# BALANCING THE URANIUM PRODUCTION CYCLE: CENTRAL ASIA AS A CASE STUDY

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**Abstract**

This paper examines the lessons learned from studies of the status of uranium mining and milling legacy sites in the countries of Central Asia. A review is given of the condition of the sites, of the potential risks associated with them and of the remediation needs. Drawing on experience from around the world, guidance is given on how to avoid some of the problems of the legacy sites when entering into new uranium production programmes.

## 1. URANIUM PRODUCTION LEGACY SITES AND WHAT THEY TEACH US REGARDING MANAGEMENT OF THE URANIUM PRODUCTION CYCLE

### 1.1. Introduction

During the Cold War era, the global uranium production industry generated huge volumes of radioactive mining and processing waste and caused a degradation of land and surface and groundwater resources on an unprecedented scale.

The end of the Cold War coincided with a period of low uranium prices. As a consequence, several of the companies which generated these legacies went out of business, leaving the former production sites unremediated. In most cases, this was because there were no regulations regarding remediation and long term safety and no requirements to deposit remediation funds.

In response to the increase in environmental awareness of this problem, in the period from 1989 to the early 1990s, governments in several countries deployed large scale programmes for mitigating the liabilities caused by the uranium industry. The best known of these programmes are:

The US Department of Energy's Uranium Mill Tailings Remedial Action (UMTRA) Programme;
The Wismut Remediation Programme of the German Federal Ministry of Economics;
Programmes in Canada (e.g. the National Uranium Tailings Programme and decommissioning at Elliot Lake and elsewhere) and Australia (e.g. Rum Jungle);
The European Commission's multi-country Phare pilot projects for remediation of the uranium legacy sites in Central and Eastern European Countries.

### 1.2. Analysis of the unit remediation costs

Taking the year 1992 (i.e. three years after end of the Cold War) as a baseline for comparison, an analysis of the above 'old' remediation programmes provides the remediation costs per unit of 'yellow cake' production, Table 1 [1, 2, 3].

TABLE 1. TOTAL PRODUCTION AND UNIT COSTS OF REMEDIATION PER URANIUM PRODUCTION (IN ORDER OF INCREASING CUMULATIVE PRODUCTION)

| Country | Cumulative production by end of 1992 (metric tonnes of $U_3O_8$) | Unit remediation costs ($ / kg $U_3O_8$) |
|---|---|---|
| Australia | 54 225 | 1.3 |
| Canada | 257 702 | 0.3 |
| Gabon | 21 446 | 1.2 |
| Germany (Wismut) | 232 000 | 22.6 |
| Hungary | 19 970 | 3.7 |
| Namibia | 53 074 | 0.9 |
| Slovenia | 379 | 80.5 |
| South Africa | 143 305 | 0.5 |
| Spain | 3 777 | 11.0 |
| Sweden | 200 | 89.0 |
| USA (UMTRA, Title I) | 56 000 | 32.4 |
| USA (UMTRA, Title II) | 254 000 | 1.0 |

Table 1 indicates that the unit cost of remediation (except for a few outliers) generally decreases with the volume of production. However, a more detailed look reveals that beyond production size, the unit remedial costs are affected by a series of other factors. In the case of large remediation programmes, the indicators are based on average remediation costs, which depend on the range of variation of the individual project costs. For instance, the costs for Uranium Mill Tailings Remedial Action (UMTRA) Project Title I sites in the USA are based on 22 tailings remediation projects (i.e. on a large number of projects dealing with the remediation of the tailings ponds only), the costs of which vary from \$2.6 to \$375 per kg of $U_3O_8$.

The WISMUT Remediation Programme comprised the full scale of uranium mining and processing wastes remediation; it included remediation of underground mines, an open pit mine, waste rock dumps, tailings ponds, area remediation, decommissioning and demolition. The programme costs (approximately US \$6.2 billion) also included compensation for damages caused during the period of production, social mitigation and corporate restructuring.

The mines Rudnik Žirovski Vrh, RŽV (Slovenia) and Ramstad (Sweden) can be used as examples of small projects. At RŽV, approximately 380 t of uranium were produced from 1984 to 1990 and approximately \$36 million was spent on closeout and remediation (until 1992). Accordingly, the unit costs were approximately \$80 per kg of $U_3O_8$. These costs are at the upper end of the unit costs in Table 1. Although the project in Ramstad is comparable in terms of total production (200 t U) and remediation costs (approximately US \$89 per kg of $U_3O_8$), the technical comparison is flawed because Ramstad was an open pit mine and RŽV an underground mine.

Thus, the real unit costs of U production and remediation depend on the characteristics of the specific site and on the design selected and agreed upon (with regulator and stakeholders) for implementation.

## 2. ASSESSMENT OF PRIME LEGACY SITES OF URANIUM PRODUCTION IN CENTRAL ASIA

Based on results and observations during the International Atomic Energy Agency's (IAEA) Technical Cooperation Regional Project on Monitoring and Assessment of the Uranium Production Legacy Sites in Central Asia, 2005–2008, a preliminary expert opinion is provided in Table II on the prime uranium legacy sites in the region. In spite of the IAEA Regional Programme and numerous other international programmes, there is still a shortage of reliable and systematic measurements from the Central Asian legacy sites. For this reason, the characterization and comparison of the legacy sites and facilities cannot be based on 'classical' environmental/radiological impact assessments (EIA). The assessment in Table II goes beyond environmental and radiological aspects, taking into account 'politically' justified remediation criteria as well as cross-boundary and socioeconomic impacts and possible economic benefits from retreatment of legacy waste for recovery of valuable constituents (Au, Ag, Mo, V, rare earth element residues, etc.).

Although qualitative in nature, the structure of Table II follows the principles of risk assessment:

Risk = Likelihood × Consequences
where

Likelihood or probability is
(Frequency of impact) × ((Frequency of failure events) / (Lifetime of waste facility))
Frequency of Impact = How often the release of contaminants occurs

and consequences or impact includes:
Severity (how much contamination is released);
Extent (how many people are affected, size of territory involved etc.);
Duration (of damage, exposure after release and/or cumulative effect of continuous small releases)

TABLE 2. ASSESSMENT OF PRIME URANIUM PRODUCTION LEGACY SITES IN CENTRAL ASIA

| Country: Kazakhstan, Kz | | | |
|---|---|---|---|
| Site and waste facilities | Vulnerability and likelihood of release | Potential impact | Remedial measures needed |
| *Sites in N, E and S Kazakhstan*: | | | |
| Mines, ore and mine waste piles* *(national remediation programme; completion in 2010) | Robust piles; direct radiation and wind erosion prevented by remediation; Seasonal release of contamination into groundwater; Sustainability of remediation results needs regular maintenance; flooded open pit mines left unremediated. | Steady local accumulation of contaminants from seepage and discharge in soil, aquifer(s) and river sediments; Geomechanical damage to open pit mines; Contaminated water left in open pits; Seasonal exposure of summer house residents using contaminated water for irrigation. | Assess contamination release via water pathway; Establish long term monitoring and maintenance programme. |
| *Koshkar Ata*: | | | |
| Tailings pond (TP) on the Caspian Sea, near Aktau | Stable TP; Contaminants release due to dusting from the dry tailings surface; Hydrogeology of site prevents leakage from TP; Scrap metal scavenging prevented by a concrete cover in parts of TP. | Local accumulation of contamination in soil due to continuous dusting; No public exposure due to long distance from Aktau; TP is an obstacle to development of town to a seaside resort. | Assess contamination release via air pathway; International peer review prior to remedial works. |
| *Stepnogorsk TP at Aksu*: | | | |
| 3 compartments filled to 95% with legacy tailings | TP in operation and under operational monitoring; Contaminants release from the dry tailings surface due to dusting; Responsibility for legacy tailings unclear. | Local accumulation of contamination in soil due to continuous dusting, occasional seepage and leakage through base of TPs; Leakage from TP does not reach the deep groundwater; No public impact. | Assess contamination release via air pathway; Enforce legal commitment to legacy remediation. |

| Country: Kyrgyzstan, Kg | | | |
|---|---|---|---|
| Site and waste facilities | Vulnerability and likelihood of release | Potential impact | Remedial measures needed |
| *Mailuu Suu*: | | | |
| Mine and mine waste, tailings piles | Tailings piles prone to sliding on mountain slopes; some relocated and/or confined;<br>Release probability aggravated due to potential earthquakes. | Threat of damming up of river and contamination of site eliminated;<br>Assessment of radiation exposure insufficient. | Complete remediation in agreement with radiation safety standards. |
| *Ak Tuz*: | | | |
| Mine and mine waste, four tailings ponds | Failure of some TPs likely due to questionable dam stability and neglected maintenance;<br>Water diversion canals not functional;<br>Release probability aggravated by seasonal surface water runoff from mountains and/or earthquakes. | Animal grazing at contaminated site;<br>Potential 'tailings flow' would damage and contaminate the downstream plains;<br>Release would cause radiation exposure of local population;<br>Potential contamination of the transboundary Chu River;<br>Potential dispute with Kz;<br>Potential for tailings re-treatment. | Enforce site security;<br>Perform EIA;<br>Remediate TPs;<br>Regular maintenance and monitoring;<br>Retreatment to be made conditional on remediation. |
| *Min Kush*: | | | |
| Mine and mine waste TPs:<br>Tuyuk Suu,<br>Taldy Bulak | Potential acid mine drainage (AMD) may enhance contaminants release in mine water discharge;<br>Tuyuk Suu: Probability of overtopping and loss of containment likely due to a landslide, seasonal surface runoff from the mountains and earthquake;<br>Taldy Bulak: Failure of crucial drainage pipe under load of tailings and seasonal mountain runoff without regular maintenance very likely. | Increased contamination due to AMD would limit use of mine water for irrigation;<br>Potential 'tailings flow' after dam failure at Tuyuk Suu would damage and contaminate the river valley below Min Kush;<br>Radiation exposure of population at Min Kush mainly due to use of radioactive ash for insulation of houses;<br>Potential tailings release at Taldy Bulak would contaminate a small, uninhabited mountain valley. | Testing for AMD potential; EIA;<br>Feasibility study of Tuyuk Suu remediation options:<br>(a) in situ remediation with regular maintenance<br>(b) relocation of tailings<br>Taldy Bulak: thorough maintenance programme |
| *Orlovka*: | | | |
| TPs | Water diversion canals not functional;<br>Stability of TP Burdinskoye questionable. | Potential tailings release would damage and contaminate the transboundary Chu River;<br>Potential dispute with Kz;<br>Potential for tailings re-treatment. | EIA;<br>Feasibility study of remediating TP Burdinskoye;<br>Monitoring and maintenance;<br>Retreatment conditional on remediation. |

