

ENVIRONMENTAL REMEDIATION

STRATEGIES & TECHNIQUES FOR CLEANING RADIOACTIVELY CONTAMINATED SITES

BY W. EBERHARD FALCK

Actions for a cleaner and safer environment have risen on social and political agendas in recent years. They include efforts to remediate contaminated sites posing a radiological risk to humans and the surrounding environment.

Radiological risks can result from a variety of nuclear and non-nuclear activities. They include:

- nuclear or radiological accidents;
- nuclear weapons production and testing;
- poor radioactive waste management and disposal practices;
- industrial manufacturing involving radioactive materials;
- conventional mining and milling of ores and other production processes, e.g. oil and gas production, resulting in enhanced concentrations of naturally occurring radioactive materials (NORMs).

The IAEA has developed a comprehensive programme directed at the remediation of radioactively contaminated sites. The programme collates and distributes knowledge about contaminated sites; appropriate methods for their characterization; assessment of their potential environmental and radiological impact; and applicable methods for their clean-up, following internationally recommended safety criteria. The overall

objective is to enable regions in the world with restricted resources, and which are technologically less advanced, to focus their efforts and chose appropriate strategies for the abatement or removal of exposure to radiation. An important aspect is the intention to "close the loop" in the nuclear fuel cycle in the interests of sustainable energy development including nuclear power.

Such activities involve many interrelated factors, including the legal and institutional framework, prevailing socio-economic conditions, and the need to balance technology performance and risk reduction within fixed and limited budgetary resources. A central aspect is that the overall efficiency of a remediation project is of particular importance and not just the effect of the physical remediation effort itself.

Public perceptions of the remediation process and its results can be of overruling importance in project development, as they invariably influence strategic and technical decisions. Cost-benefit assessments vis-a-vis the availability of resources over time have a decisive influence. Underlying rationales and incentives for remediation, which may be of an economic nature -- such as future land use -- or ethical considerations, also need to be included.

Factors Influencing Decisions on Remediation Practices. The remediation of sites with radiologically relevant contamination is justified on the basis of guidance and criteria set out by the IAEA and the International Commission on Radiological Protection (ICRP). Within this framework, a wide variety of technical options may be available, ranging from a "do nothing" option to a full-scale removal of the contaminant, depending on the extent of contamination.

Proper accounting for all factors affecting the outcome of an environmental remediation project enables finding an optimum solution for a given knowledge base that will satisfy the societal goals and add value to the project itself. A formal approach to evaluating available technologies and their applicability -- and accounting for variables and factors influencing the decision-making process in technology selection -- will increase transparency and, hence, the likelihood of all stakeholders accepting its outcome. The process is also indispensable for ensuring up-to-date quality control and assurance procedures. As a

Mr. Falck is a staff member in the IAEA Waste Technology Section, Division of Nuclear Fuel Cycle and Waste Management.

IAEA DOCUMENTS & ACTIVITIES ON ENVIRONMENTAL REMEDIATION

SAFETY	MANAGEMENT	DATABASES	TECHNOLOGY	SPECIAL TOPICS
Cleanup of Areas Contaminated by Past Activities & Accidents - Safety Requirements document in preparation	<i>Factors for Formulating a Strategy for Environmental Restoration</i> TECDOC-1032	<i>A Directory of Information Resources on Environmental Restoration</i> TECDOC-841	<i>Technologies for the Remediation of Radioactively Contaminated Sites</i> TECDOC-1086	Technologies for Long Term Stabilization & Isolation of Uranium Mill Tailings TECDOC in preparation
Management of Radioactive Waste from Mining & Milling of Ores - Safety Guide in preparation	<i>Characterization of Radioactively Contaminated Sites for Remediation Purposes</i> TECDOC-1017	Directory of Radioactively Contaminated Sites TECDOC in preparation	<i>Technical Options for the Remediation of Groundwaters</i> TECDOC-1088	Environmental Contamination by NORMs and Relevant Abatement Measures TECDOC in preparation
Monitoring & Surveillance for Ensuring the Radiological Safety of Residues from Mining and Milling of Uranium/Thorium - Safety Report in preparation	<i>Compliance Monitoring for Remediated Sites</i> TECDOC-1118	Restoration Costs TECDOC in preparation	<i>Site Characterization Techniques Used in Environmental Restoration</i> TECDOC-1148	Remediation of Sites Contaminated by Hazardous and Radioactive Substances TECDOC in planning
	Factors Impacting on Environmental Restoration Practices TECDOC in preparation		Remediation of Sites with Low Levels of Radioactive Contamination TECDOC in planning	

IAEA publications are available from the IAEA Division of Conference and Document Services. Email: sales.publications@iaea.org. Also see the WorldAtom web site at <http://www.iaea.org/programmes/ne/nefw/nefwpubl.htm>

consequence, the technology and strategy selected may not necessarily be the best in a purely technical sense, but also takes social and economic considerations into account.

