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Planning for environmental restoration of uranium mining and milling sites in central and eastern Europe

Proceedings of a workshop held under the Technical Co-operation Project RER/9/022 on Environmental Restoration in Central and Eastern Europe, Felix, Romania, 4–8 November 1996

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FOREWORD

Environmental degradation is a serious issue in most countries of central and eastern Europe and the former Soviet Union. As a result of extensive exploitation of natural resources and in particular of the mining and milling of uranium ores, large areas have become radioactively contaminated necessitating restoration and/or appropriate land use management techniques to ensure that the health and safety of affected population are not compromised. Further exploitation of large territories is thus severely limited and the long term impact, e.g. use of groundwater, is of prime concern. The Member States in the region are aware of the problem, but environmental restoration does not as yet enjoy high priority owing to prevailing economic conditions.

An IAEA Regional Technical Co-operation (TC) project RER/9/022 on "Environmental Restoration" for central and eastern Europe and the former USSR was launched in 1992 and concluded at the end of 1996. The first phase of this project had the primary purpose of identifying and characterizing radioactively contaminated sites in the region, including evaluation of doses to the general public and other environmental impacts. The main results of this phase of the project were published in IAEA-TECDOC-865. During the implementation of the project, it became apparent that most countries in the region share the problem of contamination from uranium mining and milling. A new 1995-1996 phase of the project focused on the radioactive contamination of uranium mining and milling sites and the development of plans for environmental restoration of these sites.

While the 1993-1994 phase aimed at attracting the attention of Member States in the region to a long neglected problem, the second phase served as a stimulus to initiate concrete planning activities that would lead to corrective actions in highly contaminated areas in those countries. As a consequence, the project emphasis shifted from scientific discussions to the identification of responsibilities, planning activities, and the assessment of existing and required resources for the eventual implementation of restoration plans. It was also expected that the end result of the project would increase regional co-operation in the field of environmental restoration as a means of assisting Member States in building up capabilities to solve environmental contamination issues. The project made use of the regional expertise already acquired in the countries which had more experience in the field of environmental restoration as well as in countries outside the region with similar experience.

The 1995-1996 phase of the project consisted of a planning meeting and three workshops that addressed different topical themes. Throughout the course of the project, participants presented the progress achieved and difficulties encountered in the implementation of environmental restoration plans in their respective national context. The papers compiled in this publication were presented at the last workshop, held in Felix, Romania, 4-8 November 1996. They summarize national situations in environmental contamination as of the end of 1996 and ongoing or planned actions for remediation.

The IAEA technical officer responsible for the workshops was M. Laraia of the Division of Nuclear Power and the Fuel Cycle. The project was managed and implemented by the Department of Technical Co-operation. The papers were compiled and edited by A.N. Prasad, India.

The IAEA wishes to express its thanks to all participants in the programme and would like to take this opportunity to acknowledge the excellent co-operation and hospitality of the institutions which hosted the project workshops.

EDITORIAL NOTE

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INTRODUCTION

1. INTERNATIONAL CO-OPERATION IN ENVIRONMENTAL RESTORATION

In the new and somewhat transformed world, international co-operation seems to be a rule rather than an exception. New alliances are made in technological as well as in economic fields. Countries with political differences in the past now work together to reap mutual benefits. Parties working in the same field should also take advantage of these changes and trends, and collaborate to make the best use of available technology and expertise.

It is a fact that the need for safe management of uranium mining and milling (M/M) waste exists in all continents of the world and as such there is international interest in this field. Broadly, three main modes of international co-operation can be visualized. The first through bilateral arrangements between individual countries and/or organizations. The second based on co-operation on a multi-lateral level among states regionally or interregionally and the third is through international organizations. The co-operation through international organizations in particular, with emphasis on information and technology exchange, including joint research and development and demonstration projects, has been very successful. Co-operation of this nature has many benefits and is extremely practical for several reasons. First, it makes good economic sense to share and learn from each other's experience and compare future strategies. The resulting benefit is that it prevents some duplication of effort. International organizations such as the European Commission (EC), the Organization for Economic Co-operation and Development/Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) play a major role in this area by facilitating information and technology exchange and transfer. A second point worth noting is that projects initiated by any or all of these international organizations tend to carry more credibility and therefore attract better financial support. Third, joint projects create a support network and a system of formal and informal peer reviews. This external review process enhances and adds technical credibility and validity to national approaches and methodologies. And, finally, technical co-operation and international exchange are used by countries as a measure of their own progress.

International organizations can be useful in areas other than information and technology exchange as well. They can also, for instance, set up standards and guides on how to perform environmental restoration projects in the safest and most effective way. As an example, standardized procedures for deriving cleanup levels for contaminated land areas and guidelines regarding disposal of large amounts of low level waste in the best possible way could be set up by an international organization drawing upon the knowledge and expertise of the Member States.

2. IAEA ACTIVITIES IN ENVIRONMENTAL RESTORATION

The IAEA has a long history of publications and technical co-operation (TC) projects in the field of uranium M/M waste. In the late 1980s, TC projects in this field were successfully implemented among others in Argentina and Portugal. An IAEA TC mission in 1992 to the Rössing Uranium Mine in Namibia disclosed that despite limited resources, dedicated efforts of the management yielded highly satisfactory results in achieving acceptably low levels of contamination and prevention of spread of radioactive contaminants. IAEA sponsored assessments of the radiological conditions at mines and mills in several other countries have shown that uranium production can be carried out in a safe manner without detriment to the environment. A list of IAEA publications in the field of environmental restoration is given in Table I. Two reports are particularly relevant in this regard. A report published in 1992 [1] discusses the current practices used in the design, siting, construction and operation of impoundment facilities for uranium mill tailings. The objective is to present an integrated overview of the technological safety and radiation protection aspects in order to ensure that the potential radiological and non-radiological risks associated with the management of uranium mill tailings are minimized now and in the future.

Table I
LIST OF IAEA DOCUMENTS PUBLISHED SINCE 1980 ON ENVIRONMENTAL RESTORATION OF RADIOACTIVELY CONTAMINATED SITES INCLUDING URANIUM MINING AND MILLING SITES

	Safety Series (SS)	
1.	Safe management of wastes from the mining and milling of uranium and thorium ores: Code of practice and guide to the code	SS No. 85 (1987)
	Technical Reports Series (TRS)	
1.	Cleanup of Large Areas Contaminated as a Result of a Nuclear Accident	TRS No. 300 (1989)
2.	The Environmental Behaviour of Radium	TRS No. 310 (1990, 2 vols.)
3.	Planning for Cleanup of Large Areas Contaminated as a Result of a Nuclear Accident	TRS No. 327 (1991)
4.	Disposal of Wastes From the Cleanup of Large Areas Contaminated as a Result of a Nuclear Accident	TRS No. 330 (1992)
5.	Measurement and Calculation of Radon Releases from Uranium Mill Tailings	TRS No. 333 (1992)
6.	Current Practices for the Management and Confinement of Uranium Mill Tailings (Supersedes TRS No. 209)	TRS No 335 (1992)
7.	Decommissioning of Facilities for Mining and Milling of Radioactive Ores and Closeout of Residues	TRS No. 362 (1994)
	Technical Documents (TECDOC)	
1	Environmental Migration of Radium and Other Contaminants Present in Liquid and Solid Wastes from the Mining and Milling of Uranium	IAEA-TECDOC 370 (1986)
2.	In-Situ Leaching of Uranium: Technical, Environmental and Economic Aspects	IAEA-TECDOC 492 (1989)
3.	Uranium In-Situ Leaching	IAEA-TECDOC 720 (1993)
4.	Planning and Management of Uranium Mine and Mill Closures	IAEA-TECDOC-824 (1995)
5	Planning for Environmental Restoration of Radioactively Contaminated Sites in Central and Eastern Europe	IAEA-TECDOC 865 (1996, 3 Vols.)
6.	Closeout of Uranium Mines and Mills: A Review of Current Practices	IAEA-TECDOC-939 (1997)
	Proceedings Series	
1.	Management of Wastes from Uranium Mining and Milling, IAEA-OECD/NEA Symposium, Albuquerque, USA, 1982	Proceedings Series

The report

(a) identifies the nature and source of radioactive and non-radioactive pollutants in uranium mill tailings;

(b) identifies the important mechanisms by which pollutants can be released from the tailings impoundment and the variables that control these mechanisms;

(c) reviews radiation protection aspects of these mechanisms;

(d) describes the pathways by which the pollutants may reach humans; and

(e) describes some of the site selection and design options that may be implemented to facilitate disposal and/or control the extent of releases from the impoundment.

Aspects related to decommissioning of facilities for and closeout of residues from M/M of uranium ores are emphasized in another technical report [2], which presents an overview of factors involved in planning and implementation of decommissioning/closeout of uranium mine/mill facilities. The information contained applies to mines, mills, tailings piles, mining debris piles and leach residues that are present as operational, mothballed or abandoned projects, as well as to future mining and milling projects. The report identifies the major factors that need to be considered in the decommissioning/closeout activities, including regulatory considerations; decommissioning of mine/mill buildings, structures and facilities; decommissioning/ closeout of open pit and underground mines; decommissioning/closeout of tailings impoundments; decommissioning/closeout of mining debris piles, unprocessed ore and other contaminated material such as heap leach piles, in situ leach facilities and contaminated soils; restoration of the site, vicinity properties and groundwater; radiation protection and health and safety considerations; and an assessment of costs and post-decommissioning or post-closeout maintenance and monitoring aspects.

The political changes in Central and Eastern Europe (CEE) and the former Soviet Union have revealed the state of the environment in these countries. An extensive industrial build up and heavy depletion of natural resources in these countries to accomplish the quota based productivity goals have resulted in neglect of the preservation and protection of the environment.

The radioactive contaminant materials resulting from diverse activities related to the nuclear fuel cycle, defense and industries, in addition to medical and research applications have taken a heavy toll on the environment causing severe pollution, a legacy from the past era. The waste resulting from some fifty years of activities has piled up - often at unregistered sites - leaving the public with the potential danger of long term radiation exposure.

The political changes not only brought forward a fragmentary disclosure of the nuclear contaminated sites, but also resulted in a condition in which these countries became receptive to co-operation from a category of countries the region had previously been isolated from.

It was in these circumstances of change that the IAEA decided to launch the Technical Co-operation Project RER/9/022 on Environmental Restoration in Central and

Eastern Europe. The first phase of the project was initiated in the latter part of 1992 and concluded in 1994.

The main focus of the project was the identification and characterization of radioactively contaminated sites in the region of CEE. Before any action in regards to environmental restoration could be taken, the countries involved and the IAEA needed to obtain an overview of the environmental status in each of the countries. The Agency requested selected experts from the targeted Member States to present a comprehensive report identifying contaminated sites in their home countries. The experts have, as thoroughly as possible, surveyed and categorized each site according to location, volume and radioactive concentration. Also included were data on radioactive concentrations in the sites, source(s) of contamination, description of radiological hazard (e.g. proximity to population areas), potential for spreading of contamination, etc. Wherever possible, organizations responsible for the monitoring and cleanup of each of the contaminated sites have also been identified. The results of the 1993-94 phase have been published in a TECDOC [3] and summarized in a paper [4].

During implementation of the IAEA project, it became apparent that most countries in the region share the problem of contamination from uranium M/M (accident-generated contamination involves relatively fewer countries; and other TC projects deal with these matters). As a follow-up, a second phase was therefore established for 1995-1996 with the aim of focussing on radioactive contamination from uranium M/M and the development of plans for environmental restoration.

While the 1993-1994 phase aimed at attracting the attention of Member States to a long neglected problem, it was felt that the time has come for Member States to initiate concrete planning activities that would lead to corrective actions in highly contaminated areas. The emphasis shifted from scientific discussion to the identification of responsibilities, to planning activities, and to assessment of existing and needed resources for the eventual implementation of restoration plans.

3. MECHANISMS FOR THE IMPLEMENTATION OF THE 1995-96 PHASE OF THE IAEA PROJECT (RER/9/022)

This phase included a preliminary planning meeting and three workshops. The planning meeting, involving designated experts from the region, had the purpose of determining the expected inputs from the Member States of the region. It should be noted that two years was not enough to allow detailed elaboration of environmental restoration plans. However, preliminary plans were expected by the end of the project. Based on the results of the planning meeting, subsequent workshops were conducted in parallel with planning activities in Member States. During workshops, designated experts presented progress reports. Countries with hands on experience in environmental restoration provided practical information and knowhow. Project schedule included a planning meeting in Vienna (March 1995), workshops in Bulgaria (October 1995), Ukraine (April 1996) and the latest one in Romania (November 1996).

The second objective of the Vienna meeting was to establish the implementation mechanisms of future meetings within the Project. Following the discussions, it was decided to use three mechanisms in parallel at any given workshop:

1) **Peer review of selected environmental restoration projects/studies**. This mechanism was ideally implemented when the site subject to peer review was visited by the group of designated experts. To improve efficiency of the peer review process, the host country sent relevant information to the experts well before the workshop when the site in question was to be visited. The scope and extent of the peer review process depend on the information provided by the host country. For example, at the workshop in Sofia, Bulgaria in October 1995, such a mechanism was successfully implemented for the Bukhovo (near Sofia) environmental restoration project.

2) **Progress reports**. Member States participating in the IAEA project are developing environmental restoration plans and studies which were presented in progress reports.

3) **Discussion on specific topics.** Such topics are assigned to specified experts from and/or outside CEE for workshop presentation. Some of the topics dealt with in the project have been as follows:

- radiological characterization and dose assessment;
- cleanup standards and other regulations;
- groundwater contamination and remediation; and
- costs.

The following countries were primarily addressed by the project: Bulgaria, the Czech Republic, Estonia, Kazakstan, Kyrgyzstan, Poland, Romania, Slovenia, Ukraine and Uzbekistan. Designated experts from these countries took part in the above-mentioned workshops and delivered the papers which are included in this publication. Invited speakers from the following countries: Canada, France, Germany, Russian Federation, Spain and the USA provided information on planning for and implementing environmental restoration based on their national experience. It is felt that the attendance of experts from industrialized countries has greatly contributed to technology and know-how transfer to project recipient countries. Papers describing environmental restoration activities underway in industrialized countries may provide orientation and guidance to countries embarking on similar projects and have therefore been also included in this publication. Although environmental conditions and other factors may differ from country to country and from site to site, similarities in technical factors may also be found.

In the context of the uranium M/M industry in CEE, a particularly significant case is the contamination in the former East Germany. Unlike other uranium producing countries, the German mining operations are situated in a relatively small district, stretching 150 km east to west and 50 km north to south, in Saxony and Thuringia in the southern part of eastern Germany. Especially in the early post-war years of uranium production, the company Wismut carried out mining/milling practically without considering damage to the environment or effects on humans. The result of the years of uranium M/M is many square kilometres of contaminated land and facilities. These were used during various periods for different purposes, including intermediate storage, transport, mining and milling of ore, as well as the deposition of waste rock and tailings. The environmental problems are serious for such a densely populated region.

Just by comparing the Wismut case with the situation of the uranium industry in Eastern European countries the following similarities become obvious:

- the location of the deposits in rather densely populated areas;
- the types of deposits, which are hardly competitive by world standards; and
- the technologies used, which were developed in a political and economic environment of central planning for self-sufficiency and full employment.

The Wismut case, however, differs completely with regard to the financial situation. After Germany's reunification, the German federal government has fully accepted the financial responsibility for decommissioning and rehabilitation of the Wismut facilities. The Eastern European countries, however, are in a difficult economic situation as they move towards free market economies. Funds for environmental programmes will be limited in the short- and medium-term future [5].

4. IMPACT OF THE PROJECT

It is expected that the IAEA project will increase the awareness of Member States in CEE and the former Soviet Union of the need for timely environmental restoration planning. In some countries, in particular those facing the most critical environmental conditions, this should lead to the formulation of detailed environmental restoration plans. The project offered Member States the opportunity of estimating financial and other aspects of environmental restoration so that plans can be drafted without undue delay. At the same time, the project should have provided motivation to look closely at the undesirable consequences of not taking action. Thus, the project is expected to trigger a process leading to implementation of large-scale environmental restoration activities.

In more general terms, the project should have contributed to enhance the organizational capabilities of the Member States which participated. Since environmental restoration is a multi-disciplinary activity, the project will stimulate these countries to develop an integrated approach to optimize resources. Also, it should be noted that radioactive contamination is part of the overall environmental contamination in the region. In this respect, the impact of the project will be more significant.

5. CONCLUSION

According to all accounts, the countries in Eastern Europe and the former Soviet Union are already aware of their serious environmental contamination. The governments of several of these countries are already initiating action plans. The full participation of these Member States in the TC regional project described in this TECDOC clearly demonstrated that they are seeking international assistance and guidance to embark on environmental restoration programmes. It is therefore expected that within a short timespan, most Member States should have developed the needed expertise to formulate their environmental restoration plans. This includes identification of relevant technical, administrative and financial resources. More distant developments would be related to the practical implementation of national projects.

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SUMMARY

The following is intended to give an overview of special issues of environmental restoration in central and eastern Europe (CEE), as they have emerged in the course of the IAEA project and are highlighted in papers submitted by national respresentatives in the course of RER/9/022.

1. TECHNOLOGICAL ASPECTS

Although the need for environmental restoration is not limited to the CEE regions, a few distinctive features may raise additional complications. For example, if the uranium production facilities are found to require some form of remedial action, the size and location of the CEE production centres pose potential complications in the restoration work. Unlike some countries in which mineral development occurred in remote areas (e.g., the USA) or resulted in relatively small volumes of waste, the CEE countries face greater logistical complications for two obvious reasons. Firstly, the volumes of the accumulated radioactive waste are far too large to be removed at a reasonable cost. Secondly, safer alternative disposal sites are either not available or else are impractical.

During the 1980s and early 1990s, many older uranium mines were closed because of a decrease in the demand for uranium and an increase in the overall supply. The resulting low prices and the cost of providing the extra measures needed to satisfy society's higher expectations in the area of environmental and radiological protection made production of uranium unprofitable for many low grade mines. Moreover, the economic difficulties being faced by these countries have further complicated the implementation of site restoration.

Although some of these mines/mills will probably reopen when demand and prices start to rise, many will be shut down permanently and need to be decommissioned/closed out. As this situation has evolved in a relatively short period of time, limited resources have been spent on remediation or even securing contaminated areas in CEE countries.

The following factors contribute to an increased risk of radioactive contamination:

- Long operational periods contribute to greater risk of contamination;
- Higher ore grade increases radiation dose rates from the residues;
- Natural climatic conditions (e.g., rain, wind) significantly enhance dispersal and contamination; and
- Countries with limited resources can only allocate marginal resources to environmental restoration.

Unfortunately, most of the CEE countries "qualify" under these factors.

2. BASIC CONDITIONS AND PROBLEMS

Although some political, economic, and infrastructural conditions are common to many countries in the CEE region, large variations exist. In general, three categories of basic environmental restoration situations can be identified:

- countries with limited development of the uranium industry resulting in small amounts of mining/milling waste and few contaminated sites (e.g., Poland);

- countries with more developed uranium industry having several mines/mills and moderately committed resources (e.g., Romania); and
- countries with a fully developed uranium industry having many mines/mills and severely committed resources (e.g., the Czech Republic).

Typical problems associated with past practices in CEE include radon release; groundwater contamination; proximity of population to contamination; lack of resources to conduct restoration; non-availability of disposal locations/alternatives; absence of regulations or regulatory infrastructure for restoration; misuse or removal of tailings for use in construction; absence of responsible operators; and large inventories and aereal dispersion.

In some cases, groundwater contamination is such a severe issue that major sources of drinking water are threatened by radiological and chemical contamination. Another typical situation in CEE countries is the proximity of uranium production sites to population centres. This proximity has, on occasion, lead to the use of some of the waste rock and tailings materials for building purposes. Such structures are constant sources of indoor radon; one of the most significant radioactive hazards.

3. OTHER ASPECTS OF ENVIRONMENTAL RESTORATION IN CENTRAL AND EASTERN EUROPE

Site specifications. The siting and characterization of radioactively contaminated sites in CEE countries is probably the most difficult problem in relation to environmental restoration projects. The available data is not only incomplete but also somewhat questionable. A precondition for environmental restoration projects must be the availability of sources of data pertinent to the specific radioactively contaminated sites; otherwise the efforts and resources put into the process are useless.

Organizational problems associated with the political changes. In many CEE countries, the old regulatory framework is being changed to reflect newly independent or radically altered political structures. Such frameworks, including the development of new laws and regulations, are planned or are just coming into existence. In some countries, existing laws will necessarily be adapted to changed political situations. There will be a period of transition, as such changes occur and ambiguities in new responsibilities are resolved. This situation is likely to complicate decision making in environmental restoration.

The funding of environmental restoration work. A number of outside agencies, such as the World Bank and European Bank of Reconstruction and Development, as well as individual countries and groups of countries such as the European Union, are offering support for environmental restoration. However, there can be a lack of co-ordination and, therefore, duplication among these projects that could result in inefficient use of available funds. Moreover, effective allocation and distribution of financial resources within countries may also prove to be difficult.

Available infrastructures for managing the wastes and residues from remediation programmes. To manage effectively the residues and wastes from the cleanup programmes, countries need waste management infrastructures/facilities to process, store and safely dispose of any resulting radioactive wastes from restoration. In many of the CEE countries, the stages of the nuclear fuel cycle were co-ordinated regionally. In most countries only parts of this infrastructure remain. Without having practical access to radioactive waste disposal facilities there could be constraints and limitations in the cleanup efforts.

Increasing differences among the CEE countries. Large co-ordinated projects are likely to be more cost-effective and beneficial for these regions than separate national programmes. Nevertheless, there are tendencies that these countries will go in different ways because of the dissimilarities in the nature of their present economic and political conditions and goals. This is not beneficial for achieving the overall goal of efficient use of resources on environmental restoration. Geographical proximity, similar political structure, and the same types of waste call for close co-operation and more effective use of similar technology and experience to deal with common problems.

Public attitudes. Another problem with environmental restoration projects is the *governmental, scientific and public view of the problem of radioactive waste.* Since radioactively contaminated materials have been commonly used in these regions for nearly 50 years, in conjunction with outdated practices in the handling of such material, the public has had little recourse but to accept the presence of radioactive contamination around them. In many instances, the public did not even know that these materials were in such close proximity to their homes. This situation appears to be changing, as people in these countries come to understand the hazards associated with them.

PLANS FOR ENVIRONMENTAL RESTORATION OF URANIUM MINING AND MILLING SITES IN BULGARIA

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Abstract

In 1992, uranium mining and milling industry in Bulgaria was closed down by Decree No. 163 of the Council of Ministers of the Republic of Bulgaria which defined the procedure for development of liquidation plans, their approval and the procedure for funding from the national budget.

The 1994 Decree No. 56 of the Council of Ministers assigned the organization of the liquidation and rehabilitation activities to the Committee of Energy (later, in 1996, transformed to the Ministry of Energy and Energy Resources). An Interdepartmental Board of Experts including representatives of all concerned ministries and agencies was established to coordinate the above activities and to approve work plans.