| Country: Tajikistan, Tj | | | |
|---|---|---|---|
| Site and waste facilities | Vulnerability and likelihood of release | Potential impact | Remedial measures needed |
| *Degmay (near Chkalovsk)*: Tailings pond (TP) | Dry tailings surface exposed to wind erosion;<br>Leaky base of TP and steady release of contaminants. | Steady local accumulation of contaminants in soil due to continuous dusting;<br>Continuous leakage of contaminants in groundwater Extensive contamination of aquifer(s);<br>Downstream distance to Syr Darya River 9 km;<br>Radiation exposure of local population due to use of contaminated groundwater, scavenging of scrap metal and animal grazing on contaminated site;<br>Potential disputes with Uz due to contamination of transboundary Syr Darya River. | EIA; assessment of groundwater contamination and impact on Syr Darya River;<br>Feasibility study of remediating TP;<br>Installation of an up-to-date groundwater monitoring system. |
| *Taboshar*:<br>Open pit mine<br>Mine waste, low grade U-ore pile tailings | Continuous discharge from flooded open pit mine through dewatering tunnels on outskirts of town;<br>Steady erosion of unprotected U ore pile by wind and runoff water;<br>Seasonal release of highly contaminated seepage through damaged and inadequate tailings covers;<br>Potential AMD in tailings would enhance contaminants release. | Continuous exposure of population by use of contaminated discharge from the open pit due to lack of alternatives;<br>Steady accumulation of contamination of the local creeks and flood plains on the site due to release of particulates from pile and discharge from tailings;<br>Potential AMD would fundamentally affect remedial strategy;<br>Animal grazing on-site;<br>Partial use of contaminated materials for construction. | Treatment of water discharging from open pit;<br>Enforcement of site security;<br>Testing of tailings for AMD;<br>EIA;<br>Feasibility study for a complex remediation plan;<br>International peer review prior to remedial works. |

| Country: Uzbekistan, Uz | | | |
|---|---|---|---|
| Site and waste facilities | Vulnerability and likelihood of release | Potential impact | Remedial measures needed |
| *Cherkasar 2*: | | | |
| Mine and mine waste | Abandoned mine works present a safety hazard;<br>Open shaft allows water discharge and radon exhalation;<br>Perimeter wall allows access to site. | Contaminants discharge from shaft into local river;<br>Animal grazing on contaminated site;<br>Use of radioactive materials for construction in town;<br>Economic depression of former mining town. | EIA; assess indoor radon levels;<br>Feasibility study for remediation;<br>Improve site security;<br>Educate local population;<br>Monitor site. |
| *Yangiabad*: | | | |
| Mine and mine waste | Abandoned mine presents a safety hazard and allows water and radon discharge;<br>Uncovered mine waste piles exposed to wind and water erosion. | Contaminants discharge from mine into local river;<br>Potential radiation exposure due to unsecured access to mine and waste rock piles. | EIA;<br>Feasibility study for remediation;<br>Improve site security;<br>Educate local population;<br>Monitor site. |

The assessment in Table 2 shows that the five priority (most risky) legacy sites/facilities in Central Asia are the:

Degmay tailings pond;
Taboshar site;
Tailings ponds No. 2 and 4 at the Ak Tuz site;
Burdinskoye tailings pond;
Tuyuk Suu tailings pond at the Minkush site.

The remediation priorities of these sites/facilities are justified (in addition to the local radiological risk) at Degmay by the ongoing release of contaminants into the groundwater and the closeness of the site to the Syr Darya River, at Taboshar by the extensive use of the contaminated water from the open pit mine by the population, by the high concentration of contaminants released from the low grade uranium ore pile and tailings into the creeks and by the central role the flooded open pit mine would play in any remediation strategy designed for the site. The security of the tailings piles at the Ak Tuz site primarily depends on the water diversion works, which are not functional; the dams at TP2 and TP4 are in a badly deteriorated state and the site is subject to a significant risk of seismic events and excessive water runoff from the mountains. A potential release of tailings in the form of a slurry wave would severely affect the agricultural plains downstream of the site and the transboundary Chu River. The same arguments apply at the Orlovka site and to a lesser degree at the Minkush site.

Only localized impacts can be expected at the Cherkasar and Yangiabad sites. Nonetheless, these sites will ideally also be the subject of a detailed environmental impact assessment and a monitoring and maintenance programme will ideally be established. The major tailings impoundment at Navoi in Uzbekistan, containing large volumes of uranium legacy tailings, is in operation but is presently receiving non-radioactive 'gold' tailings. Although the 'gold' tailings discharge regime is adjusted to serve the remediation of the legacy tailings, the long term performance of this remediated site warrants an international peer review.

The quantification of the specific risk factors for each site and the calculation of the health and environmental impacts is a task to be tackled in the preparatory phase of the respective remediation projects. From a pragmatic point of view, it ought to be sufficient to assume that a waste facility is safe if the risk {[(failure × release) probability] × impact} is in compliance with the regulatory requirements of the respective country. To reduce risk levels to as low as reasonably achievable, it is a good policy to follow existing internationally recommended procedures and standards for the safe management or remediation of the waste facilities. The maintenance of safety at the legacy sites requires the establishment of long term legacy site management programmes (for contaminated water treatment, site maintenance and monitoring, etc.) in each country.

## 3. OPTIMIZATION OF THE URANIUM PRODUCTION CYCLE

One of the most important lessons learned from the completed remediation programmes/projects is that prevention is less costly than the creation of new legacy sites and that minimization of waste generation is the best uranium production strategy.

Whenever a new uranium mine development is evaluated it is important to evaluate the costs of the whole uranium production cycle (UPC) which comprises all the activities involved, from exploration, feasibility studies, environmental impact studies, development of production facilities, mining and processing, through to

decommissioning, remediation and post-remedial management of the sites (i.e. from cradle to grave). Environmental issues arising at all stages of the cycle are an integral part of the UPC. Consequently, responsible decisions must be based on cost–benefit calculations derived for the lifetime costs of the entire UPC. At major decision making points, this includes taking into account any requests of the legitimate stakeholders, in order to obtain a 'social licence' from the public in addition to all the necessary legal permissions and authorizations.

TABLE 3. OPTIMIZATION OF THE PRODUCTION/WASTE GENERATION IN THE URANIUM PRODUCTION CYCLE

| Stage No.: | Uranium production<br>(Goal: Maximization of production and revenue) | Waste generation, discharges and spills<br>(Goal: minimization of waste, risk and expenses) |
|---|---|---|
| (1) | Exploration → Resources<br>Pre-feasibility assessment<br>Detailed exploration → Reserves | Segregation of radioactive (e.g. ore samples, cores) and conventional waste and disposal |
| (2) | Feasibility assessment<br>Design of mining and processing options<br>Planning of operations | EIA and reference environmental baseline<br>For each option: assessment of waste generation, discharges, risks and associated costs over the lifetime of the facility |
| (3) | Mining of ore | Contamination of land, water and waste<br>Monitoring of operations and baseline<br>Adjustments and continuous optimization |
| (4) | Ore processing →<br>'yellow cake' ($U_3O_8$) | Contamination of land, water and waste<br>Monitoring of operations and baseline<br>Continuous optimization and adjustments |
| (5) | Closure planning<br>Decommissioning and demolition | Segregation of generated radioactive/non-radioactive waste → orderly storage<br>Monitoring of operations and baseline |
| (6) | (a) Remedial preparation: design and planning; target levels according to clearance criteria and planned utilization;<br>(b) Remedial works and water treatment;<br>(c) Regulatory clearance;<br>(d) Assignment of long term institutional control of the legacy site. | (a) EIA of long term impacts for each option, including water treatment requirements;<br>(b) Monitoring of works and baseline;<br>(c) Reclaimed land utilization; provision of clean water<br>(d) Long term stewardship and maintenance (LTSM): legacy site management and supervision of confinement integrity |

The minimization of waste generation (and, thus, of the health, environmental and socioeconomic risks) cuts across the whole uranium production cycle and solutions must emerge from actions at each stage of the cycle. Although corporate commitment is crucial, the involvement of the employees at each stage will ideally be solicited and their proposals, if promising, implemented in the planning. It is assumed that production management is carried out at each stage as efficiently as possible, but the decision making will ideally include both prevention and minimization criteria and be an integral part of corporate operations that link the production cycle throughout the corporate planning process.

### 3.1 The effect of a lifetime cost–benefit assessment on decision making: an example

To be able to decide during the project preparation (the design, development and engineering stage) from among the options available for the development of a new mine/processing site or remediation of a legacy site, it is essential to make a comparison on the basis of the lifetime costs. Sub-optimal design stage decisions are difficult to correct after implementation of the works and can result in cost differences of tens to hundreds of millions of US dollars. For instance, using a probabilistic risk assessment for comparison of wet tailings remediation (such as implemented at Elliot Lake, Ontario, Canada) with dry tailings remediation (such as implemented by Wismut in Saxony and Thuringia, Germany) it was shown that the initial investment cost advantage of a wet remediation can be entirely reversed when the post-remedial phase is included in the assessment, as shown in Fig. 1 [4].

The case study is based on the situation of the Helmsdorf tailings pond in Germany. The Helmsdorf tailings pond contains approximately 50 million tonnes of tailings. It is an upstream, valley type of impoundment. In 1992, the main dam was 1800 m long and 59 m high and did not meet the safety standards for water retaining structures. In the case of a complete dam failure, 6 million $m^3$ of pond water and 15–30 million $m^3$ of tailings slurry would have been released containing, among other contaminants, 80 tonnes of uranium and

600 tonnes of arsenic. Approximately 1000 inhabitants would have been affected by the slurry wave directly, and approximately 6500 people would have been affected by the damming up of the Mulde river. An area of approximately 1000 hectares would have been damaged and contaminated.

