full range of issues linked to regulatory supervision, from the processes of raising the awareness of the legacies, recognizing the linked hazards and risks, communication to the public and between authorities, to the complete resolution of radiological protection and other hazards issues associated with management of the legacy, including the plans for future environmental monitoring and land use issues. Five sessions were organized:

- International perspectives and current activities in regulatory supervision of legacies;
- Methodologies for legacy regulation and management including long-term site management and on-site disposal;
- Scientific, technical and regulatory aspects for remediation (including safety and environmental assessments, remediation and environmental monitoring);
- Social and ethical issues: uncertainties, risk communication and engagement of stakeholders: and,
- Recommendations for future coordination of international activities and cooperation.

Altogether, there were 35 presentations across the five sessions. The number of participants at the workshop from many different organizations worldwide clearly illustrates the importance and interest around the topic of legacy site management.

A number of recurring themes were identified from presentations and discussions, such as the need for holistic and proportionate approaches for legacy management, flexibility in regulations to allow legacy issues to be addressed and stakeholder engagement. There was much discussion around these and other topics.

From presentations and discussions, the following recommendations and conclusions are drawn:

- To address legacies sites, pragmatic and flexible regulations are needed that allow prevailing circumstances to be taken into account when deciding on management options, applying a risk-based approach. Decisions on practical component can benefit from the experience acquired from managing different kinds of legacy sites.

- Residual risks and related radiation exposures are site-dependent considerations; what may be acceptable for one site may not be in another. Thus, remediation actions should be case specific and dependent on relevant considerations and flexible reference levels established by regulations.
- Holistic approaches, that consider remediation in it whole life-cycle, are needed to address the various hazards at legacy sites, from initial recognition through resolution. This includes means by which options for addressing hazards may be prioritized. Cooperation between those responsible for regulating different aspects of these sites is important. Finally, remediation options should be aligned with management strategies for materials generated during remediation, including waste. There are many uncertainties and challenges associated with holistic management of legacy sites. Further targeted discussion around these uncertainties and challenges would be very useful in supporting the development of holistic management approaches.
- Countries should establish a proper system for an active society engagement that would encompasses communications as well consultations between relevant institutions and parties in society. In such a way, mechanisms for providing a necessary information flow and constructive and complementary collaboration would be in place prior to being needed. The development of such 'routine' communication systems in order to make a framework which allows constructive decision making should therefore be encouraged.
- Dialogue between operators, implementers, regulators and researchers should be further encouraged to ensure a common ('both-direction') understanding of legacy issues and regulatory requirements and scientific results of importance for this topic. Research activities should focus on key issues that affect decisions, rather than the full range of knowledge gaps, which would be endless. The purpose is reduce uncertainties sufficiently to allow robust and reliable decisions.
- In the scope of environmental aspects, decommissioning and remediation are operations with same objectives although practically they involve somewhat different, usually closely linked activities. The development of recommendations at an international level, based on practical experience, that supports a more holistic approach that encompasses decommissioning and remediation activities, as needed, would be beneficial. This should include guidance on the application of the framework for radiological protection, in terms of planned, existing and emergency exposure situations, on remediation activities on decommissioning sites, including the setting of reference levels and other relevant criteria, and consultation and communication around reference levels and dose limits and constraints for workers and the public.

The following future work activities have also been identified:

- Develop an understanding of the different chemical and physical hazards and radiation risks to help make decisions in a holistic way and help in preventing sites from being managed solely with respect to radiation risks, ignoring other types of hazards or vice versa;
- Consider the harmonized application of the concepts of remediation and decommissioning at legacy sites? This is particularly important at sites where decommissioning plans need to incorporate remediation or clean-up of unplanned contamination from spills and leaks, but also where facilities were designed and operated without any consideration of future decommissioning;
- Explore stakeholder engagement practical experience to determine what has worked well according to some identified criteria for 'working well' and what has not, and why; and, from this, discuss how engagement with affected people can be approached to support the effective

management of legacy issues. Greater focus is needed on mechanisms to support stakeholder engagement and it could be beneficial to involve social scientists in discussions on this topic.

- Developments in communication and consultation strategies and lessons learned from experience in this area could be an interesting discussion topic for a future workshop. Communication of protection objectives and criteria to meet them (e.g. the difference between dose limits and reference levels) could also be a useful topic for further discussion.
- There could also be value in working together to find a common understanding of the meaning of some commonly key terms, such as environment, contamination, exposure, hazard, risk, impact, consequences, harm and end-state. Since many of these terms already have legal and /or technical definitions, the discussion should avoid prescription, but nevertheless help in the wider communication of the issues.

Workshop participants.

Contents

1 Introduction

1.1 Background

International events with a focus on regulatory supervision of legacy sites highlighted, in recent years, the need for intensive collaboration and mutual support in order to develop, implement and maintain efficient and effective measures for supervision and management of different sites worldwide. Concluding remarks from a previous workshop on processes from recognition to resolution of legacy sites, hosted by the Norwegian Radiation Protection Authority (NRPA) in Oslo, 2015, emphasized the gap between theory and good practice and the need for international guidance for various situations. The current workshop, as a continuation, follows up the ideas developed during this previous workshop, with the main objective being to promote sharing of experience on practical issues in regulation of a wide range of radiation legacies in an international arena.

The workshop was organized by the NRPA, with the official support of the International Atomic Energy Agency (IAEA), the Nuclear Energy Agency (NEA), the International Commission on Radiological Protection (ICRP) and International Union of Radioecology (IUR).

1.2 Objective and topics of interest

The objective of the workshop was to promote and extend the sharing of experience on practical regulation of a wide range of nuclear and radiation legacy sites, from initial recognition through to full resolution, including following topics:

- Support for development of a common methodology describing a comprehensive process for legacy management and regulation;
- Practical experience and lessons learned in hazard characterization, risk identification and management. Encouragement of proportionate management of different risks and overall optimization;
- Harmonization of protection objectives, and assessment methodologies and practice, while creating locally optimized procedures and solutions;
- Harmonization of requirements for efficient inspections and monitoring of sources and environment after clean-up or remediation activities;
- Coordination among regulatory authorities and executive organizations, including those responsible for other hazardous substances;
- Sharing underpinning scientific information, which supports sites characterization and decision making on the introduction and ending of countermeasures, remediation techniques and waste management;
- Identification of further research needs for appropriate regulatory supervision; and
- Engagement of stakeholders and effective communication measures at each stage of legacy management as part of an overall transparent and traceable legacy management process.

The scope of the workshop includes the full range of issues linked to regulatory supervision, from the processes of raising the awareness of the legacies, recognizing the linked hazards and risks, communication to the public and between authorities, to the complete resolution of radiological protection and other hazards issues associated with management of the legacy, including the plans for future environmental monitoring and land use issues.

The topics of potential interest included:

- Legacy management experience from past events;
- Basis for development and application of regulatory criteria for legacy site management;
- Effective communication processes at each stage of legacy management;
- Decision making in transition from emergency to existing exposure situation and later stages;
- Coordination among regulatory authorities and executive organizations, including those responsible for other hazardous substances; and
- Sharing underpinning scientific information, which supports decision making on introduction and ending of countermeasures, remediation techniques and waste management.

The workshop was conducted in an informal manner with a view to promoting free exchange of ideas, and development of innovative approaches to meeting regulatory challenges. To the same end, simultaneous translation between Russian and English was provided. The opinions and other material presented in the report may not be taken to represent the views of the organizations involved. However, it is hoped that the results will support the further development and application of international recommendations and standards in the regulatory supervision of legacy sites.

1.3 Participation and program of the workshop

Participation included relevant regulatory authorities, organizations responsible for management of legacy sites, site operators, technical support organizations and academic institutions. The full list of participants and their affiliations is provided as Appendix A. They included 63 representatives of 32 organizations from 18 countries as well as the IAEA, the NEA-OECD and members of the ICRP Task Group 98 (TG98).

Based on the proffered inputs, the workshop was organized into the following topical areas:

- International perspectives and current activities in regulatory supervision of legacies.
- Methodologies for legacy regulation and management including long term site management and on-site disposal.
- Scientific, technical and regulatory aspects for remediation (including safety and environmental assessments, remediation and environmental monitoring) – experiences and lessons learned.
- Social and ethical issues: uncertainties, risk communication and engagement of stakeholders.
- Recommendations for future coordination of international activities and cooperation.

The full workshop program is provided as Appendix B.

1.4 Preparation and purpose of this report

This report was drafted by NRPA and reviewed by participants for correctness prior to publication. The following Sections summarize the presentations made in each of the topical areas listed above and the discussion in each area. Section 7 provides a summary of overall discussions and Section 8 sets out conclusions and recommendations on meeting regulatory challenges rated to legacies. References are provided in Section 9.

2 International perspectives and current activities in regulatory supervision of legacies

Session 1 focused on international perspectives and current activities in the regulatory supervision of legacies. This section provides a summary of each presentation and the associated.

2.1 International Cooperation on Regulatory Supervision of Legacies: Overview of Norwegian activities

Malgorzata Sneve (NRPA) presented.

Legacy sites, or existing exposure situations, are a global issue and yet there is no current international definition of 'what is a legacy site'. There are locations worldwide where existing exposure situations are present, resulting from nuclear explosions, uranium mining activities, nuclear reprocessing and nuclear power plants (NPP). Whether or not nuclear reprocessing plants and NPPs are legacies may be questioned, but many older sites have characteristics associated with legacy sites: e.g. they were operated to standards that are not consistent with the level of protection that would be required in the present day, including record keeping, and existing exposure situations are often present alongside planned. Newer NPPs are operated to modern standards, including having currently adequate decommissioning arrangements established in many instances, and yet they could become legacies in the future if lessons are not learned from older NPPs and their management and/or if requirements for protection change.

Every legacy is different, presenting a complex variety of relevant prevailing circumstances, including:

- Sites and facilities affected by major accidents and incidents;
- Storage and disposal sites and facilities for radioactive waste;
- Nuclear technology and development centers and laboratories;
- Former uranium mining and milling facilities, and NORM; and,
- Former peaceful nuclear explosion and weapons testing sites.

Standards for protection evolve as well as the regulation of those standards, hence, even where facilities have been operated and regulated appropriately they may be newly recognized as legacies as standards are revised.

It is difficult to define a legacy, although the following IAEA working group on the Regulatory Supervision of Legacy Sites (RSLS) working definition is helpful:

> “*A facility or area that has not completed remediation and is radioactively contaminated at a level which is of concern to regulatory bodies*”

The NEA Expert Group on Legacy Management (EGLM – see section 2.4) takes effectively the same view, provisionally describing a legacy from a regulatory perspective as:

> “*a site that has not completed remediation, and that has radioactivity that is of concern to the regulator*”

The first step in the resolution of a legacy issue is to recognize an existing exposure situation. Once identified, there is no one universal answer to addressing the legacy issues; each site will vary in both the volume and activity of wastes present and in the presence of other hazards, including chemicals and physical hazards. The prevailing circumstances must, therefore, be taken into account with a proportionate approach taken to the management of the different risks. Thought should also be given to the intended end use of the site.

A graded, iterative strategy should be followed in managing legacies, recognizing that it is not possible to predict or plan everything in advance. The strategy should be appropriate to the site of interest, meet protection and safety objectives, address relevant stakeholder interests, and be practically achievable. A holistic approach should be taken, ensuring that new legacies are not created as a result of actions taken.

A wide range of topics need to be addressed when considering site decommissioning and management, including:

- Emergency preparedness and response during decommissioning and remediation activities;
- Operational safety;
- Site characterization and environmental monitoring;
- Control of discharges and public exposure during remediation;
- Radiological Environmental Impact Assessment for planned releases, accidents, transport, treatment and storage of waste on site, and disposal on site;
- Contaminated land management and support for long-term site restoration and waste management strategies;
- Security, including control of materials and post-remediation stewardship; and,
- Overall optimization.

A number of challenges may also be faced, such as identifying ownership, both in terms of physical ownership of the legacy and the financial ownership. The management of sites often involves different authorities and so it is not always clear as to who is responsible for what and what resources are available. The technical and scientific knowledge of authorities may also vary, and terminologies may differ. There may also be conflicting objectives and requirements. There is also a strategic need to link national strategies for nuclear installation decommissioning and site management with waste management, including radioactive waste management. How to maintain the interfaces between the different authorities and between regulators, operators and other organizations needs careful consideration to ensure that responsibilities are clear and to encourage dialogues.

A further challenge is how to distinguish between planned and existing exposure situations, with different exposure situations potentially co-existing within a site, and the issue has been recognized by the IAEA:

> "*The descriptions of the three types of exposure situation are not always sufficient to determine unequivocally which type of exposure situation applies for particular circumstances. For instance, the transitions from an emergency exposure situation to an existing exposure situation may occur progressively over time; and some exposures due to natural sources may have some characteristics of both planned exposure situations and existing exposure situations*." [Para 1.21 IAEA Basic Safety Standards, 2014]

Clear boundaries are needed between these exposure situation concepts to support the appropriate use of reference levels and dose limits and constraints.

Decisions about the management of sites should be supported by science, and address environmental and human health issues, not just those associated with radiation. Addressing all the different risks can, however, be challenging, and requiring both short and long-term risks to different populations to be addressed proportionately. Issues also arise concerning the practical application of protection principles. For example, the principle of optimization requires a common framework of protection objectives across different hazards for people and the environment, but such a framework is not currently available; a holistic, multi-dimensional approach to human health and environmental protection from multiple hazards is needed.

Effective risk communication is an important part of the management process for sites, but it can be difficult to convey risks across different hazards. There is a need to build trust across relevant stakeholders and to gain their support within a transparent decision-making process, helping to give a feeling of owning the situation to those people affected by a situation. How confidence and trust can be improved among stakeholders is therefore an important consideration in legacy site management.

The NRPA has a long history of working to address decommissioning and contaminated site management issues through a bilateral cooperation project with the Russian Federal Medical Biological Agency (FMBA) on radiation and environmental protection. The project has focused mainly on legacy issues in northwest Russia with the NRPA supporting the development of a long-term safety culture through practical projects at real sites. This has involved undertaking threat assessments at the sites to identify gaps and regulatory priorities, developing norms and standards and regulatory guides and procedures, undertaking independent monitoring, establishing emergency preparedness, and developing tools for dose control and remediation planning, to support the optimization of activities. The cooperation program was expanded in 2008 to address the many nuclear legacy issues in Central Asia and Ukraine. Overall, the experience gained through these cooperation programs could be very useful in developing improved international recommendations and guidance.

In addition to these cooperation activities, the NRPA has also organized a series of international workshops on a range of relevant topics to promote regulatory exchange and cooperation on the supervision of legacies.

In particular, a workshop was held in Oslo in 2015 on the 'Regulatory Supervision of Legacy Sites: from Recognition to Resolution'. The main conclusions from that workshop were as follows:

- Many countries have limited resources or capacity to address the range of scientific and technical aspects of legacy site remediation;

- There is a lack of guidelines and advanced tools to support the processes from site characterization, impact and risk assessments through to remediation;
- Legacies are complex and unique and the sharing experience and knowledge is valuable;
- A holistic approach in regulatory supervision of legacies is needed;
- Effective risk communication and engagement of a wide range of stakeholders within a transparent and traceable process is very important;
- There is a common need to identify further research and development areas;
- Harmonization of internationally recommended methodologies and practices would be useful.

The current workshop aimed to provide an opportunity to share and document what progress has been made in addressing these issues, and to promote further sharing of experience on practical regulation of a wide range of nuclear and radiation legacies from initial recognition through to complete resolution of protection issues, with a particular focus on process. As noted from the Oslo workshop conclusions, many countries have very limited resources or capacity to address the scientific and technical aspects of legacy site remediation and the sharing of experience, both good and bad, with countries that continue to face these challenges can be very useful. The experience gained internationally on addressing legacy issues could also, potentially, be used to develop international guidance. This could, for example, involve the development of a decision framework, based on practical experience for a range of different legacy types. It may also be possible to identify other countries or legacies for which joint cooperation could be beneficial.

It is difficult to illustrate the overall process for legacy management due to the multi-dimensional nature of issues faced. Nonetheless, a diagram has been developed to highlight the important steps (Figure 2-1) and feedback is encouraged.

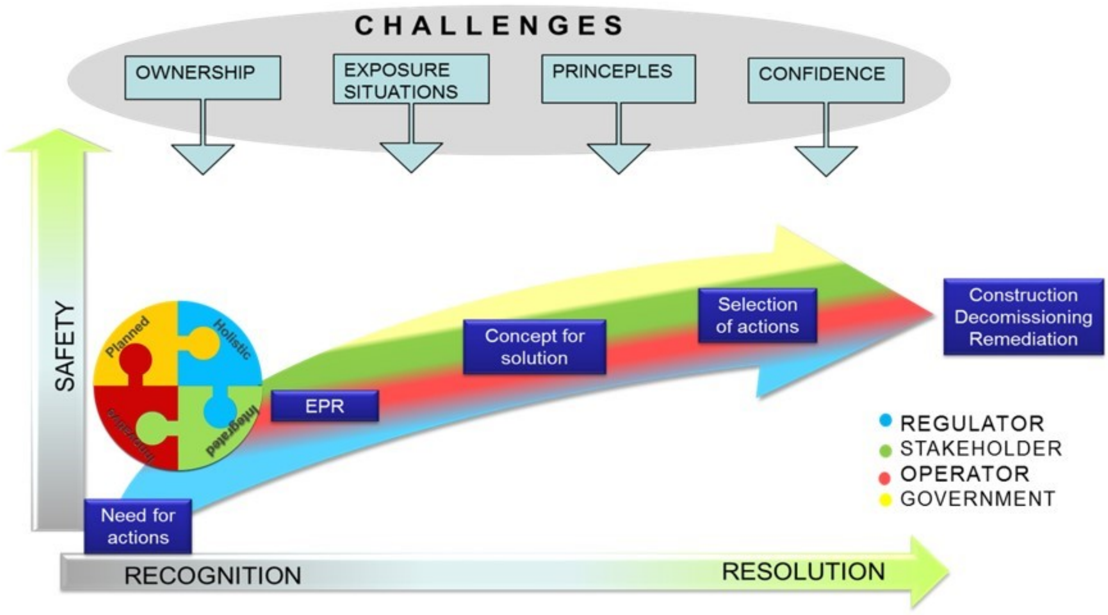


FIGURE 2-1. THE PROCESS FROM RECOGNITION TO RESOLUTION FOR LEGACIES (ILLUSTRATION FOR DISCUSSION).

The diagram aims to illustrate the various challenges and the interaction between regulators, stakeholders, operators and government from the time that a legacy issue is recognized, through to the complete resolution of the issue, noting that actions should be planned, holistic, integrated and innovative.

Discussion

Decommissioning tends to be considered within a planned exposure situation, and is considered as such within the IAEA Safety Standards, whereas the remediation of areas that have been contaminated with radioactivity as a result of other activities (e.g. mining or accidents) being considered as existing exposure situations. For the former, the intention is to release a site from regulatory control, whereas for the latter the intention is to bring the site or area (back) under regulatory control. For newer nuclear facilities, decommissioning plans are commonly considered during the planning stage and subsequently refined throughout the operational life of the facility. However, for older facilities, plans may not be available and past practices may mean that exposure situations may be intermingled, with decommissioning being considered alongside further remediation of the site. Experience from bilateral cooperation programs has shown that it is difficult to differentiate between planned and existing exposure activities when addressing the decommissioning of old facilities. Whilst decommissioning is a planned activity, there is often existing exposure situations present as a result of land contamination.

It is not, therefore, easy in practice to separate planned and existing exposure situations at such sites. Activities need to be planned, taking a holistic view of the hazards present and overall prevailing circumstances and guidance is needed on the appropriate approach to selecting safety criteria.

2.2 Status of ICRP TG98

Michael Boyd (ICRP and US Environmental Protection Agency (EPA)) presented.

Task group 98 (TG98) of the ICRP on contaminated sites consists of six full members from the USA, Russia, Argentina, Norway and France plus five corresponding members from the NEA, Japan, Canada, Australia and the UK. Gerhard Proehl had been a corresponding member from the IAEA, but has recently retired and a new member is therefore being sought. Three critical reviewers from ICRP Committee 4 have also been assigned.

The terms of reference for TG98 were to describe and clarify the application of the Commission's Recommendations on radiological protection of workers, the public and environment for sites contaminated from past industrial, military and nuclear activities, excluding sites contaminated as a result of nuclear and radiological accidents. The report will consider characterization of sources, exposure pathways, dose distribution, categories of exposure, protection of the environment, and the setting of reference levels for sustainable protection strategies. Stakeholder involvement will be considered in all steps.

In developing the report, consideration is being given to a range of ICRP publications to ensure consistency. These include:

- Publication 111 (ICRP, 2009): Protection of people living in long-term contaminated areas, which is currently being revised by TG93 and consistency between TG98 and TG93 is therefore required due to similarities in addressing prevailing circumstances at contaminated sites.
- Publication 126 (ICRP, 2014a): Radiological protection against radon exposure.
- Publication 124 (ICRP, 2014b): Protection of environment in different exposure situations.
- Publication 122 (ICRP, 2013) on geological disposal and TG97 on near surface waste disposal.

- TG76 (NORM) and TG83 (Cosmic radiation), which, like TG98, are working to apply the current ICRP system of radiological protection to specific conditions of existing exposure situations.

There is a lot of overlap between TG93 and TG98, with the former being concerned with the protection of people in emergency exposure situations, and people living in long term contaminated areas after a nuclear accident or a radiation emergency. As such, a common framework is to be developed with reports having a similar structure.

In terms of TG98 activities, a sixth conference call was held in October 2016 at which comments from critical reviewers were discussed. A further steer was given to the TG in that the remit should be the production of guidance on how to promote the principles of ICRP103, and not produce a 'how to' manual. The group was also informed that non-nuclear power plant (NPP) accidents could be considered within the scope of the TG, with TG93 being focused solely on NPP accidents. The first face-to-face meeting of the TG took place in Oslo in 2015, with the second being held in Paris in the spring of 2017 where refinements were made to the table of contents and assignments for writing of sections were made and there was agreement reached on case studies that would be included. A draft table of how to manage a variety of exposure situations was also provided by Gerhard Proehl (IAEA) which promoted discussion. The table sets out the applicable exposure situation and radiological criteria, along with relevant exposure groups (e.g. public, workers) for different legacy types. Based on this table, workers undertaking activities within an existing exposure situation would be regulated as if it were a planned exposure situation, illustrating the overlap between existing and planned exposure situations.

The seventh conference call took place in August 2017 during which there was further discussion and refinement of Gerhards table. There was also general agreement that the IAEA Draft Safety Guide DS468 (see Section 2.3) does not significantly overlap with the TG98 report, the former providing more 'how to' guidance.

Since August, there has been substantial new text submitted by TG members which was reviewed in October by ICRP Committee 4. It was emphasized that the report should not focus on how to manage or clean up a contaminated site, and that special emphasis should be given to the ethical basis of radiological protection, involvement of stakeholders, sustainability, and protection of the environment. A planned spring 2018 meeting of TG98will provide an opportunity to address these comments, building on discussion at an informal meeting held in Lillehammer prior to this workshop. This meeting was attended by four TG98 members plus some observers from the workshop, as interested stakeholders. A revised table of contents was developed, as follows, based on the form of other TG reports addressing existing exposure situations:

- Section 1 – Introduction (including a description/definition of what is meant by legacy sites)
    - Section 1.1 Background (mentioning current set of publications on existing exposure situation and why this publication is needed)
    - Section 1.2 Scope (mentioning wide range of legacy sites and radionuclides (short and long-lived that affect how a site needs be managed)
- Section 2 – Characteristics of exposure from legacy sites
    - Section 2.1 Exposure pathways
- Section 3 – Application of the Commission's System of Protection to Legacy Sites
    - Section 3.1 Types of exposure situation

   - Section 3.2 Categories of exposure (public, occupational, environmental)
   - Section 3.3 Protection of people and the environment
   - Section 3.4 Justification of protection strategies
   - Section 3.5 Optimization of protection (including selection of dose criteria: reference levels and dose limits where appropriate). Consideration of the environment. Involvement of stakeholders
- Section 4 – Implementation of the Commission's System of Protection to Legacy Sites
   - Section 4.1 Protection of Public and the Environment (discussing the process: identification, characterization, dose assessment, radiological and other goals, option selection and combining (examples), deciding on the strategy, implementation, monitoring and evaluation with the involvement of stakeholders at all steps and with special consideration of waste from remediation).
   - Section 4.2 Protection of Workers (discussing graded approach, selection of reference levels, protective actions, regulatory aspects)

Annexes will present case studies that illustrate and support the guidance and a common structure for these is to be agreed that will help ensure key messages are highlighted. The choice of case studies will aim to provide examples that exemplify the system of protection whilst being broad enough to provide experience around the practical application of the guidance to sites.

Discussion

For sites contaminated by NORM there can be difficulty in understanding how dose should be evaluated in terms of whether the dose from background radiation and from radon should be included. For the sites being considered by TG98 it is dose above background that is evaluated. However, for NORM sites, the contamination is the background. Clarification around this issue would be beneficial.

2.3 Draft IAEA Safety Guide: Remediation process for areas affected by past activities and accidents (DS468)

Tamara Yankovich (IAEA) presented.

The fundamental safety objective, as set out in IAEA Safety Fundamentals (SF-1) is to protect people and the environment from harmful effects of ionizing radiation. The safety fundamentals set out ten safety principles. Those relevant to existing exposure situations are:

- Justification of facilities and activities
- Optimization of protection
- Limitation of risks to individuals
- Protection of present and future generations
- Protective actions to reduce existing or unregulated radiation risks

To address the fundamental principles, General Safety Requirements Part 3 (GSR Part 3) provides a system of radiation protection that identifies the different exposure situations (planned, emergency and existing), exposed groups that need to be protected (public, workers, and patients), and the principles of radiation protection (justification, optimization and limitation). For existing exposure situations, the relevant exposed groups are workers and the general public. Draft Safety Guide DS468 then provides more detailed guidance on the protection of exposure groups from existing situations, from the basis of the radiation protection principles.

Existing exposure situations are those where a problem already exists and when a decision on the need for control needs to be taken. This could include areas with high natural background, areas affected by residual material from past practices that were not subject to regulatory control or not subject to regulation in accordance with current standards, or areas affected by nuclear or radiological emergencies, after the emergency has been declared to be ended. A new IAEA General Safety Guide (GSG-11) is in the process of being published on 'Arrangements for the Termination of a Nuclear or Radiological Emergency' that will provide guidance around the transition from emergency to either a planned or existing exposure situation (depending on the magnitude of the impact).

Since existing exposure situations often have a history that is not in accordance with current standards, a more flexible approach is required to addressing issues, taking the prevailing circumstances into account and applying the graded approach, such that the level of regulatory oversight and level of effort required in planning and implementing remediation is commensurate with risk. Therefore, whereas for planned situations where an inflexible dose limit is applied, more flexible reference levels are used for existing situations that are set within a range taking account of the circumstances. A reference level is not a limit, but rather a target that is situation dependent, falling within the range of 1-20 mSv/y. In setting the reference level, the radiation protection principles of justification (to ensure net benefit) and optimization (to balance radiation risks in the context of other relevant factors in consultation with interested parties) are applied to identify the appropriate level at which to set the reference level. All reasonable steps should be taken to prevent doses from remaining above the reference level. Regulations need to be adequately flexible to accommodate the range of prevailing circumstances (e.g., site-specific or situation-specific factors) within a situation and to determine what is 'reasonable' in addressing the issue.

Three key questions then arise and have been subject to much discussion:

- What is considered as "reasonable" (noting that what is 'reasonable' in one situation may not be in another)?
- What is considered as "adequate"?
- What is considered as "appropriate"?

The GSR Part 3 radiation protection principles help address how situations can be practically addressed:

- Justification – actions should be commensurate with risk, and there should be adequate net benefit (judgement being required).
- Optimization – key impacts should be weighed out and balanced with consideration of relevant factors and in consultation with interested parties.
- Limitation – establish criteria in terms of dose targets, that take account of the situation.

These principles should be applied in the context of a graded approach where the stringency of control measures is commensurate, to the extent practicable, with the likelihood and possible consequences of, and the level of risk associated with, a loss of control.

The need for practical guidance on the implementation of international recommendations (e.g., ICRP) and safety standards (e.g., GSR Part 3) that can be applied on the ground to address existing exposure situations has been discussed internationally. For example, with respect to remediation planning and implementation, concepts, such as how the radiological protection principles of justification and optimization can be applied in the selection of remedial options and the establishment of reference levels, is a topic of broad interest. In addition, during remediation, residual materials are generated, which include materials that may be recycled or reused, conventional waste and radioactive waste. In general, waste generated during remediation needs to be minimized, characterized and classified and sustainable practices, such as recycling and reuse, implemented where possible. Integral to the planning and implementation of remediation is ensuring adequate communication and consultation with interested parties (including members of the public) throughout the process. To address this need, the IAEA has initiated an update of the 2007 Safety Guide WS-G-3.1 on Remediation Process for Areas affected by Past Activities and Accidents (currently in draft as DS468), in support of the safety requirements on existing exposure situations. The intention is to provide guidance on planning for remediation, where remediation is defined as:

> "Any measures that may be carried out to reduce the radiation exposure due to existing contamination of land areas through actions applied to the contamination itself (the source) or to the exposure pathways to people. [IAEA Safety Glossary, 2016 Revision (IAEA, 2016)]"

Complete removal of the contamination is not implied; remediation targets should be practicable.

No two situations are the same so the guidance will need to set out a clear process that can be used by Member States in support of judgements around what is relevant to a site or area that is being considered for remediation. Annexes will be included that provide examples of how the guidance can be practically applied, including an example of how to establish reference levels.

The guidance will set out a step-wise process-based approach to address diverse prevailing circumstances, with clear decision points at each stage of the process. Criteria will, therefore, need to be developed at key decision points throughout the remediation process.

The first step is to carry out a preliminary screening-level evaluation whereby the situation is characterized to identify exposure pathways and doses, and decisions made on criteria to determine whether or not there is an issue that would merit remediation and/or restrictions. The criteria should help rapidly identify those sites for which more knowledge is needed, while screening out sites for which no further detailed information is needed to determine how to proceed (e.g., no remediation needed).

If the preliminary screening indicates that impacts may occur, more detailed investigation of the system would be required in terms of characterization, monitoring and modelling to identify the key radionuclides present, their distribution and key exposure pathways. Other aspects that may be addressed at this stage are the current exposures, how radioactivity is predicted to change over time and space, and the projected exposures which should inform on the criteria or targets, such as reference levels, developed for this stage. If criteria are met, remediation may not be deemed necessary, but a decision should be made as to whether restrictions are required to meet reference levels. If screening criteria are not met, the next step would involve the planning of remediation.

The detailed characterization work from stage two is an important input to remediation planning and 'realistic' reference levels should also be established, taking account of the prevailing circumstances, along with feasibility to determine whether or not remediation is justified and, if so, to identify a set of optimized remedial options. The remedial options should be evaluated in terms of the reference levels, technical feasibility and experience, and be captured in a remediation plan that will require authorization by the appropriate regulatory body. Sustainable remedial options are needed and, as such, waste minimization planning should form a part of the overall remediation plan.

In implementing the remediation plan, the remediation itself will be carried out, and the effectiveness of the actions determined to evaluate whether additional measures would be beneficial and justifiable. There is, therefore, iteration required between the planning and implementation stages. Once implementation has been completed and the reference level and other criteria have been met, as applicable, post-remediation management is initiated. This may involve the establishment of institutional controls, long term surveillance and monitoring programs and the periodic review of these programs with adjustment, as needed.

In developing DS468, there is a need to engage with a range of international organizations to ensure that the guidance developed is consistent with other recommendations that are being developed internationally. This will help to ensure cohesiveness and harmonization between recommendations and guidance provided to Member States by international organizations.

The current status of DS468 is that text is being finalized, incorporating comments received from IAEA Safety Standards Committees. Once complete, there will be a consultation process with international organizations.

Discussion

There are examples of where risks from radiation in existing exposure situations have been evaluated and the conclusion made that the risks did not present a danger and, hence, remediation would not be justified. However, there have been significant disadvantages to society resulting from loss of economic activity arising from knowledge that radiation is present, even if at very low levels. How the presence of radioactivity, as opposed to radiation doses, should be taken into account in decision-making requires more consideration.

Within the DS468 framework, such aspects would fit within the process of optimization, being a factor taken into account in the selection of remedial options. A work program is ongoing within the IAEA MODARIA II program to look at decision making for legacy sites, which is considering, in more detail, the different tools that can aid in the decision-making process. It is clear from this example that engagement with stakeholders is very important when considering remedial options.

Environment is often mentioned in terms of protection endpoints, but the focus tends to be on non-human biota. Material assets, such as soil and water, are also part of the environment, however, and a broader view on 'environment' would, therefore, be useful. The IAEA Safety Standards recognize the need to consider resources, and this, therefore, should be captured within DS468 in an appropriate way.

Clearance levels are commonly applied to remove materials from regulatory control, for example, in determining the possibility for reuse and recycling. There may need to be a more flexible approach taken for specific remedial activities, however, that would allow for prevailing circumstances to be taken into account. An example could be in the selection of the mass over which concentrations are averaged for comparison with clearance criteria. This concept will be covered in a revised report from the IAEA on clearance levels (DS500).

DS468 will be a key source for guidance on remediation, but it will not provide detailed information on specific remediation technologies that could be used during implementation. Additional technical reports will, therefore, be developed to support the guidance provided in DS468, subject to its finalization.

2.4 Ongoing NEA legacy management activities: EGLM and links to radioecology

Edward Lazo (OECD NEA) presented.