The main stages of liquidation of the uranium industry and its after-effects were defined as follows: (1) environmental status (maintenance of a minimized service mode in order to preserve the state of the site-environment system); (2) technical liquidation; (3) technical recultivation; (4) biological recultivation; (5) purification of contaminated waters; and (6) monitoring.

In 1992 and 1993, preparation for the above activities was carried out by development of detailed preliminary studies and work plans for the first stage - the stage of technical liquidation. Their implementation was launched by evacuation of mining and drilling machinery, haulage and processing of finished products etc.

1. NATIONAL CONDITIONS REQUIRING ENVIRONMENTAL RESTORATION

Specific aspects and conditions of uranium mining in Bulgaria require separate examination (fig. 1, Annexes 1, 2, 3).

1.1. For conventional uranium mining:
1.1.1. Numerous thin bed deposits which are exploited through small mines and sections.
1.1.2. Mining sectors are situated in mountainous areas with highly folded relief, difficult mining, technological and hydrogeological conditions as well as high water inflow.
1.1.3. The two largest mining districts (Buhovo and Eleshnitza) are located in densely populated areas, close to settlements.

1.2. For geotechnological uranium mining:
1.2.1. Mining is conducted on quality agricultural lands in highly developed and densely populated agricultural areas.
1.2.2. The mine levels are laid deep under thick waterproof layers without tectonic dislocations.

The above situations require large-scale and diverse series of activities in order to restore environmental balance in the mining districts and to prevent the harmful after-effects of uranium mining on the environment and the population.

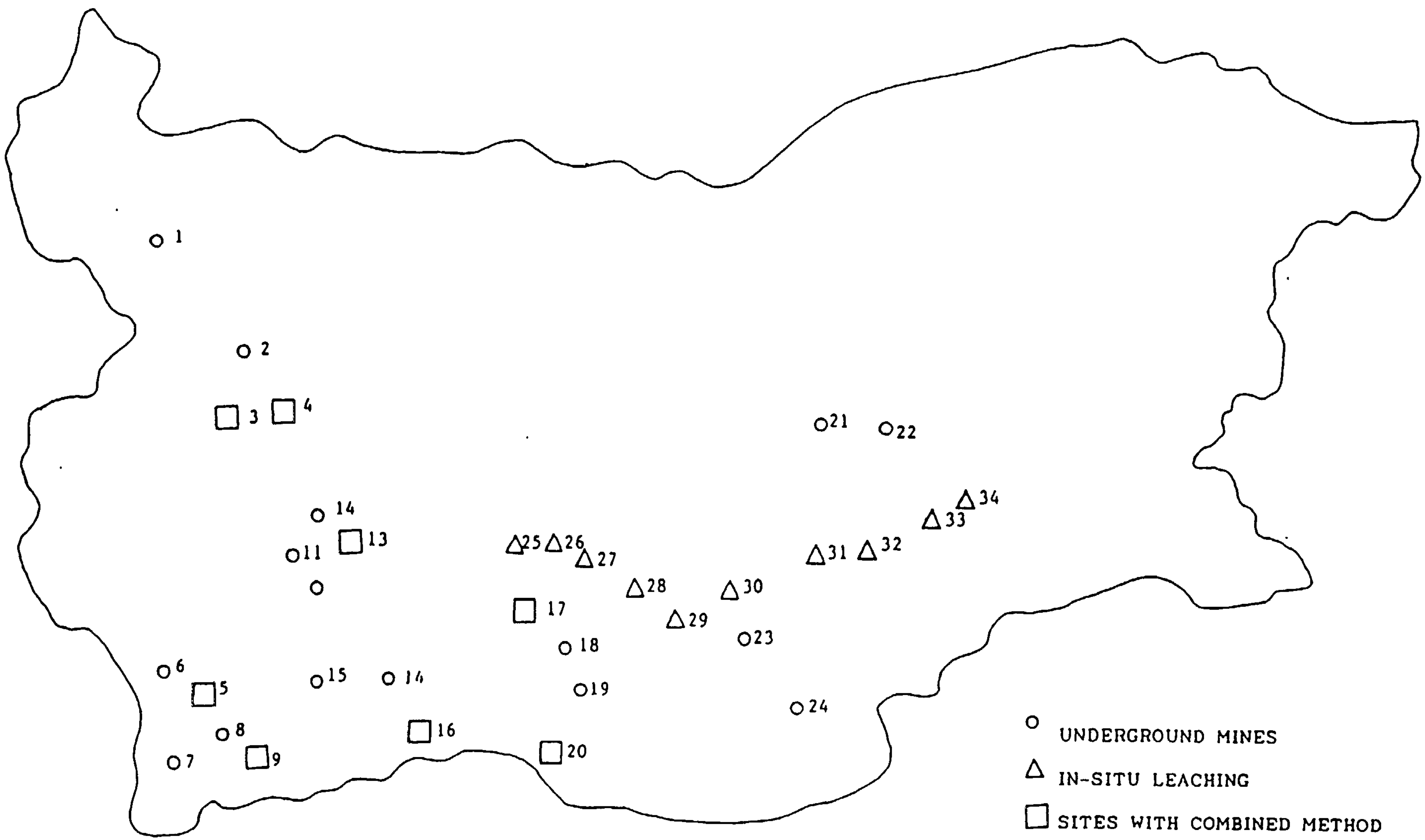

FIG. 1. URANIUM MINING SITES IN BULGARIA

2. LEGISLATION, REGULATIONS, POLICIES

2.1. Regulations with regard to the maximum allowable concentration of radionuclides in the environment, dose loads and other requirements concerning the radiation protection of the population have been harmonized with the European standards.

2.2. The organization, responsibilities and funding of the liquidation of uranium mining after-effects have been set forth in the 1994 Decree No. 56 of the Council of Ministers.

2.3. The governmental policy, proclaimed in the above decree is aiming at full implementation of the program for complete liquidation of uranium mining and uranium processing after-effects and at establishing of a long-term monitoring system in the endangered regions in Bulgaria.
(1992-1994 expenditures incurred in pursuance of Decree No. 56 are given in Annex 4)

3. ACTIVITIES IN 1995-1996

3.1. Technical liquidation of uranium mining and milling sites.
3.1.1. In 1995-1996 the technical liquidation was completed on 45 sites out of a total of 55 sites subject to the provisions of Decree No. 56 of the Council of Ministers.
3.1.2. Minor finish-off works for approximately 22 million levs (150 000 DM) remain to be performed on 8 of the sites.
3.1.3. The project for technical liquidation of the Zvezda processing plant in the village of Eleshnitza is currently in the stage of implementation.
3.1.4. The implementation of the accepted project for technical liquidation of the second processing facility - the Metalurg plant in the town of Buhovo is scheduled for the end of 1996.

(The technical liquidation expenditure by single companies are given in Annex 4.)

3.1.5. Main principles and technical solutions for the process of technical liquidation
3.1.5.1. For underground mines with classical and combined mining method:

- closing the exits of all level and sloping workings with double cast-in-place walls and covering up the entrances;
- filling of entrance level and sloping sections to prevent terrain dislocations due to self-caving of galleries;
- erection of barrage walls, syphon installations and pipe systems for free-flowing ground water management, conditioning and purification;
- filling and closing of shaft mouths with double slabs of reinforced concrete;
- demolition of pithead complexes and radiologically contaminated buildings;

3.1.5.2. For openpit sections:

- covering openpit bottoms with a watertight layer;
- filling of ore reveal zones until they are at least covered;
- correction of boards to the self-caving angle;

3.1.5.3. For geotechnological mine fields:

- filling of technological boreholes with sand-cement mixture

- dismantling of concrete borehole well heads
- dismantling of technological pipelines and of the entire technological equipment
- excavation and raking out of radiologically contaminated soil plots
- neutralization of chemically contaminated areas
- demolition of radiologically contaminated equipment foundations, production platforms etc

Note· A passive liquidation scheme was adopted for all technological sections on the basis of preliminary studies and examinations

3 2 Technical recultivation

Technıcal recultivation has been performed on 28 sites (expenditures are listed in Annex 5)

3 3 Bıological recultivation

At present, biological recultivation projects are in different stages of implementation on 18 sıtes (see Annex 6)

3 4 Current monitoring

The followıng items were monitored during the period

- waters in the areas of underground mines, open pits and dumps with increased radionuclide content;
- borehole fields in the geotechnological mining sections in the course of the ımplementation of recultivation projects

4. PROJECTS UNDERWAY

4 1 Technical liquidation

- one project is being currently implemented - the technical liquidation of the Zvezda processing plant in Eleshnitza,
- in 1997 the remaining work will be carried out on the technical liquidation projects for 8 sites,
- the technical liquidation project for the last remaining site - the Metalurg processing plant in Buhovo will be launched in 1997

4 2 Technical and biological recultivation is currently performed on 18 sites, and in 1997 is slated to begin on 21 more sites.

- Anticipated technical and biological recultivation expenditures for 1997 amount to 445 millıon levs (about 3 million DM)

4 3 Water purification in 1995-1996 has been performed on 4 sites

- Incomplete sorption purification and neutralization was employed
- 1995-1996 expenditure totaled 14 million levs (300 000 DM)
- 1997 operatıon and construction expenditure is expected to reach 271 5 million levs (1 8 mıllion DM)

5. PRIORITIES AND PLANS

5.1. Implementation of work projects for recultivation and management of ground and surface waters in:

- Buhovo district (Redki Metali Ltd., Podzemno Stroitelstvo Ltd.)
- Eleshnitza district (Zvezda Ltd. and Redki Metali Ltd.)
- Simitli district (Georesurs Ltd.)

5.2. Implementation of work projects for biological recultivation of agricultural lands:

- East and West Thrace districts (Trakia RM Ltd. and Geostroikomplekt Ltd.)
- Simitli district (Georesurs Ltd.)

5.3. Development and implementation of work projects for construction of monitoring networks around the uranium sites
5.3.1. Organization of the monitoring system for control and analysis

5.4. Technical liquidation of the two processing plants

5.5. Development of comprehensive rehabilitation programs for the areas of the tailings ponds

5.6. Development of work projects for purification installations for ground and surface waters contaminated with radionuclides from the uranium mining and processing sites.

6. WORK PROGRAMMES OF DIFFERENT COMPANIES

6.1 The work programmes of the different companies provide for implementation of the projects for technical liquidation, technical and biological recultivation, water purification and monitoring.

6.2 The total amount of funds needed for these programs is given in Annex 7.

7. DIFFICULTIES ENCOUNTERED OR ANTICIPATED

7.1. Difficulties caused by the existing regulatory base
7.1.1. The 1992 governmental Decree No. 163 for immediate close-down of uranium mining in Bulgaria forced preparatory works for liquidation to be carried out in a situation of acute time shortage. In view of this, initial efforts were focused on the development of work projects for technical liquidation without developing comprehensive programs for all liquidation and sanitation stages of the sites and adjacent areas. The lack of such program co-ordination among separate work stages could result in deterioration of work organization, cost overrun and revisions in the project schedule.
7.1.2. The regulatory base does not differentiate between maximum allowable concentration of natural and technogenous radionuclides which complicates their treatment.
7.1.3. Lack of regulatory criteria for the degrees of purification of uranium industry waste waters depending on their usability and genesis leads to inefficiency.

7.2. Difficulties caused by the existing organization

7.2.1. The complete legal and financial independence of the nine companies and the lack of a legally competent administrative body are impeding:

- co-ordination of action;
- application of uniform criteria;
- establishing priorities for action.

7.2.2. There is no joint structure which could organize:

- the monitoring systems for operation of monitoring networks;
- the operation of the water processing and purification systems.

7.3. Difficulties caused by inadequate approaches

7.3.1. The lack of comprehensive projects for liquidation of the sites presenting complete concepts for realization of all stages

7.3.2. Development of work project technical and economic assignments by the different companies without the evaluation of a centralized institution results in errors in the choice of the optimal version.

7.3.3. Problems related to participation in international projects.

8. CONCLUSIONS

8.1. A change in the organization and implementation of the activities directed towards liquidation of uranium mining after-effects is needed.

8.1.1. A legal entity has to be established in order to administer and coordinate all liquidation activities in Bulgaria.

8.1.2. Work projects for technical and biological recultivation should be combined with the projects for water purification and setup of monitoring networks and be included into comprehensive programs for the particular sites.

8.2. The monitoring system has to carry out monitoring of all uranium sites.

8.3. The scope of recultivation works and monitoring has to be expanded to include all uranium sites, not just the sites that have been liquidated in the recent years.

ANNEX 1

URANIUM SITES IN BULGARIA - TYPE OF OPERATION

No	Company	Deposit (sites)	Type of operation						
			Exploration	Prodaction					Processing
				Konventional		ISL			
				open pit	Undeground	ISL fields	underground	Heap leachin	
1	Redki metall Ltd		8	3	8	1	4	4	2
1.1.1.		Izgrev	+	+	+		+	+	
1.1.1.		Eleshnitca - Polyane	+		+	+			
1.1.3.		Eleshnitca - Drujba 1	+	+	+		+	+	
1.1.4.		Eleshnitca - Drujba 2	+	+	+		+	+	
1.2.1.		Smollan -Shaft 7	+		+				+
1.2.2.		Smollan -Shaft 8	+		+		+		
1.3.1.		Smolianovtci	+		+			+	
1.3.2.		Vinishte	+						
1.4.1.		Metalurg - HM plant							+
2	Trakia - RM - Ltd.		19		2	16	1	1	
2.1.1.		Tzeretelevo	+			+			
2.1.2.		Tzarimir	+			+			
2.2.1		Trilistnik	+			+			
2.2.2.		Momino - Rakovski	+			+			
2.2.3.		Belosem	+			+			
2.3.1		Maritza	+						
2.3.2.		Cheshmata	+			+			
2.3.3.		Navasen	+			+			
2.3.4.		Debar	+			+			
2.3.5.		Troyan	+			+			
2.4.1.		Orlov dol	+			+			
2.4.2.		Madrec	+			+			
2.4.3.		Vladimirovo	+			+			
2.4.4.		Chucarovo	+			+			
2.4.5.		Okop	+			+			
2.4.6.		Tenevo	+			+			
2.4.7.		Selishte	+		+	+			
2.4.8.		Dobroseletc	+						
2.5.		Byalata voda	+		+		+	+	
3	Geostroikompekt Ltd		6		3		2		
3.1.1		Sborishte	+		+		+		
3.1.2.		Sliven	+		+				
3.2.1		Zdravetz	+				+		
3.2.2		Kara tepe	+						
3.2.3.		Kalach borun	+						
3.3.1.		Sarnitca	+		+				
4	Georesurs Ltd.		6	1	1	2	1	1	
4.1.		Struma - 1	+		+				
4.2.		Struma - 2	+			+			
4.3.		Gradeshnitca	+			+			
4.4.		Igralishte	+				+	+	
4.5.		Senokos	+	+					
4.6.		Brejiani	+						

ANNEX 1
(Cont.)

No	Company	Deposit (sites)	Type of operation						
			Exploration	Prodaction					Processing
				Konventional		ISL			
				open pit	Undeground	ISL fields	underground	Heap leachin	
5	Podzemno stroitelstvo		6	1	6		2	1	1
5.1.		Goten	+		+				
5.2.		V-ta shahta	+	+	+		+		+
5.3.		Chora	+		+				
5.4.		Iskra	+		+		+	+	
5.5.		Chamilov kamak	+		+				
5.6.		Borche	+		+				
6	Balkan Ltd.		1		1				
6.1.		Probolnitca	+		+				
7	Zlata Ltd.		2	1	1				
7.1.		Yamka	+						
7.2.		Gabra	+	+	+				
8	Zvezda Ltd.								1
8.1.		Zvezda - HM plant							
9	Georedmet Ltd		1	1	1				
9.1.		Narechen	+	+	+				

ANNEX 2

URANIUM PRODUCTION AND PROCESSING SITES

No	Company	Depozit (site)	Nr	konve		I S L			HM		Year of production																																												
				op	un	fie	un	he	ac	al	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92
	Uranium production mine			+	+	+	+	+	+	+	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##
1.1.1.;1.1.3.;1.1.4.	Redki metali Ltd.	Eleshnitca	3	+	+	+	+	+	+	+											##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##
1.1.2.	Redki metali Ltd.	Dospat	1	+	+		+	+		+												##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##									##	##	##	##	##		##	
1.2.1.;1.2.2.	Redki metali Ltd.	Smolian	2		+		+	+															##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##
1.3.1.	Redki metali Ltd.	Smolianovtci.	1		+			+	+																																									##	##	##	##	##			
1.4.1.	Redki metali Ltd.	Metalurg							+	+			##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##
2.1.1.;2.1.2.	Trakia-RM Ltd.	Tzarimir	2			+			+																																							##	##	##	##	##	##	##	##		
2.2.1.	Trakia-RM Ltd.	Trilistnik	1			+			+																																					##	##	##	##	##	##	##	##	##	##		
2.2.2.	Trakia-RM Ltd.	Momino	2			+			+																															##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##
2.2.3.	Trakia-RM Ltd.	Belozem	1			+			+																																						##	##	##	##	##	##	##	##	##		
2.3.2.	Trakia-RM Ltd.	Cheshmata	1			+			+																																	##	##	##	##	##	##	##	##	##	##	##	##	##			
2.3.3.	Trakia-RM Ltd.	Navasen	1			+			+																																		##	##	##	##	##	##	##	##	##	##	##	##	##		
2.3.4.	Trakia-RM Ltd.	Pravoslaven	1			+			+																																									##	##	##	##	##	##		
2.3.5.	Trakia-RM Ltd.	Ttroian	1			+			+																																													##	##		
2.4.1.	Trakia-RM Ltd.	Orlov dol	1			+			+																									##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##					
2.4.2.	Trakia-RM Ltd.	Madretc	1			+			+																														##	##	##	##	##	##	##	##	##	##	##	##							
2.4.3.	Trakia-RM Ltd.	Vladimirovo	1			+			+																																			##	##	##	##	##	##	##	##						
2.4.6.	Trakia-RM Ltd.	Tenevo	1			+			+																																										##	##	##	##	##		
2.4.7.	Trakia-RM Ltd.	Selishte	1		+	+			+																	##	##	##	##	##	##	##	##			##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##		
2.5.	Trakia-RM Ltd.	Kosten.	1		+		+	+		+																											##	##			##	##	##	##	##	##	##	##	##	##	##	##	##	##	##		
3.1.1.	Geostroikomplekt Ltd.	Sborishte	1		+		+		+																											##		##	##	##	##	##	##	##	##	##	##	##	##	##		##	##	##	##		
3.1.2.	Geostroikomplekt Ltd.	Sliven	1		+																						##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##													
3.2.1.	Geostroikomplekt Ltd.	Zdravetc	1				+		+																																												##	##	##		
3.3.1.	Geostroikomplekt Ltd.	Sarnitca	1		+																								##	##	##	##	##	##																							
4.1.	Georesurs Ltd.	Struma 1	1		+																																												##	##							
4.2.	Georesurs Ltd.	Struma 2	1			+			+																																										##	##	##	##	##		
4.3.	Georesurs Ltd.	Gradesnitca	1			+				+																																												##	##		
4.4.	Georesurs Ltd.	Igralishte	1				+		+																																						##	##	##	##	##	##	##	##			
4.5.	Georesurs Ltd.	Senokos	1	+																																																##	##	##	##		
5.1.;5.2.;5.3.;5.5;5.6.	Podzemno stroitelstvo L	Buhowsko rudno pol	5	+	+		+			+	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##	##		
5.4.	Podzemno stroitelstvo L	Iskra	1		+		+	+	+											##	##	##	##	##	##	##	##	##																						##	##	##	##	##			
6.1.	Balkan Ltd.	Proboinitca	1		+																								##																					##	##	##	##	##			
7.2.	Zlata Ltd.	Gabra	1	+	+																																												##	##	##	##	##	##			
8.1.	Zvezda Ltd	Zvezda							+	+																																															
9.1.	Georedmet Ltd.	Narechen	1	+	+																			##	##	##	##									##	##	##	##	##	##	##		##			##		##	##							
	Nonassociate	Nonassociate	5																		##	##	##	##	##																																		

ANNEX 3

BULGARIA - RESULTS OF URANIUM MINING

Location		Total	Icluding Non associate
Current Status in 1996	* 1)	cl	cl
Ownership		State property	state property
Time of operation	from - to	1946-1993	1955-1986
Type of operation			
Exploration	type/size	Bore holes and mine works	15 sites-Bore holes and
Open pit mine(s)	Nr/size/v	1 mine and 11 sites	
Undegroun mine(s)	Nr/size/	29 mines	6 mine
ISL-fields	Nr/field s	19 mines/1260.8 ha + 4 mines/un	2 mine
Underground leaching	Nr/type/	4 mine-ac; 5 mine -al; 5 h.l. ac and 4 h.l.- al	
Production		1946-1993 - 39 deposits had been woks	1956- 1973
ore	Mio t		
uranium	ty U		
grade	% U		
Processing facilities			
time to operation	from - to	194-1996	
type to operation	* 2)	Gr, HM- ac and al	
capacity	t U/d		
Dump sites			un
ore dumps	Nr	10	un
area	ha	1.089	un
volume	Mio m^3	0.131	un
mass	Mio t	0.198	un
grade U	ppm U	100-2600 g/t	un
grade others			un
waste dumps	Nr	506	un
area	ha	303.226	un
volume	Mio m^3	23.350	un
mass	Mio t	38.350	un
grade U	ppm U	0.01-0.04 %	un
grade others			un
heap leaching dumps	Nr	8	
area	ha	9.630	
volume	Mio m^3	1.115	
mass	Mio t	1.933	
grade U	ppm U		
Tailings ponds	Nr	6	
size	ha	102.3	
depth	m	3-75 m.	
volume	Mio m^3	16.34	
mass	Mio t	23.02	
grade U	ppm U	67-400 g/t	
grade others		Ra 6394 - 14671 Bq/kg	
cover (type/ constrict.)	* 3)		
Rehabilitation work	* 4)	16 un, 7 pl, 45 og, 3 fi	15 un
commenced in	year	1990	
percentage completed	%/ year		

* 1) op=in operation; sb=on standbay; cl=closed; pl=close planned; un=unknown; ot=others
* 2) HM=hidrometalurgical; GR=gravitional/mechanical; ac=acidic; al=alkaline
* 3) please explain cover type, material, thickness, layering, revegetation, erosion barrier, etc.
* 4) pl=in planning; og= on going; fi= finished; un=unknown; ot=others

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ANNEX 4

EXPENDITURES
incurred in pursuance of Decree No. 56 of the Council of Ministers of the Republic of Bulgaria for the period 1992-1994
(maintenance of environmental status and technical liquidation) in thousands of levs