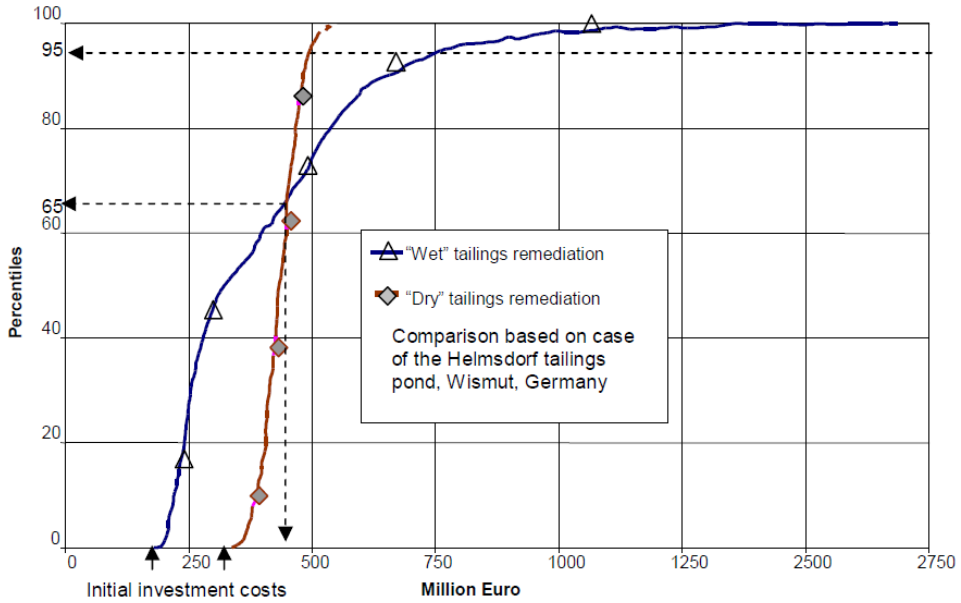


*FIG. 1. Example of increase of cumulative probabilities of equivalent costs for maintenance, damages and mitigations over the lifetime of a tailings pond for wet and dry tailings remediation options in a low to moderately seismic zone (based on the Helmsdorf tailings pond, Wismut, Germany) [4].*

After having worked out the risk–cost relationship for the entire lifetime of the Helmsdorf tailings pond (Wismut, Germany), a remediation leading to a dry landscape proved to be both safer and more economic than the 'wet' remediation option, which had lower initial investment costs.

Both technical options were feasible except for the long term risk management. Because the regulator and the main stakeholder (the local community that would be impacted in case of a failure) requested a safety performance of 95%, the initial cost advantage of a wet remediation option was lost because in the range above the 65% safety level, the cost–benefit ratio of the dry remediation was considerably more favourable. This, however, does not mean that the wet remediation is, in all cases, worse. Unlike the Elliot Lake site, the Helmsdorf site has a history of seismic activities that made it imperative to design for a 95% safety performance.

As demonstrated, fundamental decisions — irrespective of whether they concern the development of a mine, processing plant, waste management or waste containment facility — will ideally only be made on the basis of full lifetime costs.

## 4. REGULATORY CHALLENGES OF THE NEW URANIUM MINING PROJECTS IN CENTRAL ASIA

The orderly management of the uranium production cycle requires that an appropriate legislative and regulatory framework, a responsible regulatory agency and national policies, programmes and plans are in place in this regard.

In view of the lessons learned from the legacy sites, the rush to develop new uranium mines in Kazakhstan and Uzbekistan presents a considerable challenge for the existing legislative and regulatory systems. The regulators in these countries have to realize that it is not sufficient to rely on 'end of the pipe' regulations. Instead, the regulatory policy will ideally aim to ensure that uranium mining companies consider and manage potential environmental liabilities as part of their fundamental business practice and ensure that these activities are accounted for in both the project financing and plans submitted for approval. The costing of the projects must be based on the lifetime costs of the uranium production cycle.

After closure of most of the conventional uranium mines in Central Asia in 1995, the new mining projects focused on in situ leach mining (ISL) for uranium. During the last decade, ISL mining has been continuously growing in the region because of the low capital expenditure required and because it can exploit low grade ore

deposits. Besides economic advantages, compared to conventional mining, the ISL process generates little waste and has only a small impact on the surface. Current ISL plants use an 'enclosed system' for the recovery and ion exchange process steps thereby reducing the possibilities of radon release; furthermore, vacuum dryers are used (rather than higher temperature calciners) with little, if any, particulate emissions. Taking into account all these advantages, a further growth of ISL mining in Central Asia can be expected over the coming years.

From a long term perspective, however, there is a need in Central Asia to give greater attention to the prevention of aquifer degradation and the protection of scarce groundwater resources. ISL requires that mining operators have good control of the injection and recovery flows and therefore a good monitoring system for the well field is essential. For this reason, cautious ISL operators install, in addition to monitoring wells in the aquifers below and above the mined unit, observation wells in the well field itself (trend wells) to obtain a better control of the dynamics in the mined unit. In addition, these wells can act as an 'early warning' system. Unfortunately, the transfer of the most modern ISL technologies to Kazakhstan and Uzbekistan has not been matched by the introduction of up-to-date groundwater monitoring instruments and methods.

Experience from Kazakhstan shows that, due to the convenient geology of the ISL aquifers, there is no immediate need to remediate the mined units afterwards; the acidic conditions in the units become neutralized relatively quickly. In this connection, it ought to be noted that the required environmental impact assessment and monitoring for ISL facilities places the same requirements as those applied to conventional mills (i.e. the aquifers are considered as receptors instead of being assessed as a mined medium). The remediation bond can accordingly be kept very low (sometimes less than $1 million per ISL field).

Even in the case where the leached out ISL field really does not require any remediation, the regulators would be well advised to request the installation of some monitoring wells in the abandoned mining fields to observe the rate of reinstatement of natural conditions in the aquifers. The natural buffering capacity of the mined aquifer can come to an end with the progress of ISL from mining unit to mining unit.

The return of the aquifer to natural conditions or restoration to conditions consistent with the original designated use of the groundwater is essential for long term use. If needed, the restoration of the 'mined out' units is usually done in stages. This involves pumping of residual fluids from the well field and conventional treatment of the fluid; the radioactive constituents, primarily radium-226, are removed by standard methods, such as barium sulphate precipitation, reverse osmosis, etc., and disposed of subsequently as a small volume of naturally occurring radioactive material (NORM) residue.

In view of the ever increasing withdrawal of water for agricultural purposes in Central Asia, the economics of water resources management is bound to change drastically in the near future. From a macroeconomics point of view, when considering the revenues generated from $U_3O_8$ production by ISL, it ought to be borne in mind that it takes, on average, approximately one litre of water to produce one calorie from food crops.

To achieve the remediation of the numerous legacy sites and to master the present uranium 'boom' in a balanced way will require pragmatic policies, programmes and plans at the policy making level, a well established legislative framework and effective regulatory institutions in the Central Asian countries. The international community, and primarily the IAEA, will ideally face up to this challenge and provide as much assistance in this matter as possible.

## 5. CONCLUSION: A NEW BUSINESS MODEL OF URANIUM PRODUCTION

The amount of long term savings in a life cycle based costing comes not only from adjusting production; there are important planning and accounting issues as well. The proposed changes have to respect the fact that cash flow projections show the fair value of the mining project but must at the same time address the environmental and stakeholder issues affecting the mining corporation from the earliest stages of the mining project.

International cooperation and coordination are essential to support these efforts and any State action aimed at regulating uranium production. National regulations need to be attuned to individual circumstances by the implementation of suitable policies, programmes and plans at government level. However, uncoordinated actions using diverging instruments will only confuse uranium producers and distort competition.

What is needed is a strengthening of the leadership role of the international organizations, such as the IAEA, through their engagement with the industry, stakeholders and regulators in creating an environment which is protective of the public and the environment whilst simultaneously encouraging economic development of uranium mining and production.

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# IAEA PRELIMINARY ASSESSMENT OF THE FORMER FRENCH NUCLEAR TEST SITES IN ALGERIA

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**Abstract**

In 1999, the International Atomic Energy Agency received a request from the Government of Algeria to perform an assessment of the radiological conditions of the former sites used by the French Government in the early 1960s for the testing of nuclear weapons. This paper describes the history and the nature of the test site and the tests that were performed, the methodology of the IAEA assessment and the results and conclusions drawn from the mission of international experts.

## 1. INTRODUCTION

In 1999, the International Atomic Energy Agency received a request from the Government of Algeria to perform an assessment of the radiological conditions at the former sites used by the French Government in the early 1960s for the testing of nuclear weapons. In response to this request, in late 1999, the IAEA sent an international team of experts to perform a radiological assessment. The expert team was composed of experts from France, New Zealand, Slovenia, the USA and the IAEA.

The terms of reference for the expert mission were to:

- Make a preliminary assessment of the existing radiological situation at the Reggane and In-Ekker test sites by performing radiation/radioactivity measurements at the sites and at selected inhabited locations;
- Collect selected environmental and food samples for analysis;
- Based on the results of these measurements, perform a preliminary dose assessment and develop a plan for monitoring the test sites more comprehensively, if justified.

The mission was able to achieve more than initially expected because of the detailed information provided by France related to the history and location of the tests.

## 2. TEST SITES

Nuclear tests were performed at two test sites in Algeria, they were Reggane and In-Ekker. Both of these sites are located in the southern central part of the country and are shown in Fig. 1.

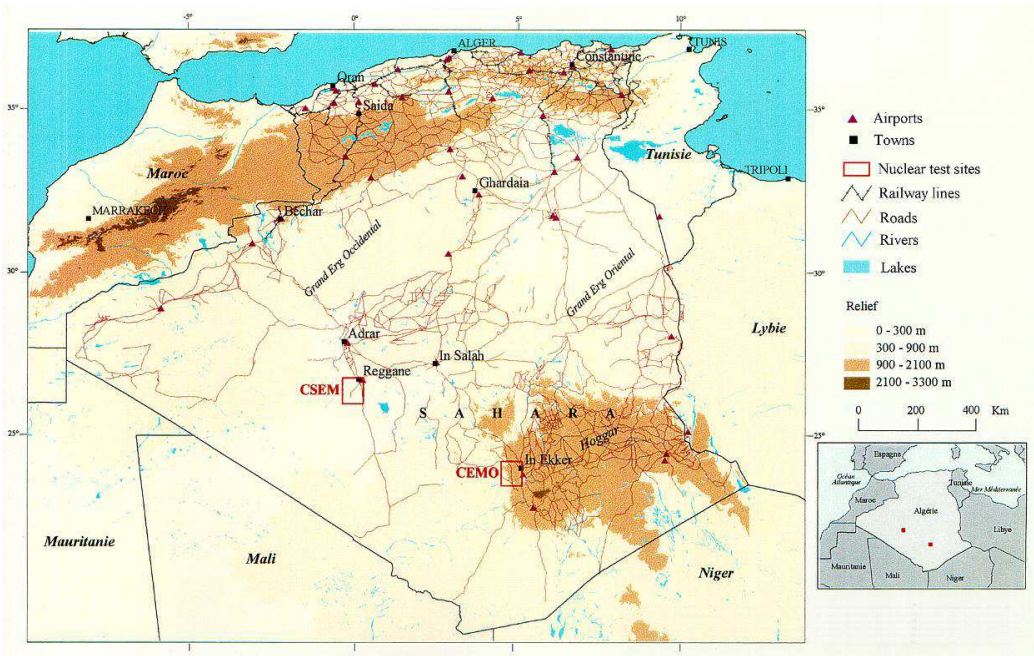


*FIG.1. Location of Algerian test sites.*

*Reggane test sites*

The Reggane test sites were used for above ground nuclear weapons tests and are located approximately 50 km south of Reggane, a small oasis village and 150 km south of Adar, a city of approximately 50 000 inhabitants. Table 1 provides information concerning the four atmospheric tests performed at the Reggane site.