The IAEA, ICRP and NEA are all working on the topic of legacy management. This reflects the fact that there are many countries facing problems in the management of legacies, with different approaches and standards being applied. The need for practical international guidance on the regulation of radiation protection at legacy sites and how to regulate existing exposure situations has therefore been recognized and the NEA Expert Group on Legacy Management (EGLM) was created in 2016. The objective of the group is to promote practical regulatory guidance for legacy sites. The mandate of the EGLM is to:

- Assist in deriving practical interpretation and application of generic radiation protection guidance to nuclear legacy site management;
- Enhance safety and security culture as it applies to legacy sites;
- Address specific situations at real sites within NEA member countries;
- Support a holistic approach to all the risks; and
- Develop better regulatory understanding of diverse radiation risk to diverse groups on diverse temporal and spatial scales.

The EGLM description of a legacy, from a regulatory perspective, is a site that has not completed remediation and that has radioactivity that is of concern to the regulator. There are similarities, therefore, between legacies and sites subject to decommissioning.

Legacies are diverse. They can be NORM processing sites, post-accident sites, nuclear testing sites or national laboratories with hot cells that have remained unused for some time and for which knowledge has been lost, amongst others.

The EGLM report includes a chapter on challenges and uncertainties with legacy sites that covers aspects such as regulatory framework, characterization of circumstances, end-states and long-term protection values, and societal aspects. Decisions made within a regulatory framework require judgement. Science can support, but ultimately judgement is needed as to what can/should be done and whether actions are appropriate and justified. Prevailing circumstances must be taken into account and judgments made in the context of the site and its conditions and the defined end state. Ensuring that societal expectations are taken into account within a transparent decision-making process is important. Radiation risks may be very low in many instances, but ensuring that stakeholder trust has been gained is important and this can be a long-term process. The objective should be to achieve a reasonable balance between potentially competing objectives.

There are many different aspects to legacy management for which a balance needs to be achieved (Figure 2-2). Management of legacies should be planned, holistic, integrated and innovative.

FIGURE 2-2. BALANCING ASPECTS IN THE MANAGEMENT OF LEGACIES.

Some of the key outputs from the report will be lessons learned in the management of legacies and recommendations for the future in aspects such as the regulatory framework, characterization of the circumstances, societal aspects, end-states, optimization and long-term protection values. One particular recommendation will be to be flexible in adopting ICRP recommendations with regard to existing situations. For example, most authorities consider workers to be within planned exposure situations, but for existing exposure situations there will be a need to consider how best tools and approaches for protecting workers can best be applied in light of the prevailing circumstances.

The report will be based around case studies that illustrate the challenges, actions and lessons learned. A provisional list of 11 case studies from Japan, Czech Republic, Italy, Australia, Sweden, Norway, UK, Russia and USA has so far been developed and a site visit took place in May 2017 to Sellafield in the UK to develop an understanding of the challenges of management and regulation of legacy facilities at this site. It is intended that the learning from this visit will be captured within a case study. Further site visits are envisaged, including a trip to the US DoE Hanford site early in 2018.

Judgement is a link between science and values and there is a societal responsibility to allow thinking rather than applying a strict yes/no approach. Protection should therefore be informed by science, but driven by societal values. Science and radioecology can help support the process of legacy management at all stages, supporting the process of defining and achieving an effective solution that is both practical and addresses the often-contradictory stakeholder needs and policy objectives. There remain a number of challenges however, such as defining sources, pathways and receptors. For example, groundwater can be a source, and a pathway, and a receptor according the EU Groundwater Daughter Directive. There are some helpful factors though. For example, there tends to be only a few radionuclides that matter in the source term however, and only a few migration and accumulation mechanisms and a few modes of exposure for those radionuclides and pathways. There is, however, a need to bring together radiological and chemotoxic assessments to ensure a holistic and balanced approach to the management of legacies can be achieved. Work is ongoing to address this need (see, for example, NRPA, 2015).

A draft of the EGLM report is due to be completed for review in April 2018 with a possible workshop being held in late 2018/early 2019 in Australia on 'national approaches to legacy management'. It is anticipated that a new NEA Standing Technical Committee on 'decommissioning and legacy management' could be created in April 2018.

Discussion

The need for stakeholder engagement is often raised with regard to legacy site management and it may therefore be beneficial in future workshops to invite social scientists to participate. Whilst it is recognized that judgement is an important factor in legacy management, perception is equally important. Engaging with social scientist could help support strategies for stakeholder engagement and in achieving an appropriate balance between potentially competing interests. There is work ongoing within the NEA with in-house social scientist to develop understanding around stakeholder perceptions and communication. There will always be judgement involved to take account of specific circumstances that need to be addressed, but it should be remembered that, whilst the public can provide input to decisions, they are not responsible for making decisions. The decision-making process should therefore ensure that all concerns have been considered; there will be a range of perceptions and opinions that will be based around different levels of information and understanding and these perceptions and opinions must be recognized and communication appropriately targeted to address concerns.

It is unlikely that decisions will be able to please everyone and this has to be recognized. Some decisions may be politically driven and, since politics can be swayed by the views of people, some compromise may be necessary that may not be seen as the most justifiable or optimized solution. For example, a costlier solution may be selected than is justifiable on the basis of risk. The prevailing circumstances that must be taken into account when addressing legacies include the political position that must be worked to.

2.5 Do legacy sites deserve special treatment?

Anna Clark (NDA) presented.

There are a number of legacy sites throughout the UK, where the state bears the cost for addressing the site, but for which there are often no dedicated funds available. Many sites have arisen due to facilities not being designed or operated with decommissioning in mind.

Whether the term 'legacy' is a useful label is questionable. A legacy is something that is not wanted, but for which something needs to be done to address the situation. Such sites often attract extra scrutiny from the public, particularly since it is often public money used to address the issues. Ultimately, sustainable solutions that are cost-effective are needed and people that can make decisions on what is right for a site should be brought together.

Regulations should be flexible, proportionate and enabling, recognizing that there are different ways to protect people and the environment regardless of the situation. The source of the issue is not what matters; the focus should be on the prevailing circumstances irrespective of how they arose.

The Sellafield site in the UK is a substantial example. The site has over 200 active facilities over a very small area and has a lifetime plan out to 2100. Unlike new facilities being built today, funds were not put aside for decommissioning of the site and the state now bears the cost. Furthermore, not all facilities were operated with decommissioning in mind, which adds to the challenges faced.

The Nuclear Decommissioning Authority (NDA) was established in 2004 by an Act of Government. The overall aim of the NDA is to secure active decommissioning. It is not a regulator or operator. It does, however, stipulate strategy and what is required by decommissioning sites. A key remit is to deliver value for money such that the greatest benefit to the public is achieved.

Benefits change throughout the lifetime of a nuclear site (Figure 2-3), with both benefits and disbenefits occurring at different stages. The greatest benefit occurs during operation, whilst, during construction, there are both costs and risks to workers, but benefits are on the horizon. However, when it comes to decommissioning, it is harder to identify the benefits, other than reducing hazards and risks to people and the environment and delivering these outputs safely. There is the potential for more harm than good to be done during final decommissioning stages, particularly for those sites that were not designed with decommissioning in mind.

Decommissioning of a site requires the site end-state to be defined. This sets out what will remain on the site versus that which will be removed. The end state can vary considerably from site to site and experience suggests that describing the end state in terms of inventory is not enough; the controls that will remain in place and intended land use should also be defined. In the UK, many nuclear sites are like icebergs in that the below ground structures and voids are as large as those above ground. There can also be land contamination. To address voids during decommissioning, decisions will be required as to whether clean material is imported or whether lightly contaminated material from the site can be reused. The more contamination that is left in place will require greater restrictions on the end use of the site.

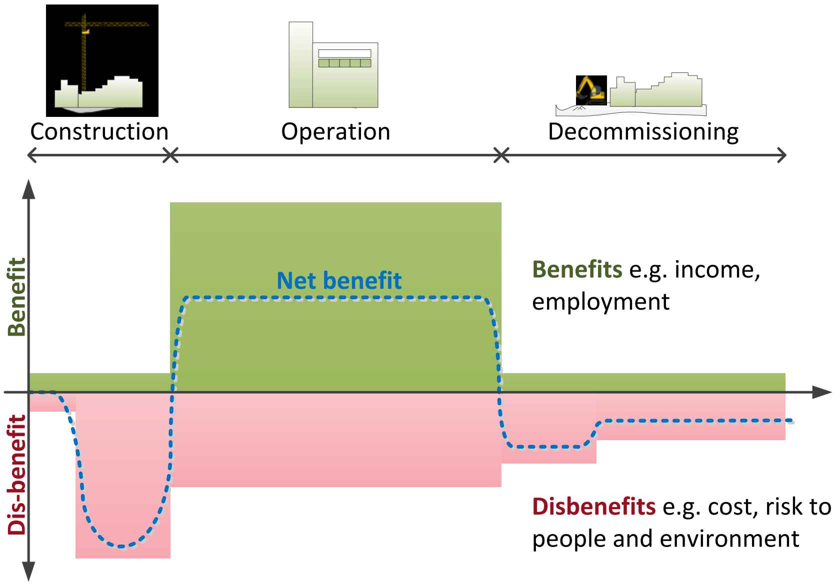


FIGURE 2-3. COSTS AND BENEFITS ASSOCIATED WITH NUCLEAR FACILITIES FROM CONSTRUCTION THROUGH TO DECOMMISSIONING.

There is a range of remediation and waste management options involved in end state decisions and no options are without some impact to workers, members of the public and/or the environment. The impact of options on the site itself, on disposal facilities and on transport routes all need to be considered. The NDA strategy is therefore to *''employ pragmatic, risk-informed remediation objectives that balance the benefits and detriments of decommissioning and remediation''*.

Within the Sellafield site there are large areas of contaminated land and buried structures. Removal of all would create vast amounts of waste for which new disposal facilities would require construction. Thought therefore needs to be given as to how clean is clean enough and how safe is safe enough?

To support transparent decision-making, the NDA has developed a value framework (Figure 2-4). The framework was developed in consultation with stakeholders and stakeholders are again involved within any decision-making process. The objective of the value framework is to help describe, in a consistent way, different options, allowing those options to be evaluated consistently in terms of performance against different value criteria, including social factors.

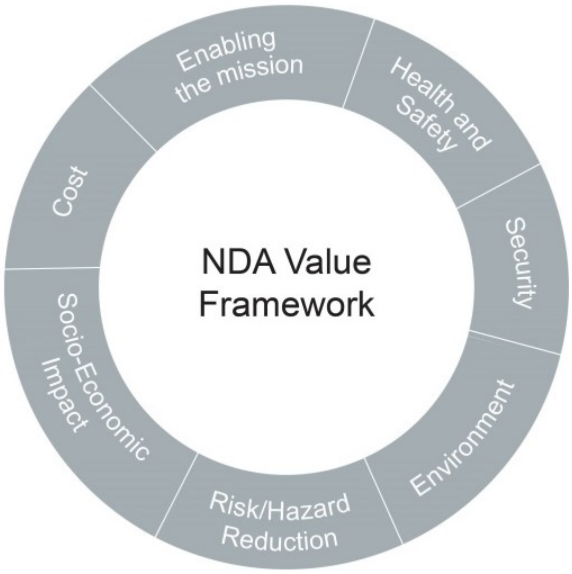


FIGURE 2-4. THE NDA VALUE FRAMEWORK.

Stakeholders tend to value risk / hazard reduction. Risk and hazard reduction activities impact on workers, however. There can also be financial and environment costs as well as socioeconomic impacts to the area. As hazards reduce, social factors tend to dominate. Balancing social and technical factors is a qualitative rather than quantitative process so requires judgement.

Preferred options need to be evaluated to ensure that they are achievable. For legacies, a dominating question is whether there are funds and skills available to deliver the preferred option. If there are not sufficient funds or skills available, that does not necessarily mean that the preferred option needs to be abandoned, it may be feasible to implement a staged process such that the situation is managed in the short term to ensure protection of people and the environment, but with full implementation occurring at a later date. Competing demands on public finances in the UK means that interim solution approaches tend to be adopted.

A collaborative approach to regulatory supervision is being taken and a G6 forum has been established for Sellafield, resulting in huge steps forward in terms of proportionate management of decommissioning at the site. The main purpose of the G6 forum was to drive for the earliest possible hazard reduction at the site through removal of blockers that would allow more active progress toward solutions. The collaborative approach to working has already resulted in large benefits in addressing some of the most hazardous issues, whilst recognizing that risks would increase in the short term in order for the overall strategy to be delivered.

The appropriateness of UK regulations is also being considered in terms of whether policy and legislation are enabling for what needs to be done in decommissioning sites and a discussion paper has been published on the regulation of nuclear sites in the final stages of decommissioning and clean-up. Since the state is paying for the clean-up of these nuclear sites, key players were brought around the table to work on issues collaboratively. It is recognized that there is no one solution that will fit all issues; solutions must be site and case specific. The overall value in decommissioning is in delivering safety and other benefits can be hard to identify. Nonetheless, optimization and justification can be applied in terms of safety, with optimization being key to the whole process.

An amendment of legislation is currently under consultation in the UK. The aim of the amendment is to allow for more sustainable remediation practices that focus on end states.

In summary, all nuclear facilities will benefit from flexible and enabling regulation, irrespective of whether decommissioning or remediation is being undertaken. It should be recognized that there can be many ways to protect people and the environment, and that staged solutions may be required. Stakeholder engagement is key to identifying solutions that are most beneficial to the public.

Discussion

There has been a lot of work undertaken with regard to interim states and some guidance has been produced on this. A key point is to ensure that the overall solution is not forgotten and that the interim steps are taken to enable the overall solution to be achieved. Where work is to be deferred it should be transparent as to how long it is safe to pause the work. An important part of describing interim states is therefore the timeframe over which the interim state should last.

With public funding being required to address issues at many sites throughout the UK, it is questioned whether the term legacy is helpful.

2.6 Determination of Site End-State in Environmental Remediation – The IAEA ENVIRONET-DERES Project

Horst Monken-Fernandes (IAEA) presented.

ENVIRONET is an international network dedicated to environmental management and the remediation of radiologically contaminated sites. Within ENVIRONET a range of training and demonstration events disseminating proven methodologies, good practices and state-of-the art technologies are organized. The network also aims to facilitate information exchange and the sharing of experience amongst organizations with advanced programs and to create a forum in which expert's advice and technical guidance may be provided.

The scope of the network includes legacy sites, including:

– closed uranium mining and processing sites;
– closed NORM sites;
– former nuclear industry sites and former military sites;
– land contaminated by nuclear and radiological accidents/incidents; and,
– orphan radiological sites.

Emergency response, the decommissioning of facilities and disposal of radioactive wastes are not included, but contaminated land is considered.

A plenary meeting of the ENVIRONET is held annually. During the 2014 meeting, the topic of how to achieve consensus with stakeholders on environmental remediation End States was suggested, leading to the formation of the DERES project. The objectives of the project are to:

– raise awareness of the importance of a consistent determination of end-states for the ultimate success and sustainability of environmental remediation efforts;
– gain an overview of the international state-of-the-art in end-state selection; and
– provide participants with approaches to determine and reach consensus on end-states through a decision-making process and make sure these tools and approaches are of practical relevance and applicability.

One issue that was recognized early on in the project was terminology and the need for harmonization; different definitions already exist and are used for end-state and this can result in different understanding. Definitions have therefore been proposed for a range of terms, including end-state, end-point, end-use, clean-up, Reference Level and limit. In terms of end-state, the group is working under the concept that the term, in the context of environmental remediation, describes "the physical conditions to be achieved that make intended future use of the site possible and are appropriately protective of people and environment”. The definition addresses many of the aspects raised in the workshop, including the presence of different contaminants at a site.

A definition of end state is also required for decommissioning, and clear boundaries between decommissioning and remediation are needed. Within part 6 of the IAEA GRS on the decommissioning of facilities, decommissioning is considered complete when the end-state has been reached and the facility released from regulatory control with or without restrictions on its future use.

For legacies, the definition of end-state is important in the context of exposure situations (

Figure 2-5). For planned exposure situations, dose limits and dose constraints are applied whereas for emergency and existing exposure situations, reference levels are applied. The reference level should be within the range of 1 to 20 mSv and can change over time, particularly when moving from an emergency to an existing situation. Dose constraints for planned exposure situations are more within the µSv range. Whether or not dose constraints can be applied to planned remediation activity situations is questionable; it may not be practicable to apply such values. This becomes an increasingly difficult concept when considering a ‘legacy’ within an operational site.

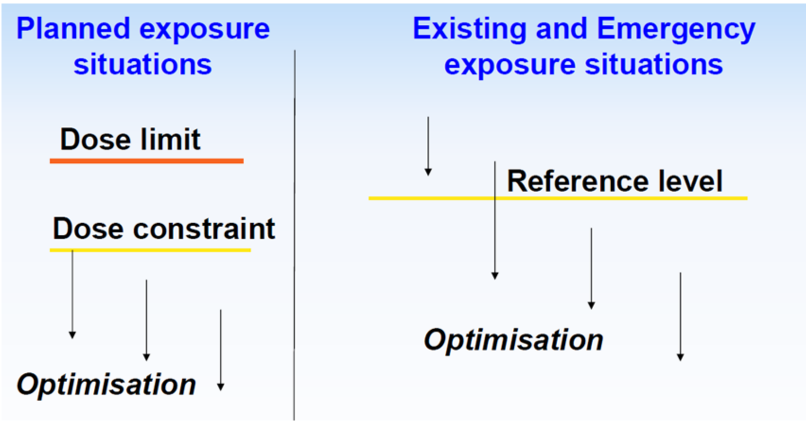


FIGURE 2-5. REGULATORY FRAMEWORK FOR DECOMMISSIONING (LEFT) AND ENVIRONMENTAL REMEDIATION (RIGHT).

It is important to distinguish between end-state and future use of the land. They are different, but closely related issues; many future uses will only be possible if a particular end state is achieved.

There are two broad choices for end state, either reuse for any purpose, which gives the maximum benefit, or restricted future use due to the end state not being clean enough for unrestricted use. This of course has less benefit than unrestricted use, with areas potentially falling into disuse as a result of residual contamination.

In the process of defining an end state it is necessary to consider both drivers and constraints (Figure 2-6). The deployment of technology, availability of disposal routes and resources are all constraints that may apply, but international initiatives may be available to provide support.

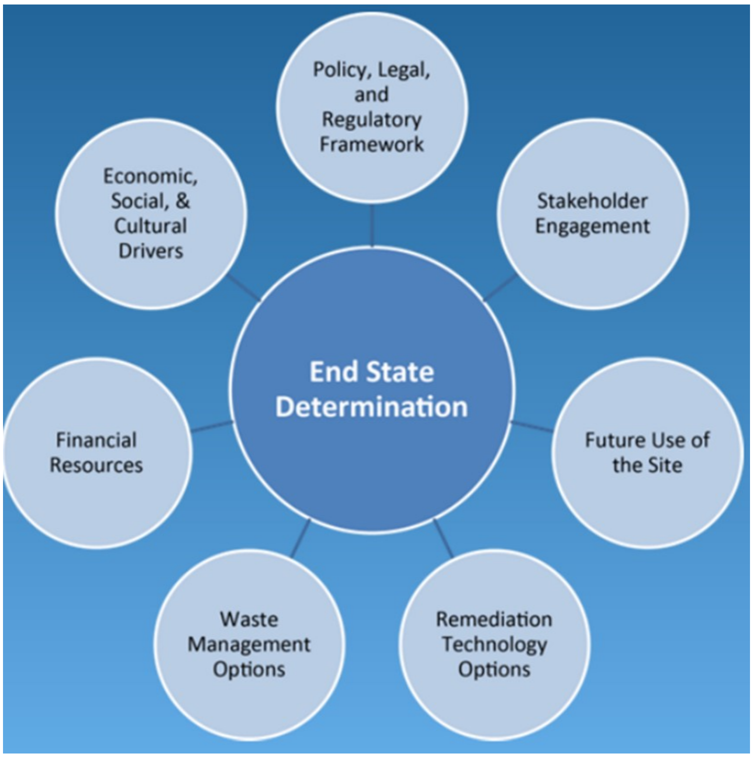


FIGURE 2-6. DRIVERS AND CONSTRAINTS IN THE DETERMINATION OF END STATE.

The process for determining end state being proposed is straight forward. From initial characterization and risk assessment, the drivers and constraints are analyzed and end state options are identified and evaluated to identify the preferred end state. The end state options should be identified in the context of established reference levels and the assessment of potential doses and other risks associated with different future use scenarios. Options should then be evaluated in terms of their ability to meet known constraints and drivers and stakeholder expectations. Stakeholder engagement is an important part of the process, not just in terms of interaction and communication, but also in terms of integration within the decision-making process to ensure that those affected have some ownership of the process. It should be recognized that an interim end state may be required as a temporary solution due to critical constraints such as funding availability or additional infrastructure needs. It should also be recognized that it is not always possible to satisfy all stakeholders and, as such, the determined end state may be a compromise.

Remediation and reuse objectives are not always aligned, but should be with the pursuit of site reuse being the objective whenever possible. Remediation and site reuse should be considered as a single, interlinked process with developers being encouraged to implement innovative development and sustainable remediation to convert sites to beneficial reuse.

The remediation of some sites requires long-term thinking. For example, uranium mining sites usually require wastes (tailings and waste rock dumps) are retained on the site and, hence, the site may not be released for unrestricted use. Therefore, some sort of institutional controls will be required. The sustainability of options will be an important consideration in such instances; the company responsible for the mining activities may leave the country once operations have ceased and the country that is left to deal with the situation may not have the appropriate resources, financial and/or technical.

There has been some work internationally on the concept of sustainable remediation with a report recently having been published by the OECD/NEA on 'Strategic considerations for the sustainable remediation of nuclear installations' (OECD/NEA, 2016).

The document that will be produced as a result of the DERES project will not be a safety standard or safety guide, it is the result of a group of experts working together. It is suggested that, following a sustainable remediation approach, it is not always optimum to remove all contamination, or to clean up sites to be fit for any use, and that the optimal remedial approach may be to include administrative controls (long-term stewardship) to break the pollutant linkage. The NDA in the UK is also working to produce and outline an approach to explore and make an informed and transparent decision on what is the end-state for a site. These initiatives are being considered within the DERES project.

The IAEA has been tasked to exposure Member State experience around end state definition and it is evident that decommissioning and remediation can be considered in very separate ways or linked, depending on the country. At a national level, there are large-scale programs underway and the IAEA aims to collect together experience and provide options that can benefit other countries in terms of end state definitions. It is important from a regulatory point of view for a pragmatic approach being taken in terms of adopting sustainable remediation strategies.

An e- learning module on end state determination was produced and is now available - at the ENVIRONET web space in CONNECT platform. The next DERES meeting will take place from 19-23 March 2018 at the IAEA in Vienna, to which participation is invited to increase the sharing of experience.

Discussion

Uncertainties are an important component of sustainable remediation and a fundamental uncertainty is how future benchmarks will be set. Any change in benchmarks can lead to significant shifts in values, such that a site may no longer be suitable for unrestricted use. We need to acknowledge that we are living in a changing world and it is important, therefore, not to over-promise, but do the best we can in the most transparent and consistent way possible.

There is some concern that the use of interim end states could hinder the achievement of an overall end state, with potential confusion arising over why the overall agreed end state is not being achieved. It may therefore be useful to use a graded approach from the outset, with gradual improvements being made to meet the ultimate end state objective. When a commitment is made to an end state that proves not to be achievable in the short term, this can result in a loss of trust. As noted, reference levels can be revised over time and the use of interim reference levels and remediation targets / end states can help to avoid such situations arising, ensuring that interim states are set at a level where there is confidence that the targets can be achieved. Strong engagement with stakeholders is necessary, however, to ensure that everyone is aware of the implications of an interim approach. Where people feel they have ownership, a graded approach can be feasible.

It is suggested that the term 'contamination' should be avoided in the context of remediation. This term is commonly viewed as being consistent with danger and stakeholders are likely to want decontamination, which suggests the complete removal of contamination.

In order to further consider the regulatory framework that is required to support end states, a strong connection is needed between the regulatory and technological sites. This is an area for which greater thought should be given.

2.7 US approach to legacy management – Hanford processes

Patricia Worthington (US Department of Energy (DoE)) presented.

In the US, a site-specific approach is applied to address legacy issues so there is no one single and universal approach. The Hanford site is very useful in terms of lessons learned.

The Hanford site is located in the south of Washington State, in the tri-cities area. It is a large site that forms part of a reservation. The site was historically used for plutonium production. Clean up at the site has been progressing since 1989 and is the largest nuclear cleanup project in the country.

The Hanford site was initially selected for plutonium production due to the abundant cold-water resource available from the Columbia River, combined with the sites proximity to the Grand Coulee Dam for power provision and its isolation from large cities. At the time, residents of the site were Native Americans, settlers and farmers. Residents were given just 30 days' notice to vacate the area and were given very little compensation. Construction at the site took place between 1943 and 1945. At its peak, there were around 50,000 workers present at the site. Over 8,000 pieces of construction equipment were used at the site and 75,000 m^3 of concrete put in place, along with 40,000 tons of steel. Plutonium production ended at the site in 1989 and the mission changed to that of clean up, with the DoE, the EPA, and the State of Washington signing a Tri-Party Agreement. This agreement requires that stakeholders be involved in decisions around next steps for the site within a formal, yet flexible, process.

Many decisions that have been made regarding the site have been deemed to be final, but as processes have progressed, changes have been made resulting in moving objectives and end states. Nonetheless, working with local communities has helped ensure that the needs of local people are understood. Congressional individuals typically chair the committees that are making the decisions.

The production area layout of the site is illustrated in Figure 2-7. A large priority has been to reduce the footprint of the area. The area used for the site was large with distinct activities spread out across the site. By reducing the footprint, the objective was to target funding and improve security. Reducing the footprint also helped inform on next steps in terms of clean-up priorities.

In May 2017 there was a partial collapse of a dirt cap over a PUREX plant tunnel storing equipment within the 200 Area, which raised concerns as to whether safety was being adequately addressed in prioritizing clean-up activities. No contamination was released as a result of the collapse and work has been done to refill the hole with dirt and sand and to place a large plastic cover over the entire tunnel. There is the potential for further tunnel collapse in a second tunnel and options for stabilization are being evaluated, in consultation with stakeholders.

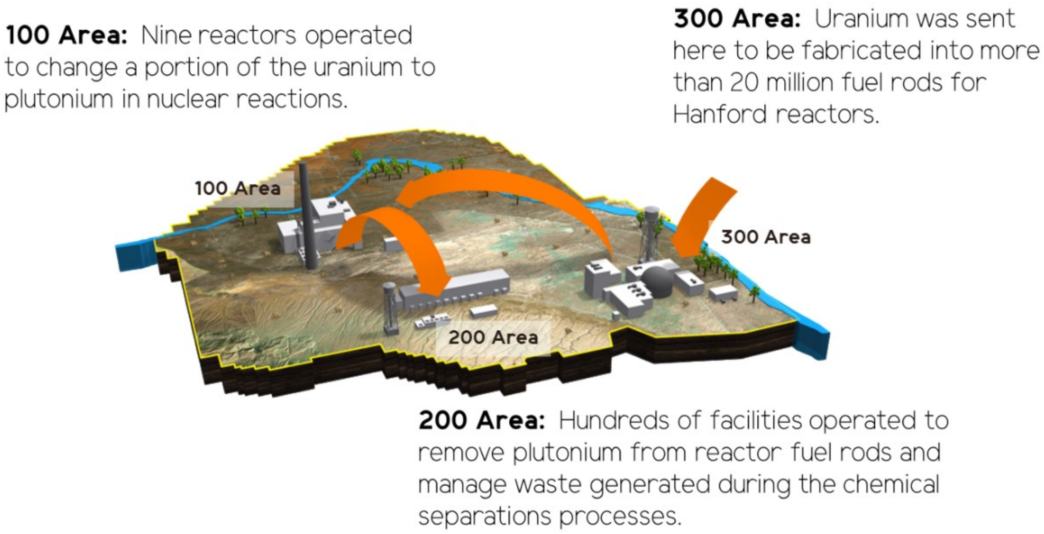


FIGURE 2-7. PRODUCTION AREAS AT THE HANFORD SITE.

The overall clean-up scope at Hanford is varied and extensive, involving:

- removal of radioactive/hazardous materials and demolishing facilities;
- digging up contaminated soil and solid wastes and transporting to an engineered disposal facility;
- pumping and treating groundwater to remove contaminants and immobilizing contaminants in soil to reduce groundwater contamination; and,
- managing the sites 56 million gallons of liquid chemical and radioactive waste, currently stored in 177 large, aging underground tanks.

Many of these activities are aimed at reducing environmental risks, including protection of the Columbia River. Washington State is important in terms of wine production and the aim is therefore to make land available for wine production and other uses as soon as feasible.

Among the highest hazard facilities in DoE waste management is the Hanford plutonium finishing plant, which is scheduled for demolition by late 2017 or early 2018. There is also a sludge treatment project that is ongoing. The sludge treatment is located near to the Columbia River and the objective is therefore to address the hazards and ensure the river is available to the many people that live in the area. Acceptance testing of equipment that will be used for treatment and retrieval is underway and there has been a lot of work undertaken in developing mock-ups of activities to train workers and test technologies and procedures. The workers at the site are very knowledgeable and engaged and will frequently offer suggestions on how best various activities can be approached.

Many of the buildings on the site are labelled by numbers and decommissioning and clean-up will be similarly labelled. This includes the building 324 disposition project for which remote-operated equipment will be used to remove highly radioactive soil from beneath the building that will ultimately allow for building demolition. A mockup will be used to improve safety and reduce project risks.

Within the sites waste encapsulation storage facility, work is ongoing to plan for the removal of over 1900 capsules that, together, contain one third of the caesium and strontium on the Hanford site. The capsules are currently stored in pools of water and they will be moved to dry storage casks.

The waste treatment plant (WTP) on the site has been a source of considerable criticism for the department in terms of cost. The objective for the WTP is to immobilize tank waste in glass for environmental protection and long-term storage. It is hoped that treatment of low activity waste could begin in 2022, but technical issues need to be resolved with a pre-treatment facility which could cause this date to be revised.

The near-term priorities for the site are to:

- complete the demolition of the Plutonium Finishing Plant;
- clean up the research waste burial ground (618-10) and nearby waste site (316-4);
- move highly radioactive sludge from storage near the Columbia River for future treatment/disposal
- upgrade/replace and optimize Cold-War-era systems to support Central Plateau cleanup;
- complete the design of the Low Activity Waste Pretreatment System, to provide the near-term waste feed for treatment at the WTP; and,
- retrieve, manage, and treat 56 million gallons of radioactive waste, currently stored in 177 aging underground tanks.

The clean-up of the Hanford site is a collaborative process, involving the tri-party agreement, the Hanford Advisory Board (a board of 32 interest groups), members of the public and elected officials and tribal leaders (there ae three treaties with tribes that must be honored). There can therefore be considerable differences of opinion, with many having very rigid views. Any disagreement around decisions requires a very formal process to be undertaken that can lead to delays. The press is also an interested party with newspapers picking up on any changes in detail around the site. However, whilst collaboration may be difficult, it is also very necessary.

Other potential issues associated with the management of the site include that the DoE is headed by a selected individual that can change over time. New heads may therefore have to come in and work to decisions made by their predecessors. The work also has to be run according to available funding. Whilst the site does have good funding availability, the funds may not be sufficient for some activities and this can result in changes to priorities and commitments. There can also be additional delays as a result of contractors changing over time. A further potential issue is that the people responsible for designing plan are not going to be present on site during operation. Whether plant will work in the desired way may therefore be questionable and could lead to major issues in the forward program.

Despite the difficulties faced, there have been a number of recent successes in the clean-up of Hanford, including:

- the vast majority of clean up in a 220-square-mile area near Columbia River (428 facilities demolished, 984 waste sites cleaned up, 6 reactors cocooned) has been completed;
- demolition of the Plutonium Finishing Plant is continuing; and,
- remediation of a highly radioactive waste site near the Columbia River (618-10 Burial Ground) is nearly complete.

In addition, around 1640 acres of land has recently been transferred for redevelopment. Public tours are also arranged once a year that have proved very popular as people are interested in the history of the area and progress with clean-up of the site. The tours have resulted in increased tourism in the area that has benefitted the local economy. There have also been a number of Science, Technology, Engineering and Math's (STEM) outreach programs. These programs are aimed at helping students create a pathway from school to their career goals by understanding the skills needed by people working in the occupations of their career; ensuring that students understand and act on STEM career opportunities available through career and technical education and training programs, including youth from underrepresented populations; and, engaging students in new fields of study.

Discussion

There is a schedule for key activities at the Hanford site and one major milestone will be the removal of hazardous material from aging underground tanks. It will take 20 years or more for the material removed from these tanks to be treated.

The projects at Hanford are therefore long-term and residual activity will remain on site following clean-up activities, such that surveillance monitoring will be required. It is unlikely therefore that the site will be released for greenfield activities, but other industrial uses are likely to be possible. Mutual benefit arrangements for private industry may help encourage the development of new facilities on the site.

The criteria for prioritizing activities are variable, with some being driven by safety concerns and others being more political. Funding is also a priority.

The collaboration applied within the decision-making process for Hanford means that there is no one particular organization with decision power over others. Whilst the DoE will ultimately say what they are going to do at the site, the EPA can reject these plans. Community and stakeholder buy in is therefore important. The Tri-Party Agreement is very detailed in describing all procedures that must be followed so there are no doubts around how the process should proceed. However, funding limitations may mean that decisions cannot be implemented for some time and views may change over that time.

2.8 The International Forum for the Regulatory Supervision of Legacy Sites (RSLS)

Monika Kinker (IAEA) presented.

In 2009, the international community came together to consider global progress in remediating areas contaminated by radioactive materials during a conference on 'Remediation of Land Contaminated by Radioactive Material Residues'. This was followed later that year with a resolution being passed by the IAEA General Conference, encouraging Member States to collaborate in addressing legacy states. This led to the Regulatory Supervision of Legacy Sites (RSLS) project being set up in 2010, the goal of which was to promote effective and efficient regulatory supervision of the management of legacy sites, consistent with IAEA Fundamental Principles, Safety Standards and good international practices. The scope of the project was to support the development of effective and efficient regulatory processes, such as regulatory requirements and guidance development, licensing and authorization, inspection and compliance monitoring, and enforcement. Regulatory bodies are the primary target audience, but participation is also open to those responsible for managing sites and technical support organizations, as well as international organizations.