	Company	Period			Total Expenditures
		1992	**1993**	**1994**	
1	Redki Metali Ltd.	109 042	120 293	117 361	346 696
2	Trakia - RM	103 818	112 601	119 273	335 692
3	Podzemno Stroitelstvo	11 054	16 062	59 000	86 116
4	Geostroikomplekt	16 451	15 103	21 200	52 754
5	Georesurs	14 185	23 707	47 745	85 637
6	Balkan	8 739	11 006	15 501	35 246
7	Zlata	4 726	4 821	7 639	17 186
8	Zvezda	27 665	49 683	77 209	154 557
9	Georedmet	4 399	-	2 458	6 857
	TOTAL	300 079	353 276	467 386	1 120 741

ANNEX 5

EXPENDITURES
incurred in pursuance of Decree No. 56 of the Council of Ministers of the Republic of Bulgaria for the period 1995-1996
(by types of activities) in thousands of levs

	Company	technical liquidation	recultivation	monitoring	water purification	social	Total:
1	Redki Metali Ltd.	128 722	24 508	1 212	-	14 013	168 455
2	Trakia - RM	113 520	63 784	125	1200	379	179 008
3	Podzemno Stroitelstvo	45 048	3 208	-	11 678	9 811	68 745
4	Geostroikomplekt	30 433	4 622	908	-	3 039	39 002
5	Georesurs	13 737	32 120	684	1500	1 480	49 521
6	Balkan	12 829	6 800	-	-	962	20 591
7	Zlata	17 656	4 178	-	-	-	21 834
8	Zvezda	74 012	-	-	-	-	74 012
9	Georedmet	23 942	546	-	-	175	24 663
	TOTAL	459 899	139 766	2 929	14 378	29 859	646 831

ANNEX 6

BIOLOGICAL RECULTIVATION
1995-1996

	Site	Company	Areas (ha)			Total
			1st year	2nd year	3rd year	
1	Tzarimir and Tzeretelevo	Trakia - RM	79.1	-	23.0	102.1
2	Belosem	Trakia - RM	94.6	-	86.0	180.6
3	Momino	Trakia - RM	261.0	-	86.0	347.0
4	Cheshmata and Maritza	Trakia - RM	53.9	-	19.1	73.0
5	Trilistnik	Trakia - RM	-	25.8	-	25.8
6	Navasen	Trakia - RM	60.2	-	-	60.2
7	Debar	Trakia - RM	67.9	-	-	67.9
8	Troyan	Trakia - RM	12.8	-	-	12.8
9	Orlov Dol	Trakia - RM	82.0	-	-	82.0
10	Madretz	Trakia - RM	34.5	-	-	34.5
11	Vladimirovo	Trakia - RM	19.0	-	-	19.0
12	Chukarovo	Trakia - RM	19.0	-	-	19.0
13	Okop	Trakia - RM	65.6	-	-	65.6
14	Tenevo	Trakia - RM	23.0	-	-	23.0
15	Senokos	Georesurs	13.0	-	-	13.0
16	Struma -1	Georesurs	2.0	3.0	-	5.0
17	Struma -2	Georesurs	-	14.0	-	14.0
18	Igralishte	Georesurs	-	-	5.6	56.0
	TOTAL		887.6	42.8	214.7	1150.1

ANNEX 7

INFORMATION ABOUT THE FUNDS NEEDED IN 1997 IN PURSUANCE OF ART. 6 PARA 2 AND 3, SUBPARA 1 AND 2 OF DECREE No. 56/94
(in thousands of levs)

	Company	unused technical liquidation funds	Funds needed for 1997 (by type of activities)				Total
			technical liquidation	technical and biological recultivation	water purification	monitoring	
1	Redki Metali Ltd.	587.3	151972.0	11862.7	49385.2	1590.0	215397.2
2	Georedmet	-	-	34812.6	-	1790.0	36602.6
3	Balkan	1343.2	-	14000.0	-	1200.0	16543.2
4	Georesurs	-	-	18146.4	60733.3	6114.3	84994.0
5	Zlata	3800.0	-	12878.0	800.0	2000.0	19478.0
6	Podzemno Stroitelstvo	-	-	107530.0	130000.0	5300.0	242830.0
7	Trakia - RM	3661.7	-	152670.0	-	74500.0	230831.7
8	Zvezda	-	32370.0	23430.0	-	440.0	56240.0
9	Geostroikomplekt	12240.0	-	69958.0	30540.0	5033.0	117771.0
	TOTAL	21632.2	184342.0	445287.7	271458.5	97967.3	1020687.7
		205974.2					
	In DM:	**1.37 mln**		**3.0 mln**	**1.8 mln**	**0.6 mln**	**ca. 6.8 mln**

ENVIRONMENTAL RESTORATION OF URANIUM MINES IN CANADA: PROGRESS OVER 52 YEARS

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Abstract

In Canada, the technology for disposal of uranium mine wastes and reclamation of mines has evolved over a period of 52 years. Early practice involved dumping untreated wastes into the nearest depression or lake and leaving rock and infrastructure in place. Now, the practice is to deposit chemically-stabilized tailings, waste rock and building rubble into highly engineered waste management facilities or mine openings. Similarly the "footprint" of the mining activity has been reduced to a very small area and the site is restored as-close-as-possible to pre-mining status. This paper describes the evolution of disposal and reclamation methods and the criteria which have determined the development path followed. Remediation techniques to bring older and now unacceptable tailings deposits into satisfactory compliance with current regulations are reviewed. Some monitoring results are presented.

All of the uranium mines in Elliot Lake, Ontario, a large uranium producer since 1957, are now permanently closed. Considerable progress has been made on decommissioning the tailings areas by developing long term maintenance of water covers on some, and water treatment plants and stable soil covers on the others. The innovative methods being used to develop the water covers are described, along with the challenges remaining. Methods now under development in Saskatchewan for subaqueous deposition of paste tailings for permanent disposal in mined out open pits are also described. This method will provide for the first time, "walkaway", meaning no long term monitoring and maintenance will be required.

1. SUMMARY

The technology for the reclamation of uranium mine and waste management areas in Canada has evolved considerably over the past 52 years. The driving force for the evolution has been increasing knowledge and understanding of how best to safely and permanently store tailings and waste rock, in conjunction with stricter environmental protection regulations. Old uranium mine waste sites are being decommissioned in situ, but may require long term care and maintenance. The use of water covers is an important technique in eastern Canada to prevent intrusion, radon emission and, for the Elliot Lake tailings, acid generation. The major drawback of water covers, and any above ground disposal method, is the requirement that a long term maintenance and monitoring plan be put into effect for each site. A major public review has recently been completed, and an official decision is expected soon on the acceptance of the closure methods and the requirements for long term surveillance and maintenance.

New higher grade mines in Saskatchewan are developing waste disposal technology in mined-out pits with the pervious surround method and/or "paste" tailings technology as a method to permanently dispose of these wastes and to permit "walkaway" after a few years of monitoring. The continuous production of paste is proving to be a challenge; it is possible that the tailings will be thickened to a consistency less than that termed "paste"

Pit and underwater disposal of waste rock is also now being proposed. The use of natural lakes for the permanent disposal of uranium mine wastes is technically acceptable, but questions are being raised about water quality during deposition, and the destruction of biological habitat. As a result, the use of mined-out pits for waste disposal is increasingly favoured.

2. CANADA'S URANIUM INDUSTRY

Canada is fortunate to have an abundant supply of economic mineral deposits. On a world-wide comparative basis, Canadian uranium deposits are currently of the highest grade, contain the largest quantity of the element, and cost the lowest per unit of uranium produced.

Uranium production in Canada began in 1944 at the Port Radium operation in the Northwest Territories. The 1950's saw start of production in the Beaverlodge area in the extreme north of Saskatchewan (1953) and at numerous uranium mines (1955 to 1958) in the Elliot Lake camp in northern Ontario and in the Bancroft area in southeastern Ontario. In 1975, production from the Athabasca Basin deposits in northern Saskatchewan began at the Rabbit Lake operation. This was followed by the start up of additional Athabasca Basin operations at Cluff Lake in 1981 and at Key Lake in 1983. More Athabasca Basin operations are under execution (McClean Lake) or are planned for start up, pending regulatory approvals, before the turn of the century (Cigar Lake and McArthur River).

The Athabasca Basin deposits are, by world standards, exceptionally rich, grading up to 15 to 20% U. Prior to exploitation of these deposits the Elliot Lake camp was the largest uranium producing area in Canada, and one of the largest in the world. Although the Elliot Lake reserves are not depleted, these mines are no longer economic; uranium grades of less than 0.08 %, mainly as brannerite mineralization in pyrite-rich siliceous deposits, make production costs four to five times the current market prices. The last of the 10 Elliot Lake mines was closed in June, 1996.

Since 1944, over 280,000 tonnes of uranium have been produced in Canada. During these 52 years, significant technologies for uranium mining and milling, waste management, and environmental restoration have been developed.

Canada is the second largest country in the world with almost 10 million square kilometres (after Russia) and is sparsely populated (30 million people in total) in regions where mineral deposits are found and mining is undertaken. Most of the population of Canada lives along the Canada-United States border. Other distinct feature of the geography of Canada that affects mine reclamation, is the fact that all regions have a net positive precipitation and the surface was extensively glaciated till about 15,000 years ago.

Canada is a federal state, and the responsibility for regulation of uranium mining, processing and materials export is split between the provincial and federal governments. As of June 30, 1996, the last mine in the Elliot Lake region, the Stanleigh mine, was permanently closed. Only the province of Saskatchewan is now producing uranium, but since the grades and size of the Saskatchewan deposit are high and extensive, Canada will remain the largest producer of uranium in the world.

3. ISSUES OF URANIUM MINE CLOSURE AND RECLAMATION IN CANADA

As shown in Table 1, there are now about 200 million tonnes of uranium mine tailings and mine waste rock on the surface in Canada. Some of the waste deposits have been decommissioned (and now being monitored), some are actively being closed out, some abandoned, and some waste disposal areas are active.

Table 1. Uranium Mine Wastes in Canada

Area	# of mines	Tonnes (10^6)
Northwest Territories	2	<1
Saskatchewan*	6	28
Southern Ontario	3	6
Northern Ontario	11	165
TOTAL	22	200

* in addition, 4 new mines under development

As with uranium mines everywhere, the principle issues are radioactivity, dispersion and water contamination. In some remote localities, the public access is less of a concern than elsewhere; at the same time ingestion of contaminants by plant and animal species is an issue. On the other hand, casual access to former mine sites by native population who use the land for hunting and fishing, provides added impetus for reclamation in remote regions.

Acid generation in some uranium tailings and waste rock is particularly problematic; acidic waters will mobilize radionuclides - principally thorium and uranium and toxic levels of metals and non metals. In the uranium mines of the Elliot Lake district of Ontario, 3 to 5% pyrite was found in the quartzite conglomerate deposits. The uranium mineralization of these deposits is composed of both easy to leach uraninite (U_3O_8) and difficult to leach brannerite ($(U,Ca,Fe,Y,Th)_3Ti_5O_{16}$). Very strong acid (100 g/l H_2SO_4) was used to extract the uranium from the brannerite, and in doing so all natural mineral alkalinity was destroyed. If Elliot lake uranium tailings are left exposed, they generate acid from pyrite oxidation and mobilize metals such as thorium, uranium, iron and aluminum.

Faced with technical and regulatory challenges, uranium mining companies and their expert consultants have teamed up to provide innovative and breakthrough techniques for minimizing the impacts on the environment - mainly the aqueous environment, and in minimizing the chance of exposure to ionizing radiation. Paradoxically the most important technique to minimize contaminant dispersion is the use of water saturation and water covers to immobilize contaminants. An important advance in the hydrological isolation of contaminants has been the development and implementation of the pervious (or porous) surround technique that permits the permanent disposal of wastes below grade and below the water table. This technique has recently been refined to include the use of thickened slurry tailings technology.

Old, inactive mines generally mined low grade (0.1 % to 0.3% uranium) deposits. Casual exposure to wastes from these mines resulted in low radiation and toxic element exposure. However, new mines have grades of uranium as much as 100 times higher than old mines and contain significant concentrations of heavy metals and arsenic. Therefore, more stringent, and hence more costly, disposal technologies needed to be developed.

In discussions about proposals for new uranium mines, the three stakeholders (industry, regulators and public) want these new uranium mines to provide for "walkaway" when the mining ends. For this to be realized, tailings, waste rock and building rubble will be disposed below surface in mines, mainly mined-out open pits.

However, significant technical and economic challenges remain for abandoned uranium mine/mill and inactive sites in Canada.

4. REGULATORY ENVIRONMENT

The Atomic Energy Control Board, an independent agency of the Government of Canada, is responsible for matters related to nuclear energy and radioactive materials through the Uranium and Thorium regulations. Regulation R-90 deals with mine decommissioning and site reclamation. Although Canada regulates uranium mines, the provinces are the principal landowners. Therefore, closed uranium mines ultimately will revert to the provinces, or once again become "crown land". The provincial environmental agencies are the chief regulators of water quality from all mine sites, including uranium facilities. The net effect is that both provinces and the federal government are responsible for regulating operating and closed uranium mines.

Although the regulators contend that long term control and monitoring is not a desirable strategy, permanent, "walkaway" management of uranium tailings is only becoming reasonably possible at mines currently operating or planned. It is clear to most stakeholders that, because of costs and physical barriers, there is no other place to dispose of uranium mine wastes at old mines than leaving them where they are. Therefore, interim controls and a monitoring program for the transition phase will be needed. The time of the transition phase will depend on site-specific characteristics.

Canadian regulation objectives are:

* to minimize future burdens;
* to protect the environment, taking into account social and economic factors;
* to minimize the need for long term institutional controls;
* to ensure that risks to health and environment meet current standards; and
* to not prohibit the future use of natural resources contained in mine wastes.

What this in effect means is that, site specific reclamation scenarios are developed.

The Canadian Environmental Assessment Act (CEAA) of 1995 provides for public hearings on development projects, where public financial resources are implicated, and where "significant" concern is raised by the general public. Public hearings on the closure and reclamation of the Elliot Lake tailings areas started in November 1995 under a precursor to CEAA, the Environmental Assessment and Review Process (EARP). The EARP expert panel submitted it's report in June 1996. Public hearings on the Cigar Lake and McArthur River uranium projects in Saskatchewan began in June 1996. These reviews are providing the opportunity for significant public input into management of uranium mining and wastes in Canada.

5. REVIEW OF WASTE MANAGEMENT AND MINE RECLAMATION METHODS

A chronological and a site by site review of Canadian uranium tailings management methods will illustrate the trend towards better methods of safely and permanently storing or disposing wastes, in conjunction with stricter environmental protection regulations.

The Port Radium operation on the east shore of Great Bear Lake was opened in 1933 by Eldorado Gold Mines Limited to produce a pitchblende gravity concentrate from which radium was extracted and refined. Tailings were deposited near the mill, underwater in Great Bear lake. The plummeting price of radium forced closure of this operation in 1941. It was reopened for uranium production in 1944; the operator was then Eldorado Mining and Refining Limited, a federal government corporation. This was Canada's first uranium producer. Gravity concentration continued as the sole treatment method until 1952, and tailings continued to be dumped into Great Bear. In 1952, along side the gravity circuit, an acid leach plant commenced operation, and with its development the old tailings were rendered economic as a source of uranium. Tailings were reclaimed by dredging and, in a 1:1 ratio with the gravity circuit tailings, constituted the leach circuit feed. Tailings from the leaching plant were placed in nearby surface depressions. This operation was shut down in 1960.

In the late 1970's, the Port Radium mine was reopened by a precious metal mining company and the remaining silver reserves were recovered. The mine was closed and the site cleaned up in 1986. Building rubble was placed underground and mixed in with tailings. A soil and rock cover was placed over the tailings. Periodic site visits have been made to the site since closure by the national regulator, the AECB.

In 1953, the second Canadian uranium mine and mill commenced operation at Beaverlodge on the north shore of Beaverlodge Lake, 10 km. east of Uranium City. A total of 8 mines fed the mill over 29 years of operation; production ceased in 1982. The process had involved sulphuric acid leaching of a small amount of pyrite flotation concentrate and alkaline carbonate leaching of the much larger amount of flotation tailings. Eleven million tonnes of tailings were produced by the Beaverlodge mill. About 5 million tonnes were used as mine backfill and placed underground. The other 6 million tonnes of tailings were deposited in nearby natural lakes, with the coarser sands forming a beach.

The Beaverlodge site was decommissioned over the years 1982 to 1985. The mill tailings were reclaimed by maintaining a water cover and covering a relatively small beach with clean rock. Incidental spillage over the 29 years of operation was cleaned up and deposited underground by dumping into shafts and ventilation raises. Waste rock, being of low contamination source was recontoured in situ and all buildings were demolished and buried in situ, or dumped down shafts and ventilation raises. Over the past 11 years, the site has been monitored.

Since the completion of reclamation in 1985, the Beaverlodge site has been monitored and the principle focus has been on water quality. As shown in Figures 1 and 2, the uranium and dissolved solids concentration have declined as predicted, and can be seen to meet water quality objectives in a few years.

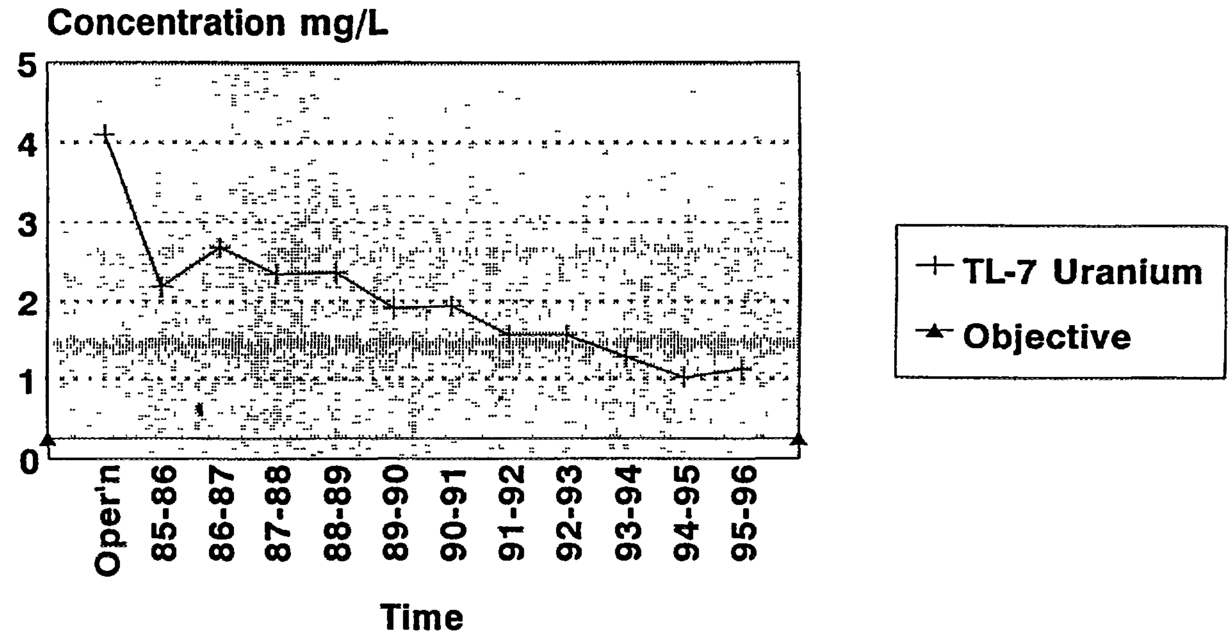

Figure 1
Uranium Concentrations in Effluent from Beaverlodge Mine

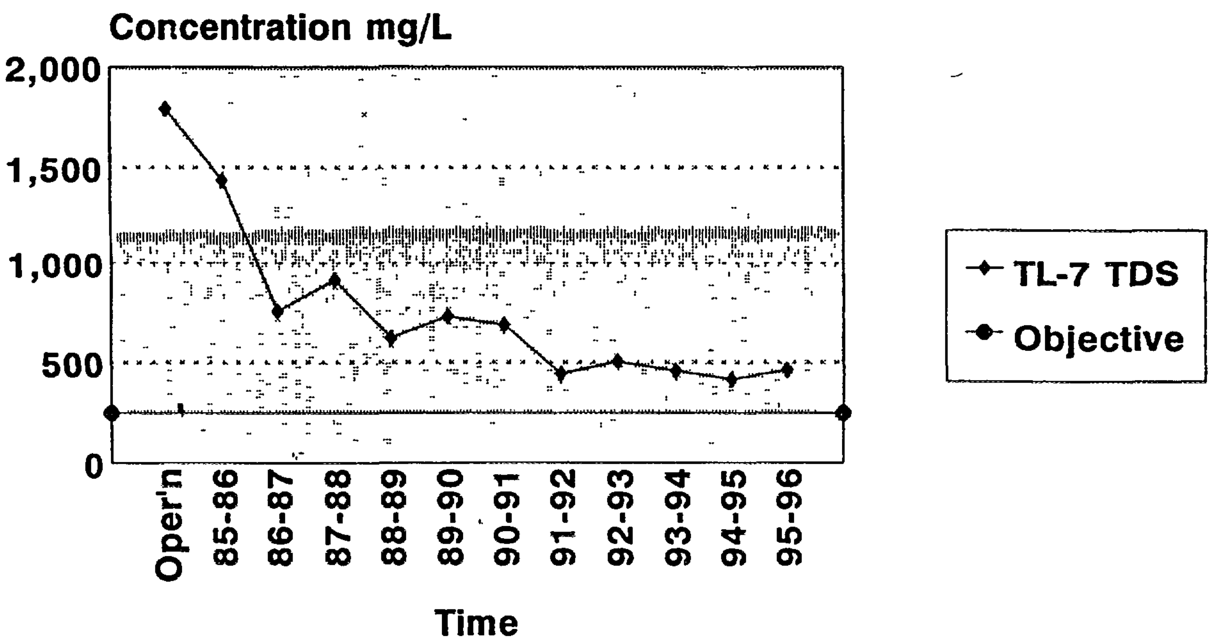

Figure 2
Total Dissolved Solids Concentrations in Effluent from Beaverlodge Mine

However, as shown in Figure 3, the dissolved radium concentrations are increasing with time A possible explanation for this phenomena is the lowering of sulphate levels in the surface waters

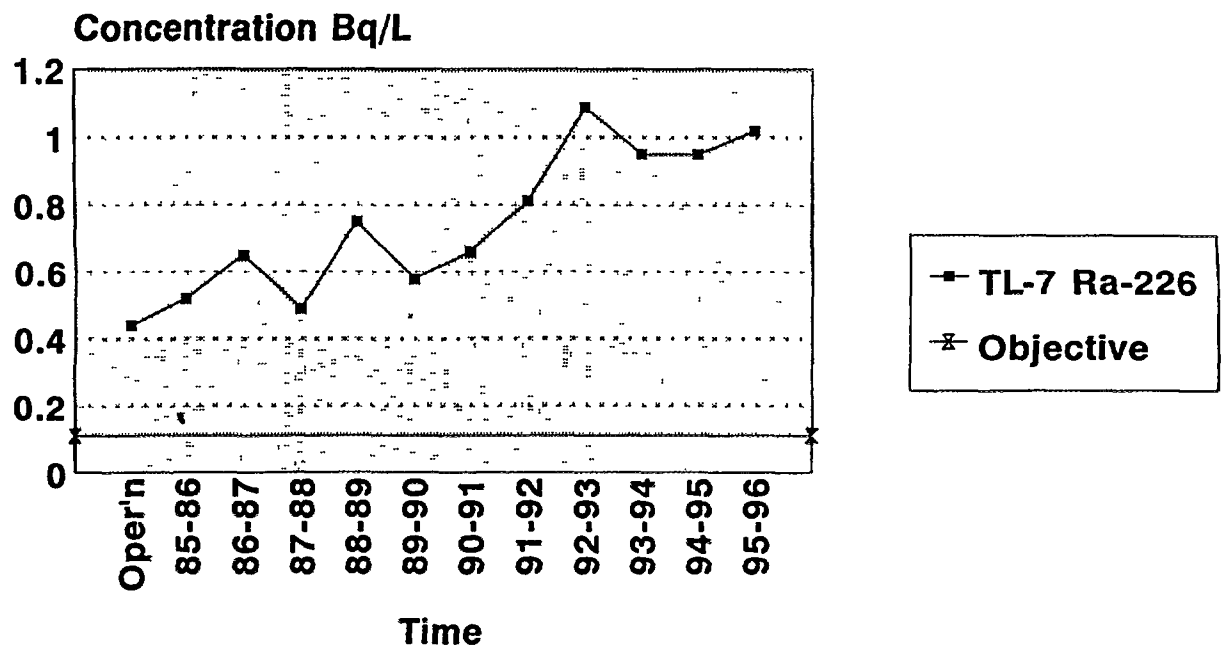

Figure 3
Total Dissolved Ra-226 Concentrations in Effluent from Beaverlodge Mine

Mining and milling commenced in 1955 at Gunnar Mines, 25 kilometres southwest of Uranium City on the north shore of Lake Athabasca. A sulphuric acid leach plant operated until 1964 After 1960 a mine backfill plant directed approximately 40% of the tailings underground. The remaining unneutralized tailings, which are not acid generating, were deposited into Mudford Lake, which is now called the Gunnar Main Tailings site The Mudford Lake basin eventually filled and the tailings flowed north through two small lakes into Langley Bay of Lake Athabasca. The Gunnar site was the subject of an extensive field investigation by the National Uranium Tailings Program in 1985. The tailings and waste rock were measured to have low impact on the local environment, but can be classified as abandoned at the present time.