TABLE 1. ATMOSPHERIC NUCLEAR TESTS CONDUCTED AT REGGANE

| Test | Date | Type | Yield, W (kt) |
|---|---|---|---|
| Gerboise Bleue | Feb 1960 | Tower, 100 m | 40 < W < 80 |
| Gerboise Blanche | Apr 1960 | Surface | W < 10 |
| Gerboise Rouge | Dec 1960 | Tower, 50 m | W < 10 |
| Gerboise Verte | Apr 1961 | Tower, 50 m | W < 10 |

The largest contribution to the radiation dose that can be measured at the present time is due to $^{137}$Cs; other fission or activation products contribute less than 5% to the dose rates. Figure 2 shows the radiation dose rates and surface activity levels of $^{137}$Cs in the surface areas of the fallout zones. The Gerboise Blanche test was performed on the surface and a crater was produced that was later filled in. Consequently, a large amount of the residual activity remains in material buried under several metres of sand.

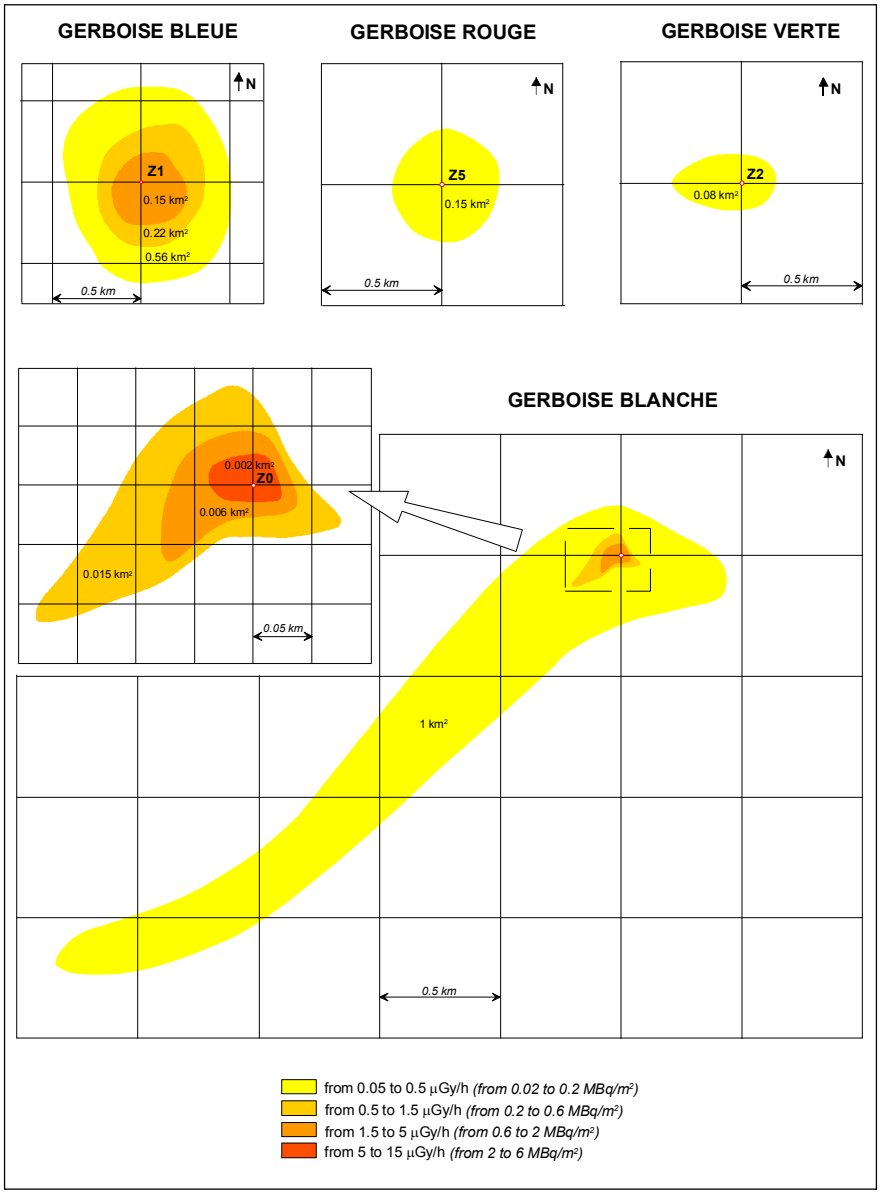


*FIG. 2. Radiation dose rates and surface activities of $^{137}$Cs at Reggane (in 1999).*

In the area of the Gerboise Rouge test site, an additional series of tests was performed to measure the velocity shock wave in a pellet of plutonium. A total of 35 experiments were performed, each using a plutonium pellet weighing about 20 g. These tests were performed in pits designed to limit dispersal. The majority of the plutonium remained in the pits after the tests, but low residual activity can still be detected near to the pits. The pits have been backfilled with sand.

*In-Ekker test site*

In-Ekker consists of two sites, Taourirt Tan Afella and Adar Tikertine. Underground nuclear weapons tests were performed in tunnels that were dug into the granite massif at Taourirt Tan Afella. This area was virtually uninhabited at the time of the tests. Thirteen tests were performed at this site; details are given in Table 2. All of these tests were performed in tunnels that were designed so that the radioactive products would be confined within the mountain at the ground zero point in rock that would become molten at the moment of firing.

TABLE 2. UNDERGROUND NUCLEAR TESTS CONDUCTED AT TAOURIRT TAN AFELLA

| Test | Date | Yield, W (kt) |
|---|---|---|
| Agate | Nov. 1961 | W < 10 |
| Beryl | May 1962 | 10 < W < 40 |
| Emeraude | Mar. 1963 | 10 < W < 40 |
| Amethyste | Mar. 1963 | W < 10 |
| Rubis | Oct. 1963 | 10 < W < 40 |
| Opale | Feb. 1964 | W < 10 |
| Topaze | Jun. 1964 | W < 10 |
| Turquoise | Nov. 1964 | W < 10 |
| Saphir | Feb. 1965 | W > 80 |
| Jade | May 1965 | W < 10 |
| Corindon | Oct. 1965 | W < 10 |
| Tourmaline | Dec. 1965 | 10 < W < 40 |
| Grenat | Feb. 1966 | 10 < W < 40 |

Nine of the tests (Agate, Emeraude, Opale, Topaze, Turquoise, Saphir, Corindon, Tourmaline and Grenat) were fully contained. Two tests (Rubis and Jade) were not fully contained and some radioiodines and gases were released from the tunnel openings. Two tests (Beryl and Amethyste) were only partially contained and significant releases of radioactive material occurred. None of the tests, except these last two, produced any significant radiological residues outside the tunnels.

To contain the tests, a spiral shaped tunnel opened into the firing chamber as shown in Fig. 3. The spiral was designed to be closed off by the shock wave before the lava could reach the entrance to the tunnel. During the Beryl and Amethyste tests, this blocking of the main tunnel did not occur. During the Amethyste test, a small quantity of molten rock was deposited near the tunnel entrance. In 1965, the residual dose rate 1 m above the lava surface was reported as exceeding 50 Gy/h. In 1999, the residual dose rates were just above 1 Gy/h. The Beryl test resulted in a much more significant release to the environment. Approximately 5–10% of the test product activity was released as lava, aerosols and gaseous products. Most of the residual contamination is fixed in the lava. The 1999 estimated dose rates in the area of contamination are shown in Fig. 4. These levels are not insignificant but the Beryl test site is located in an area that is very difficult to gain access to. Nevertheless, to prevent access, the area contaminated by the test was fenced off and appropriate warning signs were affixed to the fence. However, over time, this fence has become ineffective, as shown in Fig. 5.