There is a considerable divergence of thoughts, however, on the methods for the formal incorporation of all these factors. The methods used range from a straightforward reliance on experts' opinion, through qualitative ranking, to complex quantitative multi-variate option assessments. Quantitative assessments often require a common denominator and the conversion of non-numerical properties into numerical categories for the purpose of comparison. There exists a considerable controversy over acceptable conversion methods, mainly due to the often inevitable "monetarization" of ethical values.

The factors influencing the decision-making processes in technology selection for

environmental remediation are the focus of an IAEA project and a planned technical document will outline possible approaches and concepts.

Scoping the Problem of Contaminated Sites. Although a Herculean task, the IAEA is seeking to create a worldwide Directory of Radioactively Contaminated Sites (DRCS). The DRCS is intended to become a major vehicle for the collection and dissemination of such information via the World Wide Web. Relying on Member States' contributions, the DRCS will provide information on remediation measures undertaken, in addition to basic data on a wide variety of radioactively contaminated sites.

The definition of what constitutes "contamination" continues to be a major obstacle in developing such a directory. Due to the wide variation in national legislation, a unanimous definition of what is "contaminated" is difficult to achieve.

Apart from scientific definitions based on concentration/activity data or dose rates, definitions or classifications may be undertaken for administrative purposes, where wider considerations, including socio-economic and political ones, are taken into account. Having a site listed in an international directory can have significant implications and that is why Member States are sometimes reluctant. For the further development of the DRCS, therefore, a mechanism was adopted, whereby sites are only listed for which Member States officially provide information.

The directory's purpose is not just to be a mere listing of contaminated sites, but to serve as an information source on suitable remediation measures. It also could serve as a role model for similar undertakings on a national level.

Promoting Cost-Effective Techniques. IAEA Member States have quite different levels

of experience and knowledge with respect to remediation of radiologically contaminated sites. The field of environmental remediation has seen rapid advancements over the past decade, adding to the importance of disseminating knowledge about appropriate, efficient and cost-effective methods for clean-up.

Owing to the diversity of the causes and forms of environmental contamination with radionuclides, the technical solutions are varied. Each contaminated environmental medium requires its own approach. Appropriately the IAEA has addressed the problem of contaminated soils and groundwaters, and the monitoring of compliance with pre-set standards and accepted residual contamination levels in dedicated technical documents. (See box, page 21.)

Remediation techniques for sites with well-defined contamination of relatively high concentrations levels are well developed by now. Clean-up and remediation of disperse and relatively low levels of contamination, however, still constitute a challenge when considering factors such as cost and minimal additional disturbance of the environment.

Similar deliberations apply to further lowering the residual contamination following other remedial measures, since the efficiency of most techniques decreases exponentially with the remaining contamination. The probable answers are low-intensity, low-tech and, hence, low-cost solutions. A forthcoming technical document on this subject will collate and review information and performance data on

SUPPORTING STEPS IN BULGARIA

Many Central and Eastern European Countries had uranium mining activities of varying size and importance. While in many countries activities did not develop beyond exploratory digs, in Bulgaria ore quality and reserves enabled establishment of several mines and two mills. However, in the wake of political changes and owing to the falling market price for uranium, mining and milling was abandoned in the mid-1990s. An IAEA technical cooperation project has helped the authorities to establish a radiation monitoring infrastructure and to provide advice for the decommissioning and environmental remediation of the mining and milling sites. Much of the work has focused on the Buhovo mill tailings ponds, which were unstable and released contaminants to the floodplain beneath. The training and advice included expert missions on specific subjects, such as effluent treatment, and a two-week workshop on risk-assessment methodologies for aspects of uranium mining and milling. Participants included not only staff from the responsible ministry departments, but also staff from the former mining company in charge of the actual remediation operation. The IAEA's support and training helped national authorities to better understand and focus the aid provided under umbrellas such as the CEC PHARE programme, which supports much of the actual remediation work now being undertaken.



Photos: Top, mining waste heaps at Buhovo in 1995. Below: the sorption facility at Buhovo in 1995.