A custom built mill for Beaverlodge district ores was operated from 1957 to 1960 by Lorado Uranium Mines Limited at a site about 10 kilometres southwest of Uranium City on the west shore of Nero Lake. This was also an acid leach plant. The acid for leaching was made from pyrite, part of which was recovered from the uranium ores. The tailings were still sufficiently pyritic to be acid generating. Tailings were deposited at pH 2 directly into Nero Lake This site is yet to be reclaimed

The Rayrock mine, 450 kilometres north west of Uranium City, was a small tonnage uranium mine that produced under 100,000 tonnes of tailings from 1957 to 1959. Since that time the site had been essentially abandoned. Concerns raised by native population who from time to time use the mine area for hunting and fishing trips, led an agency of the Government of Canada (Indian and Northern Affairs) to develop and implement a site remediation plan. This was put into effect this year at a cost of $2.5 million. The very large cost of this remediation for such a small amount of wastes is mainly due to the cost of mobilization of workers and equipment to the site. Five options for reclamation of tailings at the Rayrock site were considered and costed:

1. Do Nothing
2. Cover and Freeze - $3.5 million
3. Soil Cover - $3.8 million
4. Reprocess - >$25 million
5. Lake Disposal - $2.5 million

In the end a less costly version ($2.5 million) of the soil cover option was chosen scheduled for completion by November 1996. The main objective of this option as is evident from Table 2 is to reduce dispersion of wastes and gamma exposure rate.

Table 2
Effects of Mining and Reclamation on Direct Radiation at Rayrock

Dates		**Mean Exposure Rate μR/hr**	**Mean Dose Rate μSv/h**
pre 1997	**Pre Mining**	**15**	**0.09**
1959-1995	**Post Mining, Pre-reclamation**	**144**	**0.87**
Oct 1996	**Rehabilitated**	**34**	**0.2**
Post 1997	**Post rehabilitation**	**36**	**0.2**

Production in the Bancroft area began in 1957 at the Bicroft and Faraday Mines, both of which used acid leaching. Mining and milling took place at the Faraday mine from 1957 - 1963 and 1977 - 1982, (later renamed Madawaska). Tailings were deposited in surface depressions and dewatered by decant structures. These tailings have been reclaimed in situ with a simple soil cover, and both direct radiation and water quality are being monitored annually. Since both these mines are near small towns and vacation homes, they are being monitored for intrusion. Some results of water monitoring are shown in Table 3.

Table 3
Water Monitoring Downstream of Madawaska Mine

	1992	1993	1994	1995
Ra^{226}(Bq/l)			0.007	.05
U μg/l	45	41	33	43

Also in 1957, production commenced at the Elliot Lake camp with the start up of the Quirke mill. Additional plants subsequently came into operation (Nordic, Denison, Panel, Stanrock, etc) until eventually 10 mines were running at or near Elliot Lake. A strong acid leach was used to extract uranium from uraninite and brannerite. Tailings were and are strong acid generators because of residual pyrite as noted above. Tailings were typically stored in surface depressions behind embankments, on areas of relatively impervious rock. The ore grade was low at approximately 0.1% U_3O_8, but the deposits contain 0.03% Th232 and a wide assembly of rare earths that might be economically extracted from tailings in the future. Therefore, leaving the tailings in a position of possible future exploitation was a consideration in the choice of the tailings storage method and, recently of tailings closure options. The selected options for the Elliot Lake sites are water covers for the major tailings areas and in situ management for Stanrock. Permanent water covers are being established by engineering low permeability dams and providing for a continuous feed of fresh water upstream. Reclamation is under way at 4 sites and is well nearing completion. Four other sites have still to be reclaimed.

A summary of reclaimed uranium mine waste sites is given in Table 4.

Table 4
Reclaimed Uranium Mines Sites in Canada

Site	Years 19-	Tailings t (10^6)	Action		
			Tailings	Waste Rock	Status
Bancroft	57-63 77-82	2.4 2.0	In situ, soil cover	In tailings	Monitoring
Agnew Lake	77-83	0.4	In situ, soil cover	waste with precipitates	State
Port Radium	33-60	0.9	Soil, rock cover	In situ	Monitoring
Rayrock	57-59	0.1	Soil cover	In situ	Just complete
Spanish American	58-59	0.5	Underwater	None	Monitoring
Beaverlodge	53-82	6.0	Underwater	In situ	Monitoring

The four uranium mine sites in Canada that can be classified as "abandoned" are shown in Table 5. These wastes are in remote locations and present little potential for future impact on the environment, but are nevertheless a concern to some members of the public and to the regulators of uranium mines.

Table 5
"ABANDONED" URANIUM MINE WASTES IN CANADA

Site	Years	Tailings t (10^6)	Issues		
			Tailings	Waste Rock	Owner
Gunnar	55-64	4.4	dispersion, direct γ radiation	acid, uranium	yes(*)
Lorado	59-63	0.6	acid, γ radiation	none	yes(*)
Rayrock	57-59	0.1	dispersion direct radiation	little	State

* Company with limited assets

A list of "inactive" mine waste sites in Canada is shown in Table 6. The property owner is currently developing reclamation plans for these sites. It is expected that an in-situ reclamation strategy will be employed.

Table 6
"INACTIVE" URANIUM MINE WASTE SITES

Site	Years	Tailings t (10^6)	Issues		
			Tailings	Waste Rock	Owner
Nordic	57-68	12	Acid	Roads, embankments	yes**
Lacnor	57-60	2.7	Acid	none	yes**
Pronto	55-60	2.1	Acid, copper tails on top	none	yes**

** Unlicensed properties

Four sites in the Elliot Lake are currently being reclaimed, following extensive public review of the company proposals. These sites are listed in Table 7. The results of the expert panel review are now public, and the in-situ reclamation proposals are being recommended. The expert review Panel had the following recommendations:

- water covers are the best options for 3 sites;
- elevated water table, for the Stanrock site;
- in the short term, containment for the long term must be demonstrated;
- in the intermediate term, the containment must be verified;
- care and maintenance with hard financial assurance is needed; and
- curiosity driven research (mainly biological) is needed.

Table 7
URANIUM MINE WASTE SITES RECLAIMED OR CURRENTLY BEING RECLAIMED

Site	Years	Hectares	Tailings t (10^6)	Issues and Strategies	
				Tailings	Waste Rock & Buildings
Panel	58-61 79-83	123	16	Acid - underwater	In tailings, underground
Quirke	56-61 68-83	192	46	Acid - water covers	In tailings, underground
Denison	57-83	271	64	Acid - water covers	Underground
Stanrock	57-64	7.5	6	Acid - elevated water table	Underground, tailings

The concept of water covers over uranium tailings has had and continues to have extensive research conducted on it. The Quirke tailings as shown in Figure 4 has a "rice paddy" profile. Therefore water will pass across the surface and permeate through the tailings.

Processing the relatively high grade Athabasca Basin ores was first done at the Rabbit Lake operation, which started up in June 1975. The Rabbit Lake mill initially used sulphuric acid for leaching and ammonia for solvent extraction (SX) stripping and uranium precipitation. From 1975 to 1985 neutralized tailings were deposited in a conventional manner in an on-surface tailings pond. This facility consists of two earth-filled dams constructed across an elongated valley between two north-south trending ridges. To process higher grade ores scheduled for exploitation beginning in 1985, the Rabbit Lake milling process was modified to strong acid stripping and hydrogen peroxide precipitation of uranium. To hold the tailings from these higher grade ores the pervious surround tailings disposal method was developed. Tailings are placed in the mined-out Rabbit Lake pit inside a pervious envelope of sand and coarse crushed rock. Tailings water flows out of the tailings through the pervious surround and is collected and pumped to a treatment plant.

After shutdown, groundwater in the area will short-circuit around the tailings because the resistance to flow of water is very high in the consolidated tailing and negligible in the coarse

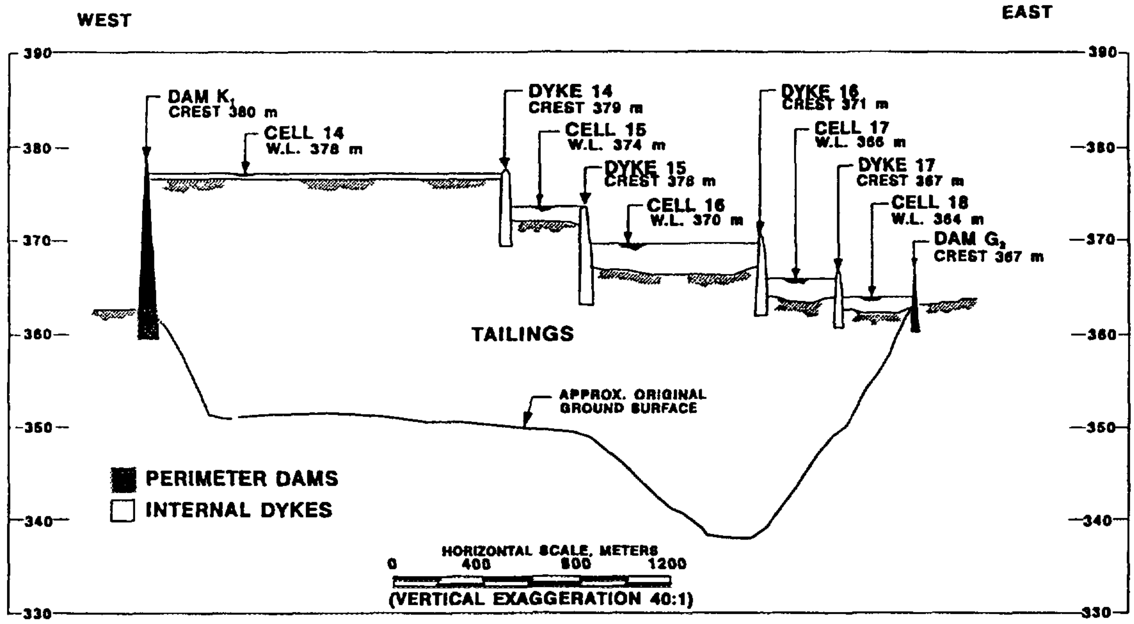

Figure 4
Quirke Tailings Flooding

rock of the pervious surround. Groundwater contamination is thus avoided. Considerable experimenting has been done over the last 10 years to find the optimum method of transferring tailings into this tailings management facility. Originally, tailings were dewatered by filters prior to placement in the facility. This was altered to partial filtration and then to direct placement of unfiltered tailings slurry. Presently, injection of tailings slurry below the consolidated tailings surface is being tested and evaluated.

Cluff Lake, the second Athabasca Basin operation, started up in 1981. For the first two years, Cluff Lake processed high grade "D Zone" ore. Tailings from this ore were temporarily stored in concrete vaults, and later reprocessed to recover gold. The reprocessed tailings were diluted with neutralized tailings from the lower grade ores then being processed. Tailings are placed in surface impoundment with low permeability embankments. Equipment to thicken tailings to a paste prior to deposition has been commissioned, but operating challenges remain.

The third Athabasca Basin operation, Key Lake, began producing in 1983. The mill uses sulphuric acid for leaching and ammonia for SX stripping and uranium precipitation, and produces an ammonium sulphate byproduct. Until November 1995, neutralized tailings were placed in clay-lined surface impoundment surrounded by engineered dams on all four sides. Since then, thickened tailings have been placed in the mined-out Deilmann pit using the pervious surround system. Key Lake is exploring the possibility of reprocessing the tailings in the surface facility to extract nickel and cobalt. After processing, the reprocessed tailings would be placed in the Deilmann Tailings Management Facility (TMF).

Although both the Key Lake and Rabbit Lake tailings facilities have operated more or less the way they were designed, residual frozen tailings from winter operations have been recognized as an issue requiring solution. Frozen tailings that could thaw in a matter of years and facilitate continuing pore water release and possible disruption of surface covers.

The latest concept in tailings disposal in Saskatchewan is subaqueous deposition of paste tailings by "tremie" piping into open pits as shown in Figure 5. This innovative method will combine the advantages of the pervious surround method with subaqueous paste deposition, thereby minimizing segregation, freezing, dusting and radiation exposure.

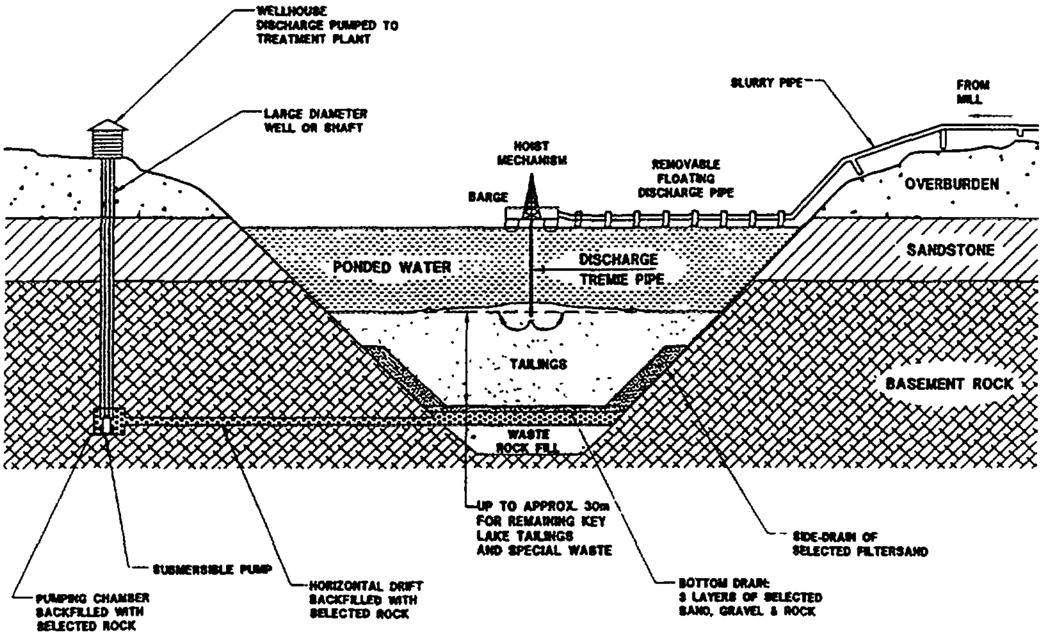

Figure 5
Pit Disposal of Thickened Tailings

A tailings "paste" or thickened slurry is to be made by thickening tailings in the mill to 40% solids or more in a specially designed thickener and possibly with the assistance of filters. No chemical agents to alter tailings rheology are predicted to be needed. Two concepts are being considered for the final decommissioning of the tailings basin: water covers and a soil/wetlands cover. The choice will depend on the local hydrology, the availability of clean fill and the actual state of consolidation of the tailings deposited under water. Two major technological barriers need to be overcome to ensure success in the paste tailings deposition under water: abrasion in the paste pumps caused by extreme pressures, and the dispersion of pastes under water. The abrasion problem appears to have been overcome by the use of ceramic pump parts. The dispersion of paste underwater is expected to be complicated by the fact that the paste does not easily disperse, and will form a series of shallow cones as the dispersion location is changed. A new system of monitoring will need to be developed once the underwater paste system starts operating in the near future.

6. CONCLUSIONS:

Uranium mine waste disposal technology has evolved considerably in Canada in the last 52 years. For low grade uranium ores (< 0.3% U) where the environmental issues have been intrusion and acid generation, the use of engineered water covers is now the primary closure method. Where water covers are not possible or uneconomical, dry soil covers or elevated water tables are preferred methods.

For high grade deposits (0.3% to 15%U), the evolution over the last 15 years has been:

Concrete vaults → Surface impoundment (Cluff Lake)

Surface impoundment → Pit disposal with porous surround (Rabbit Lake)

Subareal → Pit disposal with thickened tailings (Key Lake)

Pit disposal → Pit disposal with paste or thickened tailings (JEB/McLean/Cigar)

By using the thickened tailings- paste/pit disposal concept, true "walkaway" is expected to be achieved in 10 to 15 years after mine closure. This concept may be adapted for special situations in the base metal industry where:

- acid generation is a concern;
- a mined-out pit is available; and
- the hydrology of the pit is subject to water level control (no underground mines connecting).

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PLANNING ENVIRONMENTAL RESTORATION IN THE NORTH BOHEMIAN URANIUM DISTRICT, CZECH REPUBLIC: PROGRESS REPORT 1996

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Abstract

Uranium ores have been mined in Bohemian Massif in different mining districts i.e. in West Bohemia, Příbram region and Middle Bohemia, Rožná district and in Stráž pod Ralskem district. The latter is represented by stratiform sandstone type of deposit where acid in-situ leaching has been applied as mining method since 1968. More than 4 million tons of leaching acids have been injected into the ore bearing sandstones. The district falls in an area of natural water protection in North Bohemian Cretaceous platform. A complex evaluation of negative impact of uranium mining and milling in this area has been clearly articulated in Government Decrees Nos.:366/92, 429/93, 244/95 and 170/96. A special declining regime of mining has been ordered for the implementation of which together with the Government Commission of Experts a remediation programme has been designed and put into operation in 1996.

The uranium producer DIAMO a.s. prepared a Concept of Restoration of the area affected by in-situ leaching and MEGA a.s. has prepared the Environmental Impact Assessment (E.I.A.) according to the law No.244/1992. The Ministry of the Environment issued an Environmental Impact Statement which included evaluation of the condition of mining and restoration programme because both activities will influence the environment of the district.

1. HISTORICAL REVIEW

The Bohemian Massif is a very important uranium bearing province. Uranium mineralization has been connected with post-Variscan hydrothermal activity and emplacement of carbonatic dikes with uranium mineralization. Uranium ores have been mined in Jáchymov (Joachimsthal) since 1840, first for making paints and later when radium and polonium were discovered by Mme Curie, also for radium production. During the years 1907-1939 a total of 2,5 - 5,5 g of radium per year were produced there.

During the years 1945 - 1960, the period of exploitation of uranium ores for army purposes began and from uranium ore of Jáchymov the first Soviet atom bomb was manufactured.

After the World War II uranium exploration grew rapidly as a large scale programme in support of the Czechoslovak uranium production industry. A systematic exploration programme including geological, geophysical and geochemical surveys and related research, was carried out to assess the uranium potential of the entire country. Subsequently the following uranium districts were opened and exploited :

West Bohemian District
Príbram and Central Bohemian District
Rozínka District
North Bohemian Uranium District

Until the year 1994 a total of about 100 000 tons of uranium have been produced from all mines (about 20 000 tons from in-situ leaching fields).

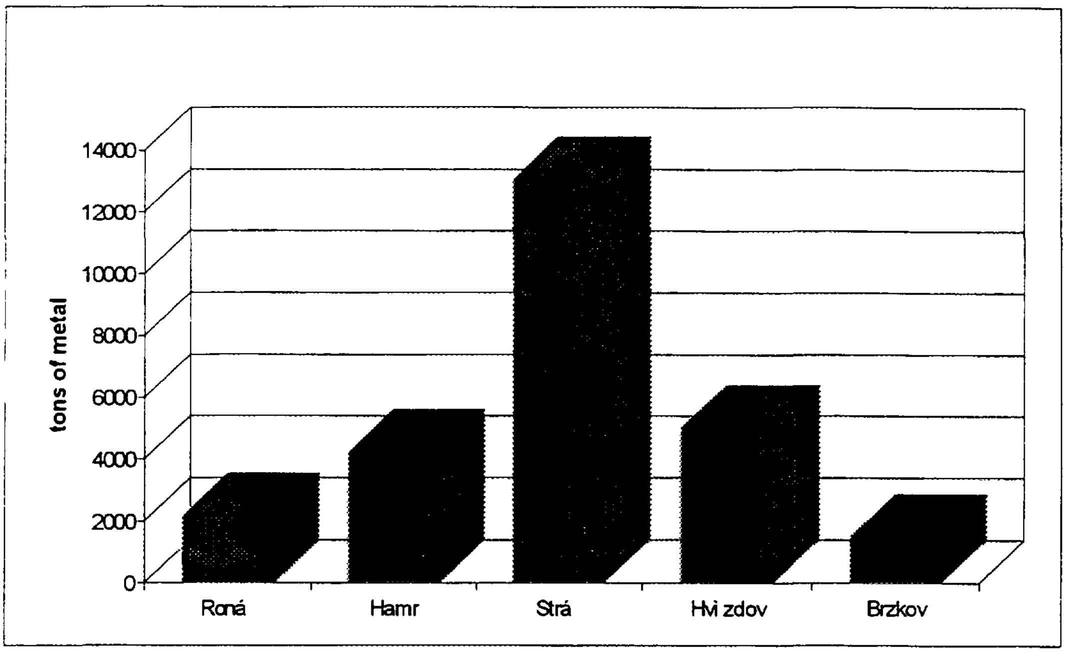

Figure 1 Uranium reserves in Czech Republic (1995)

During the long period of underground mining, especially since the end of World War II, devastation of the landscape from waste dumps accumulation, tailings and other workings themselves has been enormous. Subsequently all these activities have had a negative impact on the environment including surface and ground waters and soils.