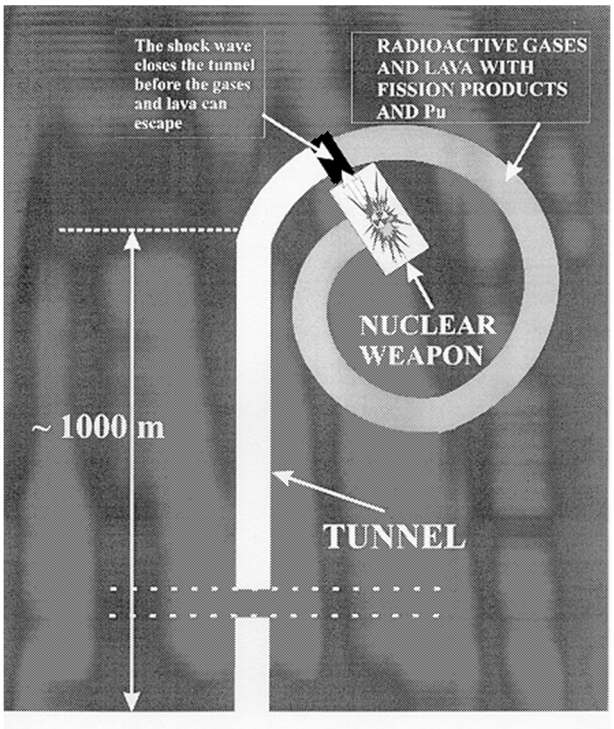


*FIG. 3. Arrangement of tunnel used for weapons testing.*

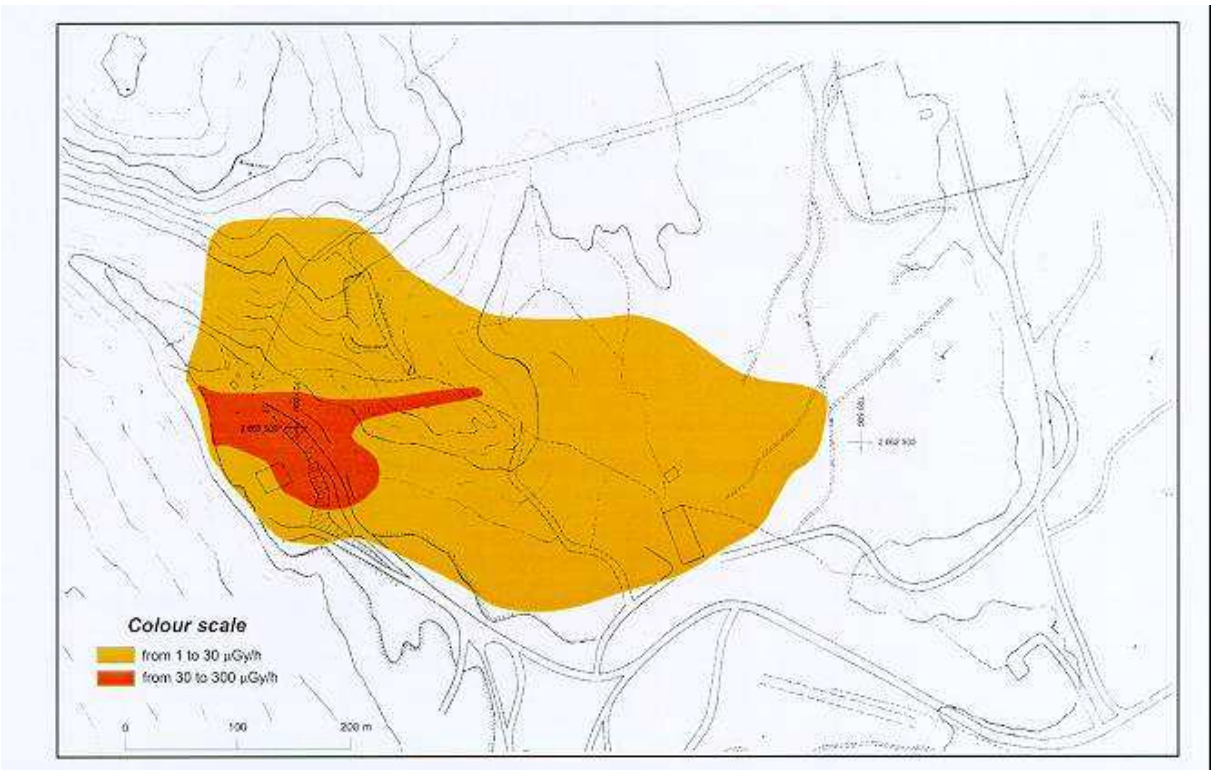


*FIG. 4. Radiation dose rates in 1999 in the area contaminated by the Beryl test.*

*FIG. 5. Typical fence surrounding area where nuclear tests were performed.*

Five additional experiments were performed about 30 km south-west of Taourirt Tan Afella, in the region of Adar Tikertine. The purpose of these experiments (called the Pollen experiments) was to simulate an accident involving plutonium and to measure its consequences, including the degree of contamination that might be produced in the vicinity of the tests. The method involved measuring the amounts of plutonium aerosols generated by pyrotechnic dispersal. The experiments involved 20–200 g of plutonium and were performed when the wind was blowing across the area planned for collection of the fallout. After each test, the most contaminated area was covered with asphalt to limit resuspension. Low levels of residual activity can still be detected near the ground zero point.

## 3. FIELD SAMPLING

Some field sampling was performed during the mission. This sampling was not as comprehensive as would be required for a full scale radiological monitoring programme and only a limited number of samples were taken. All the samples were analysed at the IAEA laboratory in Seibersdorf, Austria.

Soil, water and vegetation samples were taken. Soil samples were taken for evaluating the resuspensible fraction that might expose intermittent visitors and travellers as a consequence of high winds in the area. The water from three different wells in the area of In-Ekker was sampled by collecting water directly from the buckets used by travellers. Vegetation samples were taken from near the Beryl tunnel entrance where the largest release occurred. The plant types collected were known to be used by camels as food.

The results of these samples are provided in the IAEA report of this mission [1].

## 4. CONCLUSIONS AND RECOMMENDATIONS

The two areas that had the highest residual activity were:

- The ground zero locations at the Gerboise Blanche and Gerboise Bleue atmospheric test sites located near Reggane;
- The vicinity of the tunnel where highly radioactive lava was ejected during the Beryl underground test.

Two additional areas had residual activity but at a lower level: the vicinity of the tunnel for the Amethyste test and at the Adrar Tikertine site where the Pollen tests were performed. All of the other areas had little

residual activity. A conclusion of the assessment was that environmental remediation is not required at any of the test areas in order to reduce doses below established safety standards, and that any possible exposures at Taourirt Tan Afella can be controlled through access restrictions. However, future decisions by the Algerian authorities to carry out further remediation or to further limit public access might be appropriate if economic conditions change in the area and a more permanent presence of people is indicated.

### 4.1. Specific conclusions

*Reggane*

Radiation doses to visitors to the remote desert tests sites area are estimated to be less than a few Sv/day. Residual steel fragments and fused sand, if removed from the site, do not present any significant radiological risk. However, if fused sand were ground to respirable dust without respiratory protection, this could present an inhalation hazard.

Calculated radiation doses to residents of the town of Reggane from the airborne transport of dust from the test areas are predicted to be very low, much less than 1 Sv/a.

*Taourirt Tan Afella*

Nomadic camel and goat herders grazing their animals on the sparse vegetation in the area of the Beryl and Amethyste galleries might receive small doses, principally from external radiation, of less than about 50 Sv/a. Persons scavenging metals in the immediate vicinity of the lava from the Beryl tunnel might receive doses of up to about 0.5 mSv in 8 hours. Current external exposure dose rates are less than one tenth of those existing in 1966. These dose rates are decreasing annually due to the decay of $^{137}$Cs (1999 maximum concentrations were 2 kBq/g). The alpha activity concentration in the lava is in the range 40–400 Bq/g, which is roughly similar to that of natural rock with 0.2% uranium content, and below that of a commercial uranium ore body.

*Adrar Tikertine*

The concentration of plutonium was determined in a small number of sand samples — too few to be representative of the area. Nevertheless, the activity concentration of anthropogenic radionuclides in those samples measured was generally below laboratory detection limits. Thus, it is expected that the residual surface contamination from the plutonium dispersion experiments is unlikely to give rise to doses to nomadic herdsmen or their families exceeding 1 Sv/a.

### 4.2. Recommendations

The integrity of the fence constructed in the 1960s after the accident at Taourirt Tan Afella will ideally be restored and maintained to avoid exposures arising from human and animal intrusion in the region around the Beryl tunnel entrance or through any removal of samples of lava from the site.

The upper bound evaluation of the radiological conditions assessed in this preliminary study is considered robust, and further extended sampling for radiological assessment is not considered necessary. Corroboration of the predicted low inhalation doses arising from the Reggane site could be readily achievable through an appropriate air sampling programme, and it is recommended this be carried out.

Similarly, corroboration of the findings of no dose impact to the local herdsmen and nomadic people in the In-Ekker area will ideally be achieved by an appropriate environmental monitoring programme; in particular, water from wells adjacent to the Taourirt Tan Afella test site could be analysed.

Better descriptions of the lifestyles of the people that frequent these areas would add credibility to the findings of the assessment.

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# SOCIAL AND ETHICAL ISSUES IN REMEDIATION

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**Abstract**

The contamination of environments with radionuclides can give rise to consequences additional to the health risks from exposure to radiation. As experience from Chernobyl has demonstrated, both accident and remediation measures can have serious social, ethical and economic consequences. This paper presents a review of some of these issues and presents a 'checklist' of the socioethical aspects of remediation measures. The paper also discusses remediation measures that are directed towards benefits other than dose reduction.

## 1. INTRODUCTION

Remediation measures can do much to alleviate anxiety and restore the way of life in communities living in contaminated areas. However, remediation is rarely without side effects: the Chernobyl accident showed that remediation can be expensive, socially disruptive or damaging to the environment [1–4]. On the other hand, remediation can have benefits that go beyond radiation dose reduction, such as restoring ecosystems, increasing public understanding and control, restoring consumer confidence in a product, or securing the livelihood and social structure of affected populations.

While the primary objective of remediation is usually dose reduction, for an action to be justified, the benefits from dose reduction or averted dose will ideally outweigh the costs of implementing the countermeasure [5]. It follows that a decision on how to reduce exposure to radiation will involve an ethical judgement: a choice is being made about which doses to reduce and at what cost. While the main criteria for remediation are usually based on technical or economic constraints, an extended evaluation can include social factors such as public perceptions of risk and dialogue with affected communities, as well as ethical aspects such as informed consent and the fair distribution of costs and benefits [1, 2, 6].

This paper reviews the main social and ethical issues associated with remediation decisions. It includes a summary of the generic social and ethical aspects of remediation, and concludes with a presentation of some of the remediation measures that are not primarily intended to reduce radiation dose.

## 2. MULTIDIMENSION ASPECTS OF REMEDIATION

The multidimensional aspects of remediation were an important part of the STRATEGY 5th Framework EU project – Sustainable Restoration and Long Term Management of Contaminated Rural, Urban and Industrial Ecosystems, and the follow-up EURANOS project (www.euranos.fzk.de), both of which included a number of remediation evaluation criteria, such as practicality and acceptability, socioethical aspects, environmental consequences and indirect side-effect costs [6, 7]. Stakeholder evaluation of countermeasures suggested that many options were as likely to be rejected on socioethical grounds as on technical and economic grounds [8]. Examples included a strong aversion to any measure that would bring about contamination of previously uncontaminated foods (e.g. mixing milk from different sources) or environments. Legal constraints also play an important role, particularly with respect to environmental legislation (e.g. habitat protection) and labour rights [1]. The summary of social and ethical factors below is taken from previously published work carried out under the STRATEGY and EURANOS projects [1, 6, 9]. The focus in this paper is on issues that are grounded in fundamental ethical values, and which are relevant to any risk assessment. Obviously, the list is not exhaustive and can provide only an illustration of some of the issues that might be considered, hence descriptions and examples are rather general.

*Self-help/disruptive*: 'Self-help' addresses the extent to which the affected persons themselves can implement actions and their degree of control or choice over the situation. Voluntary actions that are carried out by the public or affected individuals themselves, or that increase personal understanding or control over the situation, are usually deemed positive as they respect the fundamental ethical values of autonomy, liberty and dignity. Concrete examples include the provision of counting equipment, dietary advice and certain agricultural procedures that could be carried out by the farmer. On the contrary, imposed measures that are highly disruptive, infringe upon liberty or restrict normal practices can often be judged to be negative. Examples include relocation, bans on amenity use or a radical change in farming practice.