The first phase of RSLS ran from 2010 to 2015 during which time there were annual meetings held in Vienna and additional workshops and site visits were planned. In 2012 a workshop was held in the USA and in 2014 there were workshops in Canada and Moscow. The final workshop was held in Romania in 2015.

There were three working groups during this first phase. Working group 1 focused on enhancing regulatory infrastructure for the management of sites, including national strategies and plans and lessons learned. The focus of working group 2 was on safety assessment methods and environment impact assessments and the development of guidance on methodological criteria for operators and regulators as well as guidance on review methodologies. Working group 3 was then focused on professional development for regulators, including on project management, technical competencies and inspection. The output of this first phase will be documented in an IAEA TECDOC, which is currently undergoing final editing prior to publication.

The second phase of RSLS began in 2016 as a continuation from phase 1. There was a transition from a working group approach to one focused on distinct themes, as follows:

- 2016: Training for regulators of legacy sites
- 2017: Regulating legacy mines/mills in less developed countries
- 2018: Non-uranium mining NORM legacy site issues
- 2019: Regulating radioactively contaminated sites in populated areas

The plans are fluid such that they can be revised in line with feedback from Member States. Annual meetings will again be in Vienna.

A workshop was held in October 2017 in France, organized by AREVA. The workshop was a joint meeting of RSLS and the uranium mining and remediation exchange group (UMREG), an organization with ongoing activities in uranium mining throughout the world. Around 45 people from 20 Member States attended the workshop, which was focused on planning for the remediation of uranium legacy sites. There were 30 presentations by international experts and panel discussions on challenges in preparing for the remediation of uranium legacy sites. There was also a technical tour of four former uranium mining sites that provided an opportunity to see the AREVA approach to the long-term management of legacy sites in France, including water treatment and post-closure uses of sites.

The key themes of the workshop were:

- Social licensing and involvement of interested parties for a successful remediation program.
- Special attention to the issues of stakeholder involvement and communication and measures for the protection of the environment.
- Importance of institutional controls and active monitoring and adjusting to reflect ongoing changes to site and local, regional communities.
- Coordination of multiple responsible agencies to ensure protection of the public and the environment.

The output from the second phase of RSLS will again be an IAEA TECDOC. This will summarize the main themes, presentations and discussion points from technical meetings and provide an overview of site visits. An accompanying CD is also envisaged that will provide presentations given by participants at the meetings and workshops throughout the program.

There continues to be strong support from Member States for this forum and additional participation is invited since activities are only as good as the participants. With the continued interest from Member States it is likely that there will be further phases following the completion of the current phase.

The IAEA RSLS public website provides information on upcoming events, terms of reference and relevant publications (https://nucleus.iaea.org/sites/connect/RSLSpublic/Pages/default.aspx). Registration is also possible to gain access to additional information, including event and reference materials.

Discussion

There is no formal definition of legacies that is recognized by the IAEA, but there is a description and RSLS uses a working definition that will be detailed in the phase 1 TECDOC. It is however recognized that there can be different ideas of what is meant by a legacy and the term 'past practices' was suggested as potentially helping to avoid some issues. In the IAEA the term existing exposure situations is used since it is the exposure situation that defined the radiation protection framework that should be applied. When it comes to the control of exposures, it doesn't matter what the reason for the contamination is, the main issue in addressing the situation is to consider whether a planned, existing or emergency situation is to be addressed.

Issues around the definition of legacies are discussed in some depth in the TECDOC. One such issue is that legacies may already be defined in national strategies and the IAEA defining the term now would not be helpful. The working definition that is being used in RSLS is broad enough that it does not prejudice anything, but is intended to give a position by which regulators can stand.

The management of legacy sites is a wide and interesting area. The discussions and conclusions arising from the workshop reported herein, along with output from other initiatives internationally could help in informing on what is needed to be produced in terms of guidance by the IAEA.

3 Methodologies for legacy regulation and management including long term site management and on-site disposal

Session 2 focused on methods for legacy regulation and management, including long-term site management and on-site disposal. Presentations in this session are summarized below.

3.1 Why is basic radioecological research relevant to regulators?

Brit Salbu (CERAD/NMBU) presented.

Regulation is an abstract concept of the management of complex systems according to a set of rules and trends. There can be many different sources and release scenarios that affect what may be released and the potential for other stressors to be present. The source and release conditions will also affect the physico-chemical forms of radionuclides, which can affect particle size, oxidation state and the crystalline structure of released particles. The physico-chemical forms of radionuclides released from a source determines the mobility of radionuclides in a contaminated ecosystem and the biological uptake and, hence, affects risk.

To assess the impact of particle contamination, detailed information is needed on particle characteristics that determine the behavior of associated radionuclides. Information is also needed on ecosystem processes that can influence the behavior of radionuclides, including climate and soil parameters, particularly those affecting the speciation of radionuclides that in turn affects the radionuclide transfer, biological uptake and effects.

Most assessments are affected by uncertainties and decisions must therefore be made under large uncertainty conditions. Conceptual issues in models and associated uncertainties can therefore affect decisions.

The speciation of radionuclides can have a large influence on radionuclide behavior. However, in many instances, radionuclide releases are not in the form of simple ions. In the case of Chernobyl, some fuel fragments were released whereas in other instances it may be compounds that are released. The form of release will affect uptake with low molecular mass species being considered to be mobile and bioavailable whereas colloids and nanoparticles are considered to be mobile, but less bioavailable. Particles on the other hand tend to be considered in terms of point sources of concern and consideration needs to be given as to their ability to dissolve when considering uptake.

It is not considered helpful, therefore, to consider a source term in terms of becquerels (Bq). A Bq does not inform on bioavailability or on processes governing biological effects. Nor can a Bq move. A Bq is a disintegration and therefore must be fixed to something such as a molecule or particle. It is the physico-chemical form of radionuclides released from a source that is essential to determining mobility and uptake into biological systems.

Most models assume that radionuclides, as Bq, are homogenously distributed, but a large fraction (up to 90%) can be associated with discrete particles of various size, composition and specific activity, resulting in large heterogeneity in contamination. Measurements of environmental radioactivity and any associated assessments are often based on the average bulk mass or surface concentration, and assume that radionuclides are homogeneously distributed as simple atomic species. Consequently, it is generally not recognized that radioactive particles present in the environment often contain a significant fraction of the bulk sample activity, leading to sample heterogeneity problems, and false and/or erratic measurement data, and underestimation of the impact and risks. Detailed information is therefore needed on particle characteristics that determine the behaviors of associated radionuclides.

Two case studies provide useful examples of the need to consider the source term in terms of the source and release scenario.

The Kysthym accident in 1957 resulted in the East Ural Trace (Figure 3-1). This accident resulted from a loss of coolant to a waste storage tank, resulting in a hydrogen explosion and the release of low molecular mass Cs-137 and Sr-90 in a 300 by 10 km trace. There was a lot of experience on ecosystem transfer and biological effects of Cs-137 and Sr-90 by very competent scientists at that time and models with high predicting power were a good fit.

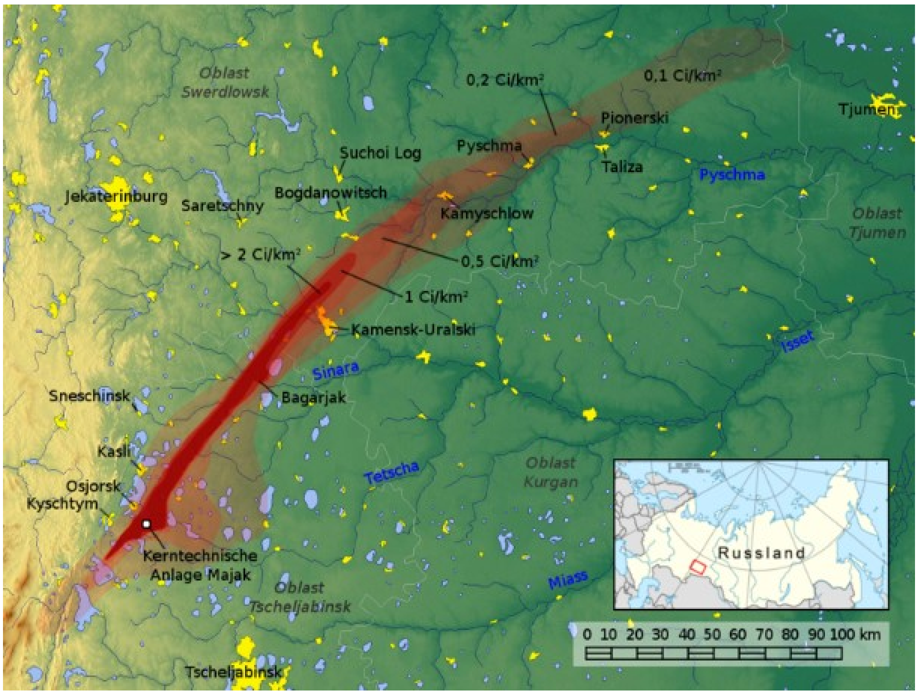


FIGURE 3-1. THE EAST URAL TRACE RESULTING FROM THE 1957 KYSTHYM ACCIDENT.

The Chernobyl accident in 1986 also resulted in the release of Cs-137 and Sr-90 and many of the scientists that worked on the East Ural Trace were involved in evaluating releases, along with radiation protection authorities and the IAEA, based on data from nuclear weapons tests and the East Ural Trace. The model predictions that resulted were wrong. This was due to Cs-137 released from Chernobyl not being associated with clay; the source term was not as expected with a large fraction of the activity being associated with fuel fragments and particles. Whilst good models were available, their implementation was not appropriate.

The Chernobyl accident resulted in the release of between 3 and 4 tons of spent fuel in a range of particle classes, each with different weathering rates and different remobilization potential for associated radionuclides. The fuel particles can be divided into three groups according to the particle properties and dissolution rates under natural conditions:

- Chemically extra-stable U-Zr-O particles depleted in volatiles, formed as a result of high-temperature annealing of UO_2 in the presence of zirconium in construction material, released during the initial explosion and deposited to the West of the reactor.
- Non-oxidized chemically stable UO_2 fuel particles formed as a result of the mechanical destruction of nuclear fuel, released during the initial release and deposited to the West.
- Oxidized UO_{2+x} particles of low chemical stability, formed as a result of oxidization of the nuclear fuel in the period 04/26/86 - 05/05/86. These particles were predominantly deposited to the North and South of the reactor.

Experimental results of the dissolution of particles under different soil acidity conditions showed that there were considerable differences with the half-life of dissolution for UO_{2+x} and UO_2 particles varying from 14 to 1 year and from 70 to 7 years, respectively, when the soil pH increased from 7 to 4. The UO_{2+x} particles were formed during the reactor core fire when oxygen levels were greater, resulting in uranium being oxidized. These particles are less stable than UO_2 particles that were formed during the initial explosion when no oxygen was present and are associated with shorter half-lives and more rapid ecosystem transfer.

The weathering and dissolution of particles can affect radionuclide uptake as evidenced by Sr-90 uptake into grain many years after the Chernobyl accident, which was not expected. Experiments have been conducted on the uptake of Sr-90 that has been remobilized from particles into grain. Results have shown that uptake dynamics are determined by the kinetics of fuel particle dissolution and by the increase in mobile Sr-90 species in the root layer.

The Chernobyl case demonstrates, therefore, that there can be different release scenarios associated with the same source that can result in different particle characteristics and different ecosystem behavior. This highlights the importance of characterizing contamination to inform on remediation.

A study is ongoing on the uptake of radioactive particles in organisms in the field within the EC-RATE project, and a position paper is currently in press in the Journal of Environmental Radioactivity. The study aims to consider whether particles matter; they present a delay to environmental transfer but remobilization should be estimable. However, analysis of particles in organisms has shown that particles can be consumed by organisms; particles have been observed in feces of musk oxen from Thule, Greenland, in rabbits and other mammals around the Maralinga test site in Australia, and in hair and snails from Palomares in Spain. Particles have also been found to be retained between the shell and soft tissue of snails that are consumed as a delicacy in Spain. The particles therefore pose a radiation protection issue for people.

There are dose recommendations for particles in terms of skin contact, but dose estimates for Chernobyl particles indicate that absorbed doses can be significantly greater. Particles can therefore represent point sources of concern.

Where particles are present, there will be a time function for uptake and time relevant ecosystem processes and other aspects should be considered. The work being done by CERAD aims to reduce the overall uncertainties in impact and risk assessments through targeted research on key areas of uncertainty that can be improved upon. In the work being done, variables, processes and conceptual models are all being considered; if particles are excluded then there can be a serious conceptual issue. For example, in an aquatic environment, ions would be assumed to be taken up by fish, but where particles are present, they will be taken up by filter feeding organisms. Where large particles are retained, these can act as point sources.

To reduce overall uncertainties, research efforts should be prioritized toward variables, parameters, processes and model structures contributing most to the overall uncertainties. Model results are only useful when uncertainties are estimated, communicated and understood.

3.2 Scientific and practical achievements in the field of regulatory supervision during remediation of nuclear legacy sites in the Russian Northwest

Nataliya Shandala (FMBC) presented.

The FMBC is responsible for implementing government policy with regard to uranium and nuclear legacies and has a target program called the ‘nuclear safety program’. This is a long-term program that is due to continue until 2030.

Russian coastal bases were established in the 1960s that served as service bases for nuclear submarines and vessels. Radioactive waste and spent nuclear fuel (SNF) were also stored. The bases were due to be decommissioned in the 1990’s, but storage conditions were poor and degradation had resulted in environmental contamination from the stored radioactive waste and SNF. Concern was raised over the situation in northwest Russia, particularly with regard to

Andreeva Bay, which is located just 70 km from the state border with Norway. This concern led to a government target program on safety that helped develop infrastructure at the naval bases. In 2000, the naval bases were to the control of the state corporation 'Rosatom' that was responsible for the management of SNF and radioactive waste, and the nuclear safety center developed for northwest Russia.

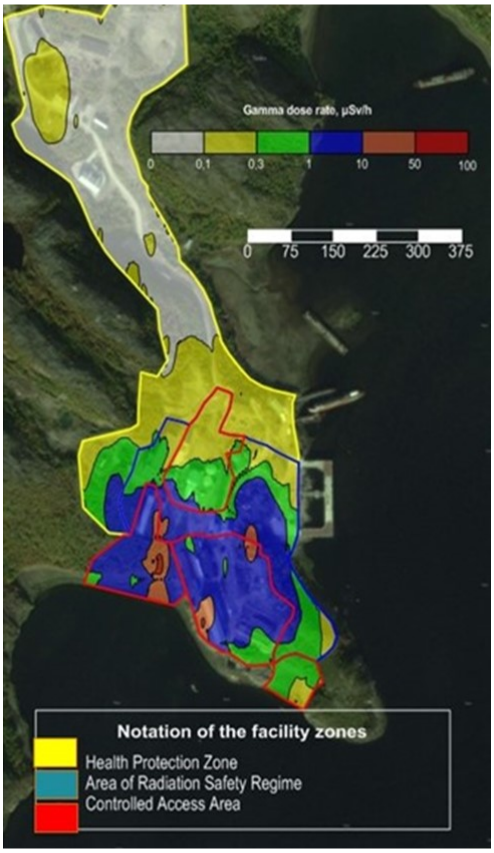
Andreeva Bay has been home to around 17,000 m^3 of solid radioactive waste, 1,300 m^3 of liquid radioactive waste and SNF from around 100 reactors from nuclear submarines. Since 1962, transport containers with SNF have rusted on the open site of the base. Concern around the situation resulted in a bi-lateral cooperation between the Russian Federal Medical Biological Agency (FMBA) and the NRPA being signed in 2008. The FMBA is responsible for:

- developing safety principles and criteria;
- establishing rules and issuing documents;
- requiring operators to conduct safety assessments;
- visiting sites or facilities for inspection purposes (at least 1-2 times per year);
- applying sanctions in case of radiation safety violations;
- communicating to the public information related to the regulatory process; and,
- communicating with the regulatory authorities of other countries and with international organizations.

Rosatom and FMBA have good cooperation and have worked on threat assessments to define the priorities for addressing the situation at Andreeva Bay. There was an unsatisfactory safety situation present, but worker doses could not be appropriately calculated. There was also a lack of communication for in case of emergencies. Overall, it was concluded that cooperation was needed in radiation protection of workers and the public and in emergency response.

The cooperation program has resulted in a number of achievements to date. For occupational radiation protection, doses have been evaluated based on monitoring. Software has been developed to allow visualization of zones with the highest radiation hazards that informs on possible exposure doses. These interactive maps have proved very useful, particularly as a tool in decision-making. There has also been considerable progress in terms of occupational reliability. Personnel are required to work in conditions that are not standard and therefore need to be trained and undergo a selection process to ensure their suitability for the required tasks; human factors need to be evaluated to ensure personnel can be relied upon. A testing system for personnel has therefore been developed. The safety culture at the sites has also been greatly developed.

Reliable monitoring data were required to support dose assessment for the population and workers and expeditions were conducted to collect samples and conduct independent surveys. Interaction maps have been developed that incorporate the monitoring data. Based on survey results, Andreeva Bay was divided into three zones, the health protection zone (HPZ), the area of radiation safety regime (RSR) and the controlled access area (CA), as illustrated in
Figure 3-2. The different areas were delineated on the basis of gamma dose rate, with the dose rate in the CA showing the most variability within a range of 0.4 to 98 µSv/h. The gamma dose rate results over time and soil specific activities for Sr-90 and Cs-137, measured through independent surveys, are illustrated in
Figure 3-2.



Industrial Site - Zone	Year of study				
	2002	2008	2010	2013	2015
HPZ	-	0.1 – 0.3	0.1-7.3	0.1-0.2	0.08-2.8
CA	0.5-450	0.7 - 260	0.07-115	0.5-150	0.42-98
Background typical for the region	0.1-0.15				

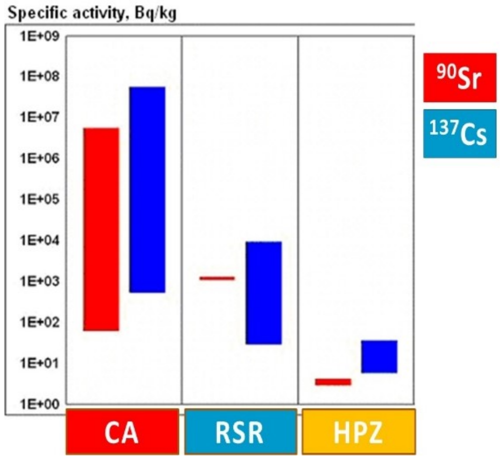


FIGURE 3-2. DELINEATION OF FACILITY ZONES AT ANDREEVA BAY (LEFT), GAMMA DOSE RATE OVER TIME (UPPER RIGHT) AND RADIONUCLIDE CONCENTRATIONS IN SOIL IN THE FACILITY ZONES (LOWER RIGHT).

A gamma spectrometry survey of the offshore marine sediments has also been conducted around the pier area that is contaminated with Cs-137 and Sr-90; the pier area being important due to transport vessels docking to allow the transport of SNF from Andreeva Bay to Murmansk. The area has therefore been characterized. Contamination is observed very close to the pier with dose rate in bottom sediments varying over the range 0.05 to 3.5 µSv/h. Concentrations of Cs-137 in the bottom sediments varies over the range 100 to 200 kBq/m^2.

Groundwater in the area has also been monitored through a series of wells and results compared against drinking water limits. Concentrations of Cs-137 were found to be significantly higher than allowable. Chemical contamination has also been assessed with results indicating that there is also significant chemical contamination with maximum permissible concentrations being exceeded in many cases and fishery regulations being violated in most samples.

Biological monitoring has also been performed to evaluate reproductive indexes of natural populations of biota in the area and to assess the ecological condition of the terrestrial ecosystem using bio-indicators. Water from wells in the area were used for growing onions in one bio-indicator test and results showed a statistically significant difference in the frequency of aberrant cells in onion roots.

Overall, three types of monitoring have been performed at Andreeva Bay: radiation monitoring, chemical monitoring and biological monitoring. All three are important in a holistic approach and experience has shown that monitoring is essential when addressing legacy issues.

All of the experience gained from the site has helped in the development regulatory documents on emergency preparedness and response that have been developed in the bilateral cooperation with NRPA. Three full-scale international exercises and training have been performed and new regulatory documents produced in relation to:

- requirements to provide radiological protection of the personnel and the public;
- criteria and norms on remediation of sites and facilities;
- arrangement of environmental radiation monitoring;
- requirements for industrial waste management;
- operational radiological and medical criteria for initiation of emergency protective actions; and,
- requirements to support the safe management of products containing nuclear materials.

Tests for SNF removal were conducted between 2010 and 2015 and, in 2017, the first removal of SNF took place with SNF being transported by ship from Andreeva Bay to Murmansk. The foreign ministry of Norway was present for this first shipment.

Populations close to Andreeva Bay and Murmansk were involved in the overall process; experience has shown the importance of communication throughout the process to ensure that concerns are addressed at an early stage.

The international focus on nuclear sites is very important and work being done within TG98 of the ICRP, the NEA EGLM and the IAEA RSLS forum is very valuable. There remains a need to develop a methodology for addressing the combined impacts from radionuclides and hazardous chemicals and to develop practical guidelines on procedures for establishing reference levels under various scenarios of legacy site remediation.

3.3 Recent developments in the regulation of the final stages of decommissioning and clean-up of nuclear sites in the UK

Simon Morgan (Office for Nuclear Regulation, UK) presented.

Nuclear legislation in the UK began in the 1950's, following the Windscale fire. This prompted the setup of an independent safety regulator, which is now a requirement under the Convention on Nuclear Safety. In 1959, legislation was passed that required a liability regime to be established along with a site licensing regime within the UK. The Nuclear Installations Act of 1965 then set out requirements on sites in terms of delicensing such that there should cease to be any danger from ionizing radiation from anything remaining on the site. No definition was given as to 'no danger', which resulted in difficulties in the regulatory interpretation of this requirement.

More recently, a delicensing criterion has been set such that any residual radioactivity remaining on site should not exceed an annual risk of 10^{-6} for any individual using the site for any reasonably foreseeable purpose. This level of risk is consistent with the level of risk people are generally willing to accept. The criterion is focused on the end state of the site, and not on off-site impacts or on what needs to be achieved to meet the criterion. Sites therefore have a responsibility to remove contamination that could give rise to risks above this level, including contaminated soils and building infrastructure. The costs of meeting this criterion can therefore be high.

The GE Healthcare site in the UK that was used for the manufacture of pharmaceuticals labelled with tritium and C-14 has ceased operations and moved toward the delicensing of the site. The buildings laboratory was lightly contaminated with tritium and, rather than decontaminating, the building was demolished. The demolition of buildings introduces conventional health and safety risks and off-site impacts due to the off-site transport of lightly contaminated materials for disposal elsewhere. Whether this approach was optimal was therefore challenged and thought given as to whether there would be a better all-round option that would provide greater protection of the environment and reduce spend. With the law as it stood there was no leeway in terms of clean up requirements and a legislative change was therefore identified as required to ensure a proportionate response could be applied to decommissioning sites.

The nature of risks associated with nuclear facilities varies throughout the lifecycle of the facility (Figure 3-3) and consideration has been given as to when a nuclear regulator is required to regulate a site. A nuclear regulator is needed for the riskiest activities involving radiation such as when radioactivity is released as a result of nuclear reactions, but a lesser degree of protection may be appropriate for other activities, such as those associated with research facilities, hospitals and universities. For these activities, radiological regulation is required rather than nuclear regulation. The use of licenses allows regulators to set hold points for activities until safety is adequately demonstrated.

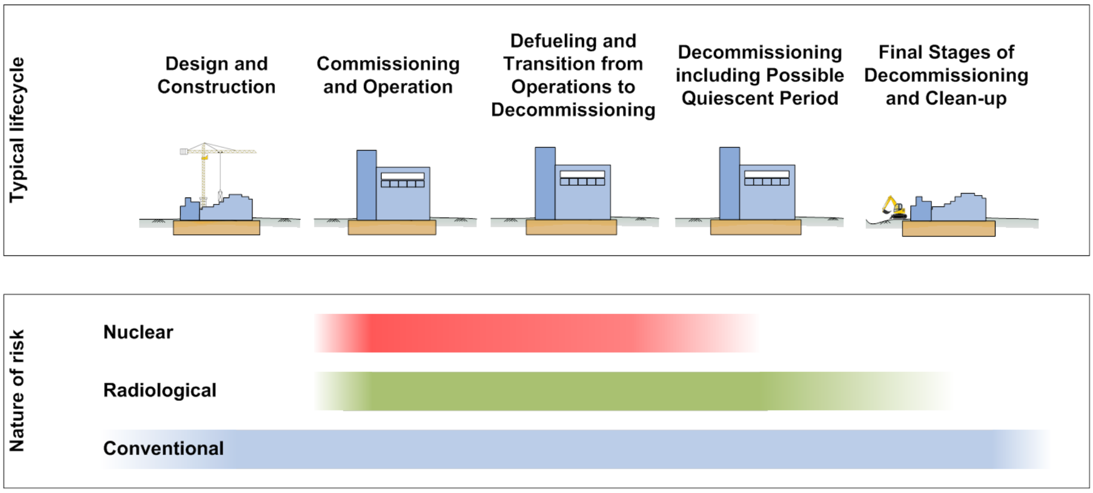


FIGURE 3-3. NATURE OF RISKS THROUGHOUT THE LIFECYCLE OF A NUCLEAR FACILITY.

A number of projects have taken place since 2014 to consider whether the regulatory system for nuclear and radiation protection can be improved upon and a set of papers on this topic have been produced. Furthermore, the Government gave permission for options for regulatory change to be looked into, and a discussion paper outlining proposals around the regulation of nuclear sites in the final stages of decommissioning and clean-up was submitted in November 2016. There has been general supportive feedback received, but greater consideration is required on the exact regulatory changes that may be needed. In March 2017, a government consultation document on the same topic was prepared and is currently under regulatory review. If accepted, nuclear site licensees will have alternative routes out of licensing arrangements. In the meantime, the ONR is working with industry and the NDA to consider what the changes would mean for sites.

Three decommissioning sites have been considered; two research establishments (Dounreay and Winfrith) and a former nuclear power station (Trawsfynydd). All three sites are well advanced in the decommissioning process. The baseline for decommissioning of each site was for all contaminated materials to be removed from the sites, in line with previous requirements. The implications of the greater flexibility that the proposed regulatory changes would make have been investigated. The additional flexibility would allow for on-site disposal of contaminated materials classified as very low-level waste (VLLW). The disposal of VLLW in the UK falls under the remit of the relevant environmental regulator, rather than being seen as a nuclear safety issue. There may also be a need for planning regulations.

There are a number of disposal options available, ranging from the construction of dedicated disposal facilities through to grouting of wastes in situ. Wastes could also be used for void filling or landscaping, depending upon the contamination levels. In each instance, the safety of the disposal option would need to be demonstrated.

The regulatory system in the UK is such that there is more than one regulatory body responsible for the safety of sites. The ONR is responsible for nuclear safety and security whereas the devolved environment agencies of England, Wales and Scotland are responsible for radiological and conventional environmental protection.

A distinction is made between radioactive waste storage and disposal. Disposal is regulated by the environment agencies and requires an environmental permit or authorization and an Article 37 submission is required under the Euratom Treaty. Disposal is also likely to require planning permission such that the local council agrees that disposal is an appropriate use of the land. There is therefore added complexity in the decision-making process for disposal. As such, a number of guidance documents are being developed, based on lead-and-learn project output. A consultation document on 'guidance on requirements for release of nuclear sites from radioactive substances regulation' was published in February 2016 and is close to completion. A joint regulators statement on common understanding of disposal of radioactive waste on nuclear sites has also been prepared (http://www.onr.org.uk/documents/2016/joint-regulators-statement.pdf).

The approach in the UK is therefore to look at the most suitable regulator for the situation. If there is a nuclear risk then the ONR is involved whereas for low levels of risk from radiation, the environmental consequences are the main concern and responsibility falls to the environment agencies. For a decommissioning site, when the end state is reached the site can be delicensed. This is a decision by the ONR. In the UK, in the future, the release of a site from regulatory control may become a decision for the environmental regulators.

3.4 On the need to revise the parameters of radioactive contamination of the territory resulted from the past industrial, military and nuclear activities

Sergey Lukashenko (Institute of Radiation Safety and Ecology) presented.

The Institute of Radiation Safety and Ecology provides comprehensive and wide scale investigations of former nuclear test sites and can provide a wide range of radioecology research experience and field equipment.

An inventory has been made of the Semipalatinsk former test site. This site is very large, at over 18.000 km^2 and has been subject to a number of nuclear tests. The site was closed in 1991. Between 2008 and 2016, large scale environmental surveys have taken place across the site (8000 km^2), the primary objective of which was to make an inventory of the radiation hazards and the radioactive species present across the site to evaluate the scale of contamination. The comprehensive studies of the territory included:

- Assessment of general characteristics of the soil cover and distribution character of the basic radionuclides in soil.
- Assessment of hydrogeological conditions, characteristics of the water environment and a forecast for dynamics of change.

- Studying the character of air basin contamination.
- Geobotanic description, theoretical and experimental assessment of the level and character of the soil cover contamination.
- Assessment of fauna and the content of radionuclides in the bodies of the main wild and domestic animals.
- Assessment of possible concentrations of radionuclides in agricultural and cattle breeding products produced at the territory.
- Assessment of radiation exposure doses for the population, based on a farmer scenario.
- Issuing recommendations for the use of conditionally “background” territories for the national economy based on the international and republican requirements.

Contamination across the territory is not uniform, but rather hotspots of contamination are present. Over 70% of the overall territory has contamination levels similar to global fallout. The more contaminated sites together equate to a maximum area of 1000 km^2.

The investigations considered not only the current situation, but also the situation as it may change into the future to ensure safety over time. No people are present at the site at the current time, with special licenses being required to carry out any activities in the territory. Therefore, no habit data were available upon which dose calculations could be based. A conservative scenario was therefore adopted, assuming a person lived in the area and consumed only crops and livestock produced in the territory.

For some calculations it was evident that there was a lack of data for some radionuclides and/or pathways. In the absence of transfer factors, it is not possible to evaluate the transfer of radionuclides through the food chain. As such, an experimental farm was established in 2007 to allow transfer studies to be undertaken for a range of different wild plants and crops plus livestock. These studies were undertaken between 2007 and 2017 and were focused on an area of the territory associated with the highest levels of contamination. As a result of the project, reliable transfer coefficient data have been obtained for a wide range of agricultural products. Some of the data are within IAEA compendium data ranges whereas for others the transfer coefficients are lower.

Air data are also important for dose calculations, with Pu-241 inhalation being an important exposure pathway. Rather than using a coefficient for resuspension, a theoretical equilibrium formula was applied to calculate the average concentration of artificial radionuclides in air.

The wide range of data from the site for various exposure pathways were used within an assessment model to calculate soil limit values that represented the concentration of radionuclides in soil corresponding to an acceptable exposure level, based on national criteria for soil contaminants. The criteria that were in place initially were not considered acceptable since they were not based on real research and accepted science. A request was therefore made to the Kazakhstan Government for the criteria to be changed and, in September 2017, this request was approved. Whilst the new criteria have been justified and approved, some improvements could still be made. For example, in deriving the new criteria, account was not taken of specific parameters such as particle size and solubility and, in some cases where data were not available, conservative assumptions were made. In future work it is hoped that criteria for different end uses could be developed.

Model sensitivity analyses are planned for 2018-2019 to consider soil limit values corresponding to an annual effective dose of 1 mSv, taking account of the parameters chosen for the model and for different exposure scenarios. Variability will be assessed for each parameter and estimates made of the degree of impact of each parameter on internal exposures. Following this, a verification of the radionuclide intake model is planned for the period 2019-2022, to provide verification of the assessment model in terms of ingestion and inhalation estimates. Calculation results will be compared against biophysical measurements.

Overall, the results of these studies are intended to support decisions around the future economic use of the territory.

3.5 Regulatory aspects of safety for the legacy sites in the Russian Federation

Andrey Lavrinovich (Rostechnadzor) presented.

Issues around legacies and radiation hazards have been increasingly recognized in Russia. Lots of waste has been gathered at different sites, facilities were aging and the need to reduce the collection of radioactive wastes at sites was recognized; a large radioactive waste burden had accumulated by the 1990’s. International cooperation in northwest Russia has helped address these issues. In 2011, a Federal Law on radioactive waste management was issued, in recognition of the scale of the legacy problems faced. This new law led to a new stage in dealing with the safety problems at legacy sites and the amassed radioactive wastes.

Nuclear and radiation hazard facilities were placed within a 3-level regime for inventory accounting. At level 0, preliminary characterization would be carried out along with preliminary risk ranking to support long-term planning of activities to address the legacy. At level 1, greater characterization would be undertaken to develop inventory information on the radioactive wastes etc. to support middle-term planning and inclusion in state programs. Level 2 then requires decommissioning activity programs to be developed and costs and times for implementation to be evaluated to support project implementation and control and supervision of decommissioning project implementation.

The renewed system of Federal rules and regulations relating to radioactive waste management established:

- new approaches to radioactive waste classification for final disposal, whereby all radioactive wastes are divided into two groups – special and removable, where special equates to those wastes for which radiological and other risks, as well as cost of its removal from storage facility and subsequent management, including disposal, exceed risks and costs of its in-situ disposal, and removable equates to wastes not placed in the category of special;
- common acceptance criteria for final disposal, and requirements for establishing acceptance criteria for specific radioactive waste final disposal;
- safety requirements for special radioactive waste management, safety criteria and requirements for the special radioactive waste storage and conservation facilities;
- common requirements to the safety foundation of radioactive waste management, including the evaluation of the long-term safety of final disposal, and the periodic safety reassessment of radioactive waste management facilities.