In the mining districts of Jáchymov, Tachov, Horní Slavkov, Príbram there are heaped more than 38 large scale waste dumps and many small waste dumps that originated during the extensive prospecting period all over the Bohemian Massif.

Table 1 Main regions, volume and areas of land affected by waste dump deposition.

Region	Volume in thousand m^3	Area in thousand
West Bohemia	10662	641
North Bohemia	1302	114
Příbram region	28511	1299
Dolní Rožínka	2623	406
Total	43107	2460

2. URANIUM MINES IN CZECH REPUBLIC

The majority of uranium deposits in the Bohemian Massif are of vein type but the deposits of primary interest are of a stratiform, sandstone type and are situated in North Bohemian Cretaceous basin. Until 1989 a total of 96 000 t of uranium have been produced in all mines in the Czech Republic (85 000 t from underground mines and 11 000 t from ISL fields)

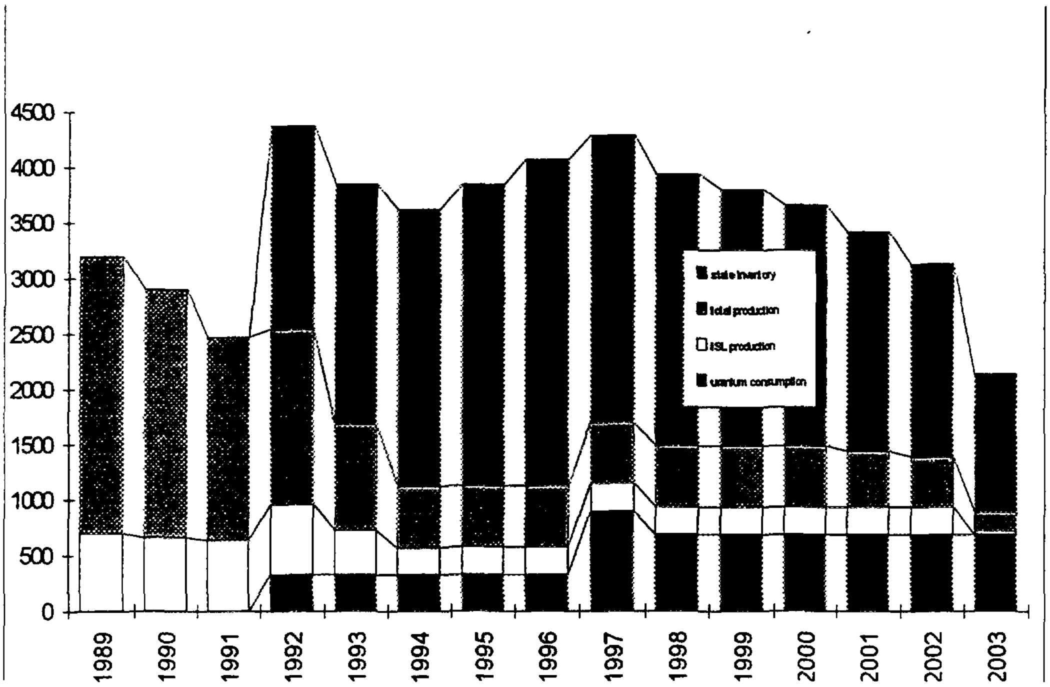

Figure 2 Uranium production and use in the Czech Republic 1989 -2003 in Kt

The North Bohemian area with its stratiform sandstone type of uranium deposits is the newest ore producing district in Czech Republic and its exploration started in 1969. Because of relatively large deposit (about 200 000t) the uranium production was meant to cover all the long term needs of nuclear power programme, including export to former COMECON countries.

This situation has changed dramatically after 1989 with the political and economic changes in the whole of Europe. The uranium spot prices in the world dropped down rapidly and uranium mines were not able to meet even the average of uranium prices on the world market.

Figure 3 depicts the declining trend in the mining production in the Czech Republic during 1989 to 1994, which originated after the collapse of former Soviet Union when a world wide nuclear disarmament programme started.

Government Decrees have been issued to close down majority of uranium mines and the subsequent assessment of negative impact of uranium mining on the environment has shown the necessity to implement remediation measures in all areas where the uranium mines had operated.

3. COEXISTENCE OF UNDERGROUND MINING AND IN-SITU LEACHING OF URANIUM IN NORTH BOHEMIA

The main problem for uranium exploitation in this area is the coexistence of two large production complexes - classical deep mining on the Hamr deposit and ISL on the Stráz deposit. These deposits are situated near each other and they have negative influence on the geological environment of the whole area.

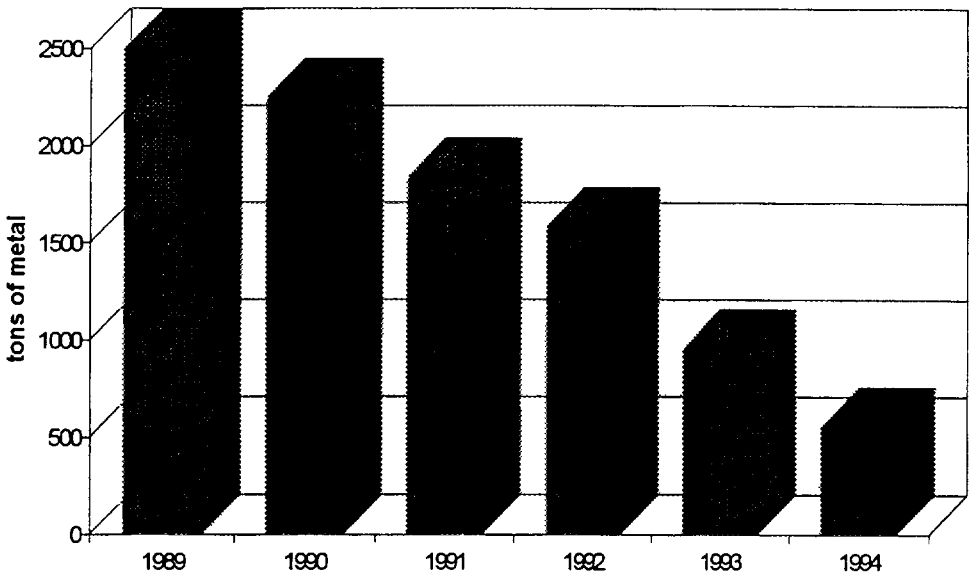

Figure 3 The uranium mining production in the Czech Republic 1989 - 1994

3.1. Geological setting

Uranium concentration in Northern Bohemia occurs within sediments of the Upper Cretaceous platform unit of Bohemian Massif which are tectonically heavily affected and forming tectonic blocks. The most important concentration of uranium ores were found in the s.c. Stráz block.

Cretaceous sediments have been deposited on a metamorphosed basement consisting of low grade metamorphosed rocks and acid granitoids. Their sedimentary sequence range from Cenomanian to Turonian and represent from the hydrogeological point of view important aquifers of drinking water.

The average thickness of the whole Cretaceous complex in Stráz block is about 220 m. The basalt volcanics of Terciary age are penetrating the Cretaceous beds.

The stratiform uranium mineralization is confined to the lowest part of Cenomanian beds (washout sediments) and has an unusual association of elements: U-Zr-P-Ti (uraninite UO_{2+x}, ningyoite ($CaU(PO_4)_2.nH_2O$), and hydrozircon ($Zr(Si_{1-x}O_{4.4x}(OH)_{4x}).nH_2O$).

3.2. Methods of extraction of ore

Two methods of extraction have been applied within the Stráz block since the late 1960s:

a) Classical underground mining in Hamr mine and Brevniste. The panel and fill (room and pillar) method is used in the Hamr mine and a stable depresion of the water table in Cenomanian aquifer has been achieved due to long term water extraction at the mine. The depression is kept up by pumping out mine waters at a rate of about 50 m3 / min.

b) The ISL has been in operation for about 25 years and so far 32 ISL claims have been commissioned covering a total area of about 6 000 000 m^2.

4. NEGATIVE IMPACT ON THE ENVIRONMENT

After 1989 the political and economic situation in Europe has changed and finally attention has been paid to the evaluation of negative impacts of the extensive mining activities of the past 50 years on the environment of the Czech Republic.

In the Bohemian Massif the main impact of mining is in North Bohemian brown coal basins, then in North Moravian Ostrava pit coal basin and last but not the least in the areas of uranium underground mining and in-situ leaching. Therefore the Czech Government has paid serious attention to the restoration programme of uranium locations followed by remediation of the areas affected by the uranium mining and milling.

The environmental issues connected with uranium mining can be listed as follows:

- old uranium mine and mill sites and their assessment
- old uranium mines waste dumps
- waste dumps left after uranium prospecting
- tailing impoundments

Government Decrees have been issued to close down all uranium underground mines except the Rozínka Mine (Czech-Moravian Highland) and the subsequent assessment of negative impacts of uranium mining and milling on the environment has shown the necessity to start with a wide remediation programme of all environmental issues connected with uranium mining as listed above.

The uranium mines in Hamr and Stráz pod Ralskem were chosen as the first heavily affected areas for the restoration programme because in-situ leaching and underground mining were operating together there in one geological unit i.e. Cretaceous Cenomanian sandstones. The mining activities, especially in-situ leaching are influencing ground water regime and the pollution is enormous.

A quantity of 3.8 million tons of H_2SO_4, 270 000 tons of HNO_3 and 103 000 tons of NH_4 have been injected into the leaching fields of the Stráz deposit in the last 25 years (Figs. 4, 5). This has affected a total of 188 million m^3 of Cenomanian water over an area of 28 km^2.

Leach solutions from ISL fields have dispersed horizontally and vertically not only to the Cenomanian horizon but along the extraction boreholes and tectonic lines to the Turonian drinking water aquifer.

To solve the negative influence of coexistence of Hamr mine and ISL Stráz mine a protective hydraulic barrier has been built between these two deposits.

According to hydrogeological investigation and hydrological modelling of water and acid solutions the first steps have been already executed. Circulation water from Hamr mine is pumped out at a rate of about $50m^3$/ min and forced into the Stráz hydraulic barrier. This will make a steady overpressure in the SW part of the Stráz block behind the hydrological barrier. Solving the hydrogeological situation, to suppress the above mentioned negative impact of ISL on the environment the construction of a desalination plant with a capacity of $5m^3$/ min has been proposed. These technologies started to operate in 1996 and the first positive results have already been achieved.

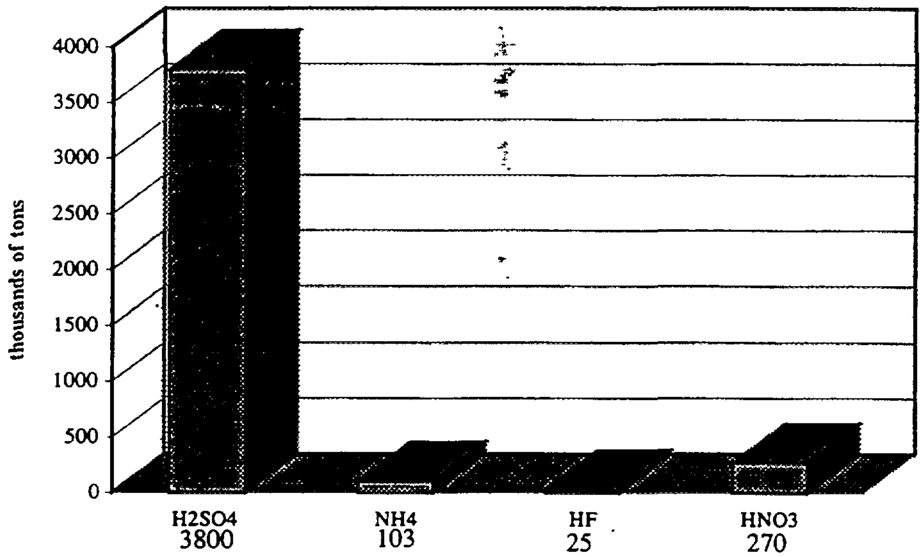

Figure 4 Total quantity of chemicals injected to ISL fields in Stráz pod Ralskem 1969-1992

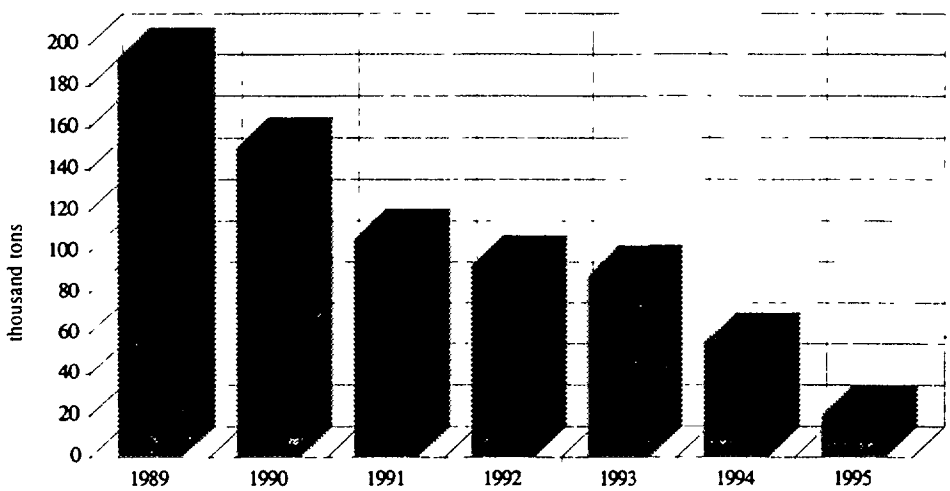

Figure 5 The amount of H2S)4 input to the leaching fields in Stráz pod Ralskem uranium deposit (1989-1995)

5. ENVIRONMENTAL REMEDIATION PROGRAMME

The assessment of different environmental issues connected with in-situ leaching in North Bohemia has been submitted to the government. Taking this into consideration the Czech Government has issued Decrees on which the environmental restoration programme was started in 1992 with declining uranium mining programme. The following Government Decrees have been issued on this issue:

No.366/1992 - Complex evaluation of chemical mining in North Bohemian area. A programme for closing ISL and remediation of uranium mines.
No.429/1993 - Concept of the recession programme of underground mine Hamr and its "dry" conservation.

A Government Commission with Interministerial Experts has been established to help the uranium producer DIAMO a.s. to analyse the problem, to design the methods of restoration of ISL, to supervise the process and to control the execution of the programme stated in the Government Decrees.

The final analysis of problems (Analyza CHT - III) connected with the evaluation of the environmental impact of uranium mining has provided a complex set of data dealing with this issue. The main contractor of the project is the uranium mining company DIAMO a.s. together with co-operating institutions (e.g. MEGA a.s., Aquatest a.s., Universities). The financing of restoration programme is covered by the state budget with support from international sources (EC, PHARE, Dutch Government, Danish Government, IAEA). The analysed problem is unique in the whole of Europe in its size and timescale.

No. 244/1995 - Realization of restriction of uranium mining and milling in the Czech Republic. It stipulates that by the end of October 1995 the Final Report should be submitted based on the above mentioned Government Decrees and on analysing the problems and prepare a clear conceptual design of the future restoration programme to be financed from the state budget.

The latest Government Decree No. 179/1996 - issued to the Final Report about the remediation of the chemical extraction of uranium in Stráz pod Ralskem. It announced the end of the chemical extraction of uranium from 1 April 1996 and assigned responsibilities for the Ministries involved to submit yearly progress reports about the remediation programme.

5. ANALYSIS OF PROBLEMS (ANALYZA CHT - III)

The analysis of uranium mining and milling in North Bohemian cretaceous platform prepared by DIAMO a.s. et al has two parts:

I. Geological environment and underground physical and chemical processes

This part deals with following problems:

- geological, hydrogeological and geophysical research covering the mines and wider environment
- evaluation of ground water contamination caused by ISL
- assessment of long term hazards for Cretaceous aquifers arising from the existence of large volumes of contaminated ground water

- hydraulic and hydrodynamic models for establishing a suitable "algorythm" for the quantification of long term risks
- quality limits of ground water after finishing the restoration of the site
- optimal regime of ISL, underground mine and remediation programme

II. Technologies recommended for the restoration of the environment

The technology of volume reduction by evaporation followed by processing of the concentrate was chosen for decontamination of the strongly saline Cenomanian waters It is expected that a volume of 5 m^3/ min will have to be pumped from the aquifer For the decontamination of slightly polluted water from the Turonian aquifer a volume of about 2 - 3 m^3/ min is subjected to cleaning using membrane processes An evaporation station has been built by RCC (USA) and started operation in 1996

Technological decontamination of polluted waters is divided into two basic stages

Stage I - Evaporation with separation of uranium concentrate and injecting the concentrated solution back into the Cenomanian aquifer with the aim of reducing the spacial dispersion of salinated liquids in the geological environment This stage is expected to operate till the year 2000

Stage II - Separation of precipitated salts from the concentrated solution and processing of separated salts focusing on the commercial application of final products or their stabilization The technological unit attached to the evaporation station will have provision for multigrade crystallization and final processing of products These are mainly aluminium-ammonium sulphate and remaining constituents, the latter supposedly transformed by calcination into unsoluble waste for safe storage

6. ENVIRONMENTAL IMPACT ASSESSMENT

As an independent part of the Final Report prepared for the Czech Government the E I A which evaluated not only the negative impact of uranium mining and milling on the environment but also the activities proposed by DIAMO a s as designed restoration programme has been concluded

Both the reports i e Analysis of Problems (Analyza CHT - III) - DIAMO a s and Environmental Impact Assessment (MEGA a s) have been reviewed by the Government Commission of Experts and passed the public hearing

The Ministry of Environment, as per law No 244/1992 issued a statement on the conclusions with comments which were included in the Final Report for the Czech Government regarding the future Restoration Programme of the areas affected by uranium mining and milling under consideration

7. THE STATEMENT OF THE MINISTRY OF ENVIRONMENT

The Ministry of Environment taking into consideration the reports on the restoration programme of the area affected by in-situ uranium leaching in Stráz pod

Ralskem agreed with the concept of remediation programme and E.I.A. submitted to the Ministry of Environment within the following conditions:

The first stage of the remediation programme will start on 1st January 1996 and will be followed by the operation of the evaporation station to stabilize and control the leach liquors in the Cretaceous aquifers. This stage represents the beginning of the complex programme of restoration of the environment in the whole area. Uranium extraction from the leaching fields will continue as subordinate process of restoration programme.

At the same time the monitoring system will be modified according to the results gained to assure the system will register the effectiveness and progress of the restoration process.

The restoration steps will be coordinated with the liquidation of the Hamr underground mine and tailing impoundments in the Stráz region. Simultaneously the geochemical contamination of the surface sediments and waters along the river Ploucnice will be solved.

The recultivation of the surface will be coordinated with the technological regime of rehabilitation and parts of natural reservation (Ralsko, Velký a Malý Jelení vrch, Lipka) will be preserved for ecological stability.

DIAMO a.s. will arrange a complex socio-ecological study which will consider the programme of revitalization of the area.

Taking into consideration the difficult nature of the problem the Ministry of the Environment requires from DIAMO a.s. further to accomplish:

- A complex analysis of the critical parts and risks of proposed concept of the remediation programme with special attention to the contamination of the Turonian aquifer.
- A report on the possibility of immobilization of the contaminants underground in the Cenomanian aquifer as an alternative programme in the last stages of decontamination.
- Define and prepare a follow-up project dealing with the products of the evaporation station extracted from underground and particularly dealing with the remaining constituents (incl. radioactive wastes).
- Simultaneously conduct processes to produce materials which will be suitable for further technological use or for sale.
- Safe storage of products - minerals potentially feasible for reuse.
- Prepare a study regarding the minor elements content which have been enriched during the circulation of salinated liquids underground (REE, Al, Be, Ni etc.) as future non-traditional mineral resources.
- Evaluate the content of radioactivity and radionuclides in the liquors and evaporation station products especially in final calcinate.
- Prepare a broad research programme and follow up studies with the aim to finalize the technological programme and verification of executed steps.

8. SUMMARY

According to the international statistics the Czech Republic belongs to the area with the strongest potential for extraction of minerals both in the European as well as the world scale. Czech Republic ranks among the states having high intensity of mining per square km. The situation in the country is complicated by high density of population with an average of 130 persons per square km. This critical situation has gradually arisen over the past 50 years through extensive and in many places haphazard exploitation of minerals and industrial activities. The ecological stability in many regions of the Czech Republic has been completely destroyed.

The Ministry of Environment has become particularly conscious of the need for competent environmental management in view of the past unsustainable mineral exploitation practice. In 1992 a map was produced entitled *Impact of Mining on the Environment of the Czech Republic*. This was probably one of the first attempts to determine sustainability indicators, and the environmental hazards associated with mining and processing of various minerals which are listed and classified.

One of the very negative impacts of the past and recent mining of minerals, among many other environmental issues, is in-situ uranium leaching in Stráz pod Ralskem. This mine is situated in Cretaceous sandstones creating a platform over the northern Bohemia and represents a reservoir of drinking water for the Czech Republic.

A quantity of about 4 million tons of acids and other chemicals were injected into the leaching fields of Stráz pod Ralskem deposit in the past 25 years which affected a total of 188 million m^3 of ground water in an area of 28 square km. Technological solutions from in-situ leaching fields dispersed horizontally and vertically not only within the cenomanian horizon where the uranium mineralization is present but also along the inadequately sealed extraction boreholes and tectonic lines up to the turonian aquifer of drinking water.

The broad remediation programmeme is recently executed by the Ministry of Industry and Trade and by the uranium producer DIAMO s.p. The Ministry of Environment has stipulated conditions regarding the environmental issues.

The Czech Government has issued Decrees on which is based and supported environmental restoration programme which was started in 1992 with declining uranium mining programme. The following Government Decrees have been issued regarding this problem:

No.366/1992 - Complex evaluation of chemical mining in North Bohemian area. A programme for closing ISL and remediation of uranium mines.
No.429/1993 - Concept of the recession programme of underground mine Hamr and its "dry" conservation

A Government Commission of Interministerial Experts has been established to help the uranium producer DIAMO a.s. to analyse the problem, to design the methods of restoration of ISL, to supervise the process and to control the execution of the programme stated in the Government Decrees.

The final analysis of problems (Analyza CHT - III) connected with the evaluation of the environmental impact of uranium mining has provided a complex set of data dealing with this issue. The main contractor of the project was the uranium mining company DIAMO a s together with co-operating institutions (e g MEGA a s , Aquatest a s , Universities). The financing of restoration programme was covered by the state budget with support from international sources (EC, PHARE, Dutch Government, Danish Government, IAEA) The analysed problem is unique in the whole of Europe in its size and timescale

No 244/1995 - Realisation of restriction of uranium mining and milling in the Czech Republic It stipulates that by the end of October 1995 the Final Report should be submitted based on the above mentioned Government Decrees and on analysing the problems and prepare a clear conceptual design of the future restoration programme to be financed from the state budget.