*Welfare (*doses, costs and side effects): The averted radiation dose and the calculated cost of remediation have direct consequences for the welfare of society and/or individuals, and are thus also important ethically

relevant aspects. Remediation may have additional impacts on community or cultural values in a number of ways. Negative side effects can include rural breakdown, loss of consumer faith in a product and the stigma of being 'contaminated communities'. Disruptions to existing social and cultural patterns — such as those requiring changes in employment or lifestyle — are generally taken as negative, and the community can benefit from protection against such factors. Creation of local employment opportunities can benefit communities.

*Free informed consent of workers*: The issue of consent is strongly linked to the fundamental ethical value of autonomy. Employers have a duty to obtain the informed consent of any worker who may be exposed to chemical and or radiation risk. This is particularly important if lower paid workers are employed to carry out the measure, as it has been suggested that the necessary conditions for free informed consent are often violated for these groups [10]. The increased risk may justify some form of compensation via higher wage premiums, but compensation itself can raise questions of whether or not this may coerce people into taking risks they would otherwise not have [10]. Experience from Chernobyl illustrates the problems of compensation in promoting the 'victimization' of affected populations [2–4].

*Distribution of dose, costs and benefits*: The way in which remediation impacts on the distribution of costs, risks and benefits has significance due to the fundamental ethical values of equity, justice and fairness. Costs, benefits and risk may vary over both space and time and between different members of a community. The radiation dose distribution is obviously a main consideration for radiation protection, and many remediation measures that reduce collective dose may change the distribution of dose, for example from consumers to workers or populations around waste facilities. The question of who is paying the monetary and social costs of remediation and who will receive the benefits must also be addressed. Another question is whether the action has implications for vulnerable or already disadvantaged members of society (children, ethnic or cultural minorities). Who is being affected? Who is paying?

*Liability and/or compensation for unforeseen health or property effects*: Employers usually hold legal and ethical responsibilities over their employees, and contractors or industries may be held legally or financially liable for any damage they may cause to public or private property. The matter of who bears liability is relevant both from considerations of responsibility (moral and legal) and because of links to equity issues. Liability can become particularly important if outside contractors are paid to carry out remediation, both for the contractors themselves — will I be sued if the actions cause unforeseen damage? — and the workers/property owners who may risk injury — will I be compensated if the remediation causes me damage?

*Change in public perception or use of an amenity*: If remediation has an effect on the public's use of a particular amenity (such as restricting access to a park), then this will have an influence on acceptability. As was seen in the Chernobyl case, people place a large value on places with strong community and personal ties, such as those with childhood memories. Such effects can have deeper relevance than whether or not people are able to use the amenity. Perceptions can include, for example, that something has changed from being 'natural' to 'unnatural' or 'clean' to 'damaged'. Alternatively, remediation that brings into use a previously restricted amenity will be socially more robust.

*Uncertainty*: Uncertainty in this context can be taken to refer to an evaluation of the risk (environmental, technical, social) associated with remediation, and relate to the question of what the possible consequences of the remediation might be and the probability that those outcomes can occur. What are the main uncertainties associated with the remediation strategy? What action might be taken to avoid or reduce these uncertainties, and are some inevitably indeterminate? What are the consequences of being wrong?

*Environmental risk from ecosystem changes, groundwater contamination, etc.*: Remediation actions that change or interfere with ecosystems (e.g. ploughing or changing catchment drainage) may produce negative environmental consequences. In addition to the obvious questions of uncertainty, environmental risk raises a variety of ethical issues including consequences for future generations, sustainability, cross-boundary pollution, and balancing harm to the environment/animals against benefit to humans. The ethical acceptability of remediation will clearly depend on the ecological status of the area and the degree to which the action diverges from usual practice. In most cases, environmental legislation must be considered. Any countermeasure involving the generation of waste and/or its treatment will have ethical relevance (and controversy) in itself. Treatment of waste in situ can be positive as it avoids problems arising from 'dilute and disperse' or the 'redistribution' of exposures to persons living close to disposal sites. Such issues were seen as being very important in some European countries after the Chernobyl accident [8]. But in situ treatment may also have negative side effects because it can complicate future waste removal.

## 3. NON-DOSE-REDUCING REMEDIATION STRATEGIES

For certain remediation measures, reduction in radiation dose need not be the only benefit, or even the main benefit. In the STRATEGY and EURANOS projects, a number of remediation measures were evaluated in which dose reduction was not the primary aim [7, 9]. These included measures such as: the provision of medical checkups and dietary advice, the setting up of public information centres, the instigation of education programmes, compensation, the provision of counting equipment and the stimulation of stakeholder involvement

in the decision making process. Indeed, it is to be hoped that many of the procedures, specifically those directed towards communication and stakeholder involvement, would be generic to any remediation process.

Provision of counting equipment and independent monitoring are methods that have been successfully applied in Chernobyl affected communities. A study carried out in Belarusian villages concluded that the approach not only resulted in reducing exposures with minimal social and psychological side effects, but was also more economically cost effective than the standard 'top down' management procedures [11]. A recent stakeholder study following up on the Norwegian farming communities most affected by Chernobyl fallout indicated that access to local food monitoring stations was particularly important [12]. Independent monitoring following waste disposal are commonly requested in community stakeholder processes.

## 4. CONCLUSION

Any remediation strategy will be strengthened by an approach to remediation that integrates economic, ecological and health measures; it is not sufficient to simply focus on the dose reduction aspects of radiation protection. This is supported by many multidisciplinary research projects on the long term management of radioactive contamination. The projects highlight the importance of including the affected populations with regard to self-help measures and involvement in decision making processes. In addition to respecting people's fundamental right to shape their own future, and thereby increasing trust and compliance, such approaches can lead to significant improvements in the effectiveness of remediation measures and in their acceptance by communities.

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# A GUIDE FOR THE REMEDIATION OF RADIOACTIVELY CONTAMINATED SITES: EURSSEM

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**Abstract**

A first draft of EURSSEM (European Radiation Survey and Site Execution Manual) has been developed within the framework of the Co-ordination Network on Decommissioning of Nuclear Installations Project (2005–2008) funded by the European Community. The objective of EURSSEM is to provide a consensus approach and guidance to conduct all actions at radioactively contaminated and potentially radioactively contaminated sites and/or groundwater — up to their release for restricted or unrestricted (re)use. This approach and guidance is intended to be both scientifically rigorous and flexible enough to be applied to a diversity of site (surface) cleanup conditions. A brief description is given on the background and the need for a document such as EURSSEM, on key issues such as stakeholder involvement and archiving for future referencing, including the follow-up of the further development of EURSSEM.

## 1. INTRODUCTION

The purpose of the Co-ordination Network on Decommissioning of Nuclear Installations (CND) was to organize and operate this Network with organizations from the European Union as well from candidate countries involved in decommissioning activities [1]. An important aim of the CND was to encourage a continuous improvement in capabilities and effectiveness that will ideally lead to increased competitiveness. The CND was managed by a steering group that had the objective of driving the CND forward to increase and transfer knowledge and to exchange experience so that organizations could derive the maximum benefit from this EC funded project.

One of the main topics/work packages in the CND was Site Characterization, Remediation and Reuse. The aim of this work package was to improve the exchange of knowledge between specialists and especially experts of the European Community in this field; it had the following objectives:

- To promote common understanding of key issues in the fields of site characterization, remediation and reuse;
- To identify good/best practices in characterization, remediation and reuse of sites based on practical experience and to disseminate good practice in areas that will benefit from a better characterization, remediation and reuse of sites;
- To promote the exchange of information in these fields.

The intention at the start of the project was that each of the three topics, for example site characterization, remediation and reuse, could be dealt with separately. However, although a number of commercial firms had interests in these topics, and especially in the results and experiences of competitors, the same firms were reluctant to share their own experiences with others. For this reason, it was very difficult to demonstrate that participating in the CND project and in this working group had real added value. Therefore, the steering committee of the CND decided to change course in order to meet the project objectives. This change of course meant that the effort would be made by a motivated group of partners to develop the intended guidance documents. This effort resulted in this first draft of EURSSEM.

## 2. DEVELOPMENT OF THE FIRST DRAFT OF EURSSEM

### 2.1. Purpose and scope

The purpose of EURSSEM is to provide a consistent guideline for the execution of an environmental remediation programme for radioactively or potentially radioactively contaminated land and/or groundwater. The guidance and approaches will ideally be both scientifically rigorous and flexible enough to be applied for a diversity of sites (surfaces) and groundwaters.

### 2.2. Point of departure

The following points of departure were defined for the development of EURSSEM:

EURSSEM will ideally be written from an advisory or a consultancy point of view. This means that EURSSEM can contain all existing information and information on future developments in approaches, etc., that deal with the development, implementation and execution of an environmental remediation programme applying the best options and practices for a particular site. Due to the fact that the guidance is generic and no national or international regulations/laws are taken into account, the regulatory body in the country where it is used will ideally be consulted. Further, it is evident that the advice given will not necessarily correspond with the viewpoint of a site owner, a regulator or a public community;

Commercial interest. The authors do not have any commercial intentions considering:

(a) The use and the distribution of EURSSEM by third parties. It is evident that the use of EURSSEM is the responsibility of the user;

(b) (ii) The inclusion of commercial information, for example company names, specific commercial products, process, etc. in EURSSEM;

EURSSEM is available for all companies, regulators and members of the public (all stakeholders) involved in or interested in environmental remediation programmes;

The level of information provided in EURSSEM will ideally be acceptable for an interested member of the public as well as for specialists in the field;

EURSSEM will ideally be free from any judgement about preferred strategies, approaches, procedures and equipment that can be applied in an environmental remediation programme.

### 2.3. Need for a document such as EURSSEM

Over the last few decades, organizations like the International Atomic Energy Agency, the United States Interstate Technology and Regulatory Council (US-ITRC), the Construction Industry Research and Information Association (CIRIA), United Kingdom governmental agencies (Safety and Environmental Guidance for the Remediation of Contaminated Land on UK Nuclear and Defence Sites (Safegrounds Learning Network)), US governmental agencies (MultiAgency Radiation Survey and Site Investigation Manual (MARSSIM)), and various other national institutes have performed a substantial amount of work to improve knowledge and understanding of best practices in an environmental remediation programme. EURSSEM incorporates information provided in documents prepared by the above mentioned organizations and the importance and the quality of the information and know-how presented in their documents is acknowledged. However, this existing information was, until now, not combined into one consistent document or guideline.