APPLYING LESSONS LEARNED FROM GERMANY

The former East Germany was a major supplier of uranium and the second biggest producer in the world until 1990. After the dissolution of the Soviet Union and the unification of Germany, a political decision was taken to stop all mining activities by the Wismut company. Since the IAEA provides technical assistance to developing countries, Germany's experience benefitted the Agency's technical cooperation projects on aspects related to the closure, decommissioning and remediation of the many Wismut mining and milling sites. For instance, Wismut has made staff available for service on IAEA expert missions and receives trainees from IAEA Member States with similar problems. Thus, the IAEA programmes help to disseminate the knowledge and experience gained with the remediation of the numerous open cast and deep mines, and the disposal facilities for mining and milling residues.



Photos: Remediation of the waste rock dump at Hammerberghalde. Top: View in 1960. Middle: View in 1993. Bottom: View in 1997. (Credit: Wismut GmbH).

appropriate techniques and strategies, such as phyto- and bio-remediation, or monitored natural attenuation. The applicability and appropriateness of these technologies and their prerequisites will be discussed in it.

Many sites suffer from both, conventional hazardous and radioactive contamination at the same time. Typically, such

incidences include certain former industrial sites (e.g. NORMs as by-products and in residuals), civilian and defense related nuclear research institutions (e.g. processing solvents), mining and milling sites (e.g. heavy metals and arsenic), and former low-level waste disposal practices (e.g. co-disposal of hazardous and low-level radioactive waste). The specific environmental problems

mainly stem from the interaction between, and the diverse chemical nature and behaviour of the various contaminants, such as heavy metals and radionuclides, both under the existing conditions and in response to the remediation.

A given remediation technique might effect *in situ* fixation or the removal of one contaminant, but at the same

time result in the mobilization of another. The mixed wastes arising from remedial actions might pose an additional technical and administrative problem. Either a disposal route has to be found that accommodates the various contaminants and the legal requirements applicable to them, or the contaminants have to be separated.

These issues are to be addressed in a forthcoming IAEA project that will provide examples for relevant contamination cases and describe the remediation actions taken. These cases will be analyzed with a view to identify the controlling factors and processes. A procedure will be developed, which will help to identify potential problematic combinations of contaminants, and which aims to give guidance on how to handle such problems.

Assisting National Efforts. The IAEA assists Member States in various ways in their effort to assess radiological contamination problems and to clean such sites. In the early 1990s, the IAEA initiated a regional technical cooperation project involving most countries of Central and Eastern Europe with the objective to assess the size and scale of radiation-related environmental problems. This helped to identify problem areas and to better understand individual State needs.

There are two major problem areas which have been, and continue to be, in the focus of interest, namely the lands affected by the Chernobyl accident, and lands affected by uranium mining and milling.

Direct assistance to Member States is provided through technical cooperation projects. In such way, for instance, the Czech Republic, Slovenia and Bulgaria were given assistance to deal with the uranium mining legacy through expert missions, training courses and the provision of monitoring and analytical equipment. (*See box, page 22.*) Under a new project, similar assistance is being given to Portugal.

Member States also participate in Coordinated Research Projects (CRPs) that bring together researchers working on similar problems. Recently, a CRP on site characterization techniques was completed, and a new CRP on techniques for the stabilization of uranium mill tailings was initiated in the year 2000.

A common mode of disposal of uranium mill tailings is in near-surface impoundments in the vicinity of the respective mine or mill. Such impoundments were often arranged in a haphazard fashion, utilizing geomorphological depressions. As a result, there was little or no care taken to isolate the tailing materials from their environment. The hazard of these tailings originates in their residual contents of long-lived radionuclides and other hazardous components, for instance heavy metals and arsenic.

Geomechanical aspects, such as the stability of pile slopes, dikes and retaining dams, are standard engineering problems, and most Member States make provisions for them in the relevant building or mining regulations.

However, environmental and radiological impacts are often neglected. Typical environmental problems are radon emanation and the leaching of contaminants into surface and groundwaters. Based on the objective to keep environmental impacts to a minimum over long time periods, the task of the CRP is to contribute to conceptual and technical solutions that render tailings more inert over prolonged time-spans; that render impounded materials and engineered structures stable over prolonged time spans; that minimize the need for active maintenance; and that are both technically and economically feasible.

Networks of Cooperation. The results of IAEA activities in environmental remediation have been published in a variety of technical documents, and presented at international conferences and meetings. These activities particularly address the needs of less developed Member States, which typically have fewer resources and often little experience in handling a legacy that has arisen under past political and administrative circumstances.

Efforts to bring together experts from all parts of the world through research and technical cooperation projects foster the exchange of knowledge, thus ensuring that adequate strategies and techniques are implemented. As importantly, the transfer of knowledge can help developing countries to better understand and critically evaluate the assistance provided by donor institutions and governments. □