The latest Government Decree No 179/1996 - issued to the Final Report about the remediation of the chemical extraction of uranium in Stráz pod Ralskem It announced the end of the chemical extraction of uranium from 1 April 1996 and assigned responsibilities for the Ministries involved to submit each year progress reports about the remediation programme

In this year the 3-column evaporation station started to operate with following aims

- to prepare the hydrological depression in Cenomanian aquifer
- to stabilize the concentrated saline liqueurs in Cenomanian aquifer and prevent their spreading in southwest and southern directions
- to extract uranium as by-product

During the 72 hours trial runs all the parameters guaranteed by the contractor of technologies (RCCI) have been tested and proved The test has shown even better results than those assured in the guarantee conditions, e g 3 2% more distillate was produced and for the evaporation of 1m^3 of produced distillate only 85 5 - 92 9 % of electric energy was consumed

The results obtained during the test of evaporation station will now be evaluated and summarized in a Progress Report

The remediation programme which has started in Stráz pod Ralskem in 1992 represents an excellent example of the cooperation between the uranium producer DIAMO s p and state administrative bodies This cooperation is even more valuable knowing that the problem of uranium ISL and the necessity of its remediation was recognized as a very serious environmental problem in the European context The help of IAEA experts during the preparation of the analysis of the problems is also highly appreciated

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ENVIRONMENTAL RESTORATION OF URANIUM CONTAMINATED SITES IN ESTONIA WITHIN THE FRAMEWORK OF IAEA PROJECT (RER/9/022) IN 1995-1996

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Abstract

In Estonia there are several radioactively contaminated sites left from the military and uranium processing activities by the former Soviet Union. Enhanced radiation levels are prevalent in the Paldiski area, a former nuclear submarine training centre; on the territory of the waste depository at Saku/Tammiku, and at Sillamäe, where a large depository of uranium milling tailings is situated. During the last two years considerable effort has been put into restoration of these sites. To start with, designing of reasonably achievable remediation projects have been taken up. Estonia has received large contributions from many western countries and organisations. Practical remediation work on contaminated areas, e.g. at Sillamäe is , however, delayed due to lack of funds.

1. INTRODUCTION

Radioactive wastes are generated by a number of nuclear activities: application of radioisotopes in medicine, research and industry and nuclear power programme. In addition, waste with enhanced concentrations of naturally occurring radionuclides is generated in mining and milling of uranium and thorium. Although Estonia is called a non-nuclear country, as a consequence of military and uranium processing activities during the Soviet era, areas of higher radioactive contamination have been left at Paldiski, Saku/Tammiku and Sillamäe sites. In order to ensure safe management of these sites in the country, it is necessary to establish a proper waste management infrastructure which should include legal, organizational and technical components.

2. LEGISLATIVE ACTIVITIES

Riigikogu (the Estonian Parliament) has extended the validity of former USSR norms and rules on safety and radiation protection untill they are replaced by new national legislation. It means that in the field of radioactive waste management Sanitary Regulations for Radioactive Waste Management (SPORO-85), adopted in 1985 and developed according to the Basic Sanitary Regulations for Handling Radioactive Materials and other Radiation Sources (OSR-72/87), and Radiation Protection Norms (NRB-76/87) will be still in force.

The Estonian Radiation Protection Law has been under preparation for more than two years. The final version of this law has now been submitted to the Government and will be further referred to the Parliament in the coming months. Draft version of the law has been reviewed by the experts of the IAEA, and the Finnish Centre for Radiation and Nuclear Safety. The Law is expected to be approved by the end of 1996.

The Radiation Protection Law will be the basic law in the field of radiation protection in Estonia. This will form the basis for other regulatory documents to follow.

Saku/Tammiku waste facility

A low and intermediate level radioactive waste facility was established at Saku/Tammiku in the beginning of the 60's There is a 200 m^3 underground concrete vault for solid waste storage divided into 9 compartments [1] The facility is filled up to 55 % and delivery rates have ranged from 10 530 kg in 1963 to 480 kg in 1991 For liquid waste there is a cylindrical stainless steel tank at present containing 6 3 m^3 of waste with a total activity of about 590 GBq

A preliminary safety assessment has shown that medium and long term safety of the waste disposed of at Saku/Tammiku does not meet present day international standards To improve the physical security of the site and to modernise the facility performance in 1995, a reconstruction project was formulated by Construction Design Company "Toostusprojekt" Due to the high cost of renewal work amounting to 2 6 MEEK, this project was cancelled and only minor activities for upgrading the physical protection were carried out

The responsibility for the depository was transferred in October 1995 from the Tallinn Special Motor Depot to AS ALARA Ltd , the new institution dealing with radioactive waste management In early 1996 the waste facility was shut-down temporarily and no radioactive waste material was received for storage The present plans are to initiate a process of safety and performance assessment to facilitate decision on further management of the site One of the feasible scenarios could involve sorting and classification of the radioactive waste material over the next few years, proper repackaging and transfer to the Paldiski facility

Paldiski facility

On a special agreement between the Russian Federation and Estonia two nuclear reactors of the former submarine training facility were transferred, fuel rods and main equipment transported to Russia. Two radioactive waste storage facilities remained, one for liquid and the other for solid waste containing more than 700 m^3 of liquid and about 213 m^3 of solid low level radioactive waste, respectively. By September 30, 1995 the site was turned over to Estonia including the responsibility for radiation and environmental safety of the surrounding territory

Due to lack of expertise in the area of decommissioning and decontamination work, the Paldiski International Expert Reference Group (PIERG) was organised under the leadership of the Swedish Government Presently, this group includes experts from several countries and international organisations, as for instance, from Finland, USA, Russia, Denmark, IAEA etc

The main tasks of the PIERG are to promote safe and timely decommissioning of nuclear facilities by advising and assisting the organizations involved in the work on technical, organizational, financial, waste management and radiation protection matters. PIERG identified a number of tasks for implementation For instance, in the area of environmental radiation protection, the main tasks implemented during 1995-96 are

- treatment of over 700 m^3 of low level radioactive liquid waste so that it could be safely released into the sea This was done during the summer of 1995 (joint task of Finland, Russia, Estonia),

- site and building characterisation to determine the location and extent of radiological and other hazardous materials on the site (joint USA-Estonian task);
- airborne multi spectral analysis of the peninsula (USA task).

Presently, the work at site is focused on territory control and security, and maintaining the facilities that are expected to remain in operation.
The major tasks to be carried out in the near future and important in the field of environmental radiation protection, are :
- treatment of radioactive bottom sludge of the liquid waste storage tanks;
- treatment of separated radioactive liquid;
- proper packaging and storage of solidified waste.

Sillamäe uranium mill tailings depository (SILMET Plant)

During the whole period of operation of the Sillamäe uranium milling facility about 4 million tons of uranium ore and approximately the same amount of loparite were processed [2]. Remaining tailings are deposited in an oval retention impoundment located on the coastline of the Gulf of Finland with an overall area of about 33 ha. The bottom of the depository consists of permeable coarse-grained material lying in a 2-10 m thick layer of Cambrian clay, at about 4 m above sea level. The closest point of the embankment to the shoreline is about 30 m and the top of the dam is about 25 m above sea level. About 30% of its area is covered by a sedimentary pond containing approximately 150 000 cubic metres of acid waste water with a depth of up to 3 m.

During the period 1993-96 several international as well as national investigation projects have been carried out concerning radiation and geotechnical safety problems of the Sillamäe site [3,4]. It is concluded that the total amount of uranium mill tailings in the depository is about 6.3 million tons. The rest of the waste, about 6.1 million tons, is oil-shale sudge and residues from loparite processing. The total amount of elemental uranium and thorium is estimated to be 1830 and 850 tons, respectively, and radium about 7.8 kg. In general, investigations done up to now have given sufficient information about the distribution of contaminants in the depository and allowed to conclude that the environmental impact of the waste depository in Sillamäe is limited. The only possibility for radioactive contamination of the surrounding area could arise due to the dust lifted up from the dry surface of the depository by wind in the periods of low precipitations. As a counteraction against this, the surface was wetted artificially at some periods. Aeolian erosion of the depository has occurred very seldom as in Estonia in general, the amount of precipitation exceeds natural evaporation remarkably. However, some losses of surface water occur due to the infiltration through the embankment.

Leakage from the impoundment into the sea does occur, but radiological hazard is not very serious. However, it was concluded that there is an active erosion weakening of the barriers and that the stability coefficient of the depository dam is smaller than normally required. The stability coefficient given by geotechnicians calculated according to different methods ranges between 1.05-1.2 and 1.3-1.4, while the internationally accepted value for long-term exploitation of depository should be about 1.8-2.0 .

Two years ago a workshop was held in which all institutions of Estonia involved in the investigation of Sillamäe tailing depository participated. In this meeting the coordination flow chart was elaborated to achieve practical restoration outcomes in the site (Fig. 1). One of the urgent tasks was to promote accident prevention activities. The following example demonstrates the designing of a remediation project to reinforce the embankment from the sea side.

As the waste depository is lying on a Cambrian clay, some shifts of the embankment toward the sea can be foreseen. Slip danger dam zones with a small stability factor may exist in places where marine terrace which forms the bottom of the depository, is subjected to the wave erosion process. Geotechnical monitoring has shown that some shifts of the dam occur ranging 11 - 20 mm per year.

PROJECT IMPLEMENTATION

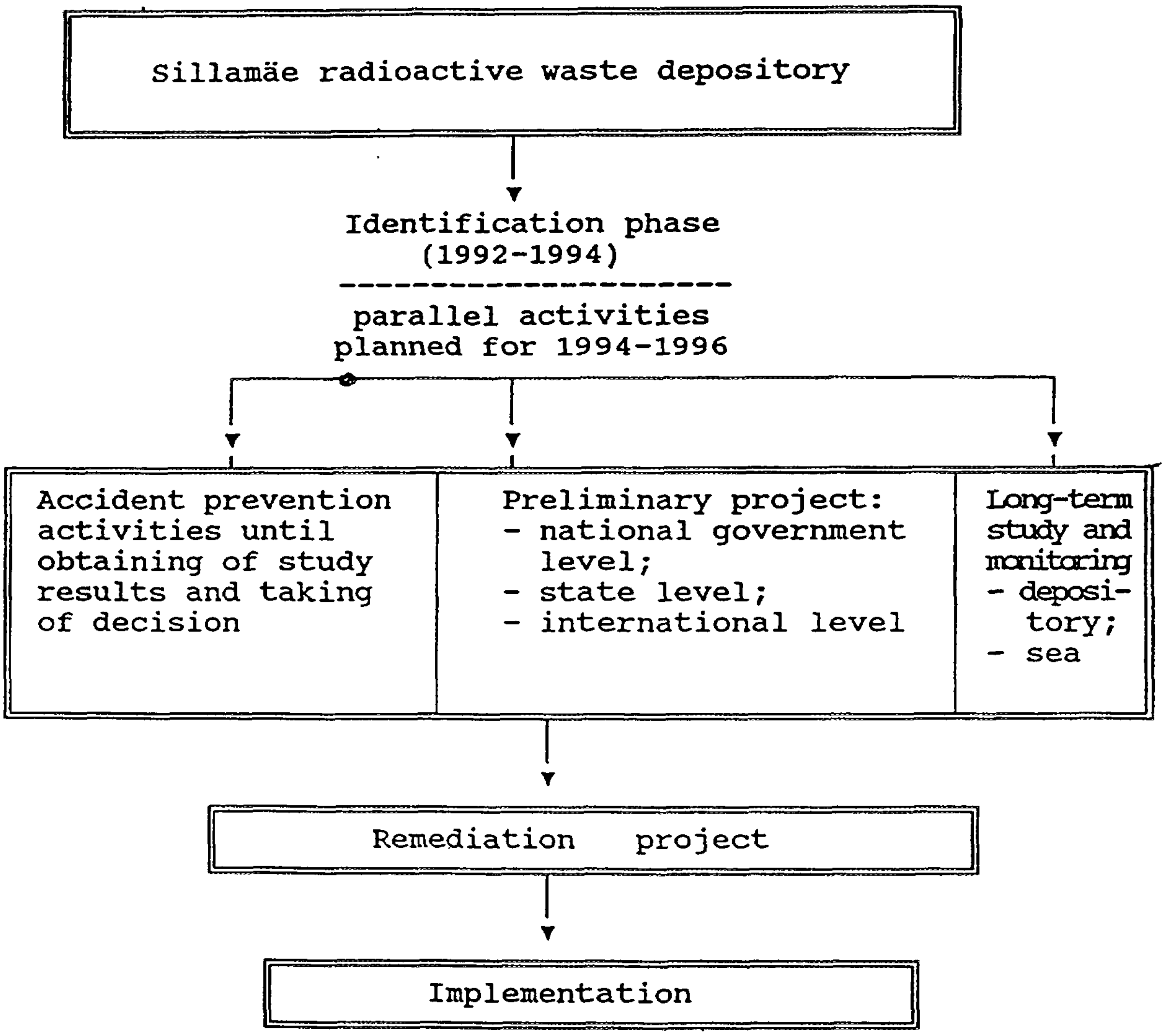

Fig.1. General flow chart of activities for environmental restoration of Sillamäe uranium mill tailings depository.

To get a preliminary overview about the sea erosion activity necessary for future planning, a special research project was carried out. This initial work [5] showed that most active damaging of shore line is occurring in the range of dam sections D and C (Fig. 2). Based on this and on the results of geotechnical observations, an accident prevention project [6] was designed to reinforce the dam in some key locations (cross-sections A-A and B-B in the Fig. 3). The main idea of the project is to build counter balance prisms on the shore-line to avoid possible slides of the dam sections where the stability factor is insufficient (Fig. 4). Designed peripheral dam will increase the stability factor estimated for the existing embankment from about 1.2-1.4 upto the value of 1.8-2.2 which will meet international requirements. However, several ways for practical implementation were indicated in the project that needed additional expertise. At present this work is going on the results which

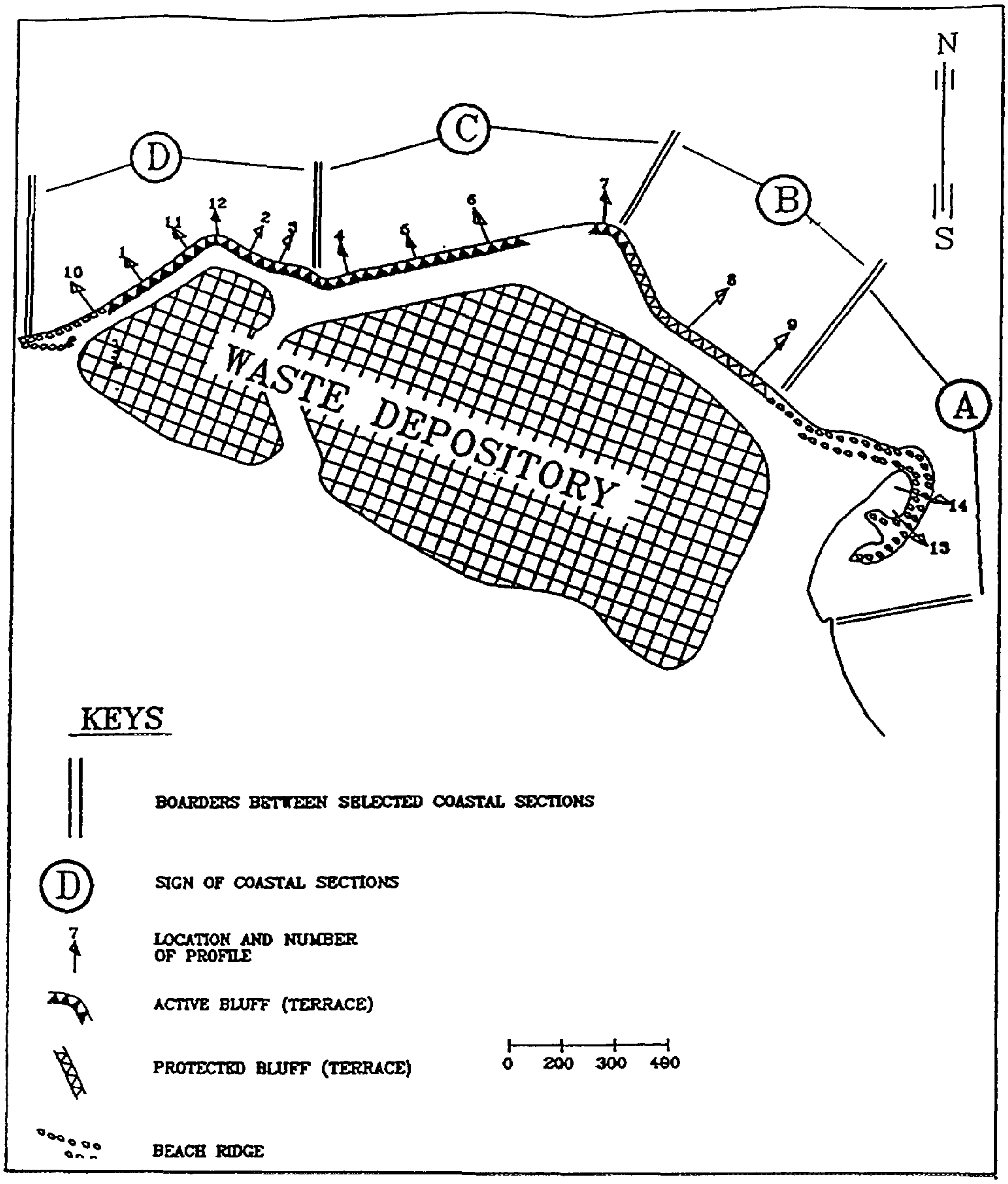

Fig.2. Geological structure of coastal area bordering to the depository.

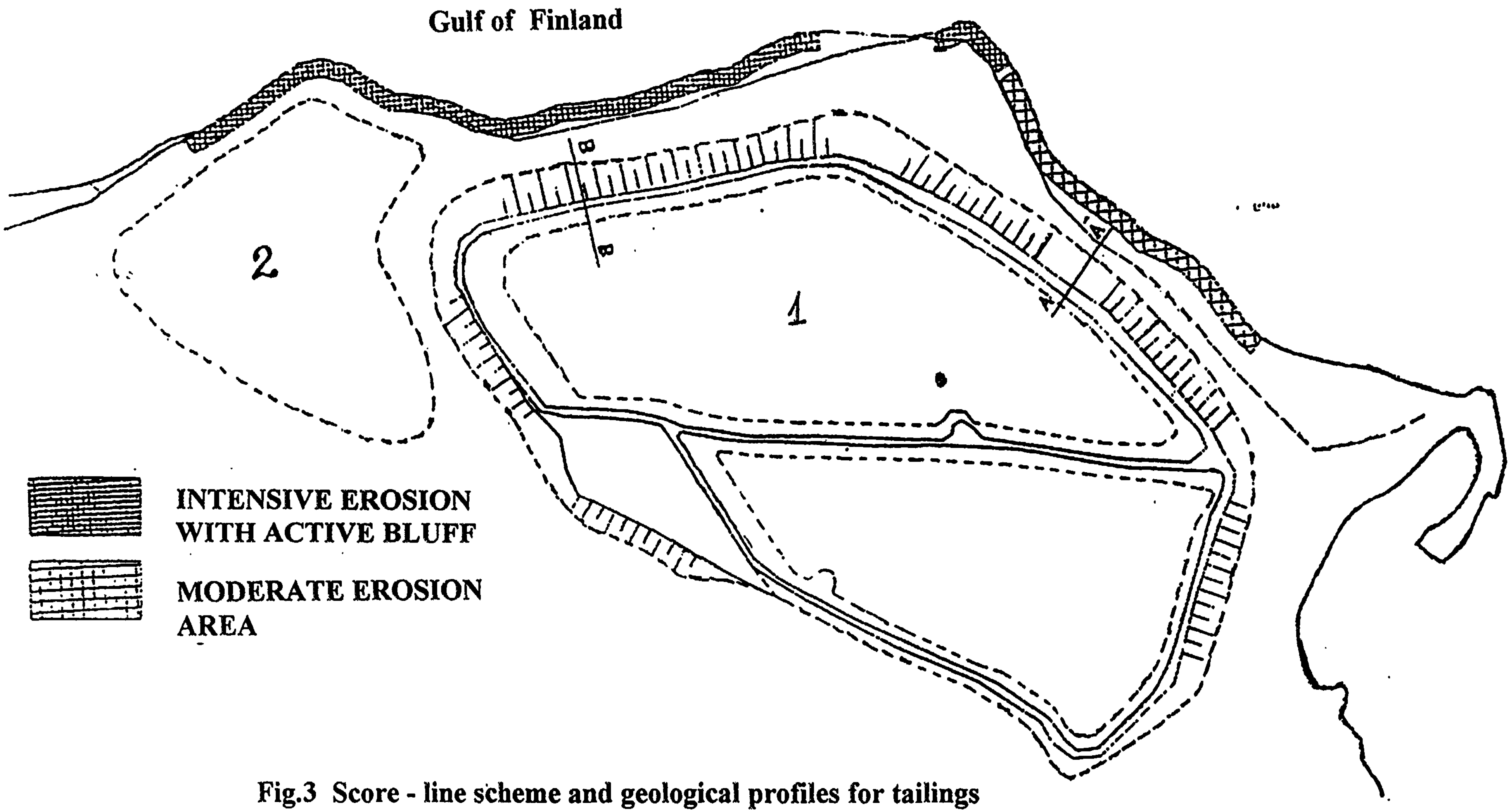

Fig.3 Score - line scheme and geological profiles for tailings depository
A - A; B - B - location of geological profiles

1 - old compartment,
2 - new compartment.