Independent of their origin (e.g. IAEA, US-ITRC, etc.), the available documents and guidelines have a kind of common structure: they present global information on all aspects that have to be considered in the design, planning and execution of an environmental remediation programme, although the level of the treatment can vary and, for specific aspects, very detailed information may be presented. In Fig. 1, as an example, an overview of topics/documents is presented that can be found on the web site of the US-ITRC. However, these documents are not combined into one consistent guide.

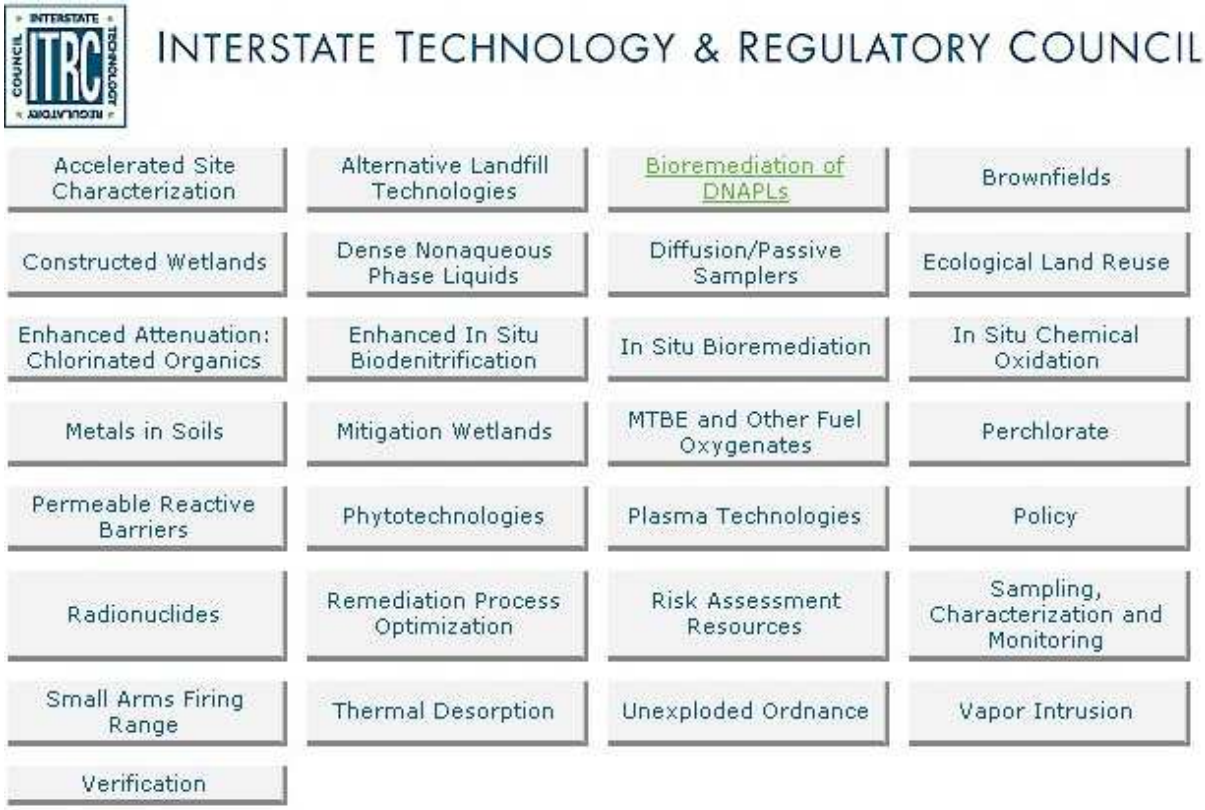


*FIG. 1. Overview of the document topics on the US-ITRC web site [2].*

Relevant documents for performing an environmental remediation programme have been prepared over a period of 10–15 years. During this time period:

Knowledge has increased; both theoretical and practical experience has been obtained;

Viewpoints and insights into the relevant science have changed;

During the preparation of these documents, a large number of authors/scientists from many fields of science were involved;

The level of the published documents is not always the same;

The applied terms and definitions have not always been consistent.

As a result, it will be difficult for some stakeholders involved in an environmental remediation programme to judge the true merits of the advice. Therefore, combining the available information into one consistent guideline will be a help for all stakeholders.

### 2.4. Literature study

An extensive literature study has been performed using the Internet and references in leading documents. All literature sources were sorted according to the different aspects of an environmental remediation programme. After sorting, emphasis was put on how to combine and re-edit the collected information to create an approach that is as consistent as possible for all aspects. The next step was to combine and re-edit the selected literature. The last step in the process was to perform a second literature study to fill in the gaps of missing information/examples and/or expanding the level of detail.

Although a lot of work has been performed by the authors/editors, they do not claim that the information on all aspects of an environmental remediation programme is equal in depth or detail.

## 3. FIRST DRAFT OF EURSSEM

### 3.1. Use of the manual

Potential users of this manual are companies, government agencies and other parties that can be described as stakeholders involved in processes to remediate or restore radioactively contaminated sites for restricted or unrestricted (re)use. The manual is intended for a technical as well as a non-technical audience.

### 3.2. Structure of the manual

EURSSEM begins with guidance on how to decide if EURSSEM guidance or part(s) of EURSSEM guidance are applicable. It is followed by the section 'Development of a contaminated land strategy' which provides a clear context and objectives, as well as information about effective external participation (stakeholder involvement) whether it is required by organizational policy or by regulations to meet stakeholder expectations or to improve decision making. This section focuses in detail on the strategy to be applied, describing two major topics, i.e. stakeholder involvement in the process and the requirements/establishment of an 'archive for future referencing'. These two topics are linked to all actions in the process. The document provides guidelines for the formulation of all necessary plans at a generic level, for example historical site assessment, risk assessment approaches, a health physics plan, a safety and security plan, an environmental protection plan, waste management and transport, record keeping, etc. The 'archive for future referencing' has not to be seen as a special part of the project file, but as an archive that will contain information that can be consulted in the short term and the long term future for answering questions concerned with former radioactive contaminants present at the site and/or in the groundwater.

In the next section, the focus is on the radiological characterization of a site and on the processes involved in doing this, for example the design of field-based site characterization, determining the radioactive contaminants and their behaviour, sampling, sampling frequencies/locations/patterns, intrusive and non-intrusive methods, field and laboratory equipment, analysis of samples, data interpretation, reporting, common mistakes, etc. and how to decide if the data obtained meet the remediation or the release criteria to an acceptable degree of uncertainty.

Remediation and post-remediation activities (restoration) guidelines are presented in the next section. These guidelines are focused on the design of a remediation plan that can be accomplished safely. Different planning approaches are described, but guidance is also given on criteria for the evaluation of an approach or technique. Further, an extensive overview is given of available remediation techniques presented in the literature, guidance on the selection of applicable remediation techniques as well as on implementing remediation and post-remediation (restoration) actions.

The last section provides information and guidelines on 'Reuse and Stewardship'. It is evident that not all radiological contaminated sites and/or groundwater can be cleaned and released for unrestricted use within an acceptable timescale. Sometimes this is not needed, for example for industrial areas. Therefore, guidance is given on decision making and the implementation of short term or long term stewardship.

EURSSEM is presented in a modular format, with each module containing guidance on conducting specific aspects of, or activities related to, the process. If followed in the related order, each module leads to the generation and the implementation of a complete plan. Where appropriate, examples and/or checklists are included that condense and summarize the major points in the process. The checklists may be used to verify that every suggested step is followed or to flag a condition in which specific documentation will ideally be provided to explain why a step was not needed.

A schematic overview of the content of the first draft of EURSSEM is presented in Fig. 2.

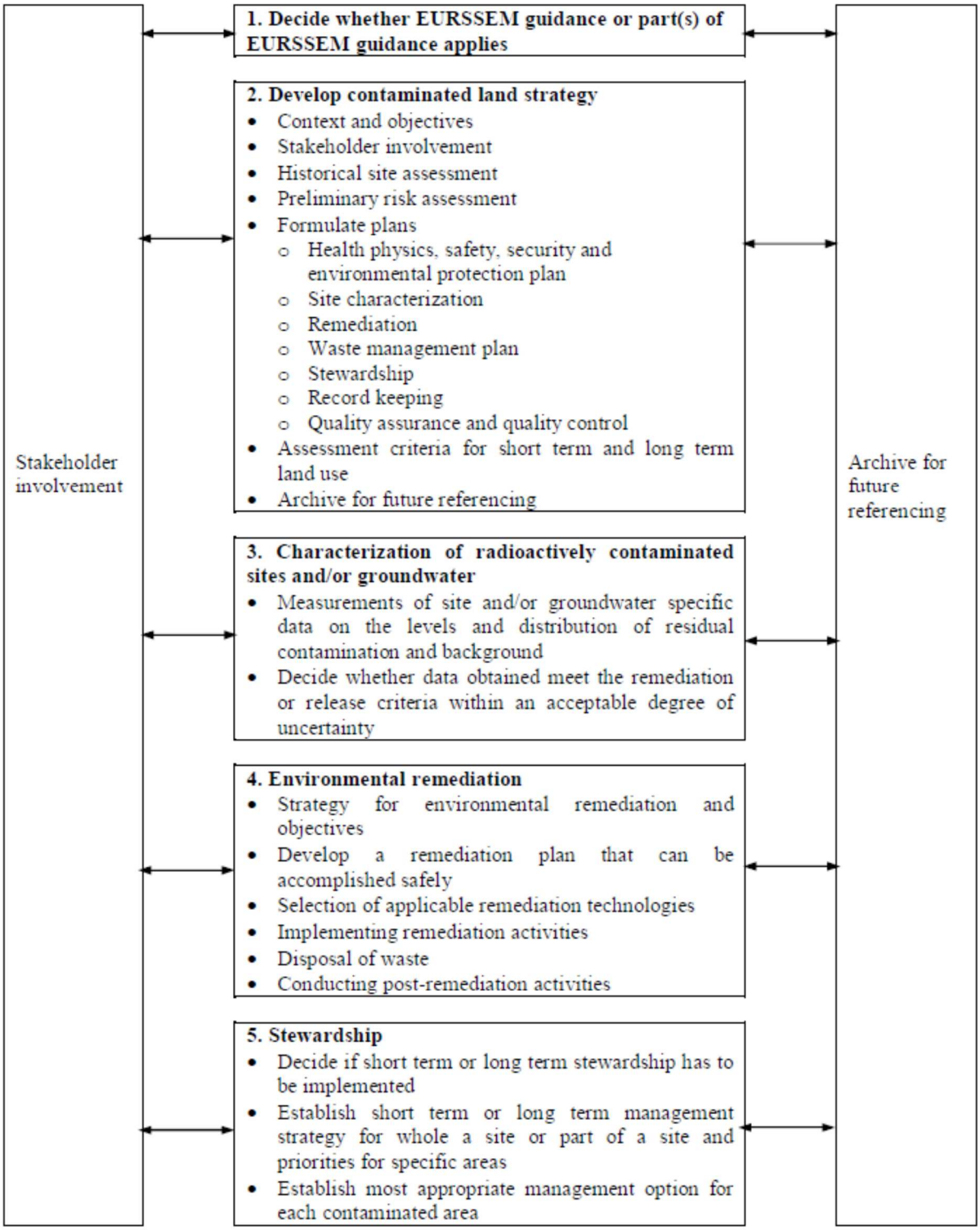


*FIG. 2. The five interrelated parts of EURSSEM. (For simplicity, the iterative issue has been omitted.)*

## 4. FUTURE WORK

At the time of writing EURSSEM is available at http://www.eurssem.eu/. The authors/editors are looking forward to working with other specialists, companies and institutes to update this draft at regular time intervals. It is intended that the web site will become a forum where specialists and non-specialists can exchange information. The web site will also offer the opportunity to upload improvements and new information. These

improvements and information will be reviewed and if they contain material with an added value, it will be incorporated into the next version of EURSSEM.