A unified State system for radioactive waste management, which provides the basis for state policy on radioactive waste up to 2025 has been signed by the Russian President in 2012. This was a key moment in solving the amassed radioactive waste issues by setting up national programs for the handling of radioactive wastes within areas of heightened radioactive risk within the Russian Federation.

The first Federal Target Program ran until 2015. The aim was the integrated solution of the most urgent nuclear and radiation problems in the Russian Federation related to the spent nuclear fuel and radioactive waste management, decommissioning of nuclear and radiation hazardous facilities, improving and development of the safety requirements for the nuclear and radiation safety regulation. In the course of implementation, an inventory was developed of nuclear and radiological hazardous facilities, taking account of their present state and ranking according to their hazards. During this programme, the infrastructure for the long-term storage of SNF was developed and much of the SNF from nuclear power plants was moved to long-term centralized storage facilities. Wet storage facilities were also modernized with technological solutions put in place to solve issues around water ingress. New centralized dry storage facilities were also created. A significant enhancement of the nuclear and radiation safety was therefore achieved for a lot of the most hazardous legacy sites.

A second Federal Target Program was approved in November 2015, the main goal of which is to achieve comprehensive nuclear and radiation safety in the Russian Federation by resolving priority issues with legacy sites and creating the necessary infrastructure for SNF and radioactive waste management to allow for the decommissioning of legacy sites. The main scientific issues to be addressed during this program, lasting until 2025, include development of:

- integrated and comprehensive analysis methods for nuclear and radiation safety evaluation of facilities to the further improvement of regulatory basis for nuclear legacy sites; and,
- methods of evaluation and prognosis of radiation impact (including emergency impact) from legacy sites to populations and the environment to support decision making.

Current activities that are ongoing involve the creation of the system for the final disposal of LLW and ILW and several possible disposal sites are under investigation. Highly enriched SNF from Russian-built research reactors in countries such as Bulgaria, Kazakhstan, Uzbekistan, Romania, Poland, Hungary and some others, has also been returned to Russia for reprocessing. The part of nuclear icebreaker fleet is also being decommissioned. Activities are also ongoing to decommission liquid radioactive waste ponds.

The regulatory basis for radioactive waste management in Russia has developed considerably, leading to a unified state system for the management of radioactive waste. This has included legislation around financial and responsibility aspects of radioactive waste management. Federal rules and regulations have also been set for decommissioning. The fundamental legislative and normative basis for the safety regulation of legacy problems has therefore been elaborated around radioactive waste management and decommissioning, taking into account international requirements and the latest trends in the nuclear activity development, resulting in a broad basis by which legacies can be managed.

3.6 Fukushima remediation update – soil storage and recycling

Haru Hashizume (Obayashi Corporation) presented.

In 2011, a huge sub-surface seismic force occurred leading to a large tsunami strike on the eastern coast of Japan on March 11, which was the largest tsunami strike in history. The Tsunami strike gave rise to a series of events at the Fukushima Daiichi nuclear power plants. The primary seawater circulation system for cooling the nuclear reactors failed. There were back-up generators, but these were located underground in the reactor buildings and they too failed. With the cooling system failing, there were explosions in the nuclear reactors and atmospheric release of radioactivity occurred with a radioactive plume spreading primarily to the northwest of the site, resulting in contaminated land.

Five months following the explosions, the National Government set out measures to address the contamination. By the end of 2011, a demonstration project was started with clean-up activities then starting around 1 year later and continuing to date.

Decontamination works have, as of January 2017, cost 24 billion US dollars, taken 26 million man-days and resulted in the consolidation of around 16 million m^3 of decontamination wastes such as contaminated soils that has been placed in temporary storage. Due to the large volume of waste, volume reduction and recycling are key and high-speed and accurate sorting technologies are required to support interim and final storage solutions. The clean-up waste is being transported to nearby the Fukushima Dai-ichi plant for interim storage. It is intended that the interim storage will last for a period of 30 years.

The decontamination works have resulted in a large reduction in air dose rate resulting from the contaminated plume during the accident. Once the majority of contaminated areas have been remediated, the shift in focus moves to the most heavily contaminated areas left untouched.

Temporary storage is being used to separate container bags from the public until an intermediate storage facility is available to receive the soil. Once available, the container bags will be transported to the interim storage facility where they will be received and wastes segregated for soil storage, volume reduction and recycling and waste storage. Soil concentration profile is estimated as illustrated in Figure 3-4.

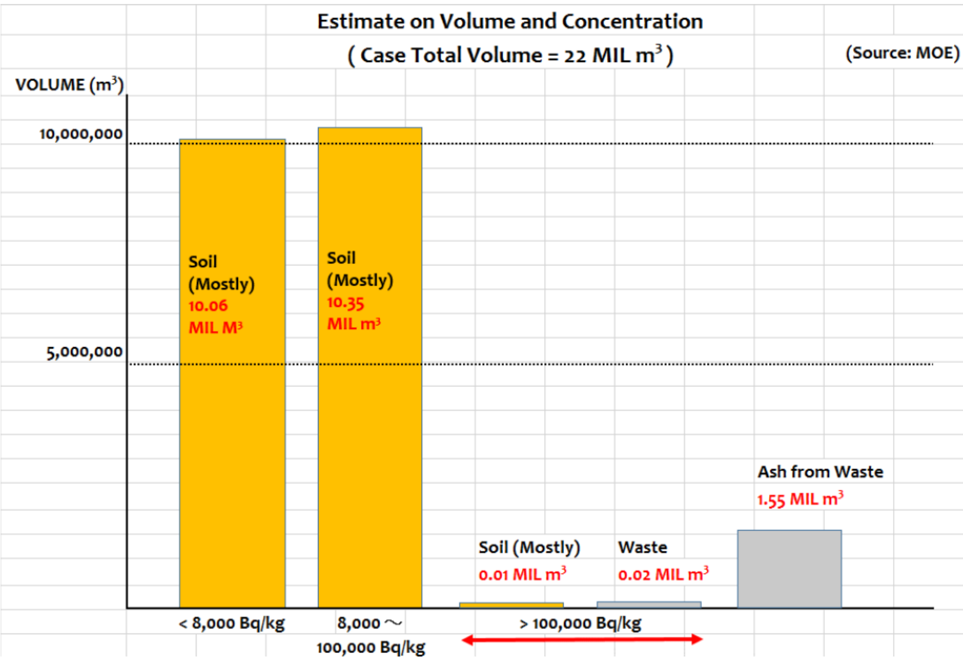


FIGURE 3-4.ESTIMATED VOLUME AND CONCENTRATION OF SOIL ACCUMULATED FROM CLEANUP

A high precision and high-speed sorting mechanisms for received soil will be needed to segregate and store in accordance with higher and lower activity. The threshold for recycling of materials has been set at 3 kBq/kg. The sorting system will be required to operate at around 140 t/h at each inlet area, so as to deal with the transfer of material from temporary storage to the interim storage facility. Over 10 million m^3 of primarily soil is concentrated below 8kBq/kg and another 10 million m3 of primarily soil is done so between 8 and 100 kBq/kg, the MOE estimates.

3.7 Regulatory supervision of legacy sites: Belarus experience

Dmitry Pavlov (Department for Nuclear and Radiation Safety, Gosatomnadzor of Belarus) presented.

There are several laws in Belarus that apply to the management of legacies, including:

- Law "On Radiation Safety of Population" of January 5, 1998;
- Law "On the Use of Atomic Energy" of July 30, 2008;
- Law "On Legal Status of Territories Radioactively Contaminated as a Result of Chernobyl NPP Catastrophe" of May 26, 2012; and,
- Decree of the President of the Republic of Belarus of September 1, 2010, № 450 "On Licensing of Certain Types of Activities"

The 2010 Decree covers the handling of radioactive waste and radioactive materials.

The licensing of the use of atomic energy and ionizing radiation sources is the responsibility of the Ministry for Emergency Situations, which is the national regulatory authority. Within this authority, the Department for Nuclear and Radiation Safety of the Ministry for Emergency Situations is responsible for carrying out state supervision in the field of nuclear and radiation safety.

There are a number of historical legacies in Belarus resulting from radioactive waste storage at former locations of the USSR military forces. Work to identify these storage facilities was completed in 2014 with 40 locations being identified. Of these, 15 comprised well storage facilities that were considered to be good storage sites for radioactive wastes. Only two facilities were filled: RWSF Kolosovo and RWSF Gomel-30. The Kolosovo well had been filled with sand and the decision was made to remove all sources and relocate wastes in a permanent storage facility. In 2008, the works were carried out and the area rehabilitated. A survey of the Gomel-30 facility indicated that wastes were contained in a cement structure that provided good assurances against leakage of radionuclides into the environment. As such, it was not deemed necessary to carry out immediate measures to remove wastes, but monitoring has been implemented to assess safety performance. Decisions around further management at Gomel-30 will be made according to the results of a periodic safety assessment that is to be carried out in 2018.

A specialized radioactive waste management enterprise (Ekores) for radioactive waste storage began operation in 1963 and is the only specialized enterprise of this type in Belarus. The facility is focused on the management of ILW and LLW and annually accepts up to 3 tons (3 m^3) of solid radioactive waste and up to 3,000 spent ionizing radiation sources, including smoke detectors, annually. There are a number of buildings located on the site, including:

- two old radioactive waste storage facilities, that operated from 1963 to 1979;
- two near-surface solid waste storage facilities that were built and operated since 1977;
- a storage facility for sealed radiation sources placement that was built and operated since 2003;
- a special laundry that has operated since 1977, and that was reconstructed in 2013;

- a unit for radioactive waste processing with laboratories, built in 2013; and,
- a conditioned solid radioactive waste storage facility, also built in 2013, and comprising four separate sections for the storage of conditioned radioactive waste of different categories.

There are a number of measures planned to improve safety at the Ekores facility, including conducting a comprehensive engineering and radiation survey of the old radioactive waste storage facilities, and removal of radioactive waste from these facilities and its treatment and conditioning. This work will be done in cooperation with Russian colleagues.

Belarus also has legacies associated with Chernobyl decontamination waste disposal facilities. There are currently 86 such facilities in three regions. Optimization of the disposal system for decontamination wastes in the Gomel region was started in 2012 and activities are planned until the end of 2020. Wastes from disposal sites are being displaced and redisposed of and parts of the territory are being decontaminated to reduce the exposure of populations.

A proposal has also been submitted to the IAEA for a regional project to conduct a detailed analysis of existing decontamination waste disposal facilities in Belarus, Russia and Ukraine and to establish criteria for monitoring these facilities in terms of the migration of radionuclides and the presence in ground water, and the dose rate on the surface of or inside the disposal areas. The project has been accepted and will run from 2018 until 2021.

Further planned activities include:

- further development and improvement of the legislative framework;
- development and approval of strategies for the management of radioactive waste and spent fuel from the Belarusian nuclear power plant;
- development of human capacity of involved stakeholders;
- improving the safety of the radioactive waste storage facility “Ekores” by removal and conditioning of radioactive wastes from old storage facilities;
- rehabilitation and monitoring of Chernobyl-origin decontamination waste disposal facilities; and,
- detection of radioactive waste storage facilities at former locations of the USSR military forces as well as their long-term safety assurance.

4 Scientific, technical and regulatory aspects for remediation (including safety and environmental assessments, remediation and environmental monitoring)

4.1 Scientific basis for future management options of the Little Forest Legacy Site

Hefin Griffiths (ANSTO) presented.

ANSTO is the license holder and operator for the Little Forest legacy site (LFLS), formerly Little Forest burial ground (LFBG).

The LFBG was operational between 1960 and 1968, during which time LLW, including effluent sludge, laboratory wastes, and contaminated equipment from the Australian Atomic Energy Commission (AAEC) and other organizations were disposed of in unlined trenches. Disposal was by tumble tipping. There were 79 trenches in total that each measured 25m by 3m by 0.6m that were spaced 2.7m apart. In total, 1675 m^3 of waste was disposed of in the trenches, equating to around 150 GBq of radioactivity. This included around 1100 kg beryllium and around 7 g of plutonium, both of which are viewed similarly by stakeholders. There was no consideration given to packaging or conditioning of wastes.

The LFLS is located to the south of Sydney, close to the Lucas Heights landfill I and II sites (Figure 4-1). There is a 1.6 km buffer zone around the LFLS, but different activities are carried out within this zone. For example, the area includes the current landfill site for the southern area of Sydney. A quarry that was used as a former landfill until 1987 is also present, along with a hazardous liquid waste disposal site. A human waste disposal area is also present. Therefore, even if the LFLS was completely remediated, there would remain existing hazards and unrestricted use of the site is therefore unlikely.

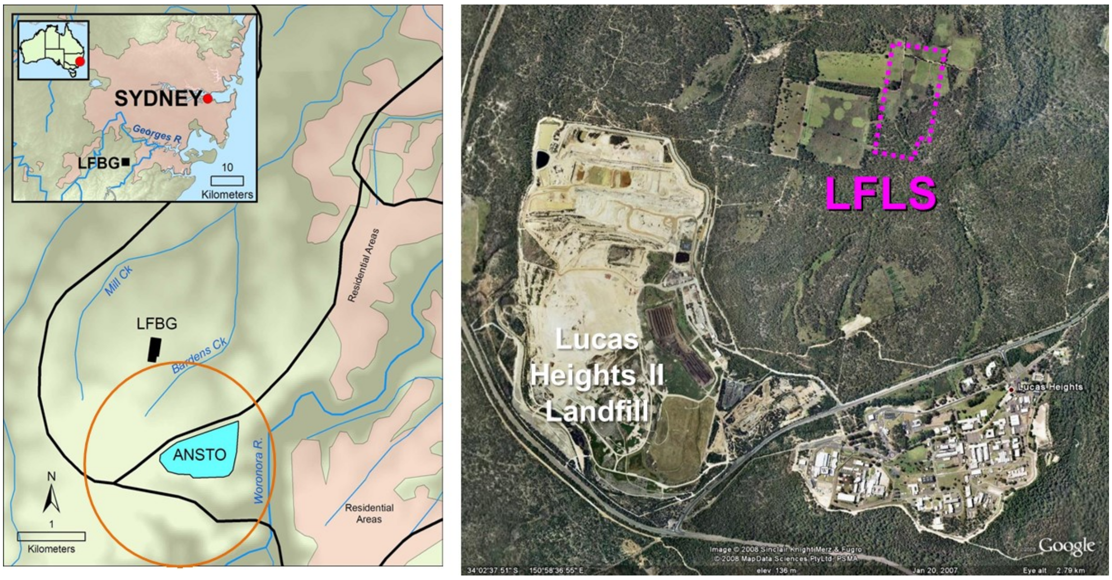


FIGURE 4-1. LOCATION OF THE LFLS (FORMERLY LFBG). LUCAS HEIGHTS I LANDFILL IS LOCATED TO THE RIGHT OF LFLS AND THE FORMER QUARRY LANDFILL AND LIQUID WASTE DISPOSAL SITES ARE LOCATED TO THE NORTH (NOT SHOWN ON FIGURE).

The trenches have been subject to significant scientific research since their closure and a number of papers have been published on the geology, hydrogeology and dose modelling for biota etc.

There were concerns locally when plutonium was found in the trenches. Only small quantities are present, but there was nonetheless concern and this triggered the need for remedial action, with a 1m soil cover being placed on top of the trenches. This remedial action was effective for over 20 years.

A trench model has been developed to see whether the processes resulting in the mobility of radionuclides could be modelled. A number of 40-gallon drums have been disposed of in the trenches and these have deteriorated and collapsed as a result of the weight of soil overlying them. This has resulted in sink holes forming that allow for greater water ingress. However, the movement of water from the trenches is limited due to the presence of shales, resulting in a bathtub effect whereby mobilized radionuclides are brought to the surface (Figure 4-2). This is supported by several decades of water sampling that has shown that, with the exception of a tritium plume, there was little evidence of radionuclide movement in groundwater. The modelling of the processes in the trenches informs on options.

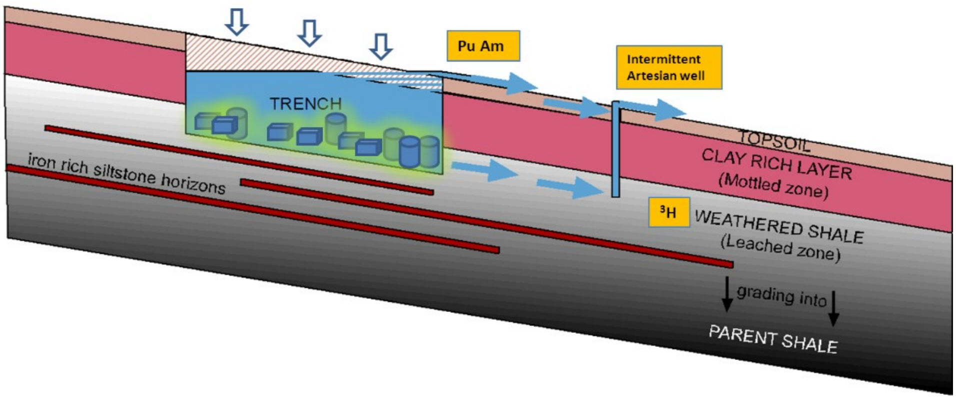


FIGURE 4-2. TRENCH MODEL SHOWING BATH TUBBING EFFECT AND THE MOBILIZATION OF RADIONUCLIDES TO THE SURFACE OF TRENCHES.

The plutonium that has been detected at the surface of trenches is at very low levels (a maximum of 0.8 Bq/g) and below thresholds for regulatory control in Australia. The plutonium is also very localized to particular trenches that ties with available disposal records. There are also clusters of Cs-137 and Sr-90 that are again localized, some being located around the area of an old receipt hut.

From the time that disposals started until they ceased in 1968, the site was not under any regulatory control; the Australian Nuclear Safety Act came much later. The lack of regulatory control subsequently created an issue both for ANSTO as the operator and ARPANSA the regulator. The situation at the site in 2013 was that the site was recognized as a legacy and was managed by ANSTO. A management, monitoring and mitigation plan was in place and there was some evidence of tritium migration and limited migration of other radionuclides for which the mechanism was understood. There was no immediate threat to public health from the legacy site, but it was not to modern standards.

A change to the site license was issued in 2016, which recognized the LFBG as the first legacy site in Australia. A license condition was set, requiring ANSTO to develop a plan for the medium and long-term management of LFLS by June 2018. The submission of the plan will be after this date, but ARPANSA has been kept informed and is happy that work is progressing in the right direction.

Options for maintaining the isolation of the waste inventory from the environment and human intrusion for a sufficient period to demonstrate public and environmental safety following release from institutional control were identified. These included:

- Do nothing. This option was rejected since it would not meet regulatory requirements.
- Full exhumation, characterization and conditioning of the waste. The environmental and worker health and safety risks would be considerable for this option and there would also be large cost implications. The option may not, therefore, be justifiable.
- In-situ remediation. This could involve the installation of an engineered cover, surface bunds or other form of interception or subsurface barriers. Alternatively, a pump and treat approach could be employed or wastes could be grouted in situ.

In situ remediation options are being considered within a project that is being undertaken jointly with the University of Newcastle, Australia, the University of New South Wales and the University of Strathclyde. Key questions for the project are:

- What was put in the trenches?
- How can the trench contents be stabilized?
- What has come out of the trenches?
- How the input and export of water be controlled?
- What chemical and physical processes are occurring?
- What are the environmental and human impacts under various scenarios?
- What are the best remediation options?

The project includes six sub-projects.

Sub-project 1 is focused on in situ grouting options. The geology in the area of the LFLS is not porous; porosity is limited to the waste form itself. As such, in situ grouting could stabilize the waste and decrease the amount of water in the trenches by filling pore spaces. This could also help minimize any further subsidence. Grouting could be performed by pumping colloidal silica into the waste at very low pressure over time, to fill as many voids as possible. This may also result in the outside of the trenches also being encapsulated.

Test trenches are being dug next to the disposal trenches in sub-project 2 to allow the effectiveness of grouting to be investigated. Test trenches will also allow studies of rainfall events to be studied, the results of which could be used to improve hydrological models as well as supporting the testing of engineering solutions.

Sub-project 3 is focused on dose assessment and beryllium. Beryllium is a major hazard at the site and exposure to beryllium and mitigation of the inhalation pathway would be a major consideration if exhumation is undertaken. A number of dose assessment scenarios are being evaluated, as detailed in

Table 4-1. RESRAD is being used for human dose modelling and the ERICA tool for non-human biota. Results of the dose modelling will inform on options selection.

Sub-project 4 is focused on records and the trench inventory. A detailed compilation of information on the trench contents is essential to assessing the status of the site and informing on the best remediation strategy. Within this sub-project, the available records on disposals will be converted into a searchable electronic format to produce a reference inventory. Uncertainties around the inventory will be evaluated through uncertainty analysis.

The fifth sub-project is on radiochemistry. The objective is to develop a greater understanding of the distribution and mobility of radionuclides within the trenches.

The final sub-project is benchmarking against international, UK and Australian best-practices, with international perspectives helping to underpin decisions.

Legacy sites present a significant challenge and remediation options must be driven by science, whilst recognizing political and social drivers for decisions. Uncertainty cannot be an inhibitor to progress in addressing legacies. Uncertainties are inevitable and must be acknowledged and evaluated. The precautionary principle is therefore being applied to the LFLS, with conservative assumptions employed in the assessments that will underpin remediation option decisions. Confidence will also be built in the assessments through sensitivity analyses.

TABLE 4-1. DOSE ASSESSMENT SCENARIOS FOR THE LFLS REMEDIATION PROJECT.

Scenario	***Receptors***	***Timeframe (years)***
Institutional Control (as is)	Workers Trespassers Offsite Public Non-human biota	0, 100
Stabilization – Capped condition	Workers Trespassers Offsite Public Future onsite (adult, child) Non-human biota	0, 100, 200, 1000
Stabilization – in situ stabilization (e.g. grout) condition	Workers Trespassers Offsite Public Future onsite (adult, child) Non-human biota	0, 100, 200, 1000
Fence interception – (e.g. hydraulic controls/ passive barriers)	Workers Trespassers Offsite Public Future onsite (adult, child) Non-human biota	0, 100, 200, 1000
Exhume and remove	Workers Trespassers Offsite Public Future onsite (adult, child) Non-human biota	0 -10 (during removal), 100, 200, 1000

Legacy trenches exist in many countries, with shallow burial of wastes being a common practice in the 1950's and 1960's. There are a number of common problems with trench disposal legacy sites, including:

- lack of site-specific information (e.g. characteristics of buried wastes, flow paths and exposure pathways, and previous management interventions);
- unclear responsibility and ownership;
- limited availability of technical expertise;
- scientific uncertainty;

– societal issues; and,

– various constraints and limitations (e.g. financial, technical, legislative, etc.).

In addressing these sites, it should be recognized that no option will be perfect. Optimization will be required to achieve the best result in the prevailing and anticipated future circumstances.

4.2 An IAEA MODARIA II Working Group 1 Proposed Study to Better Define End States for NORM and Nuclear Legacy Waste Sites

Adrian Punt (RadEcol Consulting Ltd.) presented.

MODARIA II is an IAEA work program on Modelling and Data for Radiological Impact Assessments. The objective is to enhance the capabilities of Member States to simulate radionuclide transfer in the environment and, thereby, to assess exposure levels and ensure an appropriate level of protection. The intention is not say how things should be done, but rather to provide technical underpinning and knowledge sharing around different possible approaches. The program began in autumn 2016 and will run until autumn 2019. There are seven working groups.

Working Group 1 (WG1) is focused on ‘Assessment and Decision Making for Existing Exposure Scenarios of NORM and Legacy Waste Sites’.

End state planning is an iterative process with assumptions decreasing over time (Figure 4-3) requiring benefits and detriments to be balanced through multi-dimensional thinking. The process should be adaptive to allow evolution over time as knowledge and understanding builds and allow decisions to take account of stakeholder engagement. Models can be used to support decision making.

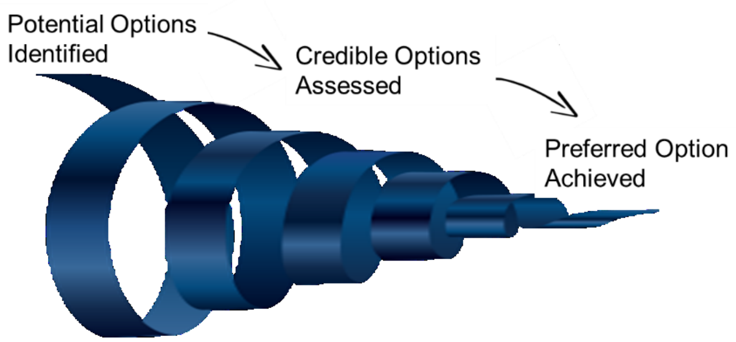


FIGURE 4-3. END STATE PLANNING.

The objective of WG1 is to further develop radionuclide transport models and radiological impact assessment approaches and develop methodologies and toolsets for conducting decision analyses that aid in decision-making. The work of the group is focused around various case studies. Two NORM case studies have so far been selected: the Tessenderlo phosphate processing facility in Belgium; and the Pridneprovsky uranium legacy site in Ukraine.

The Tessenderlo facility in Belgium processed sedimentary phosphate ore to produce dicalciumphosphate. Process effluents were discharged to two small rivers, the Laak and Winterbeek. Up to the early 1990s there was around 7 g per year of Ra-226 in effluents. This resulted in contamination of Winterbeek over 17 km with the banks of the river contaminated with Ra-226 activity concentrations ranging from 1 to 4 Bq/g. Gamma dose rates range from 40 to 1,200 nSv/h, compared with a background rate of less than 100 nSv/h. There are also high concentrations of non-radioactive contaminants such as cadmium. The level of non-radioactive contamination is such that remediation is necessary. Heavy metals and radioactivity are co-located and gamma spectrometry has therefore been used to determine where the contamination occurs.

Pridneprovsky is a Soviet-era uranium ore processing legacy site that operated from 1947 to 1991 with residues from uranium production stored directly in ravines in the immediate vicinity of the facility. Uranium milling wastes were disposed to the tailings impoundment as liquid discharges and also by dry filling. Drainage from uranium tails enters groundwater that then seeps into the Kononplyanka River. This is a small river that subsequently flows into the larger Dnieper River. Drainage waters contain uranium-series radionuclides as well as sulphate, nitrate and manganese.

The case studies are being used to document lessons learned. Numerical models are being applied to predict the transport of contaminants from each site and allow for the assessment of dose for both humans and biota as part of the end state decision making process. A range of exposure pathways are of interest, including the flooding of agricultural areas near to the rivers, and the dredging of river sediments and placing of removed sediment on the banks of the rivers. The use of river water for irrigation and abstraction for drinking water is also of interest, along with recreational use of the rivers and surrounding banks, including fishing. The focus is on uranium-series radionuclides.

The output from WG1 will include an overview of risk-informed decision analysis and the role this plays in end state planning, and considerations for radiological impact assessment and decision making. The test cases will illustrate the application of different models and decision-making approaches, supported by site descriptions, scenario descriptions and input data sets. The output will be published by the IAEA.

It is important to recognize that modelling and risk assessment have a role to play in decision making and end state planning, but these are only part of the process. Stakeholders should be engaged and local views on end use and end state and the criteria to be applied should be sought. It is also important to have a robust and independent regulatory process underpinning legacy management and to ensure the decision-making process is transparent. A holistic approach to environmental and human health protection should be achieved, avoiding short term measures that may create new legacies.

The next WG1 meeting is planned to take place in Ljubljana, Slovenia, in May 2018. The meeting will include a field trip to the Žirovskivrh uranium mine.

4.3 Scientific and practical achievements in the field of regulatory supervision during remediation of nuclear legacy sites in the Russian Far East

Sergey Kiselev (SRC FMBC) presented.

Technical bases of the Pacific Fleet were created in the Russian Far East in the 1960s at the Sysoeva and Krasheninnikova bays on the coast of the Pacific Ocean. They maintained nuclear submarines, performing receipt and storage of radioactive waste (RW) and spent nuclear fuel (SNF). The nuclear fleet was decommissioning in the 1980’s and 1990’s, but a lack of regulation resulted in poor storage conditions at these sites. In 2000 the bases were transferred to the ownership of the Ministry of Atomic Energy. Since 2011, the State Atomic Energy Corporation, Rosatom, has been responsible for the former bases.

There are three bases in the Far Eastern region of Russia (Figure 4-4).

FIGURE 4-4. LOCATION OF THE FORMER TECHNICAL BASES IN THE FAR EAST OF RUSSIA.

The Vilyuchinsk site has two shallow ground storage facilities for the temporary storage of high and medium level solid radioactive wastes. No spent nuclear fuel is stored at this site. The main remediation plans for this site are to remove radioactive wastes, demolish storage facilities, and clean up the site to the state of brownfield. The total activity accumulated at the site is approximately 6×10^{14} Bq. Radioecological situation at the Krasheninnikov Bay STS is determined by the presence of artificial radionuclides in the environment at the level of global fallouts values. The only exception is local areas, the remediation of which requires finding optimal solutions.

The Ustrichny Cape and Sysoev Bay sites are quite closely located and have been used for the long-term storage of nuclear submarine reactor compartments and radioactive waste management. The largest challenges are associated with Sysoev Bay where spent nuclear fuel and radioactive waste are managed and high activity liquid wastes are stored. The spent nuclear fuel was removed from this site two years ago, being transferred to Mayak for reprocessing. There remains one building at the site, however, that is in bad condition and where fuel elements are still present. The remediation strategy for the site is illustrated in FIGURE 4-5. The strategy will be undertaken in different stages. Initially, infrastructure such as roads will be constructed to support waste management activities. Spent nuclear fuel will then be managed with a dedicated management facility being constructed at the site. It is currently intended that a regional center for radioactive waste management will be established, that will include a reprocessing plant.

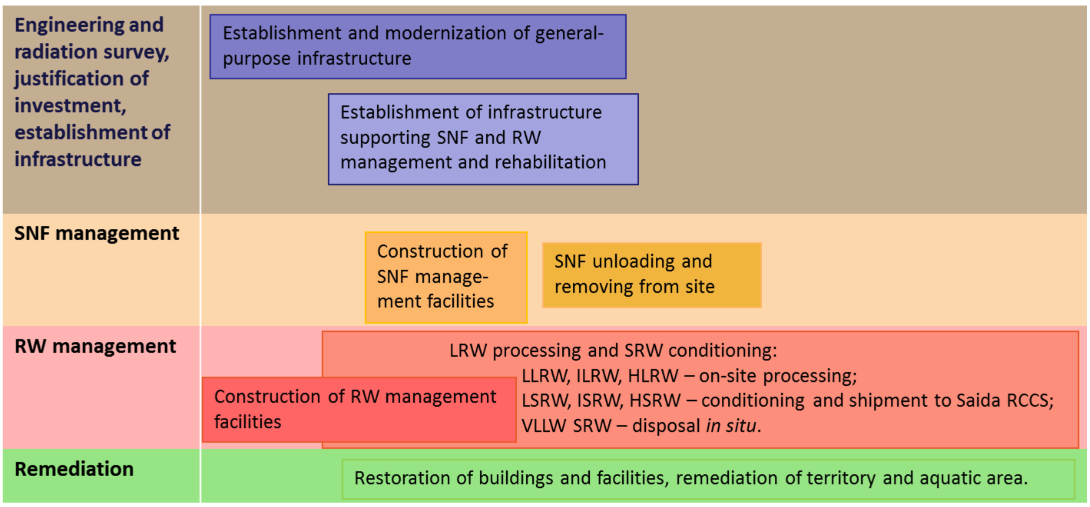


FIGURE 4-5. STRATEGY FOR THE REMEDIATION OF THE NUCLEAR LEGACY SITES.

As with other sites in Russia, characterization activities have been undertaken to develop an understanding of the environmental contamination present at the site and the site has been divided into three zones, the controlled access area (CAA), HPZ and supervised area (SA). Spent nuclear fuel and radioactive waste storage facilities are situated within the CA. Health protection zone (HPZ) – This is the area to which administrative and technical provisions of the STS relate. The SA is subject to monitoring to ensure the safety of the local population. The zones are illustrated in Figure 4-6.

Figure 4-6. The Sysoev Bay site and delineation into CAA (red), HPZ (yellow) and SA (green) zones.

The main challenges at the site arise from the discover ten years ago that RW storage facilities were in poor condition and radioactivity had leaked into the soil, resulting in soil and groundwater contamination. There was also some contamination in the coastal area. Contaminated soils have been found at three locations within the HPZ with concentrations of Cs-137 up to 14 kBq/kg and Sr-90 up to 60 kBq/kg being recorded. Groundwater contamination from radioactivity and chemicals has also been monitored (Figure 4-7). Due to the mobility of Sr-90, it has been found to penetrate to greater depths and enter groundwater whereas Cs-137 is concentrated between 1 and 2 m depth and is found in groundwater at the site in small quantities, not exceeding interventional levels. In general, the ecological situation at the Sysoev Bay STS is characterised by combined environmental impact caused by both radioactive and non-radioactive contaminants.