A-A

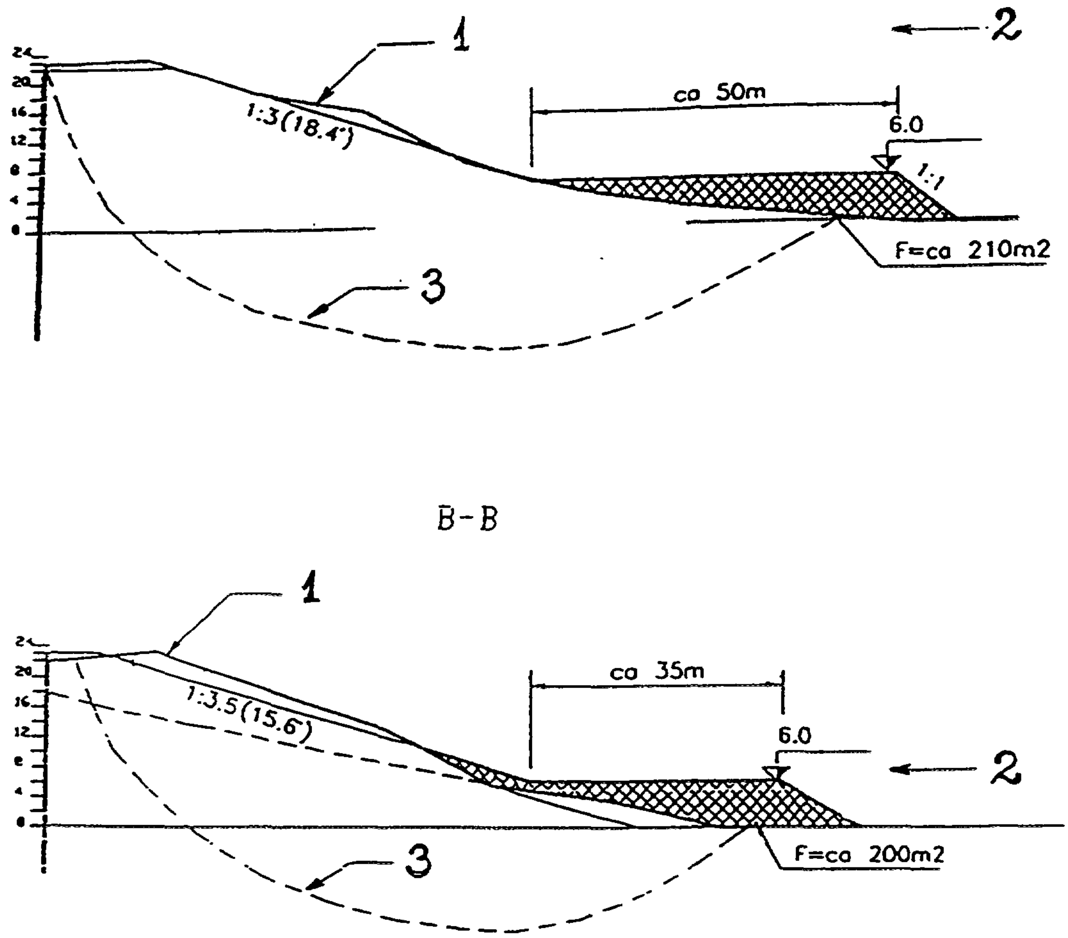

Fig. 4. Geological cross-sections of counter balance prisms designed.

1 - outline of the existing slope
2 - filling direction
3 - slide surface

will allow taking a final decision on how to perform remediation activities and to close the depository. It is proposed to include waste water seepage through the dam into the sea in the existing monitoring network of Sillamäe. Acknowledging the importance of starting practical restoration works as soon as possible, the Estonian Government has funded the factory with 4.8 MEEK for immediate remediation work this year.

In addition, a multi country PHARE project on the topic of remediation concepts for uranium mining and milling sites in the Central and Eastern European Countries was launched this year. It has been proposed to compile a detailed data bank on the situation at sites under this project and to offer basis for further design of pilot projects. The latter is planned to be carried out in the second phase of the project which will bring knowhow on remediation practices and technologies accepted world-wide to Estonia.

Under the present circumstances and plans for the future, the state as well as SILMET plant have to

- increase the stability of the impoundment dam during the next year by reinforcing the dam slope against wave erosion,
- keep under control the leaking water from the depository and work out measures for its treatment,
- start designing a project for the close-down of the depository,
- finish exploitation of the depository in 3-4 years,
- solve problems concerning storage of the radioactive and non-radioactive waste, especially of thorium, proceeding from the technology planned to be used,
- find a place for construction of the new waste depository,
- work-out a temporary solution for treatment of filtrate waters and find funding needed for practical realization

Special tasks for the SILMET plant to be fulfilled in the near future are as follows

- proceeding from the technology used to formulate a programme for management of radioactive and non-radioactive waste, plan funding,
- apply a special licence for such activities,
- within the framework of preparation for closing down the depository, to initiate design of a new depository, and arrive at a technology and technical solutions for actual closing down of the existing depository

Carborne radioactive mapping

In 1995 environmental mapping of radioactive sources along the main roads of Estonia was carried out in co-operation with the Finnish Centre for Radiation and Nuclear Safety [7] For cost-effective reasons carborne radiological surveys were used Data revealed that radioactivity was on the average 0 04-0 1 μSv/h, somewhat higher was radioactivity near Kiisa due to the vicinity of the low level radioactive waste depository at Tammiku

3. CONCLUSIONS

The overall stragegy for environmental restoration of contaminated sites in Estonia calls for several actions to solve the impending problems An Action Plan for 1995-1996 was drawn and some success has been achieved in its implementation as for example, the Radiation Protection Law finalized and Radiation Protection Centre established However, dur to very limited funding, some important tasks need urgent solutions in the near future

- passing the Radiation Protection Law in the Parliament,
- development of a monitoring system,
- refurbishment of the Saku/Tammiku and Paldiski waste depositories,
- finalization of the restoration project for the Sillamae tailings depository

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ENVIRONMENTAL RESTORATION PLANS AND ACTIVITIES IN FRANCE: 1995-1996 PROGRESS REPORT

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Abstract

In 50 years, more than 200 mining sites and 11 processing plants have contributed to French uranium production At present only two mines are still in production The others have already been restored or are in the final phase of restoration

This report gives a retrospective account of developments and statutory actions currently in progress, with examples of sites at various stages of restoration The importance of research and development studies as well as efforts being put in to communicate with all the parties concerned in these restoration projects are specially emphasized

1. REVIEW OF SITES IN FRANCE

The prospecting carried out since 1946 indicated major uranium bearing districts in France Uranium resources are related to certain types of granite from hercynian massifs (Massif Armoricain and Massif Central) and grounds of the Permian or lower Tertiary resulting from erosion of the massifs

Thus uranium ores mined in France were located in granitic and metamorphic areas (Vendée, Massif Central, Limousin) or sedimentary areas (Lodève, Coutras)

TABLE I URANIUM SITES IN FRANCE

Rocks	District	Year of discovery	Geographical location
Granitic	Vendée	1951	Near Cholet
or	Limousin	1948	Near Limoges
Metamorphic	Forez	1947	Near Roanne
Sedimentary	Lodève	1957	Near Montpellier
	Coutras	1974	Near Bordeaux

A total of 53 million tonnes of ore has been mined, containing nearly 87,000 tonnes of uranium, 81,000 tonnes of uranium was produced in the form of concentrates (1995 figures)

TABLE II URANIUM ORE EXTRACTION (10^6 t) IN FRANCE

Mining sites	Vendée	Limousin	Forez	Lodève
Mined out ore	13 3	24 8	2 6	4 4

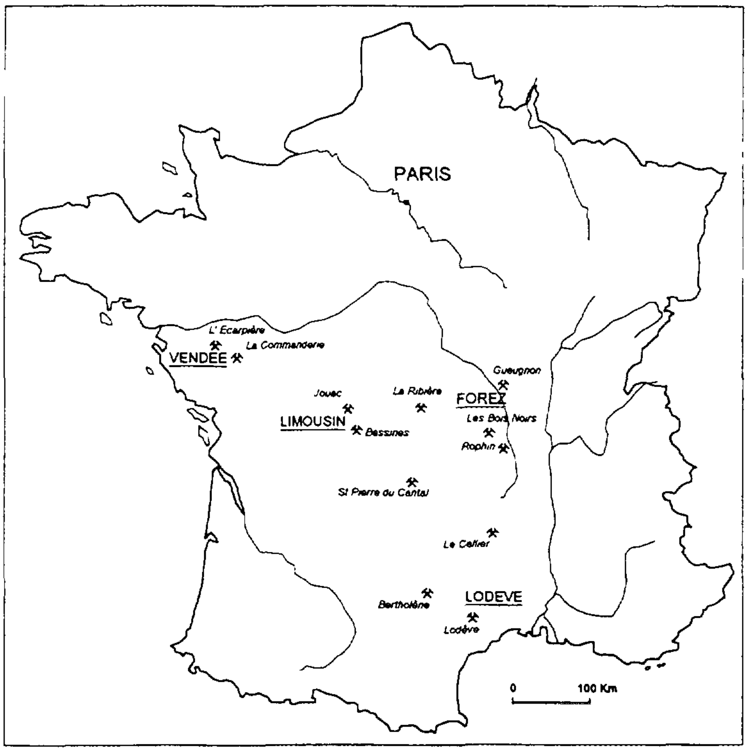

FIG. 1. Location of mining areas in France

Over the years uranium mining in France by COGEMA and its subsidiaries has lead to:

- more than 200 mining sites, three fourth of them being of area one hectare or more. Whether open pit or underground mining, the associated waste dumps have to be dealt with;
- 11 industrial sites with mill or heap leaching operations;
- 22 storage sites with residues from ore processing.

Total areas for the industrial sites and the associated impoundments range from three to more than a hundred hectares.

Due to the very low grade of uranium ore treated in France (average 0.15%U or 0.23%U if low grade ore is excluded) more than 98% by weight goes to waste and as such large tonnages have to be dealt with. By the end of 1995, a total of nearly 50 million tonnes has accumulated.

Dismantling of a mill leads to several thousand tonnes of slightly contaminated concrete debris and scrap. The most contaminated equipment are those used for chemical attack of the ore and resin extraction of uranium. The estimated radioactivity is less than one percent of the activity treated during the life time of the mill and the calculated radioactivity of the impoundment takes this into account.

Types of storages are either piles of heap leached ores or impoundments of mill tailings. Impoundments are limited by dikes or by open pit.

The present status of remediation is as follows:

- production completed; remediation completed: Gueugnon, Les Bois Noirs, Le Cellier;
- production completed; remediation in progress: L'Ecarpière, Bessines, Saint Pierre du Cantal, Bertholène;
- production in progress; remediation projected, or in progress by stages: Jouac, Lodève.

TABLE III. TONNAGE OF RESIDUES (10^6 t) OF THE MAIN STORAGE SITES IN FRANCE

Site	Forez	Vendée (Ecarpière)	Limousin (Bessines and Jouac)	Lodève	Cellier
Dumps of poor ore	none	none	none	0.8	none
Static leaching residues	none	4	8.6	none	4.5
Dynamic leaching residues	1.3	7.6	15.0	4.0	1.1

2. REGULATORY ASPECTS

Uranium mining activities in France are controlled under the general jurisdictional framework of extraction industry, with special provisions relevant to the radioactivity of the handled materials.

The Mining Code is the central point of the mining regulation; it refers to other Acts and Rules coming from the general regulation in France. The most important of these are:

- Act No 76-629 relating to the Protection of the Nature,
- Act No 76-663 relating to the Registered Facilities for Environmental Protection,
- Act No 83-630 relating to the Democratisation of the Public Inquiries and to the Environmental Protection.

These Acts are completed with regulations on Water, Air, Wastes, Noise and Landscape Protection.

2.1. The Mining Code

The objectives of the Mining Code are:

- to promote the development of natural resources by improving the extraction conditions,
- to enhance the state control over the natural resources management, and
- to reinforce the administrative supervision to achieve a better interaction of the extractive industry with the environment.

The Mining Code defines the relation between the owner of the surface, the mine operator and the State which owns ground resources of uranium.

It sets up two basic principles

- remediation is mandatory, and
- the mine operator remains always responsible for the damages caused by the mining activity even after mine closure, except where the liability of a third party is proven

It defines in detail:

- the task of the regulatory bodies involved in mining occupational and public safety, environmental protection ,
- the process of licensing in mine and mill projects before the beginning of exploration or production activities, the mine operator must ask for an administrative authorisation , the process includes an environmental impact statement and a public inquiry The license establishes constraints relating to the protection of the environment ,
- the process for the mine closure· before the mine closes, the operator must make a declaration to the administration, the file explains the measures to be taken to lessen or to mitigate the residual impacts of the activities The administrative authority gives approval in the same way as before starting the operations

A leading part of the mining code deals with occupational and public safety and thus implements the principles for protection against ionising radiations, dose limits are set to 5 mSv per year (according to ICRP 26 recommendations), calculated in addition to the natural background, using a theoretical exposure scenario for a critical group

2.2. Registered Facilities for Environmental Protection Regulation

General French regulation stipulates operators of some potentially hazardous facilities to be licensed The detailed list of such facilities is frequently updated. Some of them operate mines, maintenance shops, crushing plants or tailings ponds.

The file for licensing contains an environmental impact statement and risk analysis with a description of possible contingencies and consequences and organizational set up to deal with emergency situations. The licensing process includes administrative and public inquiries The license fixes prescriptions for the operations, particularly concerning environmental releases and waste management, site monitoring and organizational structure Financial guarantee provisions included to cover the costs of site monitoring, corrective measures in case of pollution and site reclamation are clearly stated

An administrative process is also required to close this kind of facilities, the licensing file and process are similar as for a mine closure and the administrative approval stipulates conditions of site remediation and monitoring.

2.3. Changes occurring over the period 1995 - 1996

The period 1995-96 was mainly notable in the field of environmental protection, for the promulgation of the Act No 95-101 of February 2, 1995, regarding the reinforcement of environmental protection

This Act introduces, into French law, general principles on environmental law that are largely inspired by international law These are the principles of precaution, preventive action, participation and polluter-payer

The principle of precaution is the principle according to which lack of certainty with regard to current scientific and technical knowledge must not delay the adoption of effective and appropriate measures aimed at preventing risk of serious and irreversible damage to the environment, at an economically acceptable cost.

The principle of preventive action and the correction of detrimental effects on the environment at source as a matter of priority, involves the utilization of the best techniques available at an economically acceptable cost.

The principle of participation gives every citizen the right of access to information regarding the environment.

The polluter-payer principle makes the polluter responsible for the expenses incurred on preventive measures, reduction of pollution and pollution control.

This Act also reinforces the right of Associations to take action in the field of environment by giving them the opportunity of instituting proceedings in cases of pollution.

The period of 1995-96 also saw the publication of two enforcement decrees completing the statutory provisions concerning mines and installations classified for protection of the environment.

Two of the new provisions to be noted are:

- The prefectural order authorising the opening of mining works to stipulate the conditions under which analyses, measurements and the results of tests shall be brought to the knowledge of the public. These provisions will, naturally, be applied in the field of monitoring of the environment of closed-down mining sites as well.
- The methods of establishing the financial guarantees required to cover the costs of site monitoring, corrective measures in the event of pollution and restoration on the closure of classified installations to be defined precisely.

2.4. Future development

The main development for the coming years will concern the incorporation of the EURATOM 96/29 directive of May 13, 1996 defining the basic standards regarding the protection of the health of the population and workers against the hazards of ionising radiation into the French Law.

This European directive takes into account the recommendations of ICRP 60 and defines the dose limit to be complied with for members of the public at 1 mSv per year instead of the current level of 5 mSv per year.

The effective dose is calculated on the basis of a realistic exposure scenario, whereas the scenario currently used can be qualified as very conservative.

3. ENVIRONMENTAL RESTORATION ACTIVITIES IN 1995-96

It would take too long to review all the sites concerned and looking at the most significant ones, the sites could be grouped into three categories: sites in service, sites no longer worked and currently in the process of restoration, and restored sites under monitoring. This leads to a logical chain of remediation tasks.

3.1. Sites in service

3.1.1. Lodève

The Hérault Mining Division is located in the immediate vicinity of the town of Lodève in the south of France. Activities started in 1975 with the development of the underground mine followed by open pit operation in 1978. As of the end 1995, the plant produced approximately 12,300 tonnes of uranium as concentrates. Mill tailings were stored in two disused open mines located side by side and known as "Failles Centrales" (Central Faults) and "Failles Sud" (South Faults) with a total area of 60 hectares including a tailings area of 30 hectares.

The restoration of the open pits was undertaken as and when they were closed, the main measures generally consisting of partial backfilling of excavations and landscaping of waste rock dumps which were remodelled and replanted.

Three sites with an approximate area of 10 hectares each were restored in this way.

Filling of the excavation of the "Central Faults" was completed in 1987 and covering tests on about one-third of its area were conducted as from that date. These tests contributed a wealth of information for the restoration of these storage sites.

The stopping of production at Lodève is scheduled for mid 1997. In recent years a major development is seen in the preparation for site restoration in the following fields:

- Studies concerning tailings storage facilities: geotechnical stability of the of tailing containments, geomechanical stability (erosion resistance) and geochemical stability of coverings, and geochemical changes in the tailings.
- Studies concerning the underground mine: the main study concerns the site hydrogeology which should allow the phenomena resulting from the rising of water levels during mine flooding to be predicted and the consequences to be forecast. This study required drawing up a complete inventory of the water inflows into the underground mine and to characterise them.
- Works: a second test covering about one third of "the Central Faults" pond was conducted to measure the radiological effectiveness of a 1 m thick layer of non compacted waste rock. Radon exhalation measurements were made directly over the tailings and after covering, and compared with measurements made over the waste rock dump. This test showed that the radon exhalation was only due to the waste rock.

3.1.2. Jouac (Limousin)

The Jouac mining company (Société des Mines de Jouac), a French subsidiary of Cogema, has been working the Bernardan deposit in the Limousin region in the north-western part of the Massif Central since 1978.

Extraction, which began with an open pit, is currently being continued as an underground mine with a plant to process the ore. From the beginning and up until the end of 1995, it produced approximately 6,200 tonnes of uranium in concentrates. The mill tailings are stored in cells separated by containment dikes with a maximum thickness of 15 metres Two cells are in service and two others have already been filled and are in the process of being restored The total area of this storage installation is 34 ha and the stored quantity is 1 3 million tonnes

This storage facility restoration work forms part of the normal working cycle of the mine which is expected to operate for a few more years

Action is under way which will, when the time comes, have the effect of anticipating and facilitating the closing of this mining complex The following points should be noted, in particular

- the drawing up of a study of all the waste generated on the site and the implementation of specific measures to reduce detrimental effects on the environment by means of, in particular, sorting out and recycling ,
- the hydrological and hydrogeological study of surface and underground water flows in the site's future configuration ,
- the radiological monitoring of the two restored storage cells

3.2. Sites currently being restored

3.2.1. L'Ecarpière (Vendée)

The mining complex of L'Ecarpière is located in the west of France, 30 km south-east from the town of Nantes. Its surface is 240 hectares. It comprises·

- an underground mine and three open pits from which a total of 4,100 tonnes of uranium was extracted between 1953 and 1991,
- an ore processing complex fed by the L'Ecarpière mine and, also, by other mines in the Vendée Mining Division A production of 14,800 tonnes of uranium was achieved, most of it (13,500 tU) by an ore processing plant, which was complemented (1,500 tU) by a heap leaching installation which operated from 1967
- a settling pond for ore dynamic mill tailings. The peripheral containment dike was built up gradually, using the coarsest part of the tailings The final state of the dike is height varying from 15 m to 50 m, length 3 km, maximum tailings thickness 40 m

Restoration of the L'Ecarpière site began in 1992 and had reached the following stage at the end of 1994

- Open pits restoration completed This consisted of backfilling two excavations with waste rock materials, resloping and flooding the third one, resloping and recontouring the waste rock dumps and replanting the sites.
- Mine installations and processing plant· dismantling was completed and debris was stored on mill tailings
- Tailings pond work was in progress. This consisted of covering the residues to minimize the radiological impact to as low as reasonably achievable (and less than 5 mSv), to get a good control on the run off of rain water, and in replanting vegetation to limit erosion and ensure landscaping

The main characteristics of the site are summarised in Table IV.

TABLE IV. CHARACTERISTICS OF THE L'ECARPIÈRE SITE BEFORE RESTORATION

	Area (ha)	Tonnage (10^6t)
Open pit	115	
Underground mining installations	12	
Heap leaching facilities	16	
Heap leaching dump	9	4
Mill	6	
Mill tailings pond	73	7.6
Waste water collecting zone	9	

The years 1995 and 1996 were essentially dedicated to the following tasks on the storage of tailings:

- The mill structure was demolished.
- Dismantling debris of the mine installations and the plant was covered at the same time as the tailings.
- The multi-layer cover for the storage facility was installed. This consisted of 1 to 8 metres of static leaching tailings, approximately 30 cm of compacted altered gabbros (by-products of a quarry near the site) and 10 to 15 cm of top soil. In all, 3.5 million cubic metres of material were moved.
- Two chambers were constructed on the tailings storage facility to receive the sludge produced by water treatment.
- The whole water drainage network is in place.
- Sowing of the site for vegetation has been completed.

All the work was carried out in compliance with the restoration project approved by the administration in November 1995. In appreciation of the quality of work performed, Ph. Crochon, the engineer in charge of the restoration of sites in Vendée, was awarded the "Environment" prize by the French Association for the advance of sciences (Association Française pour l'Avancement des Sciences) in 1995.

3.2.2. Bessines (Limousin)

The Bessines complex is located in the Limousin region, in the western part of the Massif Central. After the start up in 1958, the processing plant produced a little more than

27,000 tonnes of uranium in concentrates by the middle of 1993. Most parts of this was supplied by the five leading mines (50 extraction sites) in the Crouzille mining division. There are two types of mill tailings:

- heap leaching tailings on the Bessines site,
- plant mill tailings. These were, at first, tipped into a pond created by means of a dike ("Lavaugrasse") then in a disused open pit ("Brugeaud") located on the same site and finally, in two disused open pits situated a few kilometres from the plant ("Montmassacrot" and "Bellezane").

TABLE V. CHARACTERISTICS OF THE BESSINES INDUSTRIAL SITE

	Area (ha)	Tonnage (10^6 t)
Heap leaching	25	8.6
Mill	20	
Lavaugrasse pond	35	5.7
Brugeaud pond	20	5.8

Restoration work on the Bessines site was begun as soon as the plant was shut down and is conceived similar to that followed for the L'Ecarpière site:

- The static leaching tailings are used to cover the Brugeaud pond. A first cover formed in this way is approximately 2 m thick. A platform is created to receive scrap iron and other scrap from the dismantling of the processing plant. The whole facility is to be covered over with heap leaching wastes and waste rock from the former open pit. The total thickness of the cover is projected to vary from 2 to 10 m.
- The tailings and the Lavaugrasse pond dike is covered with heap leaching wastes and at least 2 m of waste rock from the disused open pit, with the exception of 2 hectares area developed as a storage chamber for the sludge produced by the water treatment plant.
- The dumps of the former open pit are recontoured.
- A selective water collecting network is constructed.
- The whole site is replanted with vegetation.

It is planned to move 2.5 million cubic metres in the course of all this work.

In 1993 and 1994, the work mainly consisted of dismantling the plant and the heap leaching installations and in covering the Brugeaud pond and the dike of the Lavaugrasse pond. The Lavaugrasse pond was, in fact, used as an industrial water reservoir and could only be emptied after the closure of the plant.