In the future, EURSSEM will be extended by including an appendix containing abstracts of published articles dealing with cases or aspects of environmental remediation.

## 5. CONCLUSION

By creating EURSSEM, a gap and a need are being filled so that the design, implementation and execution of environmental remediation programmes can be performed according to the latest approaches, techniques, etc.

By making EURSSEM available to everyone via the Internet and in combination with a forum, EURSSEM can contribute to a better understanding of environmental remediation programmes and to the harmonization of approaches.

## REFERENCES

[1] TEUNCKENS, L., Co-ordination Network on Decommissioning of Nuclear Installations; 3rd Annual Report (2008).

# IMPROVING RADIOACTIVE WASTE AND SOURCE MANAGEMENT AT THE VINČA INSTITUTE

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**Abstract**

The Vinča Institute Decommissioning Project (VIND) represents the largest project in the history of the technical cooperation programme of the International Atomic Energy Agency. Its scope is subdivided into three tasks: (1) spent fuel repatriation to the country of origin, (2) waste management, and (3) decommissioning of the RA research reactor and associated facilities. One major project involves the dismantling and decommissioning of old waste management facilities, along with processing of the waste and conditioning of the sealed sources stored in those facilities. This paper describes the progress made and problems encountered in implementing the waste management and decommissioning projects.

## 1. INTRODUCTION

The Vinča Institute of Nuclear Sciences (referred to as the 'Vinča Institute') is located within 20 km of Belgrade, Serbia, which has a population of approximately 2 million people. The Vinča Institute was built in the mid-1950s to provide nuclear research services to the former government of Yugoslavia. Two research reactors were established: a research reactor for high power irradiation services for a variety of experiments (the RA reactor), and a zero power research reactor to provide criticality research data (RB reactor).

## 2. BACKGROUND

The RA reactor, which is a 6.5 MWt, tank-type, heavy water moderated and cooled research reactor containing high enriched uranium (HEU) and low enriched uranium (LEU) fuel of Russian origin, began operations in 1959 and was 'temporarily' shut down in 1984 but was never restarted. This was linked to the severe economic crisis in Serbia during the same period. In 2004, a programme was instituted by a decision of the Serbian Government to begin decommissioning activities at the RA reactor and associated nuclear facilities at the Vinča Institute. This decision resulted in the establishment of the Vinča Institute Nuclear Decommissioning (VIND) Programme to decommission the nuclear facilities at the Vinča Institute.

The programme has attracted support from a number of organizations, including the Serbian Ministry of Science and Technological Development, the United States Department of Energy, the European Commission, the Slovenian Nuclear Safety Administration, the Czech Republic, private donors (e.g. the Nuclear Threat Initiative) and the International Atomic Energy Agency. For the IAEA, the project represents the largest project in the history of the IAEA's technical cooperation programme. The VIND Programme began in 2004 and will continue until at least 2011, and is forecast to cost as much as US $75 million dollars to conduct and complete all planned activities.

## 3. VIND PROGRAMME

The VIND Programme consists of three major tasks:

(a) Spent fuel repatriation to the country of origin;
(b) Decommissioning of the RA research reactor and associated facilities;
(c) Radioactive waste management.

Task 1 (spent fuel repatriation project) is part of a Russian Federation, USA and IAEA cooperation under the Russian Research Reactor Fuel Return programme. Non-irradiated (fresh) fuel was repatriated in 2002 and the repackaging of spent fuel begun in August 2009. Preparations for the transport of the spent fuel are currently on schedule, and transport activities are scheduled to be completed by the end of 2010.

Task 2 decommissioning activities are also on schedule; the draft decommissioning plan has been completed, 90% of the excess/abandoned materials have been removed, and physical dismantlement of related facilities (e.g. old waste hangars) is scheduled to begin in 2010. However, additional storage capacity is needed for the waste generated during the fuel repatriation and decommissioning.

Task 3 focuses on improving radioactive waste management at the Vinča Institute. The Serbian government and international donors (USA, Nuclear Threat Initiative, UK and Slovenia) are supporting the construction of new waste storage and processing facilities. The EC is contributing to this project by funding the procurement of equipment for the new facilities, including waste containers for the spent nuclear fuel repatriation project and other decommissioning projects. Currently, solid RAW from the entire former

Yugoslavia is being stored in storage Hangars 1 and 2 — both of which are in a poor condition. The stored waste comprises several hundred drums of unconditioned and uncharacterized waste that includes yellow cake, metallic uranium, hundreds of high radiation dose rate disused radioactive sources, and thousands of excess and disused sealed sources, many of which are of IAEA Hazard Category 1 and 2. Liquid transuranic waste is stored in four underground tanks. None of the waste inside Hanger 1 is properly characterized or packaged in accordance with international standards.

In order to support the VIND radioactive waste management activities, three new facilities have been built and are expected to be operational in 2009; they comprise a new waste storage facility (WSF), a secure storage bunker and a new waste processing facility (WPF). In addition, a former isotope production facility is in the process of being upgraded for use as a source conditioning facility (SCF).

Progress on this project is dependent upon completion of construction of the new WSF and the associated WPF. Significant progress has been made towards facility construction, and several of the major equipment items have been purchased. Each of these facilities is scheduled to be in startup mode at the beginning of the waste management work; therefore, in addition to the requirements for facility licences and Final Safety Analysis Reports (FSAR), Vinča will also need developed operational strategies, production schedules, safety and security strategies and staff training.

In 2008, the EC began its contribution to supporting specific waste management activities under Tasks 2 and 3 above, with a focus on resolving long term waste management issues. These comprise the decommissioning and dismantlement of the old waste storage facilities, along with the processing of the associated waste and the conditioning of the sealed sources stored in those facilities. The projects will be jointly managed and implemented by the Vinča Institute and the IAEA.

## 4. IAEA CONTRACTING APPROACH

The Vinča Institute does not have sufficient staffing or experience to implement all of the projects under the VIND Programme within the objective timeframes. The Vinča Institute also lacks clear operational/safety and security strategies and schedules for implementing non-fuel projects. Therefore, additional staff with specific expertise will be needed to support the startup and early operation of the new waste processing and storage facilities, the dismantling and/or decontamination and decommissioning of the old waste storage facilities and the training of Serbian technicians and to ensure that all programme activities are being performed in a safe and professional manner consistent with the applicable procedures, regulations, international standards and best practices. For this reason, it was decided that external contractors with expertise and experience in these areas would be hired. IAEA contracting therefore focused on augmenting Vinča capabilities in these areas.

The projects were expected to begin in early 2009. In order to reach this objective, three primary areas of preparatory activities were identified to achieve the work and funding schedules: Consolidation and Coordination of Contracts and Inputs, EC Contribution Agreements and Financial Assistance Agreement, and Procurement. Initial contract specifications were developed from the original 2009–2011 VIND Programme Design.

An expert panel met in October 2008 in order to develop detailed technical specifications and bidder evaluation criteria. The expert panel further consolidated the specifications and developed them into detailed technical specifications for 12 service contracts. These contracts were further revised to incorporate new guidance from the IAEA Office of Procurement Services, and, as a result, two service contracts were developed: (a) to provide radiation protection services for overall waste management work, and (b) to perform much of the site characterization, waste removal and dismantling and decommissioning of the old waste storage Hangers 1 and 2, source conditioning, and waste processing and storage in new waste facilities recently constructed at the Vinča Institute.

The Request for Proposal (RFP) packages were sent to over 20 companies which had international experience in RAW and sealed source management. The outcome of the bidding process was disappointing. Only a single bid was received for the radiation safety service RFP within the specified timeframe. No bids were received for the waste management service RFP. A technical evaluation was performed on the single bid received in order to determine whether it met the technical requirements identified in the bidder requirements and to provide recommendations for future submittals of this RFP. The expert panel concluded its evaluation of the bid with the determination that the single received bid was not of sufficient quality or detail to justify an award. The panel also recommended that the RFPs be revised to take account of the bidder's recommendations. After discussions with other potential bidders, the expert panel identified a number of factors resulting in their failure to produce bids. These factors, which include available human and financial resources, international teaming arrangements, manpower qualification, etc., will need to be taken into consideration for future bidding processes.

## 5. CONCLUDING REMARKS

Currently, the IAEA is working with EC and the Serbian Ministry to restructure the VIND projects, resulting in some activities being deleted, and most or all activities being postponed to late 2010 or early 2011. This is being driven by two factors: (a) the continuous delays in construction and commissioning of the waste management facilities and the source conditioning facility, and (b) the need to ensure adequate funding for spent fuel repatriation activities, all of which are critical to the new projects. As the IAEA begins the process of re-evaluating the VIND Project contracts, it is likely that the waste management and decommissioning activities will need to be re-evaluated, with priority being given to 'incremental decommissioning' of the old waste storage Hangers 1 and 2, underground liquid waste tanks, spent fuel storage pool, reactor hot cells and the RA reactor structure. Other VIND waste management and radiological infrastructure activities, including waste and source management activities, the Orphan Source Search and Recovery programme, a site-wide radiological assessment, and upgrades to the radiation protection and emergency response facilities, will be given a lower priority.