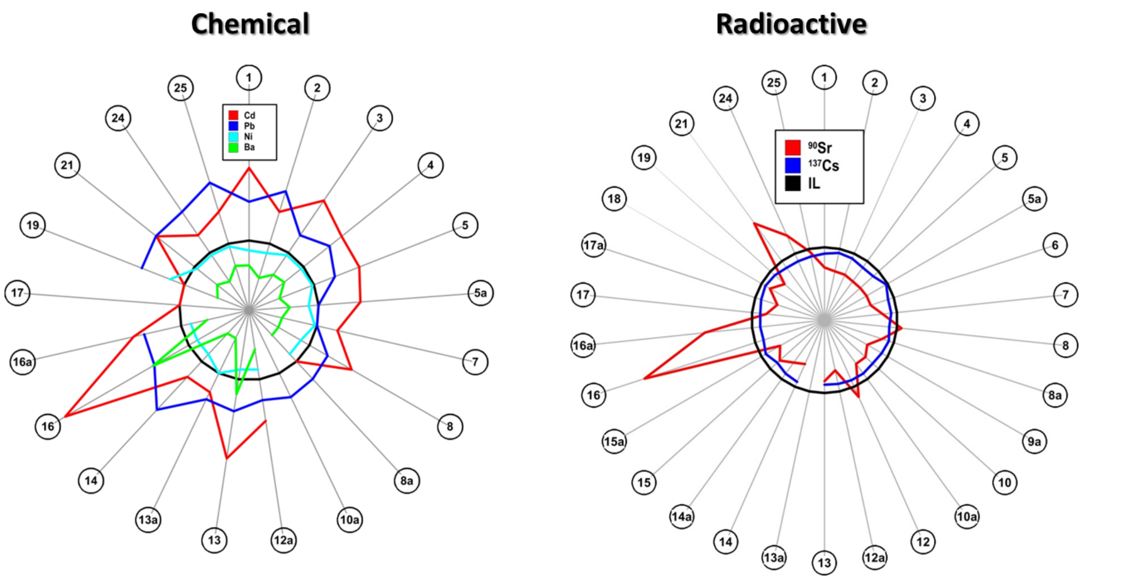


FIGURE 4-7. CHEMICAL AND RADIOACTIVE GROUNDWATER CONTAMINATION AT THE SERIES OF WELLS AROUND SYSOEV BAY AND CORRESPONDING NORMS FOR DRINKING WATER (BLACK CIRCLE).

Analyses have shown that both radionuclides and metals are present in groundwater at the site (Figure 4-6) and holistic solutions are required that will address both radioactive and chemical contamination issues. At the use of analytical techniques solely, nobody can be sure that all compounds of concern are determined. Also, consequences of simultaneous impact could hardly be forecast both for human or non-human species because of possibility for synergistic or antagonistic interactions. In contrast to the specific nature of the assessment based on exposure, studies of biological effects integrate the impacts of all harmful agents as well as their interactions. So, in addition to radiation and chemical monitoring, biological monitoring has also been used. Cytotoxicity, genotoxicity and bio-indicators have all been applied to groundwater samples with significant impacts being observed. Chromatid aberrations recognized as damage of moderate severity were prevailing type in aberration spectrum in most samples. However, in a number of samples, there were found an appreciable fraction of genomic disturbances such as laggings and conglutinations. These types of disorders are caused by damage of a spindle and are typical of chemical toxicants. Frequency of chromosome (double) aberrations, which are commonly regarded as radiation markers, is similar to the control in all cases. In total, these data prove the leading role of chemical pollutants in the observed genotoxic effect.

Exposure doses to the local population have also been evaluated. The exposure dose from artificial radioactivity is around 0.3 mSv/y, almost 15 times lower than that from natural sources (primarily radon inhalation).

The former military technical base in Sysoeva bay is therefore a key industrial site for spent nuclear fuel and radioactive waste management in the Russian Far East for which there are a number of ongoing radioactive waste management activities. There also remains a number of challenges at the site resulting from the extensive spread of contamination across the site and disposal of large volumes of industrial wastes located at the site. A key obstacle to cleaning up the site is that there is currently no disposal solution for this category of wastes. The spent nuclear fuel storage facility on the site also presents a danger to the environment and a solution for its remediation is awaited. A full scale, comprehensive monitoring methodology for both chemical and radiation pollution is needed to support effective regulatory supervision at this site based on appropriate estimation of radiological and non-radiological risks.

4.4 Safety assessment for recycling of soil generated from decontamination activities

Seiji Takeda (Japan Atomic Energy Agency) presented.

The Nuclear Safety Research Center of Japan Atomic Energy Agency (JAEA) has provided support to the Japanese Government in developing new guideline criteria for decontamination activities. One particular area of support has been in undertaking a safety assessment for the recycling of soil generated from decontamination activities.

The Fukushima Daiichi NPS accident resulted in the release of radionuclides to the environment, that were deposited onto the land up to a distance of 250 km from the NPS by both wet and dry deposition processes. The resulting contamination is illustrated in

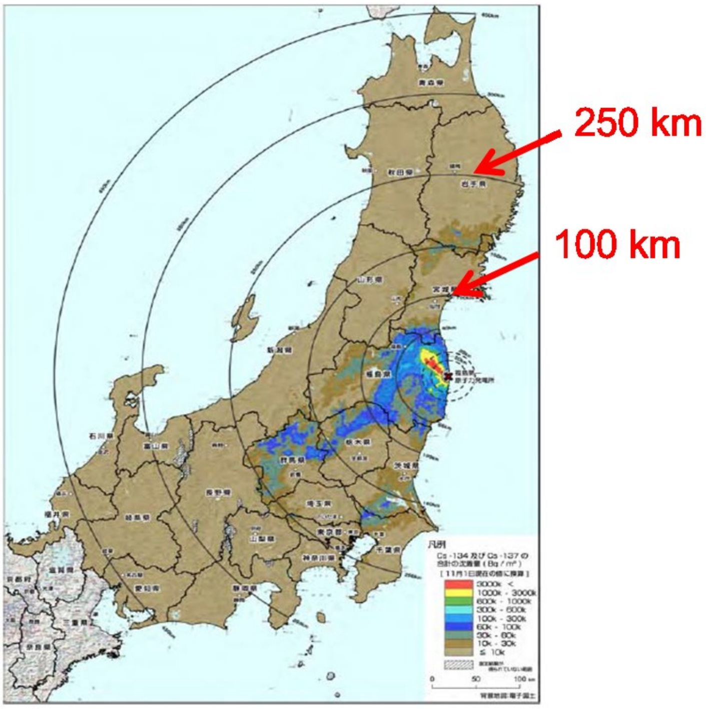


Figure 4-8.

Figure 4-8. Deposition of Cs-134 and Cs-137 following the Fukushima Daiichi NPS accident.

Decontamination is one of the measures for radiation protection to remove radioactive materials from habitation areas in order to promptly decrease the impacts on human health and the environment. The long-term goal set by the Government was to reduce additional annual dose to 1 mSv or less by comprehensive radiation risk management measures, including not only decontamination, but also monitoring surveys, food safety administration, and risk communication.

Decontamination measures have been implemented extensively, resulting in the generation of large volume of decontamination waste that has been placed in temporary storage. Within the Fukushima Prefecture, it is estimated that around 22 million m^3 of decontamination waste has been generated, 90% of which is decontamination soils. The remainder is largely incineration ash. As noted in Section 3.6, it is intended that these wastes will be placed in interim storage facilities for a period of 30 years prior to final disposal and volume reduction is required. Consideration is therefore being given as to whether an effective option could be to recycle contaminated soil as construction material and a safety assessment has been undertaken, based on a policy of separating soils according to whether they have low or high radioactive contamination with the lower contamination soils being recycled. The recycling would be limited to civil engineering structures such as coastal levees, road embankments and coastal disaster prevention forests (Figure 4-9). The concept of this recycling is different from that of unconditional clearance and criteria for recycling to specific objects need to be established. The safety assessment aimed to enable caesium activity concentrations for recycling and construction design to be determined.

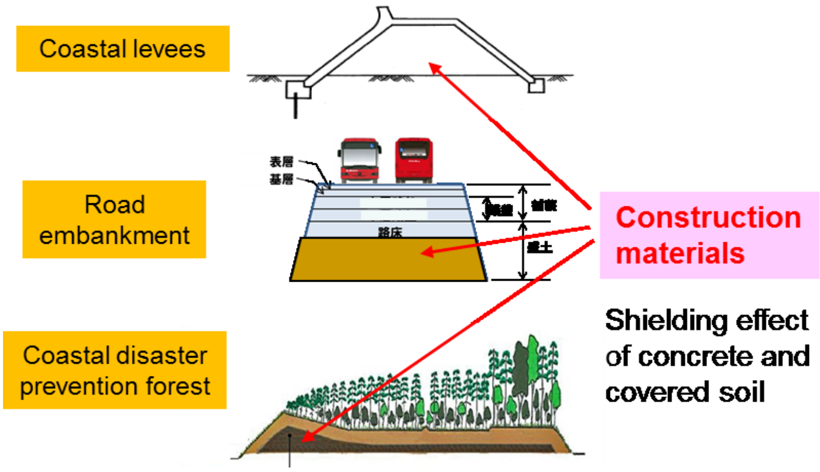


FIGURE 4-9. EXAMPLES OF CIVIL ENGINEERING STRUCTURES FOR RECYCLING DECONTAMINATION SOIL.

A step-wise safety assessment method was developed around the criteria that additional annual doses for workers and the public from recycling processes should not exceed 1 mSv and, following construction activities, additional annual doses to the public should be trivial, with construction conditions being reviewed if doses exceeded 10 µSv. Dose estimation was also required in relation to disaster scenarios, with annual exposure doses caused by collapse and restoration following disasters not exceeding 1 mSv.

These criteria have been used as the basis for deriving decontamination soil activity concentrations and building conditions for each recycling scenario.

The scenarios were developed considering typical rather than specific construction. Disaster scenarios were based on past disaster cases in Japan. Typical and generic parameter values were used, based on Japanese statistical data and construction standards. For those parameters with wide variability and high uncertainty, values were selected to be conservative.

For coastal levees, effective annual dose was calculated for a range of exposure scenarios for both construction and service phases. The maximum dose equating to the use of recycled materials of 1 Bq/g was calculated as 0.15 mSv for embankment construction workers. When placed in the context of the safety criteria (1 mSv), the maximum total caesium activity that could be used would therefore be 6,800 Bq/kg (Figure 4-10).

The public doses associated with a service scenario, based on a recycling activity concentration limit of 6,800 Bq/kg was also considered, based on typical types of coastal levees. Different heights were considered and doses estimated for four cases. For each case, additional doses were below 10 µSv.

A disaster scenario was developed, based on the recent tsunami with four disaster case categories being identified:

– Levee breach, whereby coastal levees are partially washed away;
– Collapse of slope surface;
– Collapse of parapet; and,
– Subsidence

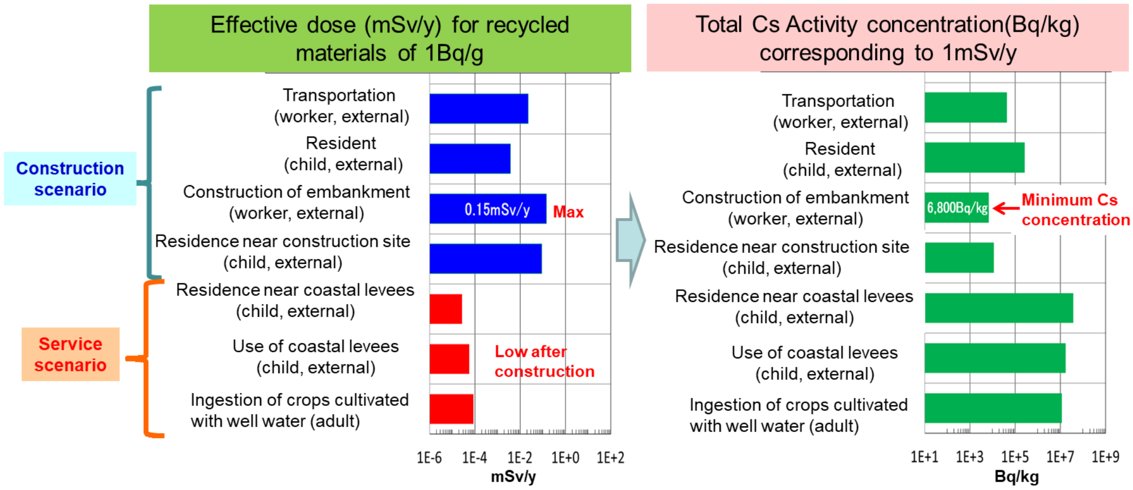


FIGURE 4-10. EXAMPLE OF DOSE ESTIMATION AND CALCULATION OF PERMISSIBLE ACTIVITY CONCENTRATIONS IN DECONTAMINATION SOILS FOR A COASTAL LEVEE SCENARIO.

The latter two cases were not considered further since they would not lead to the emergence of decontaminated soils or outflow of recycled materials. Exposure scenarios for the levee breach case included levee reconstruction workers, deposit recovery workers and members of the public ingesting fishery products. For the slope surface collapse case, the exposure of reconstruction workers was evaluated. Annual doses for each case were below 1 mSv.

In conclusion, the recycling of decontamination soil in civil engineering structures such as coastal levees is feasible and could be an important means by which volume reduction is achieved in decontamination wastes requiring final disposal. Dose assessment work is continuing on the recycling of decontamination soils within other civil engineering structures. A verification project is also ongoing to verify dose estimates through a demonstration test of the recycling of decontamination soil. Management systems and guidelines for recycling are also being developed.

This work was supported by the Ministry of the Environment of Japan.

4.5 Issues affecting the assessment of impacts of disposal of radioactive and hazardous wastes

James Wilson (Quintessa Ltd.) presented.

The work presented was undertaken within a BIOPROTA project in 2017. BIOPROTA is an international forum that aims to resolve key issues in biosphere assessments for radioactive waste disposal. The project was therefore driven by radioactive waste disposal assessment needs, but there are many parallels for legacy sites.

The project was supported both technically and financially by a wide range of organizations from Norway, Finland, Japan, Canada, Spain, Sweden and the UK. A project report has been completed and is to be made available at www.bioprota.org and issued as an NRPA report (NRPA, 2018 in prep.).

A large body of scientific and regulatory guidance materials were reviewed in the project. Key findings from the project are summarized below.

- It is clear that for many waste management organizations, non-radioactive substances present in radioactive wastes can pose a significant challenge, but good inventory data are often lacking for these substances.
- The release and transport of radionuclides and chemical contaminants should be modelled taking account of the same features, events and processes (as far as is possible).
- It is appropriate to assess exposures of humans to ionising radiations in terms of effective dose, and to assess exposures to chemical pollutants in terms of intake rates by ingestion or air concentrations. However, it is important to recognise that these are intermediate measures of impact and they both need to be related to potential health effects in order to achieve a balanced decision.
- There are a wide range of adverse health effects associated with different chemotoxic substances that occur via a range of mechanisms. Therefore, simple index quantities (such as weighted total exposures) cannot be recommended for application across wide ranges of chemicals or between chemicals and ionising radiations. However, there are contexts in which index quantities can be useful, notably for chemicals such as dioxins and dioxin-like compounds, where Toxic Equivalency Factors (TEFs) may be applied.
- It is difficult to assess the effects arising as a result of exposure to a variety of toxic agents, such as synergistic effects, although some qualitative work has been done on this topic by Radioactive Waste Management Ltd in the UK.
- Whilst standards for protection are available for ionizing radiations and chemical pollutants that are generally based on precautionary approaches, they are not applied consistently, which makes comparison of the effects of different stressors or the overall impact of multiple stressors difficult.

A number of potential 'priority' chemicals have been identified that could be the focus of future work, as detailed in under Table 4-2. For substances such as chromium, it is necessary to consider the form since some forms are more toxic than others (Cr (VI), for example, is of particular concern due to its carcinogenicity). Uranium compounds are both chemotoxic and radiotoxic.

TABLE 4-2. POTENTIAL 'PRIORITY' CHEMICALS.

Substance	Key Toxicological Properties (chronic effects)
Arsenic (As)	Dermal effects, vascular effects ('black foot' disease) and carcinogenic properties are generally of concern for environmental exposures.
Beryllium (Be)	Inhalation associated with chronic beryllium disease, lung cancer.
Cadmium (Cd)	Nephrotoxin, may cause bone disease
Chromium (Cr)	Hexavalent chromium (Cr{VI}) is of greater concern than trivalent Cr(III). Importance of inhalation pathway
Mercury (Hg)	Neurotoxin, nephrotoxin, developmental effects
Lead (Pb)	Neurotoxin; exposure may also lead to cardiovascular effects; also 'probably carcinogenic'
Uranium (U)	Nephrotoxin and radioactive
Polycyclic Aromatic Hydrocarbons (PAH)	Group of carcinogenic compounds, Benzo(a)pyrene has been studied extensively. Carcinogen, mutagen and reproductive toxin
Asbestos	Mesothelioma (+lung cancer)

Key aspects that need to be considered in risk assessments were reviewed. For chemicals, the main exposure pathways are oral ingestion or inhalation. Dermal exposure may also be important, but this can be harder to assess quantitatively. For radiological assessments, these same pathways are important, but external irradiation is also considered.

The bioavailability and bio-accessibility of chemicals are important considerations governing uptake, but risk assessments tend to rely on total intakes, although it is becoming more commonplace to undertake biokinetic modelling.

A key difference between chemicals and radiation is that chemotoxic substances may have dose-response curves that exhibit thresholds at environmental exposure levels. In contrast, for radionuclides it is non-threshold effects that are of primary interest in assessing and mitigating environmental exposures. For threshold effects, a level of exposure can be determined, above which there may be the potential for adverse physiological effects. This allows tolerable daily intake (TDI) values to be determined for chemotoxic substances, often on the basis of no observable adverse effect level (NOAEL) or lowest observable adverse effect level (LOEL) data. Such data are often only available from animal studies and therefore require the application of uncertainty factors to account for inter-species variation. Uncertainty factors are also applied to account for intra-species variation and deficiencies in source data. Uncertainty factors may also need to be applied to data from human populations, but the overall uncertainty in setting a TDI may be lower than that associated with using data from animal studies. It should be noted that intakes of a chemical above its TDI do not necessarily guarantee that appreciable health effects will be observed within a human population.

Non-threshold effects are largely determined through cancer risk models based on animal data and uncertainties can be significant due to high to low dose extrapolation and interspecies variation. Typical intakes used for setting standards and guidelines have an associated excess lifetime cancer risk of $\sim10^{-4}$ to $\sim10^{-6}$. For substances with non-threshold effects (for a given exposure pathway), the objective is to minimize exposures, and the principle of ALARP applies (i.e. efforts should be made to ensure exposures are "as low as reasonably practicable"). In recent years, there has been a move towards using benchmark dose modelling for setting limits on intakes of chemotoxic substances.

There have been a number of recent case studies on assessing risks posed by chemotoxic substances associated with radioactive materials. An example is the illustrative assessment of human health risks arising from the potential release of chemotoxic substances from a generic geological disposal facility for radioactive waste reported by Wilson et al (2011).

The key conclusions from the BIOPROTA project are that there is a continuing need to move towards some common measure of hazard that supports identification of risk management priorities for mixed hazardous waste and, while the overall picture, including the different regulatory contexts, remains complex, the non-radiologically hazardous components of many radioactive wastes appear to relate to relatively few elements and materials that are already reasonably well understood (such as U, Pb, Cd, and asbestos). Progress would, therefore, be most effective if it focusses on a limited set of hazardous components, especially for the relatively large volumes of LLW and very LLW arising in the decommissioning of nuclear facilities and remediation of legacy sites.

4.6 How to handle multiple stressors in legacy sites?

Lindis Skipperud (CERAD/NMBU) presented.

There can be a wide range of potential stressors in an environment, including the presence of radionuclides, organics, heavy metals, deficient oxygen status or climate change factors such as temperature change or flooding. In a biological system, stressors can result in the presence of free radicals that can damage cellular DNA or oxidize cell membranes. The consequences of this can be that cells die, they are repaired, or they are wrongly repaired. Two case studies were presented to illustrate how multiple stressors can be handled for legacy sites.

The first case study focused on pit lakes associated with former uranium ore mining and processing in the former Soviet Republics in Central Asia. Two pit lakes associated with these activities were studied,

Kurday pit lake in Kazakhstan and Taboshar pit lake in Tajikistan. The objectives were to assess radioactive and trace metal contamination associated with uranium mining and tailing and possible mobility and bioavailability.

The Kurday pit lake formed from an open pit that was used for uranium ore extraction and later abandoned. There are three fish populations within the lake. The nearest settlement is situated some 600 m to the north of the former mine.

In Tobashar, uranium rich ores were extracted and a pit lake has been created in the area. The upper 10 m of the lake is oxic while the deeper layers are anoxic. The only outlet from the lake is a small creek that helps maintain an almost constant water level. Both wild and domestic animals use the water for drinking purposes.

Water samples, sediments, aquatic plants and fish were sampled from each of the pit lakes and streams and other water bodies nearby. Fish were dissected to allow uptake into different organs to be determined.

Radionuclide activity concentrations and metal concentrations were measured in water samples and compared against drinking water samples. Values were elevated in a number of samples. Analysis of radionuclide and metal speciation in the water samples was also evaluated and results indicated that most uranium was present in low molecular mass fractions and was therefore potentially very bioavailable. Similar results were obtained for several metals.

A dose assessment was undertaken using the ERICA assessment tool, based on maximum radionuclide concentrations in sediments. Dose rates for a number of reference organisms were above the 10 µGy/h screening values, with the highest doses being observed for vascular plants.

The second case study considered alum shale material resulting from road and tunnel construction in Norway. Alum shale is a sedimentary material that contains a lot of radionuclides and metals and can readily exceed the basic safety standard limit of 1 Bq/g for uranium. A lot of Alum Shale is present in Norway and the rest of Scandinavia. With the construction of roads and tunnels in Norway, there is the potential for large amounts of radioactive waste to be produced and for the surrounding environment to be contaminated as a result of leachate reaching the aquatic environment and a risk assessment. The contamination of the environment surrounding construction works and potential impacts on the aquatic environment therefore required consideration.

During construction of a new tunnel, Alum Shales were placed in a bog with the intention that they would be later used in road construction. Control measures, in the form of particle traps within a cleaning facility, were put in place to prevent the migration of contaminants to nearby aquatic environments. These traps were efficient at removing particles and colloids, but some contaminants, such as uranium and molybdenum were of low molecular mass and were not retained within the traps.

Measured activity concentrations of U-238, Th-232 and Po-210 in water, sediments and organisms were used to estimate the radiotoxic effects in the aquatic environment, again using the ERICA assessment tool to calculate expected dose rates for a range of organism types. Dose rates for several organisms were above the 10 µGy/h screening value.

A cumulative risk model was applied, that considered risks from both radioactivity and heavy metals. The model allowed the risk of toxicity to be identified for a range of water sample stations with nearly all stations having a sum of toxic units in excess of 1, indicating a risk of toxic impacts when total concentrations were considered. One station was calculated to have a sum of toxic units in excess of 10, indicating a high risk of toxic impacts. If data for low molecular mass contaminants were considered rather than total concentrations, different results were observed. The same hotspot was still evident, but most sites had summed toxic units below 1. This case illustrates the importance of considering the appropriate parameters used to inform models. Where total concentrations are used as the basis for toxic risk evaluation, large overpredictions of risk can result.

In addition to the modelling studies, the benthic community was studied both before and during construction works. Results indicated that the benthic community was affected.

Both case studies considered sites with elevated concentrations of radionuclides and chemicals. In the pit lake studies, uptake of both radionuclides and chemicals was observed in the gills, kidney and liver of fish. In the Norway case, effects on the benthic community were observed. In both cases, multiple stressors are in play with both the ERICA and cumulative risk assessment models predicting co-located radiotoxic and chemotoxic effects in the Norwegian case study. These results illustrate the need for a holistic approach to studying areas that could be affected by the presence of multiple stressors, including legacy sites.

4.7 Radiation Protection of the Population during Remediation of the Uranium Legacy Sites in the Russian Federation and in the Central Asia Countries

Alexey Titov (FMBC) presented.

In the late 1940's, uranium mines in Russia began operations. Many of the mines were situated in Central Asia and Ukraine (Figure 4-11). In the 1980's, many of the mines were closed and decommissioning processes began. With the dissolution of the USSR in the early 1990's, these decommissioning programs ceased. These former Soviet Republics were left with large areas of land that were contaminated as a result of former uranium production.

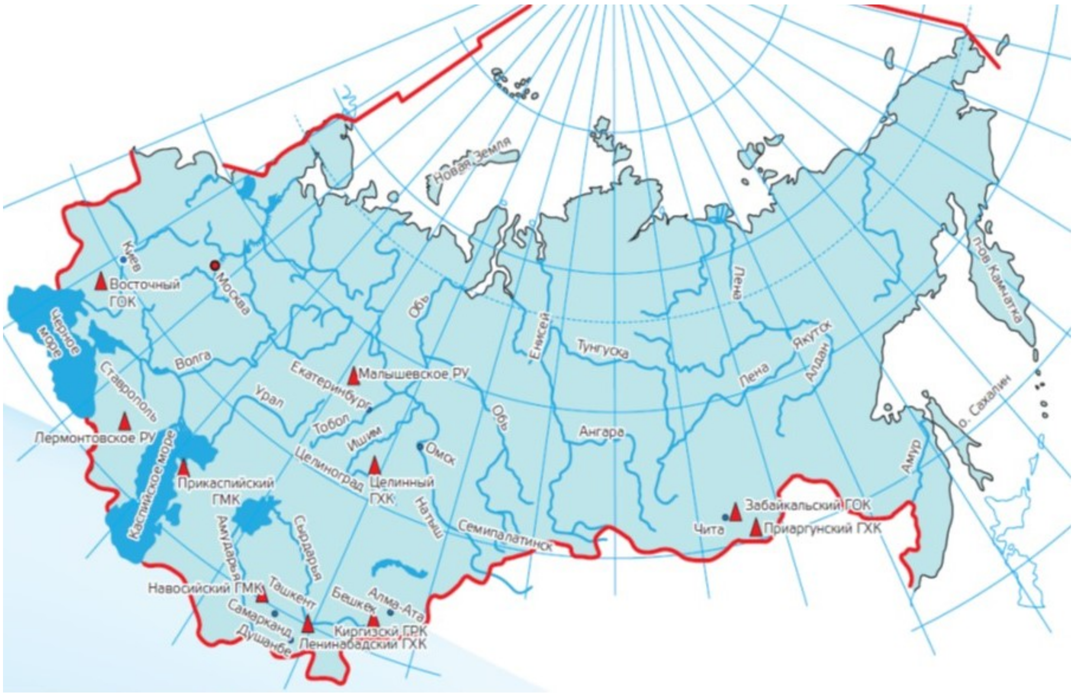


FIGURE 4-11. URANIUM MINING AND MILLING ENTERPRISES IN THE USSR.

Remediation is a long-term process that is time consuming and requires up-to-date regulations. The radiation contamination of the environment and human health must be assessed. Such assessments were previously done by the Ministry of Health, but the FMBA has now been tasked to undertake such activities. Current tasks that are being carried out include:

- scientific research at uranium legacy facilities and sites to assess radioactive contamination of the environment and associated public health effects;
- development of documents on radiation safety at different stages of uranium legacy remediation in accordance with ICRP recommendations and IAEA requirements;
- expert review of documents prepared by the operator; and,
- supervision of radiation protection of workers, the population and environment.

These tasks are being carried out within the framework of Federal Target Programs and international cooperation, including:

- the IAEA RSLS forum;
- the NRPA project 'regulatory support of radiation safety and management of radioactive waste in the Central Asia'; and,

– the Central Asia countries within the Interstate target program ‘reclamation of areas of the EurAsEC member states affected by uranium mining activities’.

There have been two main areas of research – radiation surveys and social and health physics monitoring.

Radiation surveys at sites of operational and decommissioned uranium production enterprises have been conducted, the objective of which was to evaluate the radiation situation at contaminated sites and derive parameters to support the development of regulatory documents on radiation safety and monitoring at various stages of remediation. Radionuclides in soils, sediments and water have been analyzed and the radionuclide content of industrial products monitored. Both radiochemistry analyses and gamma dose rate measurements have been made at sites and in workshops and dwellings. Radon has been measured in workshops and houses using track detectors. Together, the data obtained have allowed exposures to be calculated for workers and local populations. The assessments took account of regional food consumption habits.

Research has been conducted in the vicinity of the Priargun Mining and Chemical Production Association (PMCPA). This has included a radiation survey being undertaken within the HPZ, and in aboveground workplace buildings. High gamma dose rates were recorded in some areas of the HPZ (Figure 4-12). The higher dose rates correspond to tailings and areas with higher radionuclide contamination.

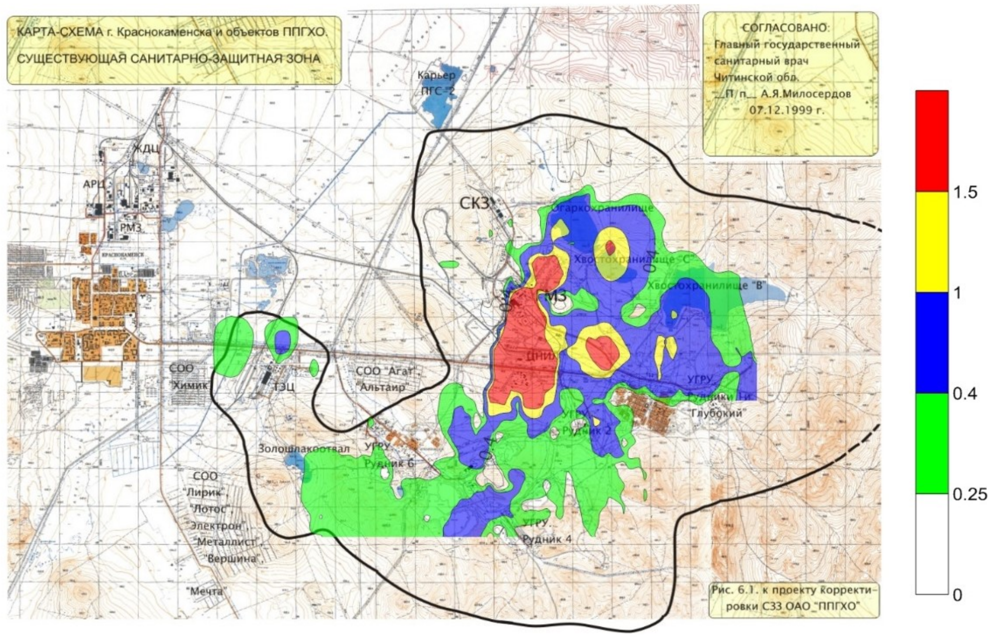


FIGURE 4-12. GAMMA DOSE RATE (μSV/H) WITHIN THE HPZ OF PMCPA.

Radiation surveys have also been done in the nearby settlements of Octyabrsky village and Krasnokamensk town, where most of the workers for the site reside. Radon induced doses were evaluated for the population of Octyabrsky village, the results of which (Table 4-3) prompted the population to move and the village is now abandoned.

TABLE 4-3. ANNUAL DOSE FROM RADON AND ITS PROGENIES IN RESIDENTS OF OCTYABRSKY VILLAGE.

Population group	Annual dose, mSv	Potential variation range, mSv/y
Retired and working mainly in buildings	14	1.3 - 85
The population working outside the village	8.4	0.82 - 52
Children	9.2	0.85 - 57

Research to assess the radiation situation of sites of former facilities on the Almaz site in southern Russia, that undertook uranium mining activities in the 1970's and 1980's, has also been undertaken. Operations at the site have ceased and remediation is underway, but not yet finalized. Two plants operate on the site:

- *Hydrometallurgical Plant*, the main activity of which is the production of phosphorus fertilizers and other products of inorganic chemistry (Phosphogypsum, formed during the activities of the plant, is used as a protective layer during the remediation of tailings).
- *Electric Mechanical Plant*, which produces water treatment equipment, submersible pumps used in various areas of the national economy (there are reclaimed rock dumps and two galleries on the site of this plant).

The hydrometallurgical plant was subject to some remediation work in the 1990's. The survey indicated that gamma dose rates at the plant were within worker dose limits. Workers are, however, exposed to radon, with the plant being located close to the former mine. Radon activity concentrations are quite high, ranging from 11 to 84 Bq/m^3. The activity concentrations were found to vary significantly over a 24-hour period.

Components of social and health physics monitoring in settlements of Central Asian countries that are located in areas affected by uranium mines of the former USSR have also been worked out to support the development of regulatory documents on such monitoring in areas surrounding uranium legacy sites. This has been undertaken within the cooperation program with the EurAsEC program. Dose measurements were made at different legacy sites in Kyrgyzstan and Tajikistan. Radon was primarily responsible for higher doses observed in Tajikistan.

Regulatory documents in Russia needed to be updated and two documents have so far been developed. One document is focused on radiation monitoring. The other is focused on safety during remediation. A lot of assistance has been received through the cooperation programs, particularly that with Norway. The cooperation will continue with further regulatory documents being planned for development.

The experience in the regulation of public and environmental protection is reflected in a new IAEA Technical Document, which includes the results of the first five years (2011-2016) of operation of the IAEA International Forum on Regulatory Supervision of Legacy Sites.

4.8 Matter, life and mind: some very personal opinions on the Asse mine

Rainer Gellerman (NCC GmbH) presented.

In 2016, the German Commission on Radiological Protection (SSK) adopted recommendations concerning radiation protection during the decommissioning of the Asse II mine. First of these recommendations provides that the three principles of radiation protection (justification, optimization, and limitation of radiation exposures) can be respected and that these principles are adequately respected. Some aspects that are necessary for understanding the assessments of SSK are described in the following.

Salt mining took place at the Asse mine between 1909 and 1964. From 1965, radioactive waste disposal occurred with operations continuing until 1978. During this time, 125,000 drums of LLW were disposed of at a depth of 750 m below surface and 1,300 drums of ILW were disposed of at a depth of 511 m below surface. The disposals were “for research”. Different disposal technologies were applied, including upright and horizontal piled up disposal. The waste inventory was only roughly documented. Since 1988, several m^3 of water per day has flowed into the mine and the state of the mine is now regarded as ‘decrepit’.

The Asse mine was selected for research around radioactive waste disposal due to its immediate availability rather than any advantageous properties in terms of safety. The legal status of the mine was that of a mine and was, therefore, regulated according to Mining Law, but the research was done in an irreversible way so it was effectively disposal of radioactive waste. Some 20 years following the first emplacement of waste, attempts were made to try and prove the long-term safety of the mine. The instability of the rock was, however, a big issue and decommissioning of the mine was declared necessary latest in 2016.

From the early times of radioactive waste disposal in Asse II this has been criticized by local citizens and the media have helped to propagate the fear of radiation among the public. In 2008, citizen movements compelled regulatory action and the Atomic Energy Act was amended such that the Nuclear Law now applied to the Asse II mine. It was set down that all costs of future decommissioning would have to be funded by the state (i.e. taxpayers) and the Federal Office for Radiation Protection (BfS) was charged with the operation of the mine beginning in January 2009.

Due to this political decision, the status of the mine was suddenly not according to the legal requirements defined by the Nuclear Law. In order to find out how the decommissioning of the mine has to be done feasibility studies were commissioned by BfS with three options being considered:

- Complete backfilling of the mine;
- Internal relocation; or
- Retrieval of waste.

The conclusion of the authors of the study regarding backfilling was that the mine would be long-term safe if proper backfilling were carried out. But the safety assessment that this decision was based upon was rather uncertain and the understanding of the behavior of the system was not robust. Nonetheless, the study stated that if the safety assessment was improved, backfilling remained an option that could be recommended for further consideration.

Summarizing the results of the three feasibility studies the final judgement of BfS was, that based on the present state of knowledge, the best option would be to retrieve the waste from the mine due to the impossibility of proving long-term safety. But because no final repository for the retrieved waste was available the option was explained with a fictional disposal site that will meet the requirements. When BfS issued its final recommendations in January 2010 it declared that further investigations of the facts were needed and, in parallel, technical measures to stabilize the mine rock were to be continued with works progressing over the next 7 to 8 years. However, in February 2013, the Atomic Energy Act was amended again to require the decommissioning of the Asse II mine after retrieval of waste. This law sets – for avoiding doses of future generations in the order of 0.3 mSv per year- a very strong legal obligation for waste retrieval and opens the possibility that authorities will increase the accidental planning dose criteria to a higher level than the current 50 mSv due to accidental risks identified in the feasibility studies of about 100 mSv. Moreover, in the parliamentary debate of this law the fundamental radiation protection principles, in particular justification and optimisation have explicitly declared to be not to apply for cancellation of the retrieval process.

The whole process that emphasises the protection of people against very low doses as its primary goal but pass in silent much higher risks in case of accident and has no sound solution for a long-term safe disposal of the retrieved waste can therefore be considered as an example of 'security theatre', a term created following the events of 9/11 (Figure 4-13).

> Security theater is the practice of investing in countermeasures intended to provide the feeling of improved security while doing little or nothing to achieve it.
>
> Security theater has real monetary costs but by definition provides no security benefits, or the benefits are so minimal as to not be worth the cost.
>
> Security theater encourages people to make uninformed, counterproductive political decisions. The feeling of (and wished for) safety can increase the real risk.
>
> The disruption, cost, and fear caused by security theater acts as positive feedback for those who wish to exploit it: even if they fail to take lives, they can cause large economic costs.

Figure 4-13. Wikipedia definition of 'Security Theatre', https://en.wikipedia.org/wiki/Security_theater.

Personal views expressed were that the emplacement of large amounts of radioactive waste in the Asse mine was never a research project and consequently was never justified. Rather, the mine was intended for the development and demonstration of safe radioactive waste disposal in salt rock, in particular in Gorleben salt dome. With the political declaration that the Gorleben salt dome is unsuitable for a final repository due to the unsafe geology, the "decrepit" Asse mine could not be declared safe for radioactive waste to be left in place. The real reason for retrieval of waste is therefore considered to stem from the parties declaring the mine unsafe need to ensure they are not proved wrong; if waste remained in the mine and no contamination of groundwater or exposure of future generations occurred.

From a scientific point of view, it has to ask for the rationale that resulted in such a contradictory situation. This leads to another important aspect, the power of emotions related to radioactive waste in a political framework. Due to the complexity of problems that are considered on the scientific level of radioactive waste disposal political and societal views tend to be more influenced by emotional rather than rational views and the problem of safe disposal of radioactive waste is superimposed by other themes of highr priority (Figure 4-14).

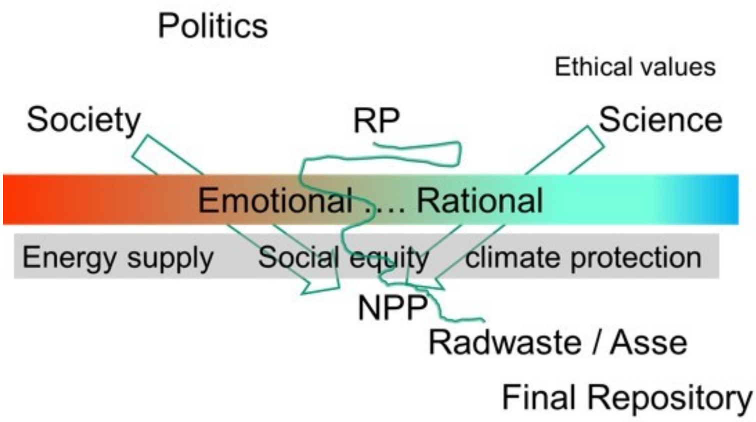


FIGURE 4-14. VIEWS AROUND THE DIFFERENT PERSPECTIVES INVOLVED WHEN CONSIDERING RADIOACTIVE WASTE.

However, the radioactive waste cannot be made to disappear and the case of Asse mine demonstrates that decisions must be made on where and how retrieved wastes will be disposed of. In order to avaoid any short-term need for decision the political wisdom is therefore that stakeholders have to be involved for reaching the best solution.

In summary it was concluded that the Asse II mine was and remains an interesting example of the views of society toward radioactive waste. It demonstrates the power of emotions and the limits of radiation protection. It is an outstanding example of 'security theatre' with respect to radioactive waste and demonstrates the meaninglessness of radiation protection principles in politics. Nevertheless, radiation protection experts should accept their role with modesty but trust in the power of scientific truths.

4.9 The importance of ichthyofauna of radioactively-contaminated reservoirs from the point of view of radiation safety provision

Evgeny Pryakhin (URCRM) presented.

A joint study has been undertaken by Urals Research Center for Radiation Medicine (URCRM) and Norwegian colleagues on the ichthyofauna of contaminated reservoirs on the Techa River and uncontaminated reservoirs of the Miass River (Figure 4-15). The effects of chronic contamination on non-human biota were evaluated in fish. The fish are also part of the human food chain so accumulation of radionuclides within fish was also of interest.

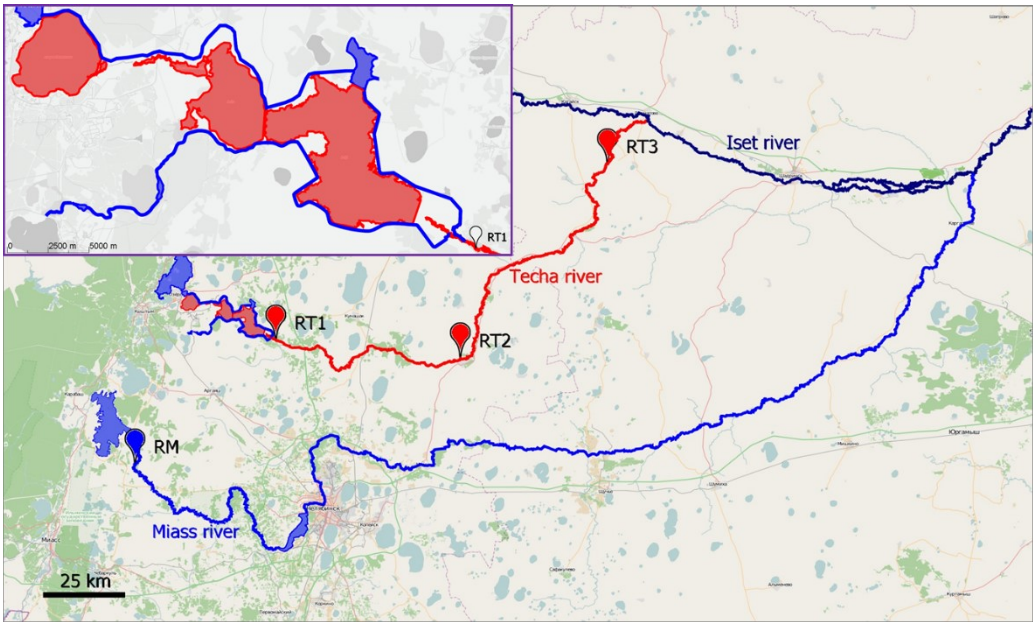


FIGURE 4-15. LOCATION OF SAMPLING STATIONS ON THE TECHA AND MIASS RIVERS.

Concentrations of radionuclides such as Sr-90 in fish tissues were compared against those from previous studies carried out in the 1960's. The results of the recent study for Sr-90 were similar to those from the past study, but differences were noted for Cs-137, with higher activity concentrations being measured in fish sampled in 2015 as compared with 1969.

Differences have been observed in the concentration of both Sr-90 and Cs-137 in spring and autumn. The differences are more or less notable depending on the sampling station (Figure 4-16). It is thought that the differences observed relate to differences in dissolution of radionuclides in spring and summer.

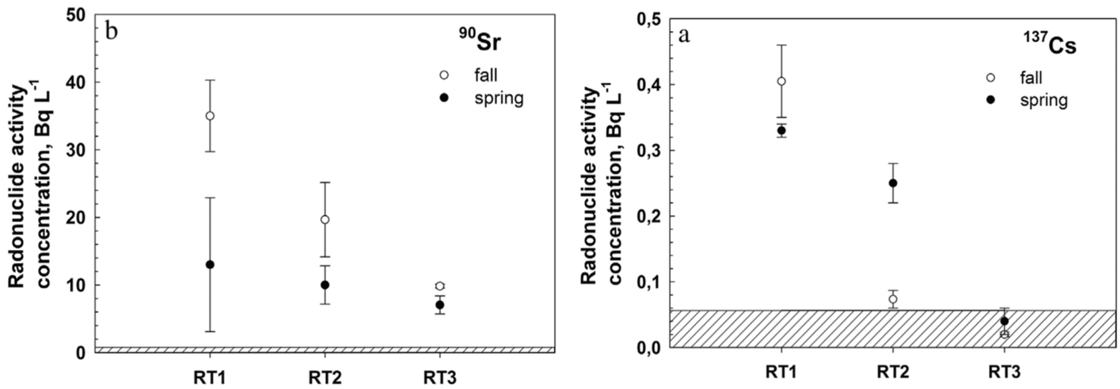


FIGURE 4-16. CONCENTRATION OF ANTHROPOGENIC RADIONUCLIDES IN TECHA RIVER WATER IN SPRING AND AUTUMN AT DIFFERENT SAMPLING STATIONS (FROM SHISHKINA ET AL., 2016).

Internal hydroxyapatite-based EPR detectors were used in fish from the reservoir to verify internal exposure doses calculated using the ERICA assessment tool with the assumption of uniform distribution of radionuclides throughout the body of the fish. The results were very close to each other and the conclusion drawn that ERICA is an effective tool for evaluating internal exposure dose.

The total dose rate to fish in different reservoirs, calculated using the ERICA tool is variable (Figure 4-17). No fish were found in reservoir R-17, but if present, doses would be around 1 Gy/d. Dose rates to fish at different stations in the Techa River are detailed in Table 4-4. The highest doses (150 µGy/d) occur in the sampling station closest to Mayak. Doses then decreased with distance down the river. The three species (perch, pike and roach) were found in each of the three reservoirs associated with the Techa River. However, one reservoir is a source of drinking water for the local population and fish were placed there artificially. The third reservoir (R3) is small and no pike are present.

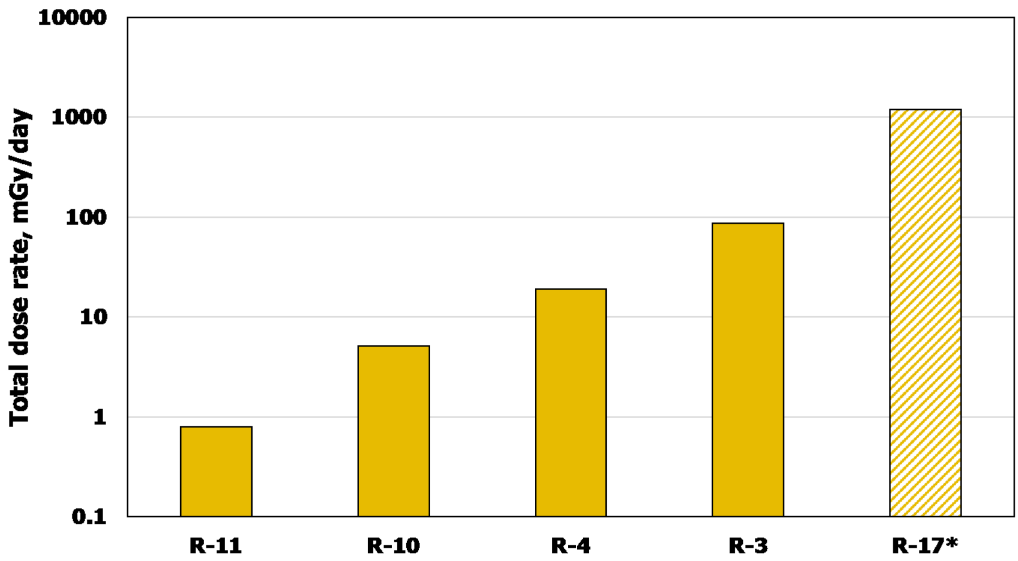


FIGURE 4-17. TOTAL DOSE RATE FOR ROACH IN MAYAK RESERVOIRS (NO FISH PRESENT IN THE RESERVOIR).*

The three species (perch, pike and roach) were found in each of the three reservoirs associated with the Techa River. However, one reservoir is a source of drinking water for the local population and fish were placed there artificially. The third reservoir (R3) is small and no pike are present.

TABLE 4-4. INTERNAL, EXTERNAL AND TOTAL DOSE RATES FOR FISH INHABITING THE TECHA RIVER

	Dose (µGy/d)		
	RT1	RT2	RT3
Perch			
Internal exposure	14	8	4
External exposure	110	3	0.5
Total	124	11	4
Roach			
Internal exposure	19	13	8
External exposure	89	4	0.7
Total	108	16	9
Pike			
Internal exposure	8	5	2
External exposure	140	4	0.8
Total	150	9	3

The species composition of fish in the Techa and Miass rivers was similar and no differences in the age structure of roach populations was detected. A difference in the age structure of perch and pike populations was observed with fewer older fish being present in the Miass River, but this is due to fishing being permitted within this river.

A range of bioindicator tests have been performed on fish. No difference was observed in body weight, but a statistically significant difference was observed for the DNA comet assay for erythrocytes from fish sampled from the upper Techa River. The frequency of roach erythrocytes with micronuclei was also significantly increased in fish from the Techa River. Peripheral blood cell number was also linked to dose rate with a threshold level being observed; a temporary reduction in peripheral cell number was observed at a dose rate of 70 µGy/d. The results suggest that radiation leads to an increase in blood cell reactions in fish.

Another detriment observed in sampled fish was the presence of trypanosome parasites. The prevalence of parasites was increased in fish exposed to higher dose rates in the Techa River. Differences have also been observed in relation to the active sperm content in fish and in antioxidant levels with higher levels being observed in fish experiencing greater dose rates.

Transplant studies have also been undertaken with fish from both the Techa and Miass rivers being transplanted in cages to the Zyuzelga River. Fish from the Miass River were similarly transplanted in the Techa River. The experiment is summarized in Figure 4-18.

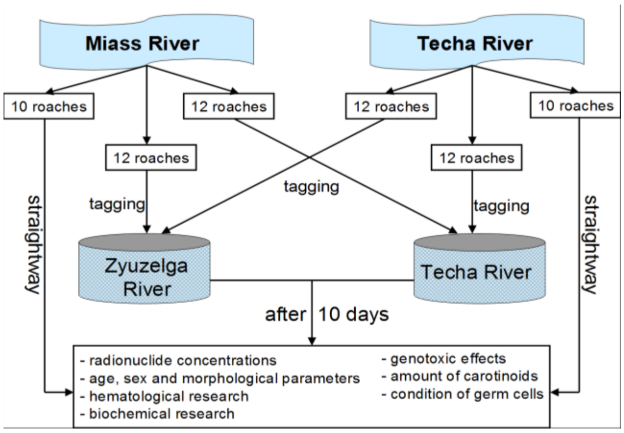


FIGURE 4-18. EXPERIMENTAL PLAN FOR THE TRANSPLANTATION OF FISH FROM THE TECHA AND MIASS RIVERS (UP) AND LOCATION OF IN SITU EXPERIMENTAL SITES (DOWN).

Fish transplanted from contaminated to clean river water were found to have an increase in peripheral blood cell number. Similar results were observed for fish transported from contaminated to clean reservoirs.

The radionuclide intake for the local population from the consumption of fish from the Techa River has also been investigated. Fishing is not permitted in the river, but does occur. If fish were to be consumed from the mid reaches of the river, the intake of Sr-90 would be higher than the allowable dose. Fish consumption could give rise to an effective dose of up to 0.5 mSv.

From the experiments conducted, it has been concluded that chronic dose rates of more than 100 µGy/d leads to genotoxic effects in fish and changes in physiological and pathophysiological reactions, as well as changes in the response to other factors. Adaptive reactions in fish allow the survival of populations of perch, roach, pike, tench, carp and ide at chronic exposures up to 18 mGy/day.

4.10 Determining limit parameters of radionuclides in soil for producing agricultural products of guaranteed quality

Zhanat Baigazinov (Institute of Radiation Safety and Ecology) presented.

The Semipalatinsk test site (STS) is one of the largest in the world, with an overall area of over 18,000 km2. Around 86 atmospheric tests, 30 above ground tests and 340 underground tests took place at the site. Following closure of the STS in the 1990's the population living near the border of the test site started to inhabit the territory and a number of farming enterprises are now present on the site (
Figure 4-19). The main agricultural practices are associated with the raising of agricultural animals and hay making. in order to evaluate the risks associated with farming practices, exposure estimates are required. There are insufficient parameters, however, for estimating transfer in IAEA data compilations and, where data are available, these can be associated with significant uncertainties. As such, the decision was made to derive site data to support exposure assessments.

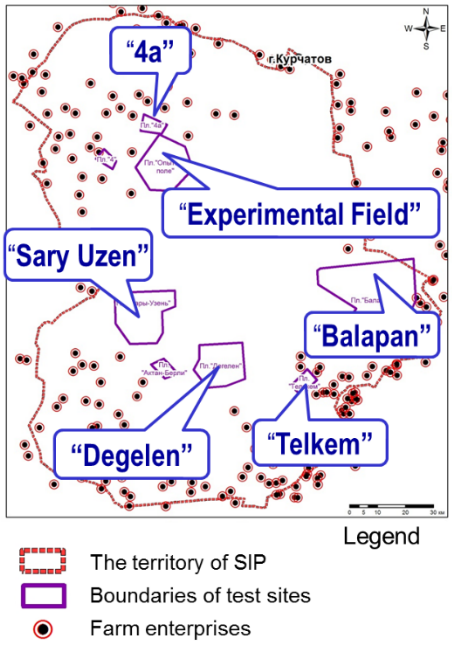


FIGURE 4-19. THE SEMIPALATINSK TEST SITE AND CURRENT FARM ENTERPRISES PRESENT ON THE SITE.

Since 2007, full scale transfer experiments have been conducted around the most contaminated area of the test site. Farm animals typical for the region were used to study migration processes for radionuclides into farm animal products from the use of contaminated soil, water and forage from different areas of the STS. The duration of experiments ranged from 1 day to 112 days.

The dynamics of radionuclide accumulation and excretion were studied. Results indicate that there are two main accumulation phases. Initially radionuclides increase rapidly in organs prior to an equilibrium state being reached. The duration of these phases is radionuclide dependent. A similar pattern is observed for excretion. For example, Am-241 excretion was observed in the first week of the study, but concentrations then stabilized.

Once in the equilibrium phase, certain ratios are observed for the distribution of radionuclides in different tissues. For example, a good correlation between the concentration of Sr-90 in bone and wool of sheep has been observed. These ratios make it possible to estimate the content of different radionuclides in different animal tissues. It was assumed prior to the studies that the distribution of radionuclides would be independent of the source of intake, but the results of the study have shown this not to be the case; the distribution of Cs-137 in wild boar and domestic pigs varied according to whether the source of intake was soil from a surface test site or an underground test site (Figure 4-20).

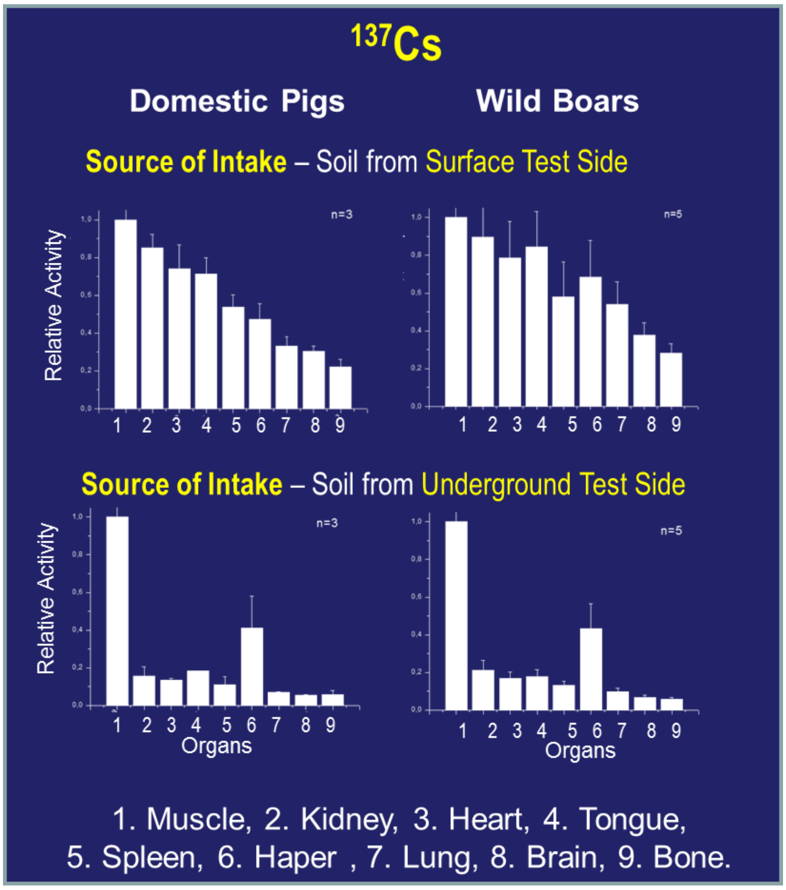


FIGURE 4-20. CS-137 IN DOMESTIC PIGS AND WILD BOAR RESULTING FROM DIFFERENT INTAKE SOURCES.

The dynamics of accumulation of two forms of tritium (HTO and OBT) were also found to depend on the source of intake, with HTO and OBT concentrations in the muscle and eggs of hens varying according to whether intake was from forage, water or air. Intake from forage was around six times lower than for water intake.

The data derived from these studies have been used to estimate the concentration of radionuclides in soils that would equate with permissible levels of radionuclides in food products. This, in turn, will allow decisions to be made around the possibility of using contaminated areas of the STS for farming. Results indicate that farming would be possible in around 99% of the territory.

Further experiments are planned for 2018-2020 to look at the species of radionuclides in soils and to consider the macro and trace element diet composition of farm animals. Animal productivity will also be taken into account.

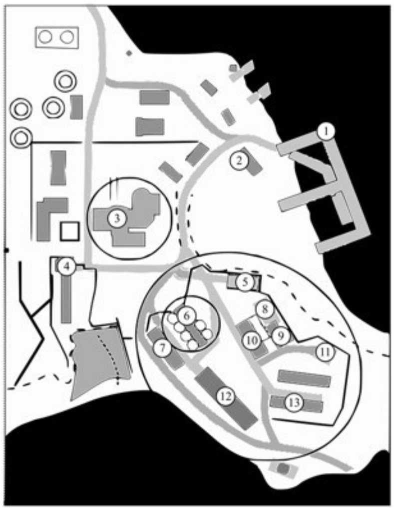
The results of the studies show the importance of considering the factors leading to the variability in radionuclide transfers to animal products.

4.11 Regulatory supervision of nuclear legacy site at Andreeva Bay using time series analysis methods

Konstantin Chizov (FMBC) presented.

Andreeva Bay is a technical site for temporary storage of SNF and radioactive waste. In 2002, the total radioactivity at the site was of the order of 10^{17} Bq. The majority of this activity was associated with Building 5 and a dry storage unit (Figure 4-21).

Ambient dose maps of the site have been developed on the basis of thousands of measurements using both nonlinear interpolation and time series analysis methods.



№	Building	Activity, Bq
1	Pier	unknown
2	Building 50	unknown
3	Dry storage unit	$1.3 \cdot 10^{17}$
4	Building 5	$1.4 \cdot 10^{17}$
5	Montejuce site	$1.9 * 10^{12}$
6	Building 6 (LRW storage facility)	unknown
7	Building 67A	$7.4 * 10^{10}$
8	Building 7E	$2.3 * 10^{14}$
9	Building 7B	unknown
10	Building 7G	$2.6 * 10^{12}$
11	Building 7V	$6.7 * 10^{12}$
12	Building 67	$3 * 10^{10}$
13	Building 7 (site)	10^{12}

FIGURE 4-21. LOCATION OF FACILITIES AT ANDREEVA BAY AND THEIR ASSOCIATED RADIOACTIVITY.

For interpolation, data from a radiometric examination database were used to construct 4970 grids of the technical area at Andreeva Bay over the time period from July 2002 to February 2016. Each grid had the same resolution and the sum of all values of one grid is the integral value of the ambient dose equivalent rate (ADER) for the current radiometric survey date.

Dose rate varies at different points on the site and a generalized indicator was therefore needed. The ADER integral can be used as such an indicator.

A number of remediation operations have taken place at Andreeva Bay in the period from 2002 to 2016 and ADER integral graph peaks are connected with these operations. Seasonal trends are also evident: the seasonal component varies the ADER integral twice, due to snowfall.

The ADER graphs can be analyzed, accounting for peaks associated with activities on site, to look at the overall trend in the integral. The ADER integral demonstrates a decreasing trend. The initial and final values differ by around a factor of ten, in part due to radioactive decay. Only a small proportion of radionuclides have migrated off-site. The remediation actions at the site account for about a sevenfold decrease in the ADER. A significant reduction of the ADER integral was reached by the personnel, who obtained individual (<1.2 mSv) and collective (<110 mSv·person) doses at that time (Sneve et al., 2015). The residual component reflects the uncertainty of the ADER integral calculation and phases of active SNF and radioactive waste management.

The analysis of dynamics of the radiation situation at Andreeva Bay between 2002 and 2016 has shown that this interpolation method can be used to derive radiation situation maps. The application of seasonal-trend time-series decomposition for analyzing the dynamics of the radiation situation makes it possible to separate the influence of various anthropogenic (protective measures) and natural (snow-cover formation) factors. The developed method is used for regulatory supervision of the occupational radiation protection. The developed method also enables the effectiveness of previous remediation works to be evaluated and supports decision-making for future activities.

4.12 NATO Trust Fund project "Remediation of radioactive waste disposal site in Ukraine: object of the State Border Guard Service of Ukraine "Vakulenchuk"

Vitalii Dem'ianiuk (NT Engineering LLC) was unable to attend the workshop, but provided presentation material. A summary of that material is provided.

The NATO trust fund project objective is to eliminate terrorist threats associated with nuclear and radioactive materials that are outside of regulatory control and to remediate the Vakulenchuk site to an ecologically safe state. The site was a nuclear waste dump dating from the Soviet era. The main contractor for the project was NT Engineering LLC.

A number of project milestones have been achieved:

- Radiation safety examination;
- Development and coordination of technical solutions;
- Preparation of the site;
- Mobilization;
- Forming the container park;
- Removal of radioactive waste;
- Removal of the body of the repository and contaminated soil;
- Conditioning of waste;
- Transportation and transfer for long-term storage; and,
- Remediation of the territory.

To date, 400 m^2 of territory has been restored with around 20 tons of radioactive waste having been removed. The residual dose rate following remediation is less than 0.11 µSv/h.

The entire infrastructure for the remediation project was created at the site with implementation being carried out in a forest setting. The waste present was mixed, including ionizing radiation sources of all types and in both liquid and solid form. The repository was intended for the final disposal of radioactive wastes, i.e. retrieval of wastes was not intended.

To support the activities at the site, regulatory documents had to be expanded and limits and levels of remediation for the territory were developed. There was a lack of data on the wastes at the site and on the structure of the repository with such data having been destroyed. Detailed planning was therefore required and a conservative approach taken to all decisions. All work was performed to the highest level of safety for personnel and the environment and the remediation works have led to substantial reduction of the terrorist threat.

5 Social and ethical issues: uncertainties, risk communication and engagement of stakeholders

5.1 Societal and ethical aspects of legacy site management

Deborah Oughton (CERAD/NMBU) presented.

Stakeholder engagement is an important part of emergency preparedness and is important also for many other nuclear related issues such as waste disposal, nuclear power plant siting and accident management. There are many driving factors, including international legislation. For example, Principle 10 of the 1992 Rio Declaration calls for environmental issues to be handled with the participation of all concerned citizens, at the appropriate level:

> Rio Declaration, Principle 10
> "*Environmental issues are best handled with the participation of all concerned citizens, at the relevant level. At the national level, each individual shall have appropriate access to information concerning the environment that is held by public authorities, including information on hazardous materials and activities in their communities, and the opportunity to participate in decision-making processes. States shall facilitate and encourage public awareness and participation by making information widely available. Effective access to judicial and administrative proceedings, including redress and remedy, shall be provided*."

The Rio Declaration is not legally binding. That which is legally binding is the Aarhus Convention on Access to Information, Public Participation in Decision-making and Access to Justice in Environmental Matters. This convention was adopted in June 1998 and was ratified in October 2001 and is the legal driving force behind stakeholder engagement.

There are also ethical driving forces for stakeholder involvement, including:

- Empowerment – control/influence over environment and well-being.
- Democratization – right to take part in decisions affecting their lives.
- Efficiency – stakeholders have important and relevant knowledge.
- Success – the public has the capacity to halt many projects.

There is therefore a progression from DAD (decide, announce, defend) to MUM (meet, understand, modify).

Stakeholder engagement models are very important in emergency preparedness; it is vitally important to have discussions during times of peace to ensure appropriate connections are made and that emergency processes are disseminated prior to any accidents. This helps in building trust. Engaging with stakeholders is also beneficial when developing management strategies. It has also been demonstrated that engagement within real situations is very beneficial. Examples include ICRP co-expertise dialogues in Fukushima and reindeer herder dialogues in Norway.

The EU has produced a handbook to assist the management of contaminated food production systems following a radiological emergency. It was developed by a multi-disciplinary group of people, including those from social and economic fields. In one of the projects, a stakeholder discussion case study was included. Stakeholders from different backgrounds (farmer unions, environmentalists, consumer organizations, industry etc.) were brought together and asked to consider a case whereby an accident in Europe has resulted in millions of liters of contaminated milk being produced at activities greater than the EU 300 Bq/L limit for sale. The product could not be stored and it is not possible to stop production so the stakeholder groups were asked what should be done with this product. UK stakeholders considered that discharge to sea could be acceptable whereas stakeholders from Finland and Belgium considered that the milk should be spread on land. In France it was concluded that the milk would have to be treated as a contaminated product and contained. What was not acceptable to any stakeholder groups was the idea of diluting the contaminated milk with uncontaminated milk or processing into milk products. This was largely driven by the views that such practices would be unacceptable to consumers and that farmers with uncontaminated products would not allow their product to be mixed with contaminated product. There were therefore clear differences in what stakeholders considered to be acceptable and these opinions were not driven by technical issues, but rather decisions were being made on social and ethical grounds. What is considered acceptable will be context driven.

There can be ethical challenges associated with stakeholder engagement. With a number of different viewpoints being expressed, there can be disagreement about the outcome. There is a need to step back from the process and decide when stakeholder involvement is relevant and appropriate in terms of making decisions. There can also be concerns around procedure. In early days of stakeholder engagement in the UK the process was not well carried out and stakeholders were not really given a voice leading to the view that the process was mainly for propaganda rather than really wanting to hear people's views. More recently there has been greater enthusiasm around giving people a voice, but this can be viewed as regulators trying to back away from responsibility. From dialogues between experts and affected populations the ICRP concluded that decisions should not be made in isolation, but through dialogue, through community support and discussions. A lot of support is needed to allow communities to take control of their situation.

The consequences of the Chernobyl accident were underestimated by many European authorities. In the UK, authorities failed to listen to stakeholders who had knowledge that would have been very useful. A statement was made following the accident that there was no risk to the UK public. However, the accident happened when there was heavy rain in the UK and deposition was much higher than anticipated and persisted; authorities got the situation wrong on many levels. The accident resulted in significantly elevated levels of radiocaesium in sheep and over 9000 farms and 4 million sheep were subject to restrictions and monitoring lasting 26 years. A social science study on the sheep farmers frustration with flawed management strategies suggested by experts and authorities highlights the importance of establishing dialogue with those affected. The public are an important source of information that can be very beneficial in informing decisions.

The take home messages are that public and stakeholder engagement is an important form of risk communication and gaining knowledge from, and opinions of, affected people and stakeholders are necessary parts of the risk assessment and management process. It is important to recognize, however, that different stakeholders need different types of information and dialogue and different engagement approaches are therefore required.

5.2 Social-psychological aspects of the usage of radioactively contaminated territories of the Urals

Elena Burtovaia (URCRM) presented.

There have been a number of radiation accidents in the Urals associated with the Mayak Production Association (PA) facility. Radioactive waste has been released into the Techa River and, in 1957, an accident occurred that resulted in the release of radioactivity to atmosphere. This was followed in 1967 by the Lake Karachay incident. Together, these accidents have resulted in high levels of radioactivity across the region, as illustrated in Figure 5-1.

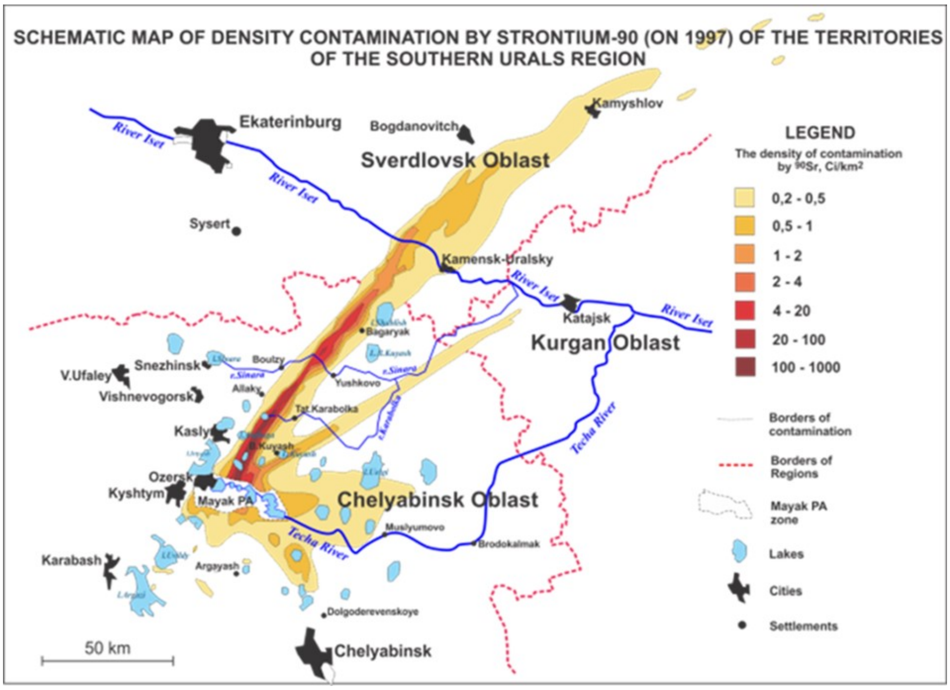


FIGURE 5-1. SR-90 CONTAMINATION OF THE SOUTHERN URALS TERRITORY AS A RESULT OF RADIATION ACCIDENTS ASSOCIATED WITH MAYAK PA.

Due to a lack of safe storage, the Techa River system became contaminated and the local population were exposed to high doses. Analysis has shown that between 1965 and 2005 Sr-90 specific activity in the river has reduced seven-fold. The percentage contribution of food and water to the dose received by the local population has changed considerably over this time. In the 1950's the dose was dominated by drinking water intake. However, in 1956, the consumption of water from the river was prohibited and the proportion of dose from food increased considerably. The majority of Sr-90 intake was associated with fish consumption (Figure 5-2).

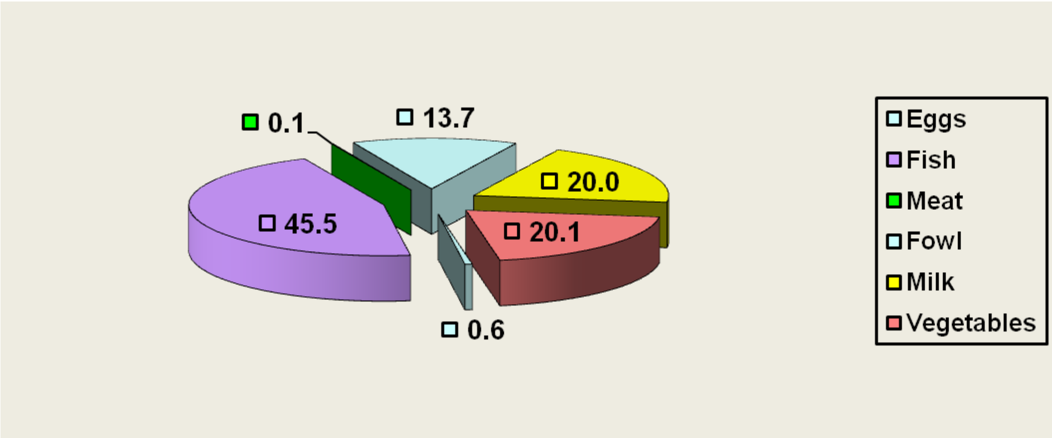


FIGURE 5-2. PERCENTAGE SR-90 INTAKE WITH FOOD STUFFS IN 1950-1952.

In 1957 there was an airborne release of radioactivity as a result of an accident at the Mayak PA site. Over a period of around 11 hours, the East Urals Radioactive Trace (EURT) was formed, with 90% of the radioactive fallout occurring on the territory of Mayak PA.

The stable wind direction at the time of the accident was an important factor in the formation of the EURT. An area of 23, 000 km^2 was contaminated to levels of 0.1 Ci/km^2. There were over 200 settlements throughout this area. However, only around 200 km^2 was contaminated to a level of 100 Ci/km^2 or more and only 3 settlements were associated with these areas.

Short-lived radionuclides contributed greatly to the total activity and decay was evident over the first 5 years following the accident such that Sr-90 is now the main radionuclide contributing to dose.

Differences in countermeasures were evident between the Techa River release and the EURT. For the former, no emergency countermeasures were taken and scheduled countermeasures were not as effective as they could have been due to delayed implementation; relocation only began 5 years following the onset of releases when residents had already received the largest part of the dose. In the case of the EURT, emergency countermeasures were taken with residents being evacuated from nearby settlements and food products and fodder were monitored. A sanitary protection zone was also established. There were also scheduled countermeasures implemented, involving additional relocation, decontamination of settlements and agricultural areas and the establishment of a radiation monitoring system for foodstuff and fodder contamination control.

One of the main issues faced in the return of the territory to normal use is the risk perception among the population. The population receives and assesses the degree of risk in a different way to experts. They worry about the health of themselves and their children and have a lack of trust in the authorities. They also want social and economic compensation.

In 2014, data from Fukushima were presented at a MELODI meeting. The people from Fukushima were being given good scientific information to say that cancer risks were low and yet people were still anxious and social effects considerable.

There are a number of factors that determine the social-psychological status of populations of radioactively contaminated territories in the long term (Figure 5-3). The quality of everyday life is determined according to a number of factors, such as the dynamics of assessment of favorable or unfavorable status of the ecological situation of the area, psychological readiness to change the place of residence and concerns around health in view of unfavorable environmental living conditions, such as the quality of food and drinking water.

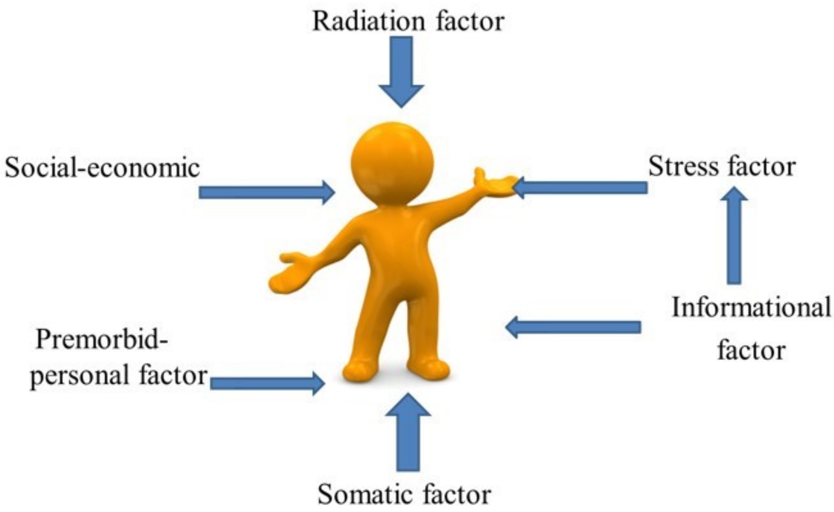


FIGURE 5-3. FACTORS THAT DETERMINE THE SOCIAL-PSYCHOLOGICAL STATUS OF POPULATIONS INHABITING RADIOACTIVELY CONTAMINATED TERRITORIES IN THE LONG-TERM.

The media had a large role in increasing stress in the populations living in the territory contaminated by incidents at Mayak PA with various alarmist news headlines. Some populations were resettled some 50 years after the accident and were given the choice of moving into new houses constructed just a few kilometers away, or receiving money to fund their own moves.

Various social and psychological aspects were measured in the population during the resettlement phase and results indicated that people were worried and frustrated. High cortisol levels were measured as people were stressed and anxious. Those being resettled from a village thought the situation was tense and thought leaving the village was negative whereas the views from a comparison group were that the moves were positive.

The main concerns of the group being resettled related to health and radiation hazards and, in terms of help from authorities, wanted improved medical services and living condition and financial reward. People were active in public hearings and when asked to evaluate their health responded with feelings of being tired and thoughts of overall health deteriorating. More than 80% of the population thought that radiation accidents could occur again.

In the long-term post-accident period, social-psychological consequences become one of the important issues for affected populations and are one of the most serious issues in the return of territories to economic use. Measures aimed at forming adequate perceptions of radiation exposure risk in the population need to be developed. Monitoring of the social-psychological status of the population is necessary to identify critical groups from the point of view of non-adaptive forms of behavior.

Delayed action was one of the biggest problems for populations in the area with a lack of action in the early stages of the incident resulting in many of social-psychological issues among the population. Early dialogue between authorities and the affected population may have alleviated some of the issues. It is important for properly phrased information to be presented and for people to be able to express opinions and proposals.

5.3 Decision processes and pathways related to NORM legacies: focus on uncertainties

Jelena Mrdakovic Popic (NRPA) presented.

The TERRITORIES project (To Enhance unceRtainties Reduction and stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife in long-lasting radiological Exposure Situations) is a European Joint Program that began in January 2017 and will run until December 2019. The project is comprised of a consortium of 11 European project partners and external experts, comprising operators, scientists and regulators.

Working group 3 of the project is focused on stakeholder engagement for a better management of uncertainty in risk assessment and decision-making processes including remediation strategies. The overall objective of WP3 is to analyze the decision-making processes in long-lasting radiological exposure situations, taking into account all components of risk assessment, with two key-points:

- management of uncertainties

- and stakeholder engagement.

Task 3.1 is focused on uncertainty management in decision-making processes and within this task, SCK·CEN and NRPA are working together on a deliverable on decision processes/pathways related to NORM contamination and remediation with a focus on uncertainties. The main objective is to review uncertainties in long-term radiological exposure situations due to the NORM, as well as remediation strategies (planned, on-going and conducted) in reducing the consequences to humans and wildlife.

Norwegian experience and lessons learned concerning the main uncertainties in decision-making processes at NORM existing exposure situations and NORM legacies is being reviewed. The largest volume of NORM waste in Norway results from rocks with the potential for acid draining, such as alum shale. There are also a number of NORM industries, oil and gas production being the main one. There are however few legacies in Norway. Lessons learned within the process of regulatory decision making at legacy sites were presented on examples of two cases: the former mining sites Søve and an old disposal site of alum shales (Taraldrud), which is close to Oslo.

The regulatory decision-making process is summarized in Figure 5-4. Decision-making is a case specific process requiring comprehensive information and the assessment of many factors, including social and economic factors and risk communication. The decision making process sets out what should be looked at, but each site must be considered in its own right, with a holistic view being taken and with realistic data being applied to support decision-making.

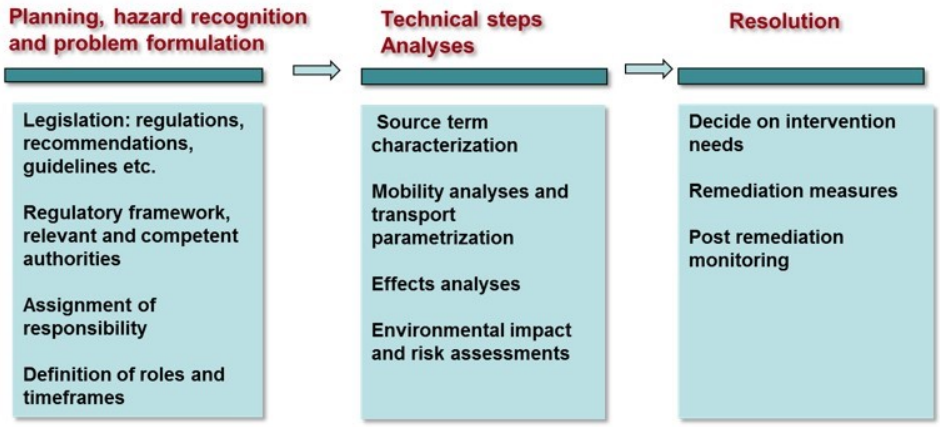


FIGURE 5-4. THE REGULATORY DECISION-MAKING PROCESS.

The Taraldrud disposal site for alum shale is an issue since, although if left alone the rock remains safe, if conditions are changed, acid leaching can occur resulting in the mobilization of uranium and heavy metals. Water from the area flows into a larger water source that is utilized by the local population. Although leaching does not currently affect drinking water quality, there is the potential that issues could arise in the future if conditions at the site aren't changed. Some actions have been undertaken at the site to address the situation, but more are needed.

Søve is the former site of niobium mining in Norway. Following closure of the mine, the area was covered by sand layers, but these have been disturbed over time. The site is freely accessible and hotspots of radiation have been measured. Some radioactive wastes have also been identified in the form of slag and shale. The site is located near to a lake. Oterstranda is a former molybdenum mine.

The NRPA is the main regulatory body for radioactive waste and discharges in Norway and is responsible for the regulation of radioactive discharges/pollution and radioactive waste at legacy sites. Norwegian legislation for radiation protection has been recently revised with new legislation (the Pollution Control Act) coming into force on the 1st of January 2011. This Act provides a holistic, ecosystem based approach to the regulation of waste management and pollution for radiation and other types of hazard, taking into account both humans and the environment. With the regulations requiring a holistic approach to addressing hazards, the NRPA and other regulatory bodies in Norway must collaborate.

Review of the regulatory framework identified no uncertainties related to national policy or the legal and regulatory framework. Effective legislation is in place with proper standards and guidelines. The cooperation between different regulatory agencies is crucial, including between environment agencies and local authorities.

In assignment of responsibilities, Norwegian experience has shown that decisions to be made on physical ownership and on financial responsibility are not necessarily the same thing and can be a time consuming and often problematic process for legacies. Several authorities tend to be involved and cooperation and collaboration is required. However, different authorities may have different protection objectives and collaboration can give rise to different requirements about responsibilities.

Science has a crucial role within the technical steps and decisions relating to legacies. Sites need to be characterized, mobility and transfer pathways analyzed and impacts assessed. There are many uncertainties relating to nature and the prevailing circumstances and in the technical steps to be taken. Radioecology has an important role to play.

Environmental and human impact and risk assessments require valid exposure scenarios and assessment models. How to model is a factor of judgement, but models should be developed on the basis of science, and intelligent models require intelligent users. Science can further contribute to decision-making processes by reducing the overall uncertainties through development of a realistic data basis, better key process parametrization and advanced dynamic model development.

Operators are often confused around dose constraints, reference levels and action levels and the correct strategy for selecting clean-up measures. This is particularly an issue at sites where there are high exposure levels, yet sites are undisturbed. Identifying the right strategy and end state can be particularly difficult. Common questions asked include:

- What is the right remediation strategy?
- How to define the realistic timeline?

- How to define the right end-state?
- What is the best solution for radioactive waste? Local disposal site, complete removal from the site?
- What kind of post remediation measures, monitoring and what, how often and for how long?

Funding decisions can also be difficult and are linked to the assignment of responsibility. Funds may not be available or the polluter may no longer be present. Funding will always be part of the optimization process supporting final decision-making.

In terms of stakeholder involvement and risk communication, Norway has both positive and negative lessons learned. At the Søve legacy site, risk communication was poor. The assignment of responsibility was unclear for a long time and there was an information overload with mixed messages being given with regard to dose magnitude. A disposal site for waste from the Søve site was identified, but the operators did not want to receive the wastes. The decision had been largely political and the community was not so happy with the decision. Generally, public perception is that radioactive substances are much more hazardous than chemicals.

Positive experience has been gained through public meetings and the involvement of stakeholders at early stages in regulatory decision-making in the NORM industry, where there has been transparency at all stages and improved reliability.

There are uncertainties and challenges throughout legacy site management. From experience, key uncertainties and challenges relate to:

- National policy, legal and regulatory framework;
- Hazard characterization and problem formulation;
- Radioecological analyses and assessments;
- Identifying appropriate clean-up actions;
- Financial decisions;
- Risk perception and communication; and,
- Stakeholder involvement.

Throughout the decision-making process, key uncertainties should be minimized where feasible and local stakeholders should be engaged to start building trust at an early stage.

5.4 Regulatory supervision of legacy sites in Republic of Serbia: Former uranium mines in eastern Serbia.

Branko Brajić (Serbian Radiation protection and Nuclear Safety Agency) presented.

There are two main applicable laws in the Republic of Serbia: the Law on Radiation Protection and Nuclear Safety; and the Law banning the construction of nuclear power plants in the Federal Republic of Yugoslavia. There are also two regulations: Regulation on determining the program of nuclear safety and security; and Regulation on the security measures of nuclear facilities and nuclear materials. Regulations on determining the program of radioactive waste management and on determining the program of radiation and security are in the process of adoption and preparation, respectively. Eighteen rulebooks were adopted in 2011 and 2012.

There are three main institutes in the institutional framework:

- The Ministry of Environmental Protection is responsible for radiation protection;
- The Serbian Radiation Protection and Nuclear Safety Agency (SRPNA) is responsible for rulebooks and programs (detailed below); and,
- The Ministry of Education, Science and Technological Development is responsible for nuclear safety and radioactive waste management.

The SRPNA was established in December 2009 according to the Law on Radiation Protection and Nuclear Safety and the Law on Public Agencies as a functionally separate organization performing authorizations in accordance with the law. Financial resources are provided from the State budget through the Ministry of Environmental Protection. Regulatory responsibilities of the SRPNA include:

- Passing bylaws for implementing the Law on Radiation Protection and Nuclear Safety;
- Adopting the Program of Systematic Environmental Radioactivity Examination;
- Adopting the Program for Additional Training and Qualification of Occupationally Exposed Persons and Persons Responsible for Radiation Protection; and,
- Adopting the Program of Early Warning of Emergency.

Administrative responsibilities include:

- Issuing, extending and revoking licenses for performing a radiation practice or nuclear activity;
- Issuing and revoking permits for trade of radioactive and nuclear materials; and,
- Producing instructions and procedures required for implementing radiation and nuclear safety and security measures.

The agency is also responsible for the monitoring of radioactivity, cooperation with the IAEA and other international bodies, publishing an annual report on exposure levels of the population to ionizing radiation and keeping a registry of applications and issued licenses, permits, decisions and centralized records on nuclear facilities, nuclear materials and radioactive waste.

Uranium mining was undertaken in Serbia at three mines (Gabrovnica, Mezdreja and Srnići Do mines) during the 1960's. All three mines were located around the Janja mineral field, located eastward from the village of Kalna. The mines closed at the end of the 1960's.

There is no current information on the state of the Mezdreja and Srnići Do mines. The facilities at the Gabrovnica mine are in very bad condition. No decision has been made regarding future activities at the site, but regular environmental monitoring is performed in the vicinity of the mine, in accordance with the Rulebook on Radioactive Monitoring. The sampling program is summarized in Table 5-1. No activity outwith permitted levels has been monitored to date and there are no signs of contamination beyond the site perimeter. Access to the site by members of the public is prevented. There is, therefore, currently no danger to the environment or to public health.

TABLE 5-1. MONITORING PROGRAM AROUND THE GABROVNICA FORMER MINE SITE.

Sampling media	***Description of the sampling location***	***Sampling frequency***	***Type and description of measurement***
Surface water	Gabrovnička river before the mine Gabrovnička river after the mine	Aggregate monthly sample, Continuous daily collection.	Gamma spectrometry analysis of radionuclide content. Analysis of H-3 contents.
Soil	Vicinity of the mine	Two samples from each depth and measurements two times a year. Three depths: 0-5cm; 5-10cm; 10-15cm	Gamma spectrometry analysis of radionuclide content. Analysis of U-238 contents.
Level of external radiation	mine site	once a month	Ambient gamma dose equivalent in the air – integral using TL dosimeters

Mining at Gabrovnica took place between 1963 and 1966, during which time around 900 kg of UO_2 and 400 kg of metal uranium were produced. The ore was of poor quality, containing very low uranium content, which required higher-cost mining and refining methods to be employed. Remediation of site is needed.

Exploitation of ores containing nuclear material is defined as a nuclear activity under Serbian Law and the Gabrovnica hydrometallurgical plant and uranium mine are considered nuclear facilities. Such facilities must be operated under a license issued by SRPNA. Any activity related to the remediation of sites of former uranium mines is subject to following legal acts:

– Law on Radiation Protection and Nuclear Safety;
– Regulation on determining the program of nuclear safety and security;
– Regulation on the security measures of nuclear facilities and nuclear;
– Rulebook on Performance of Nuclear Activities; and,
– Rulebook on Conditions for Obtaining License to Perform Nuclear.

There are four necessary activities for the remediation of former mine sites. Detailed characterization of the site and facilities must be undertaken and a remediation plan prepared on the basis of the radiological characterization and selection of the optimal solution for site end use. A public hearing for the remediation plan must then be organized prior to a request for a license to be issued for remediation activities being submitted to SRPNA.

There are two possibilities for future use of the site: use of the site without restrictions, or use of the site with restrictions. Such restrictions could include the prohibition of food production on the site or the consumption of water from the site.

The characterization of equipment and materials present on the site of the hydrometallurgical plant in Gabrovnica is planned. A site remediation plan will then be developed by a Public company established for the management of nuclear facilities in the Republic of Serbia, and approved by the SRPNA. Decisions on the further status of the plant will be made by the Government on the basis of the approved remediation plan.

6 Recommendations for future coordination of international activities and cooperation

6.1 EuCAS network – European and Central Asia Safety Network and the TSO Forum initiative

Karim Ben-Ouaghrem (IAEA) presented.

The global nuclear safety and security framework (GNSSF) is considered as the means to sustain the implementation of the international legal framework and focuses on assisting Member States to meet their national responsibilities as well as their international obligations. The GNSSF aims to develop guides to support Member States in applying the requirements on international conventions and to learn from Member States with regard to how standards are applied.

The global nuclear safety and security network (GNSSN) encompasses around 17 other global and regional safety networks and national nuclear safety knowledge platforms. The GNSSN provides a platform for the hosting of national databases for educational and training offerings and also hosts a leadership school that addresses the capacity of managers to make decisions in certain situations. The first course took place in November 2017 in France. The course was based around case studies and encouraged thinking around decision-making. There was good international attendance.

The European and Central Asia Safety Network (EuCAS) is one of the regional safety networks. It is quite new, being established in September 2016 as a result of concerns around the lack of discussion between Europe and Central Asia on nuclear safety. There are 22 countries that have officially joined the network, as well as partner organizations such as the European Commission. There is a good mix of both regulatory bodies and technical support organizations (TSOs) within the network, which is useful since a number of technical aspects need to be discussed.

The first Steering Committee meeting for the network took place in December 2016 at the IAEA. Three working groups were established:

- WG1 – safety infrastructure;
- WG2 – safety of radioactive waste and spent fuel management; and
- WG3 – environmental remediation and decommissioning.

A fourth working group is being developed on education and training. The structure of the network is illustrated in Figure 6-1.

A WG2 workshop was held in June 2017 in Sofia at whcih the main 'hot spots' for future cooperation were identified. These were:

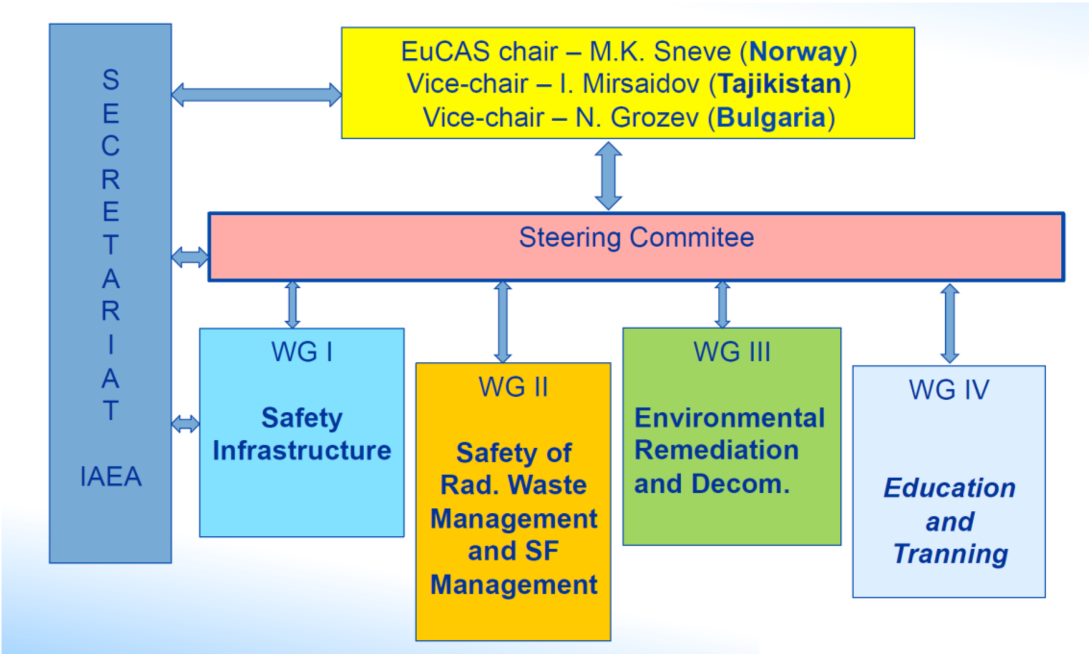


FIGURE 6-1. STRUCTURE OF THE EUCAS NETWORK.

- National policy and strategy (linked to WG1);
- Clearance of material from regulatory control;
- Disposal of radioactive waste in near-surface or geological disposal facilities;
- Inspections performed by regulatory bodies (also linked to WG1); and,
- SNF management.

Minutes of the workshop can be obtained from the EuCAS website (https://gnssn.iaea.org/main/EuCAS/Pages/default.aspx).

In terms of next steps, WG3 members were participating in the workshop reported herein. A WG3 workshop on remediation activities is then planned for June 2018 in the Czech Republic and WG1 will hold a workshop on regulatory interactions with neighbouring states in March or April 2018 in Bosnia and Herzegovina. There may also be a WG4 working group meeting on training needs assessment in the Russian Federation in 2018.

The TSO forum initiative is aimed at supporting Member States in developing and strengthening their technical and scientific capacity. There is again a good balance or regulatory bodies and TSOs involved in the forum.

A TECDOC is being developed on TSO functions and is due to be published by the end of 2017 and a conference is being organised on ensuring effective and sustainable expertise, which will take place from 15-19 October 2018 in Brussels. The objectives of the conference are to:

- Evaluate actions addressing previous TSO conferences' recommendations;
- Promote the roles, functions and value of TSOs in enhancing nuclear and radiation safety and security in addressing challenges related to nuclear power programs, with particular focus on capacity building;
- Discuss the role and achievements of the TSO forum and address key components of the TECDOC;

- Present the need for, and benefits of, self-assessment for TSOs to maintain and enhance their technical and scientific capability to support regulatory bodies' decision-making process;
- Discuss the impact on the TSOs safety assessment work and its significant contribution on the continuous update regarding the revision of the IAEA safety standards;
- Address the TSO role in enhancing nuclear and radiation safety in applications other than nuclear power;
- Highlight the main methods to support expertise, including research and development; and
- Facilitate exchange of experience and good practice in capacity building.

6.2 Radioecology in support of regulatory decision making: Conclusions from an international workshop

Jelena Mrdakovic Popic (NRPA) presented.

An international workshop on 'radioecology as a support to regulatory decision making on NORM and other legacies, related waste management and disposal' was organized as a pre-conference event to ICRER 2017 in Berlin. It was a one day workshop, held on 3 September. The workshop was organized jointly by NRPA and SCK·CEN.

Radioecology is very important for regulatory decision-making, providing answers to important questions and issues. It is defined as the study of the behaviour and effects of ionizing radiation and radionuclides in the environment.

Radioecology develops and provides the scientific basis, methods and tools underpinning the guidelines, assessments, remediation actions, compliance checking and post-remediation monitoring. However, independent development of the scientific disciplines, regulations and regulatory mechanisms, as well as management processes, has previously been internationally highlighted as not being optimal for overall efficiency, integration and harmonization.

Two workshops have previously been organized by NRPA to help resolve these issues. The first was held in Bergen in 2008 and the second in Barcelona in 2014. The third workshop was focussed on how radioecology can support regulatory decision-making and had the overall objective of evaluating progress and enabling further linking of radioecology with regulatory needs concerning NORM and other legacies, waste management and disposal.

The workshop was intended as a general forum for discussion and the development of understanding between scientists and regulators on various legacy and waste management issues, and to consider how radioecology can support a more comprehensive approach to addressing legacy issues and associated waste management and disposal.

The workshop was organised around three sessions:

- What can radioecology provide in terms of scientific input that supports the better management of NORM and other legacy sites?
- What are the needs of regulatory bodies and operators in terms of radioecology?
- What practical measures can we recommend to encourage international cooperation for policy development, setting and compliance with standards and the necessary scientific support to address the identified needs?

The workshop was a successful event with much discussion around each session topic. There were 37 participants, including international organizations. The wide international participation in the workshop serves to illustrate the importance of this topic and overall interest around legacy management issues.

The main conclusions from the workshop were as follows:

- The interfaces of science and regulatory decision making, and particularly role of radioecology, were shown in examples of joint international activities and national case studies.
- There is consensus on the need to consider risk from radiation and chemical or physical hazards equitably and in parallel, especially in NORM exposure situations.
- Risk assessment should be holistic, integrative and harmonized (humans and biota, multiple stressors, available tools and guidelines).
- There is a need for further scientific inputs, particularly in relation to:
    - parameterization of key transfer processes;
    - development of dynamic databases, models and tools and dynamic ‘fit-for-purpose’ modelling and model validation;
    - reducing overall uncertainties in risk assessments; and,
    - developing better understanding and reducing uncertainties around particular processes.
- Radioecology is of great support in decsion-making in relation to remediation and decommissioning processes, but further scientific contribution, in terms of innovative and sustainable strategies, methodologies and modelling, is needed.
- There are a number of challenges related to communication of assessment results, doses and risks and associated uncertainties and there is a need for more realistic modelling that would provide more reliable estimated doses and better understanding of uncertainties, taking into account rational but also emotional arguments.
- Stakeholder involvement early in regulatory decision making is important to reduce overall controversy, but more work on how to communicate the decisions is needed.

Ideas for further activities arising from the workshop were that:

- Joint projects involving scientists, regulators and operators could be developed that would be beneficial for all involved.
- Development of holistic approaches for impact and risk assessments (to include both humans and biota, both radiation and chemotoxic hazards) would be very beneficial, enabling harmonization with other regulatory fields.
- Further events could be organized to encourage discussion around the need for suitable and focused radioecology research to support regulatory programs such as the decommissioning of nuclear installations.

A report detailing the presentations, discussions and key conclusions from the workshop has been published (NRPA 2018:2)

6.3 Summary of issues of importance for future collaborative actions in the regulatory supervision of legacies.

Malgorzata Sneve (NRPA) presented.

Observations and preliminary conclusions, based on presentations and discussions, were presented as input to overall workshop discussions.

There were lots of conclusions from the 2015 workshop held in Oslo and it is evident that there has been some progress in addressing these, but many issues remain. One of the conclusions from this workshop was that improved coordination between international organisations and initiatives could be beneficial. During this workshop it has been shown that there are mainly three forum groups working on similar issues, but from different perspectives. No duplication in efforts is observed, but continued dialogue is needed to ensure that complimentary documents are developed from the different perspectives and to avoid any impression of overlapping. It is clear that we should continue to have coordinated dialogue to support complementary document development into the future.

Important messages from the presentations and discussions during the week include the need to ensure prevailing circumstances are taken into account when considering management options for legacies, with each legacy being different. Early engagement with affected people is also important for the management of legacies and how efficient engagement with affected people on legacy issues can be approached is a topic that could be focussed on in more detail.

There have been several examples of legacies not fitting into the national regulatory framework. Legacies can be challenging to regulate and operators need good and clear regulations that are flexible to support the work that is needed to address the issues. Present day planned activities, including remediation, can become tomorrow's legacies and there is a need for formal mechanisms for recognition of legacies within regulatory frameworks. Effective regulation is then needed to avoid the creation of new legacies. However, there will always be continuing risks that changes in circumstances could give rise to many new legacies being created (e.g. through changes in regulatory criteria). Careful consideration is required when evaluating the need for change within regulatory frameworks, as regards the implications for legacy site management.

The need for holistic consideration of contaminated site management and a proportionate approach to risk management has been highlighted by a number of workshop participants. Legacies are seldom limited to radiation hazards; chemical and physical hazards are often co-existing. A good understanding of the environment (prevailing circumstances) is needed, and the different hazards present must be considered in a proportionate way if effective regulation and remediation activities are to be achieved.

End state is important for defining remediation options, but it should be recognised that a staged approach may be needed. In such a case, a long-term management view will need to be taken. The connection between remediation activities and waste management could also be improved.

There were several presentations on decommissioning and remediation and whether these should be considered jointly or separately was raised as a question. Under existing recommendations, it is extremely difficult to consider these jointly, but separate management is difficult. Decommissioning and remediation go hand-in-hand. There may be different issues to be addressed, but as decommissioning of a site progresses it is likely that the need for remediation will be recognised. Practical experience, therefore, shows that decommissioning and remediation cannot be fully separated, which leads to issues around planned and existing exposure situations. Decommissioning would fall under the category of a planned exposure situation and limits and criteria would apply, whereas for remediation, existing exposure situations are present, for which reference levels should be applied. How to regulate such situations can be a particular challenge for regulators.

Challenges that can be faced when addressing legacies include:

- Identifying and assigning responsibilities;
- Applying the framework of protection objectives;
- Applying a holistic approach to legacy management and regulations;
- Having the right scientific support for environmental impact assessment and environmental radiological assessment;
- Management of uncertainties;
- Addressing social and political expectations, noting that the scientifically best solutions may not meet these expectations; and
- Efficient communication of risks and uncertainties and overall stakeholder involvement.

Whether or not there is a need for a formal definition of a legacy has received a lot of discussion. Defining a legacy is difficult and yet, overall, the term is well understood. There is a lot of very useful material available that describes what is meant by a legacy and the working EGLM definition is very useful in that it doesn't explicitly include or exclude anything, but places responsibility on regulators to recognise that there is a problem that needs to be addressed. As such, it was considered best to not have a strict definition as this allows for the flexibility that is required for legacy management. The RSLS working definition, also adopted being sufficient as .

A key issue relating to remediation activities is deciding whether or not it is a planned or existing exposure situation. This distinction of planned or existing is introduced in the new Basic Safety Standards, but it isn't known to what extent these new standards have been (or are being) introduced within national legislation.

Holistic optimisation is key to addressing legacies, but it should be recognised that the solution associated with least harm may not be the preferred option. What is meant by holistic and proportionate (risk) management should be further discussed.

The question of whether or not legacies require, or deserve, their own regulatory framework, i.e. special treatment, has been raised. It may be appropriate to address issues on a site basis rather than delineating into set categories, such as decommissioning, remediation or waste disposal.

It is also important to maintain or put in place measures to defend the independence of the regulator from inappropriate influence. Operators and regulators need to work closely to understand, implement and regulate the various aspects of legacies, but close working can be challenging in terms of maintaining trust in independent action.

Finally, greater transparency is required around decision making processes and communication around decisions, which are particularly important factors when considering stakeholder engagement.

Provisional recommendations, presented to prompt discussion, were that:

- Focused workshops could be organized on particular topics, such as challenges in delivering holistic optimization.

- A standing conference could be set up to maintain momentum for developing improved recommendations and guidance on legacy issues, building from practical experience. The workshop, reported herein, is the second workshop organized by NRPA on the resolution of legacy issues and there has been a notable increase in participation compared with the first workshop in 2015, which illustrates the need for a platform for organizations to discuss, from personal perspectives, and based on practical experience, the management of legacy sites. How momentum can be maintained requires further consideration.
- There may be merit in a study being undertaken to examine the factors affecting uncertainty in agricultural transfer parameters, with focus on some specific soil types of relevance.
- Proposals for international legacy related activities could be developed within a new NEA committee on decommissioning and legacy management. This could also provide the means by which a standing conference could be organized.

7 Overall discussion

There were several recurring themes from presentations and discussions, such as the need for holistic and proportionate approaches for legacy management, flexibility in regulations to allow legacy issues to be addressed, and stakeholder engagement and there was much discussion around these and other topics. Key points from discussions are presented in the sections below. How to illustratively represent the overall process for regulatory supervision of legacy sites, from recognition to resolution was also discussed.

7.1 Holistic and proportionate approach to legacy management

The need for a holistic approach to be taken in the management of legacies was a topic raised on many occasions. What is meant by holistic and proportionate risk management may benefit from further focused discussion.

Various hazards can co-exist at legacy sites, requiring regulation in terms of classic safety and security and to mitigate against human and environmental impacts from chemical and radiation hazards. Holistic assessment and plans require a good understanding of relative hazards, yet there are clear differences in approach to radiation and chemical risk assessments, reflecting different aspects of the systems of protection, such as the concept of references levels for use in existing radiation exposure situations, and the focus on optimization of radiation protection. It is unlikely that these differences can be readily solved, but developing an understanding of what the differences are can help when considering how to make decisions and help in preventing sites from being managed solely with respect to radiation hazards, ignoring chemical hazards or vice versa. To some extent, the problem is exacerbated by the typical separation of the radiation protection and wider human health and environment communities, in both a scientific and regulatory context. Sharing of a clearer and deeper understanding of the systems of protection for chemicals and radiation may also help in incorporating both within a holistic approach.

A holistic approach to the regulation of chemical and radiation hazards has been achieved in Norway, through the Pollution Act. Differences are evident between countries, however, and each Government will have its own view. The need for a holistic approach has been recognized, but addressing this need is challenging; there is no ‘one solution’ that can be recommended.

Nonetheless, some constant lines could be identified and discussed in relation to a legacy site context. For example, irrespective of the national regulatory regime, coordination between regulatory bodies responsible for the regulation of different hazards should be ensured. Furthermore, the need for a flexible regulatory framework that can address a diverse set of circumstances should be emphasized.

Where mixed contamination is present at a site at relatively low levels, there may be challenges in identifying whether or not action is required. For example, risks associated with radiation exposure may be just below a level of concern and, similarly, for chemicals. When considered in isolation, this could support a decision of no action. However, where hazards are considered in combination, remedial action may be justified. This highlights the importance of developing a good overall understanding of the prevailing circumstances.

In addition to cooperation between regulatory bodies, dialogue is also important between regulators and operators as well with engineers and scientists. Dialogue with operators will help ensure that regulators are aware of the situation and particular challenges. Dialogue with engineers and scientists will help:

- address key knowledge gaps,
- reduce key technical uncertainties,
- inform proportionate management of the different hazards present at a site,
- support development of regulatory guidance to addressing those hazards
- and open the door to innovative solutions.

A holistic approach is often discussed in terms of the different hazards that require management at legacy sites. The term also applies, however, to the approach from recognition to resolution. For example, once a situation has been identified and characterized and the need for remediation identified, consideration needs to be given to the management of the wastes arising from remediation activities. Regulations relating to radioactive and hazardous wastes should be taken into account in developing optimized remediation plans. Furthermore, decommissioning and remediation often go hand-in-hand (discussed in Section 7.2) and a holistic approach to both would be beneficial, recognizing that there would be regional differences.

7.2 Planned (decommissioning) and existing (remediation) exposure situations

IAEA GRS Part 3 covers exposure groups and exposure situations. For the operation of facilities, hard dose limits are applied. Dose constraints may also be applied where other facilities are present in the area that may add to radiological exposures.

For planned exposure situation activities, protection of people and the environment is optimized prior to the commencement of activities. Restrictions are therefore put in place from the outset with flexibility being in the optimization process such as considering the technology to be applied, in siting, and in the operational procedures and training of personnel. Dose limits are applied that represent the maximum dose that would be accepted in any such planned situations by regulatory authorities. Exceedance of a dose limit implies the breech of a regulation.

In emergency and existing situations, the situation is initially not under control and decisions are required on what can be done to bring the situation back under control. A range of reference level values are therefore proposed to provide flexibility. The reference level should be set in consideration of the prevailing circumstances, and is intended as a reasonable, situation-dependent, target. It is clear however, that there are issues around how to select an appropriate reference level, i.e. what can be considered as 'reasonable'? The principles of optimization and justification are important parts of the process, but available guidelines are not clear on the level of optimization that would be considered reasonable and on justification in terms of how far one should go; complete removal of contamination is not implied with regard to remediation. A reference level needs to be set in light of the prevailing circumstances and be commensurate with risk, with risks from different hazards being addressed proportionately. If, following the implementation of an optimized protection strategy, it is subsequently shown that a reference level is exceeded, the reasons for this should be investigated, but this fact alone should not necessarily prompt regulatory action.

Decommissioning falls within a planned exposure situation. Activities are planned prior to commencement and relate to a defined end state. As more information is gained, the plan may be refined throughout the decommissioning process. Nonetheless, a clear endpoint is set and worked towards. Decommissioning is the transition between a planned situation and one where regulatory control is no longer necessary (although restrictions may apply depending on the end state).

Remediation falls within an existing exposure situation. Activities are undertaken to bring an out of control situation back under control. However, there may be aspects of decommissioning activities that require remediation. An example could be a uranium mine with buildings under disrepair, requiring decontamination and the removal of structures. This situation may not have been planned (e.g. due to out of date regulation) and, hence, would not fall within the category of decommissioning, but would, rather, be remediation. The need for remediation on decommissioning sites may result in both planned and existing exposure situations co-existing.

Although remediation activities are used to address existing exposure situations, nevertheless, the activities undertaken are planned. The question therefore arises as to why dose limits do not apply rather than reference levels. If reference levels, there is a conceptual difficulty around why some activities are associated with higher allowable exposures; why should some activities be 'planned' and others not? The answer is a matter of control; on-site workers can have their work controlled in order to manage exposures and have higher dose limits set relative to members of the public. For an existing exposure situation, a reference level relevant to that situation should be defined for members of the public. This can lead to communication problems, however. For example, a reference level for members of the public could be set at a higher level than the acceptable dose for workers and stakeholders may challenge the justification behind their acceptable exposure being greater than workers who benefit through payed employment. Communicating the difference between dose limits and reference levels can therefore be challenging.

Not all Member States are implementing the new basic safety standards three exposure situation system. Indeed, majority of regulatory bodies are still using the previous system of planned situations and interventions. To implement the new system would require changes to national legislation.

7.3 Safety and security

Safety and security were not discussed to a great extent, but it can be recognized that there are different opinions as to whether they should be considered together or separately. One argument for considering together, in the context of legacies, is the need to consider disposal sites for contaminated material removed during remediation activities. If a holistic approach is taken to the overall management of legacies, both safety and security need to be considered in relation to disposals. To consider separately would not fit within the concept of being holistic.

Safety and security are also very important considerations when dealing with radioactive sources. To ensure safety, dissemination of information may be beneficial. However, to ensure security, information should remain hidden.

7.4 Practical and flexible regulations

Practical regulations are needed that are flexible to allow the prevailing circumstances at any legacy site to be taken into account when deciding on management options.

Regulations relating to planned exposure situations should stipulate limits on acceptable risk or dose with science then supporting implementation by addressing uncertainties in assessment parameters and risk estimates. The setting of a constraint within the limit offers room for flexibility, typically something below 1 mSv in a year, but not as much flexibility as in the case of reference levels applied in existing exposure situations, which may range up to 20 mSv/y.

The use of risk allows other elements of risk to be compared with radiation risks, so long as the risks are assessed in a commensurate manner.

Residual risk and consequence are very site-dependent considerations; what may be acceptable for one site may not be in another. The regulation of sites should therefore consider potential consequences and risks that drive remediation and determine the endpoint rather than being fixed according to the level of radioactivity present.

A prescriptive approach to legacy management is not useful; the regulatory system needs to remain flexible.

7.5 Terminology: 'Legacies', 'existing exposure situations' and other common terms

There is a lot of evidence to show that a single definition of legacy is not likely to be helpful in all circumstances. This is linked to the use of the term in many different ways, including legal frameworks. There already exist useful descriptions of the characteristics of a legacy, the type of site (area and installations) under consideration, but none of these should considered as exclusive or comprehensive. The following working definition is offered when a short description of a legacy is needed, based on discussion in the IAEA RSLS and NEA EGLM forums: i.e. that a legacy site is, from ***a radiological and*** regulatory perspective as:

> *a site that has not completed remediation, and*
>
> *that has radioactivity that is of concern to the regulator.*

Areas affected by past practices, which is a type of existing exposure situation may be a more helpful term in some circumstances, by identifying situations for which remediation activities may be required. Existing exposure situation is ''a situation of exposure that already exists when a decision on the need for control needs to be taken'' (IAEA, 2016). Relevant to legacies, the draft IAEA document DS468 says that this could include areas affected by residual radioactive material from past practices that were not subject to regulatory control or not subject to regulation in accordance with current standards, such as those of the international Basic Safety Standards (IAEA, 2014). Clarification on what else might count as modern standards could be useful, bearing in mind that many sites appear to present combinations of existing and planned exposure situations, even in the same location on site.

Decommissioning and remediation have different objectives, but experience shows that achieving those objectives may involve similar activities which need to be complementary/harmonized. Therefore, the development of international-level recommendations on remediation, based on practical experience would be useful, particularly with regard to improving regulation of decommissioning sites.

The term ‘environment’ is frequently used in the context of legacy management. In the IAEA Safety Glossary (2016) it is very broadly defined term encompassing not only plants and animals, but also includes conditions, in general, that are affected by and affecting humans. However, assessments to demonstrate environmental protection tend to focus on populations of non-human biota, but resources can also be important, such as water resources, and the environment occupied and/or used by humans. It would be useful to have further discussion on experiences and understandings what is meant by environmental protection in terms of legacies to inform on what aspects should be considered.

Another commonly used term is contamination. The common understanding of contamination is associated with something which is harmful and/or does not meet safety requirements or is otherwise degraded in quality. The IAEA definition is “radioactive substances on surfaces, or within solids, liquids or gases (including the human body), where their presence is unintended or undesirable, or the *process* giving rise to their presence in such places” (IAEA, 2016). It does not include residual radioactive material remaining at a site after the completion of decommissioning. In the IAEA safety standards, the term contamination gives no indication of the magnitude of the hazard involved. Caution is necessary in using the term contamination in communicating with stakeholders, as it could lead to misunderstanding. For example, the ready detectability of radiation, could lead stakeholders to understand, correctly, that radioactivity is present, and, given the IAEA description, that radioactive contamination is therefore present. This may, in turn, imply that there is some harm associated with that presence, even where that is not the case.

It is desirable that internationally recognized definitions for terms like those considered in this section should be constructed so as to be consistent with common understanding for those terms, even if there is some additional technical explanation.

7.6 Stakeholder engagement and communication

It is important when addressing legacies that uncertainties are acknowledged and that the rationale behind decisions is clearly expressed. Whilst stakeholders may not all agree with the decisions made, they are more likely to trust the judgement of those making decisions where the decision-making process is transparent. Early engagement with affected people is likely to be respected as constructive and form the basis for trusting and long-lasting relationships.

There are a number of examples where the management of legacies could have been improved through better stakeholder engagement. There may therefore be merit in sharing practical on stakeholder engagement experience, both good and bad. Whilst it is generally easy to identify what hasn’t worked, identifying what worked well, and why, can be more difficult. How to effectively engage with affected people on legacy issues could also be a useful topic for further discussion.

The sharing of experience was considered a very good suggestion. In the USA there is diverse interaction with stakeholders and the sharing of experience could help in bringing home the point that there is no single answer; thought should be given to the perspectives of different stakeholders and the timescale over which engagement is anticipated to last. Where timescales for a project run into tens of years, individual stakeholders may change and different views may therefore be brought into the mix.

Communicating the rationale behind dose criteria that are applied to situations can also be complex and the development of communication strategies can be very useful in ensuring the correct messages are conveyed to the affected population and the media. There is a lot of experience internationally on communication with affected populations and the sharing of this knowledge could be very beneficial in supporting countries in developing national strategies. Development of effective communication strategies could therefore be an interesting discussion topic for future workshops.

Experience from Fukushima Daiichi accident has highlighted the problem of disposal of contaminated material resulting from remediation activities. There are multiple landowners around the nuclear power plant and engagement is needed to identify a disposal site and this has been challenging. Whilst members of the public may appreciate that land may be needed for alternative uses, getting agreement for what could be seen as 'land misuse' may be more challenging. Stakeholder engagement is considered significant, but thought must be given on how to effectively communicate on the different aspects and issues relating to land use, contamination and disposal since viewpoints may be very different.

The involvement of scientists can be beneficial, with experience showing that, for some stakeholders, there can be greater trust in the science than there is with regulators and government agencies. This has been demonstrated in the US DoE experience in the Marshall Islands where members of the public wanted to hear scientific rather than regulatory views. At Rocky Flats in the USA, concerned stakeholders obtained funding for independent consultants to undertake assessments upon which their own decisions could be based. There has been similar experience in Russia where stakeholders have required scientific backing for decisions. Some boundaries should therefore be maintained between regulators and science to ensure that independence is maintained alongside public confidence. There should also be a clear distinction between those making suggestions and developing proposals and those with ultimate responsibility for making decisions to ensure there is separate and independent scrutiny of proposals.

It can be useful to explain to stakeholders during conceptual stage as to when they will be invited to engage in the process and what their roles are at each stage. During the very initial stages there can be the greatest uncertainty as the circumstances are typically not sufficiently characterized to allow robust decisions to be made. Any plans for addressing the issues are necessarily preliminary. By engaging early, stakeholders can be made aware that large uncertainties during the early stages can be beneficial in that there are greater opportunities for their views to inform decisions on options and endpoints.

7.7 Illustrating the process for regulatory supervision of legacy sites, from recognition to resolution

An illustrative figure to depict the process for regulatory supervision of legacy sites, from recognition to resolution was presented by Malgorzata Sneve (see Figure 2-1). The figure aims to illustrate the fact that activities roll across the entire process from recognition to resolution and that these activities should be planned, holistic, feasible and innovative. The need for action may not always be driven by regulations; actions may be driven by the Government or other stakeholders. This could result in the scientific and/or technical basis behind actions being more obscure, with decisions being informed by alternative drivers. For example, political and/or wider stakeholder views may drive for different remediation activities to be undertaken than would be supported through the normal regulatory decision-making process.

Figure 2-1 does not currently capture the role of TSO's and thought needs to be given as to how to capture their role. This could be as simple as revising 'regulator' and 'operator' to 'regulator and TSO' and 'operator and TSO'. Alternatively, a new colour band could be added for science and technical support.

In recognising that a situation exists and that there is a need for action, it is important to recognize that circumstances will evolve. A 'bubble' of circumstances could therefore be incorporated. People react to circumstances and this drives decisions.

8 Conclusions and recommendations from the workshop and proposals and ideas for future work

The number of participants at the workshop from many different organizations worldwide clearly illustrates the importance and interest around the topic of legacy site managament. Side workshops for NEA EGLM and ICRP TG98 also helped to encourage participation and provided an important opportunity to draw together different interested parties for discussion and sharing of practical experience.

8.1 Workshop conclusions

From the various presentations and discussion at the workshop, the following recommendations and conclusions are drawn:

- To address legacies, practical and flexible regulations are needed that allow prevailing circumstances to be taken into account when deciding on management options, applying a risk based approach. Decisions on practical component can benefit from the experience acquired from managing different kind of legacy sites.
- Residual risks and related radiation exposures are site-dependent considerations; what may be acceptable for one site may not be in another. Thus, remediation actions should be case specific and dependent on relevant considerations and flexible reference levels established by regulators.
- Holistic approaches that consider remediation in it whole life-cycle, are needed to address the various hazards at legacy sites, from initial recognition through to full resolution. This includes means by which options for addressing hazards may be prioritized. Cooperation between those responsible for regulating different aspects is important. Finally, remediation options shall be aligned with management strategies for material generated during remediation, including waste. There are many uncertainties and challenges associated with holistic management of legacies. Further targeted discussion around these uncertainties and challenges would be very useful in supporting the development of holistic management approaches.
- Countries should establish a proper system for an active society engagement that would encompasses communication as well consultations between relevant institutions and

parties in society. In such a way, mechanisms for providing a necessary information flow and constructive and complementary collaboration would be in place prior to being needed. The development of such 'routine' communication systems should therefore be encouraged.

- Dialogue between operators, implementers, regulators and researchers should be further encouraged to ensure a common (both-direction) understanding of legacy issues and the regulatory requirements and scientific results of importance for this broad topic. Research activities should focus on key issues that affect decisions, rather than the full range of knowledge gaps, which would be endless. The purpose is to reduce uncertainties sufficiently to allow a robust decision can be made.
- In the scope of environmental aspects, decommissioning and remediation are operations with same objectives although practically they involve somewhat different, usually closely linked activities. The development of recommendations at an international level, based on practical experience, that supports a more holistic approach that encompasses decommissioning and remediation activities, as needed, would be beneficial. This should include guidance on the application of the framework for radiological protection, in terms of planned, existing and emergency exposure situations, to remediation activities on decommissioning sites, including the setting of reference levels and other relevant criteria, and consultation and communication around reference levels and dose limits and constraints for workers and the public.
- Technical and scientific support in developing management options for legacies, and in building confidence among stakeholders is very important and enhanced dialogue should be encouraged.

8.2 Future work

The following future work activities have been identified:

- Develop an understanding of the different chemical and physical hazards and radiation risks to help make decisions in a holistic way and help in preventing sites from being managed solely with respect to radiation hazards, ignoring other types of hazards or vice versa;
- Consider the harmonized application of the concepts of remediation and decommissioning at legacy sites? This is particularly important at sites where decommissioning plans need to incorporate remediation or clean-up of unplanned contamination from spills and leaks, but also where facilities were designed and operated without any consideration of future decommissioning.
- Explore stakeholder engagement practical experience to determine what has worked well according to some identified criteria for 'working well' and, what has not, and why; and, from this, discuss how engagement with affected people can be approached to support the effective management of legacy issues.
- Developments in communication and consultation strategies and lessons learned could be an interesting discussion topic for a future workshop. Communication of protection objectives and criteria to meet them (e.g. dose the difference between dose limits and reference levels) could also be a useful topic for further discussion. Greater focus is needed on mechanisms to support stakeholder engagement and it could be beneficial to involve social scientists in discussions on this topic.

- There could also be value in working together to find a common understanding of the meaning of some commonly key terms, such as environment, contamination, exposure, hazard, risk, impact, consequences, harm and end-state. Since many of these terms already have legal and /or technical definitions, the discussion should avoid prescription but nevertheless help in the wider communication of the issues.

9 References

IAEA (2014). Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, Safety Standards Series No. GSR Part 3. International Atomic Energy Agency, Vienna.

IAEA (2016). IAEA Safety Glossary: Terminology used in nuclear safety and radiation protection. 2016 revision. (http://www-ns.iaea.org/downloads/standards/glossary/iaea-safety-glossary-rev2016.pdf.) last accessed 20.03.2018.

ICRP (2009). Application of the Commission's Recommendations to the Protection of People Living in Long-term Contaminated Areas after a Nuclear Accident or a Radiation Emergency. ICRP Publication 111, Ann. ICRP 39 (3).

ICRP (2013). Radiological protection in geological disposal of long-lived solid radioactive waste. ICRP Publication 122, Ann. ICRP 42(3).

ICRP (2014a). Radiological Protection against Radon Exposure. ICRP Publication 126, Ann. ICRP 43(3).

ICRP (2014b). Protection of the Environment under Different Exposure Situations. ICRP Publication 124, Ann. ICRP 43(1).

NRPA (2015). Comparison of Safety and Environmental Impact Assessments for Disposal of Radioactive Waste and Hazardous Waste. Report of an International Workshop. StrålevernRapport 2015:8. Statens strålevern, Østerås.

NRPA (2018). Radioecology as a support to regulatory decision making on NORM and other legacies, related waste management and disposal. Report of an International Workshop. StrålevernRapport 2018:2. Statens strålevern, Østerås.

OECD/NEA (2016). Strategic considerations for the sustainable remediation of nuclear installations. Organisation for Economic Co-operation and Development, Nuclear Energy Agency, NEA No. 7290.

Shishkina E.A., Pryakhin, E.A. Popova I.Ya, Osipov D.I., Tikhova Yu, Andreyev S.S., Shaposhnikova I.A., Egoreichenkov E.A., Styazhkina E.V., Deryabina L.V., Tryapitsina G.A., Melnikov V., Rudolfsen G., Teien d , H.-C., Sneve M.K., Akleyev A.V. (2016). Evaluation of distribution coefficients and concentration ratios of ^{90}Sr and ^{137}Cs in the Techa River and the Miass River. Journal of Environmental Radioactivity 158-159. P. 148-163.

Sneve M K et al (2015). Radiation Safety during Remediation of the SevRAO Facilities: 10-year Regulatory Experience *J. Radiol. Prot.* **35**(3) 571-596.

Wilson J.C., Thorne M.C., Towler G. and Norris S (2011). Illustrative assessment of human health issues arising from the potential release of chemotoxic substances from a generic geological disposal facility for radioactive waste. Journal of Radiological Protection, **31**, 411-430.

Appendix A. List of Participants

The workshop participants and their affiliations are detailed in the following table.

Surname	First name	Organisation	Country
Griffiths	Hefin	ANSTO	Australia
Pavlov	Dzmitry	Gosatomnadzor	Belarus
Tesanovic	Zoran	State Regulatory Agency for Radiation and Nuclear Safety	Bosnia and Herzegovina
Tkaczyk	Alan	University of Tartu	Estonia
Kallio	Antti	Radiation and Nuclear Safety Authority of Finland (STUK)	Finland
Blardat	Francine	IRSN	France
Gellermann	Rainer	Nuclear Control & Consulting GmbH	Germany
Ben Ouaghrem	Karim	IAEA	IAEA
Kinker	Monika	IAEA	IAEA
Monken Fernandes	Horst	IAEA	IAEA
Yankovich	Tamara	IAEA	IAEA
Hashizume	Haru	Obayashi	Japan
Takeda	Seiji	Japan Atomic Energy Agency	Japan
Baigazinov	Zhanat	Institute of Radiation Safety and Ecology NNC RK	Kazakhstan
Kim	Alexandr	Nuclear Technology Safety Center	Kazakhstan
Lukashenko	Sergey	Institute of Radiation Safety and Ecology NNC RK	Kazakhstan
Tolongutov	Baigabyl	State Regulation Centre of the Environmental Protection and Ecological Safety	Kyrgyz Republic
Andersen	Morten Sand	Tolk	Norway
Dysvik	Solveig	Norwegian Radiation Protection Authority	Norway
Espeland	Maria Kim	Tolk	Norway
Varpen Holmstrand	Marte	Norwegian Radiation Protection Authority	Norway
Mrdakovic Popic	Jelena	Norwegian Radiation Protection Authority	Norway

Oughton	Deborah	CERAD/NMBU	Norway
Salbu	Brit	CERAD/NMBU	Norway
Siegien-Iwaniuk	Katarzyna	Norwegian Radiation Protection Authority	Norway
Skipperud	Lindis	CERAD/NMBU	Norway
Sneve	Malgorzata	Norwegian Radiation Protection Authority	Norway
Ciambrello	Massimo	OECD Nuclear Energy Agency	OECD/NEA
Lazo	Edward	OECD Nuclear Energy Agency	OECD/NEA
Bobrov	Aleksandr	Burnasyan Federal Medical Biophysical Center	Russia
Bragin	Iurii	Burnasyan Federal Medical Biophysical Center	Russia
Burtovaia	Elena	Urals Research Center for Radiation Medicine	Russia
Chizhov	Konstantin	Burnasyan Federal Medical Biophysical Center	Russia
Filonova	Anna	Burnasyan Federal Medical Biophysical Center	Russia
Karpikova	Liudmila	FMBA of RUSSIA	Russia
Kiselev	Sergey	Burnasyan Federal Medical Biophysical Center	Russia
Kotova	Nadezda	Urals Research Center for Radiation Medicine	Russia
Kryuchov	Victor	Burnasyan Federal Medical Biophysical Center	Russia
Lavrinovich	Andrey	Rostechnadzor	Russia
Priakhin	Evgenii	Urals Research Center for Radiation Medicine	Russia
Salynkin	Sergey	FMBA of RUSSIA	Russia
Semenova	Maria	Burnasyan Federal Medical Biophysical Center	Russia
Seregin	Vladimir	Burnasyan Federal Medical Biophysical Center	Russia
Shandala	Nataliya	Burnasyan Federal Medical Biophysical Center	Russia
Shcheblanov	Victor	Burnasyan Federal Medical Biophysical Center	Russia
Shinkarev	Sergey	Burnasyan Federal Medical Biophysical Center	Russia
Simakov	Anatolii	Burnasyan Federal Medical Biophysical Center	Russia
Titov	Alexey	Burnasyan Federal Medical Biophysical Center	Russia
Patton	Nina	Scottish Environment Protection Agency	Scotland
Brajic	Branko	Serbian Radiation Protection and Nuclear Safety Agency	Serbia
Velinov	Sladan	Serbian Radiation Protection and Nuclear Safety Agency	Serbia
Källström	Klas	Svensk Kärnbränslehantering AB	Sweden
Wijk	Helene	Swedish Radiation Safety Authority	Sweden

Clark	Anna	Nuclear Decommissioning Authority	UK
Punt	Adrian	RadEcol Consulting Ltd.	UK
Simon	Morgan	Office for Nuclear Regulation (UK)	UK
Smith	Karen	RadEcol Consulting Ltd.	UK
Smith	Graham	GMS Abingdon	UK
Wilson	James	Quintessa Ltd.	UK
Dem'ianiuk	Vitalii	NT-Engineering LLC	Ukraine
Dybach	Oleksii	State Enterprise "State Scientific and Technical Center for Nuclear and Radiation Safety (SSTC NRS)	Ukraine
Boyd	Michael	U.S Environmental Protection Agency	USA
Worthington	Patricia	U.S. Department of Energy	USA

Appendix B. Workshop Programme

21 November 2017

Official welcome – NRPA, Norway

Session 1: International perspectives and current regulatory supervision of legacies

Malgorzata K Sneve, NRPA, Norway
- International Cooperation on Regulatory Supervision of Legacies: Overview of Norwegian activities

Michael Boyd, ICRP and EPA
- ICRP approach to legacy management: TG 98 progress

Tamara Yankovich, IAEA
- Update of IAEA DS468

Edward Lazo, OECD NEA
- EGLM working progress: status update

Anna Clark, NEA, UK
- Do legacy sites deserve special treatment

Horst Monken-Fernandes, IAEA
- Determination of Site End-State in Environmental Remediation – The IAEA ENVIRONET-DERES Project

Patricia Worthington, US DoE
- US approach to legacy management, Hanford process

Monika Kinker, IAEA
- Introduction to the International Forum for the Regulatory Supervision of Legacy Sites (RSLS)

Session 2: Methodologies for legacy regulation and management including long term site management and on-site disposal

Brit Salbu, CERAD/NMBU, Norway
- Why is Basic Radiecological research relevant to regulators?

Natalia Shandala, FMBC, Russian Federation
- Scientific and practical achievements in the field of regulatory supervision during remediation of nuclear legacy sites in the Russian Northwest

Simon Morgan, ONR, UK/to be confirmed
- Recent developments in the regulation of the final stages of decommissioning and clean-up of nuclear sites in the UK

Sergey Lukashenko, Institute of Radiation Safety and Ecology, Kazakhstan
- On the need to revise the parameters of radioactive contamination of the territory resulted from the past industrial, military and nuclear activities

Andrey Lavrinovich, Federal Environmental, Industrial and Nuclear Supervision Service of Russia
- Regulatory Aspect of Safety of the Legacy Sites in the Russian Federation

Haru Hashizume, Obayashi Corp., Japan

- Fukushima Remediation Update

Oleksii Dybach, SSTC NRS, Ukraine

- Safety Review of the Legacy Sites: Applicable Regulations, Guidelines and National

Dmitry Pavlov, Gosatomnadzor of Belarus

- Regulatory supervision of legacy sites: Belarus experience

22 November 2017

Session 3: Scientific, technical and regulatory aspects for remediation (including safety and environmental assessments, remediation and environmental monitoring) – experiences and lessons learned

Hefin Griffiths, Australian Nuclear Science and Technology Organisation (ANSTO), Australia

- The scientific basis for management of the Little Forest Legacy Site

Adrian Punt, RadEcol Ltd., UK

- An IAEA MODARIA II Working Group 1 Proposed Study to Better Define End States for NORM and Nuclear Legacy Waste Sites

Sergey Kiselev, FMBC, Russian Federation

- Scientific and practical achievements in the field of regulatory supervision during remediation of nuclear legacy sites in the Russian Far East

Seiji Takeda, Japan Atomic Energy Agency, Japan

- Safety assessment for reuse of removed soil derived from the activities for environmental remediation

James Wilson, Quintessa Ltd., UK

- Issues Affecting the Assessment of Impacts of Radioactive and Chemotoxic Wastes

Lindis Skipperud, CERAD/NMBU, Norway

- How to handle multiple stressors in legacy sites?

Alexey Titov, FMBC, Russian Federation

- Radiation Protection of the Population during Remediation of the Uranium Legacy Sites in the Russian Federation and in the Central Asia Countries

Rainer Gellerman, NCC GmbH, Germany

- Radioecology between matter, life and mind: Asse mine case

Vitalii Dem'ianiuk,, NT Engineering LLC, Ukraine

- Ukraine-NATO jointly implemented project: Remediation of contaminated military legacy site (Experience in terrorist threats mitigation projects)

Evgeny Pryakhin, URCRM, Russian Federation

- The importance of the ichthyofauna of radioactively contaminated reservoirs from the point of view of provision of radiation safety

Zhanat Baigazinov, Institute of Radiation Safety and Ecology, Kazakhstan

- Determining limit parameters of radionuclides in soil for producing agricultural products of guaranteed quality

Konstantin Chizov, FMBC, Russian Federation

– Regulatory supervision of nuclear legacy site at Andreeva Bay using the time series analysis methods

Session 4: Social and ethical issues: uncertainties, risk communication and engagement of stakeholders

Deborah Oughton, CERAD/NMBU, Norway

– Societal and ethical aspects of legacy site management

Elena Burtovaia, URCRM, Russian Federation

– Social-psychological aspects of the usage of radioactively contaminated territories of the Urals

Jelena Mrdakovic Popic, NRPA, Norway

– Decision processes and pathways related to NORM legacies: focus on uncertainties, an input to TERRITORIES project

23 November 2017

Session 5: Recommendations for future coordination of international activities and cooperation

Karim Ben-Ouaghrem, IAEA

– Introduction to the EuCAS network and TSO Forum initiatives

Jelena Mrdakovic Popic, NRPA, Norway

– Conclusions from International workshop on Radioecology in Support of Regulatory Decision Making

Malgorzata K. Sneve, NRPA, Norway

– Summary of issues of importance for future collaborative actions in regulatory supervision of legacies

Overall discussion on workshop main conclusions, draft recommendations from the workshop and proposals/ideas for future work

Statens strålevern
Norwegian Radiation Protection Authority

2018

StrålevernRapport 2018:1
Årsrapport 2017

StrålevernRapport 2018:2
Radioecology as a Support to Regulatory Decision making on NORM and other Legacies, Related Waste Management and Disposal

StrålevernRapport 2018:3
Representative doser i Norge - 2017

StrålevernRapport 2018:4
Regulatory Supervision of Legacy Sites: The Process from Recognition to Resolution

ISSN 1891-5191 (online)
ISSN 0804-4910 (print)