The covering work of the ponds continued in 1995 and 1996. They are now in the process of being completed and less than 500,000 cubic metres are still to be moved. Good progress has also been made in finishing work and one part of the site has already been replanted The plant has been completely dismantled and the debris and scrap iron has been stored in the Brugeaud pond and is waiting to be covered

All this work, carried out in compliance with the restoration project approved by the administration in December 1995, involved moving of large quantities of materials. The quantities moved per year are summarised in Table VI

TABLE VI QUANTITIES OF MATERIAL PLACED ON PONDS (10^3 m^3)

	1993	1994	1995	1996 (prev)	Total
Brugeaud pond	20	310	340	70	740
Lavaugrasse pond	0	335	565	540	1,440
Total	20	645	905	610	2,180

3.3. Restored sites under monitoring

3.3.1. Les Bois Noirs (Forez)

The mining complex of Les Bois Noirs is located in the Massif Central region of France It was worked from 1955 to 1980 and produced 6,400 tonnes of uranium in concentrates The complex included an open pit, an underground mine mainly worked by cut and fill, an ore processing plant and a settling pond formed by means of a dike

The site restoration was undertaken as follows:

- In the first stage just after the closure of the mine, restoration consisted in securing of the mine working structures, dismantling surface installations that were no longer of use, ensuring landscaping of the site and installing a water treatment system
- The second stage implemented in 1985, consisted of reinforcing the safety of mill tailing storage facilities which were completely submerged by dredging the sandy banks, and improving the safety of the dike by redimensioning the high water drainage system

Monitoring of the site concerns two points the stability of the dike containing the tailings and the radiological impact It shows that

- the dike is stable,
- the site has no significant impact on the food chain,
- the quality of the water seeping through the dike has quickly improved since the complex closed except the period during which the sandy banks were dredged (see Table VII),
- the quality of water from the underground mine has also improved (see Table VIII),
- the total added exposure above the natural background level is in the region of 1 mSv per year, compared to the limit of 5 mSv (ICRP 26) permissible.

Studies are currently in progress with a view to decreasing the site monitoring and maintenance requirements and, in particular, those of the dike and associated hydraulic structures.

TABLE VII. SEEPAGE WATER QUALITY EVOLUTION

	Standard	1981	1983	1985	1987	1989	1991	1993	1995
Ra ($Bq.l^{-1}$)	0.37	0.02	0.04	0.05	0.02	0.03	0.04	0.05	0.03
U ($mg.l^{-1}$)	1.8	0.42	0.21	0.23	0.13	0.15	0.14	0.11	0.11
SO_4 ($mg.l^{-1}$)	250	324	160	820	207	154	130	110	110
pH		6.7	6.6	6.6	6.4	6.4	6.4	6.4	

TABLE VIII. MINE WATER QUALITY EVOLUTION

	Standard	1981	1983	1985	1987	1989	1991	1993	1995
Ra ($Bq.l^{-1}$)	0.37		0.96	0.82	0.58	1.00	0.98	0.67	0.50
U ($mg.l^{-1}$)	1.8		0.64	0.27	0.20	0.19	0.15	0.13	0.18
pH		7.1	7.6	8.3	7.6	7.5	7.5	7.4	

3.3.2. Le Cellier (Lozère)

The mining complex of Le Cellier is located in the south-eastern part of the Massif Central. It was worked from 1956 to 1990, producing 2,750 tonnes of uranium in concentrates, from ore extracted from the underground mine and from the open pit. The ores were processed either by heap leaching or by dynamic leaching in a plant which operated from 1977 to 1990. The dynamic mill tailings were first stored with the heap leaching tailings and, then, in the open pit as from 1986.

The restoration of the site, undertaken in 1990 and 1991, consisted in:

- Securing the underground mine: sealing of openings, backfilling of some stopes,
- covering the heap leaching tailings and the dynamic mill tailings storage facility,
- reducing the gradient of slopes and replanting to ensure landscaping of the site.

More than two million tonnes of material were moved over a total area of 66 hectares.

These measures were completed with the construction of a water treatment plant of capacity 50 $m^3.h^{-1}$ and setting up of an environmental monitoring network to keep check on the quality of both air and water.

Tables IX and X specify the average annual values of the potential alpha activity of radon 222 and its daughters and of external radiation field, respectively, measured on the site in its immediate surroundings and in the reference natural environment. These values remain lower than the reference values which are 286 $nJ.m^{-3}$ and 570 $nG.h^{-1}$ respectively.

TABLE IX. POTENTIAL ALPHA ACTIVITY DUE TO RADON 222 ($nJ.m^{-3}$)

	1990	1991	1992	1993	1995
Le Cellier site	33	32	36	32	28
Immediate surroundings	77	35	37	34	34
Natural environment	40	36	36	31	26

TABLE X. EXTERNAL RADIATION FIELD ($nG.h^{-1}$)

	1991	1992	1993	1994	1995
Le Cellier site	360	270	270	250	240
Immediate surroundings	240	210	210	230	230
Natural surroundings	200	155	140	124	125

The monitoring of seepage water through various storage facilities shows, in all cases, a favourable trend towards a return to the natural balance. This trend varies, however, according to the storage facilities, thus reflecting the differences in the ores and in the processing they were subjected to, as for example:

- The uranium concentrations in water from the dynamic mill tailings storage facility are lower than the statutory value of 1.8 $mg.l^{-1}$ and radium showed a major decrease from five times the statutory value of 0.37 $Bq.l^{-1}$ in 1991 to only twice that value in 1995.
- For storage facilities containing ores processed by heap leaching, the radium concentrations noted in 1995 were between two and three times lower than in 1991 and uranium concentrations were five times lower.

This shows soundness of the principle of selective collection of water instituted during restoration. This allowed the water treatment system to be completed by a sodium hydroxide neutralising station reserved for water from the site requiring only simple pH adjustment before being discharged into the natural environment.

Finally, the total added exposure above the natural level is lower or in the region of 1 $mSv.year^{-1}$, compared with the limit of 5 mSv (ICRP 26).

TABLE XI. TOTAL ADDED EXPOSURE ($mSv.year^{-1}$)

	1991	1992	1993	1994	1995
Village of Le Cellier	1.1	0.6	0.6	0.65	0.55

4. RESEARCH AND DEVELOPMENT

The conceptualization of restoration of each site means, being able to predict and monitor the natural phenomena which may lead to pollution and to prevent and correct their consequences.

That is why Cogema, in close collaboration with various research organisations, is conducting an active research and development programme in three directions: characterisation of source terms, methods of transfer of contaminants, and efficiency of containment barriers.

4.1. Characterisation of source terms

This study was carried out in three phases:

- acquisition of data on the source terms to be managed,
- interpretation of data so that the operations at the storage sites can be understood,
- application of the results to predict the evolution of the tailings impoundments.

4.2. Transfer of contaminants

This line of research consists of studying the processes of dissolution of minerals by various solvents impregnating the tailings storage facilities and recrystallization phenomena.

4.3. Containment barriers

This line of research covers three types of containment:

- Natural encasing of storages: hydrogeology and hydrogeochemistry are essential aspects in these studies.
- Multi-layer covering of storages: on the basis of the mineralogical study of the materials used and full-scale tests, an attempt is made to qualify the coverings in terms of geotechnical stability, resistance to erosion and deterioration, and geochemical stability. The part played by vegetation is also taken into account.
- Water treatment: this barrier which is often indispensable just after mine closure bears heavily on the cost of restoration. It is therefore necessary to seek optimization of classical techniques. There is also a need to stabilise the sludge produced. The combination of these two lines of study is achieved through research into passive treatment processes.

5. COMMUNICATION

Site monitoring and environment protection measures as well as communication go on beyond the end of mining activities.

In conformity with Cogema's communication strategy, people living in the vicinity of mining sites are leading targets for communication specific to mining site environment. Personnel of the firm responsible for execution of the works at site are of course first informed. Cogema addresses an adapted communication to other agencies, like administrative and political authorities, press and associations.

Aim of communication is to show and to explain what Cogema does to protect environment, in order to make everyone able to form their own opinion. This is a means to ensure that remediation will be seriously performed. Communication must therefore be pedagogic and based on transparency.

Cogema ensures communication by the following means:

- mails to people living in the vicinity of the sites,
- "open" days and visits to installations and works,
- sessions of statutory commissions generally comprising representatives of administration, local political authorities and environment protection associations.

The results of site monitoring are regularly published: this is a good way of being transparent. The quality of this monitoring is, thus, essential. Every abnormality is explained and everyone can ask his own questions. This is important to win the confidence of those concerned. Constancy, coherency and long lasting are key factors of success.

6. CONCLUSION

The restoration of mining sites is the last operation carried out in the working of a mine. It may be the last but it is not, however, the least as it has long-term implications for the future.

In recent years, Cogema has successfully achieved the restoration of several major complexes, such as Bessines and L'Ecarpière. Thanks to the knowhow and experience acquired in carrying out this work, the relevant research and development studies and the corresponding communication, it can look forward to future closures with confidence.

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ENVIRONMENTAL RESTORATION PLANS AND ACTIVITIES IN GERMANY

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Abstract

The programme for remediation of radioactively contaminated sites due to mining and milling has two parts: (1) decommissioning and remediation programme for the Wismut sites and (2) investigation programme for „old" sites.

The legal basis for decommissioning and remediation of the Wismut sites is the Regulations for Radiological Protection and Control of the former German Democratic Republic (GDR). In the beginning the individual projects concentrated on the elimination of hazard sources, problems of mining safety and underground remediation including flooding of mine working areas. Now the activities have shifted more towards surface remediation. The paper discusses major problems, namely stabilization of tailings, prevention of ground water contamination, backfilling of the open pit and covering of waste rock piles. The remediation of Wismut sites will still take about 10 more years.

Investigations for „old" sites are carried out to arrive at general decisions on whether and for which „old" sites remedial measures should be considered. The results of these investigations so far show that remedial measures may be needed for 10 - 15 % of the "old" sites and, a framework legislation is required for the same.

1. NATIONAL CONDITIONS REQUIRING ENVIRONMENTAL RESTORATION AND PROGRAMMES

Mining and ore processing have a long history in the regions of Saxony, Thuringia and Saxony-Anhalt. Since the Middle Ages, ores of silver, copper, cobalt and other non-ferrous ores have been mined and processed. Waste rock of mining, slags and other wastes from ore processing have been dumped in the mining regions and as a result the view of landscape is marked by countless waste heaps. The ores have often contained uranium as mineral which remain in the residues of mining and ore processing thereby causing a radiological hazard, in particular if these residues have been used as building material or used for building up former mining sites. Immediately after the second World War, the former Soviet Union started development of nuclear capability and the well-known hydrothermal vein deposits in the part of Germany occupied by the former Soviet Union (e.g. near Aue and other places) were exploited. In the beginning the exploitation activities were concentrated on the then existing underground mines which were producing silver and other non-ferrous ores.

In 1946, the Soviet-owned stock company SAG Wismut was established and, as per the post-war conditions, the activities of Wismut were not under the supervision of German authorities. At that time there was no concern for the adverse impact on the environment and the population arising from mining activities and hazards to the employees. At first handselected pitchblende was recovered and the ores were then milled and uranium concentrate (yellowcake) produced. The rich pitchblende ores and the uranium concentrate were transported to the former Soviet Union for further processing. Simultaneously numerous exploration works carried out resulted in new uranium ore deposits; paleozoic schists, limestones and volcanic rocks in Eastern Thuringia (near Ronneburg), sandstone deposits near Koenigstein and the uraniferous hard coal of the upper Permian age near

Freital. In the 50's and 60's the uranium production was extended to these parts of the GDR, occupying considerable land, which brought about changes in the landscape as well as the infrastructure. A number of mines (underground and open pit mines), mills and other facilities were in operation. Numerous waste rock piles and tailings ponds of considerable dimension resulted.

As per regulations current at that time in the period up to the 60's many sites and facilities were decommissioned by Wismut complying with only the regulations and standards for mining safety. The aspects of radiological protection were not given importance or were not observed. Subsequently these sites and facilities were transferred to other enterprises or to communities. In 1954 the SDAG Wismut was converted into a joint Soviet-German stock company (SDAG Wismut), with equal shares held by the former Soviet Union and the GDR.

On the basis of a contract between the governments of the former Soviet Union and the GDR in 1962 the SDAG Wismut was obliged to observe stringently the German regulations, but supervision by the German authorities was possible only in exceptional cases because of the special status („state within the state") of the SDAG and because of special provisions. After the unification of Germany, the uranium production was abandoned for economic and other reasons and, based on the Wismut Act [1] 1991 the Wismut company was converted into a corporation (Wismut GmbH) with 100 % ownership of the Federal Government. It is the responsibility of this corporation to decommission the mines, mills and other facilities used by the SDAG Wismut for the uranium production and remediation of the sites if required. The Federal Ministry for Economy in its role as a shareholder of the Wismut corporation provides the financial resources because of lack of financial reserves with Wismut for decommissioning and remediation. The Wismut GmbH is also responsible for a number of underground mines and waste rock piles, two large tailings areas, one open pit mine, a few loading sites and transportation areas with a total surface area of 34 km² [cf. Table I].

The residues of the earlier uranium production and other ore mining and milling are also to be considered as a potential source of environmental contamination. The problem has been poorly analysed in the past and an assessment of the total situation is absolutely necessary before general decisions on remediation of the old sites can be taken. Accordingly the programme for remediation of radioactively contaminated sites due to mining, milling and ore processing is in two parts: remediation programme for the Wismut sites and investigation programme for „old" sites not in possession of the Wismut to facilitate general decisions on remediation of such sites.

2. LEGISLATION, REGULATIONS, POLICIES

Regulations on radiological protection and control applicable to cases of chronic radiation exposure from past or old practices are not available at present.

As a provisional legal basis, for the decommissioning and remediation of Wismut sites, the German Unification Treaty [2] stipulates that the regulations for radiological protection and control of the GDR have to be applied. As a „planned practice" uranium mining and milling is included in the area in which the Ordinance for Nuclear Safety and

Radiological Protection -VOAS - [3] is operative. The decommissioning of mining and milling facilities and sites is the final stage of such practice and therefore this regulation is also applied for the remediation that may be required in this process. Furthermore, the Ordinance for Radiological Protection at Waste Rock Piles and Tailings Ponds - HAO - [4] is still in force as per the provisions of the Unification Treaty [2]. This ordinance prescribes in the licenses the authority responsible for the radiological protection of any activities or works at piles and ponds which can cause radiation exposure to the public. In the process of decommissioning and remediation the basic components of radiological protection (justification and optimization) have to be applied for the remediation measures. Measures are justified, if the dose limit (in the context of remediation this limit is to be interpreted as a primary reference level) is exceeded and the disadvantages associated with the remediation measures are more than the achievable benefits. In the next step of the decision process all possible remediation options have to be evaluated with respect to the achievable reduction of the risks, both radiological (individual and collective dose) and non-radiological (conventional) risk. Economic aspects and other factors (public acceptance, plans for land use, the necessity for further institutional control etc.) have to be taken into account in the optimization process. In this way the optimum balance between the environmental and economic risk and benefits may be achieved.

The former abandoned sites of uranium mining and milling and the 'old' sites of mining and milling of ore and coal significantly mineralized with uranium are typical examples for an intervention situation. The existing long-term radiation exposure can be reduced only a posteriori. For such cases the Precautionary Radiological Protection Act - StrVG - [5] must be applied. This Act prescribes comprehensive investigation and evaluation of the radiological situation to assist general decisions on the necessity of remedial measures and their goals. On the basis of this Act the Federal Ministry of Environment, Nature Conservation (BMU) and Nuclear Safety instructed the Federal Office of Radiation Protection (BfS) to implement such investigations and evaluations for the old sites in the new Federal States of Germany. In 1991, the project „Registration, Investigation and Radiological Assessment of Mining Residues (Register of Radioactively Contaminated Sites)" was started to carry out this task. This project will be completed in 1997.

Besides the regulations mentioned above the National Commission on Radiological Protection recommended radiological protection principles concerning the safety, the use or release of materials, buildings, areas or dumps radioactively contaminated from uranium mining [6], the evaluation of indoor [7] and outdoor [8] radon concentration as well as the mining related radioactive contamination of water used for drinking purposes [9]. Applying these recommendations a number of problems concerning the use of radioactively contaminated areas (partly private properties) can be solved.

Furthermore the Federal Mining Act [10] and the Water Resources Act [11] must be observed in the process of decommissioning and remediation of mines, mills, waste rock piles and tailings ponds.

3. PROGRAMMES FOR THE REMEDIATION OF WISMUT SITES

The decommissioning and remediation programme of Wismut sites was initiated immediatly after the transfer of the company to 100 % ownership of the Federal Government in 1991. Numerous problems arising in the beginning were linked to the former secrecy of the Wismut company and to the lack of preparations for decommissioning and remediation. While the reduction of radiological and other risks was clearly an important consideration, socio-economic and political factors had a significant influence on the decision to take such rapid remedial action. There was the identified need to remove the distrust of the local population towards the SDAG Wismut and win the confidence of the public. On the other hand there was a need to mitigate the consequences of job losses and other economic effects arising from the termination of the uranium production which could off set to some extent by the economic activities associated with the decommissioning and remediation programme.

The sites, piles, ponds etc. in possession of Wismut are summarized in Table 1: Wismut GmbH Rehabilitation Units which indicates the areas covered by the sites under consideration. Altogether, the affected area for which remedial measures had to be considered was 34 km^2.

Immediately after the closure of the mining and milling operations for uranium production the activities were focussed on mitigating immediate risks to the public and on investigating the radioactive contamination of the sites and evaluation of their radiological impact. For these investigations the same methods that were developed by the BfS for the investigations of old sites (cf. section 4) were applied. The result of these investigations, the so-called Wismut Environmental Register is the basis for Wismut's remediation plans including several hundred individual decommissioning and remediation measures or projects.

The important long-term radiological and environmental risk comes from the tailings ponds and tailings management areas. The mill tailings (fine grained, water saturated and thixotrophic materials with the specific activity up to 10 Bq Ra-226 and other radionuclides of the uranium series of the same level without uranium) were deposited in large ponds near the former mill sites. A total of 150 million m^3 of tailings are deposited there containing about $2 \cdot 10^{15}$ Bq of Ra-226, about 15 000 t of uranium and large amounts of arsenic, pyrite and additionally large amounts of chemicals from milling. The very low geomechanical stability of the fine grained tailings is a specific problem to be solved since there is no reasonable alternative to the in-situ stabilization and encapsulation by gradually drying and solidifying the tailings and covering the surface. With the construction of the cover (waste rocks, clay materials and soil) the radon exhalation of the dried tailings is also reduced.

Another problem which needs attention generally in all sites is groundwater protection. On all mining sites, draining the mine workings has prevented significant groundwater contamination in the past. After the closure of the mine drainage systems groundwater will flow back to the mines and can be contaminated by coming in contact with the uranium bearing rock. Moreover the groundwater flow characteristic changed by mining activities as well as the contact of oxygen-rich waters with the waste rock materials used for mine backfilling resulting in the oxidation of pyrites and the formation of sulfuric acid can significantly influence the contamination of the groundwater.

Although the conceptual design of the mine decommissioning takes into account these problems and tries to minimize the groundwater contamination, the waters from the mines have to be treated over a certain period before they can be discharged into the rivers. Water treatment is also required for the process of tailings stabilization to reduce the radioactive and chemical contamination of free water and pore waters of the tailings ponds.

Tab. I: WISMUT GmbH Rehabilitation Units

Sites	Aue	Koenigstein	Ronneburg	Seelingstaedt	*Total*
Plant area (ha)[1]	494	123	1538	1281	*3480*
Shafts					
– number	9	7	15	0	*31*
Waste rock piles					
– number	42	3	14[2)]	5	*64*
– surface covered (ha)	345	38	460	237	*1080*
– volume (Mio m^3)	47	5	125	51	*228*
Tailings basins/management areas					
– number	1	3	2	4	*10*
– surface (ha)	5	2	8	670	*685*
– volume (Mio m^3)	0.25	0.22	0.22	153	*153.7*
Mine workings					
– extension (km^2)	55	10	73	0	*138*
– length (km)	32	74	150	0	*256*
Open pit mine					
– number			1		*1*
– area (ha)			160		*160*
– volume (Mio m^3)			69 (void)		*69*

1) including WISMUT GmbH head-office

2) not placed in open pit mine

The most important measures of the complex decommissioning and remediation process at the rehabilitation units can be described as follows:

A u e

The uranium deposit of Niederschlema/ Alberoda near Aue was mined up to a depth of 1 800 meters. The flooding of the mine was initiated in 1990. It will take more than 8 years to inundate the underground voids of about 36 million m^3. The current flooding level is at a depth of about 600 meters.

The expected contaminant concentrations and total quantities of WISMUT effluents usually do not allow a direct discharge into receiving streams and therefore, water treatment will be inevitable to meet the goals derived from the Water Resources Act and from the VOAS. The choice of the treatment procedure will take into account different types of effluents in question (overflowing flood water, free water from the tailings pond, waste pile seepage). In particular, the prejudging of the quality and quantity of flood waters can only be based on a rough estimate and therefore, the most frequent problem in this context is to design water treatment plants sufficiently flexible to accommodate large variations of throughput and water quality.

A water treatment plant is being designed to remove uranium and arsenic from the flood water upon reaching the surface at the end of the mine flooding and the mine water will then be discharged into the Zwickauer Mulde river.

At the subunit Pöhla, the flooding of the mine workings was terminated already in September 1995. Mine waters flowing out at the surface are purified in a water treatment plant. Operational procedures are being optimized.

Concerning the remediation of waste piles the preferred option is in situ remediation for which an application for permit has been submitted.

Koenigstein

At the former Koenigstein mine, besides conventional mining, underground in situ leaching of uranium has been applied. The leaching has chemically affected more than 55 million m^3 of rock and aquifer; about 1.8 million m^3 of sulphuric acid solution containing about 1 g/ℓ of SO_4 and more than 30 mg/ℓ of uranium is either circulating or trapped in the pore volume of the rock.

For the time being, investigations are conducted jointly with the licensing agencies of Saxony to define preventive measures to be taken in order to avoid unacceptable contamination of ground water with uranium, radium, sulphate, iron, and heavy metals contained in waters that will flow out of the mine once the flooding is under way. In line with stringent ground water regulations a concept has been developed that provides for the flooding of mine voids and pore volumes in stages and simultaneous operation of a water treatment plant. The possibility of additional chemical immobilization of contaminants in underground rock has also been investigated. In a small sector of the underground workings, a flooding experiment which has been in progress since 1993 provides significant input parameters for flooding simulations and for the development and calibration of a contaminant transport model.

The flooding of the Koenigstein mine will be conducted in a way that allows control and protection, at any moment, the quality of the groundwater flowing in the aquifer of the immediate vicinity of the mine.

Preparations are being made for the in situ remediation of the waste rock piles and the small tailings ponds at the site.

Ronneburg

In the Ronneburg mining district major mine rehabilitation goals include the safe decommissioning of mine workings and the restoration of pre-mining hydrological conditions without environmental impact.

Results obtained from the modelling of flooding processes in the Ronneburg area suggest that the restoration of the water table will be completed after in about 13 years. After consultations with the concerned approving authorities, the following preventive measures are considered for implementation, prior to initiating the flooding process:

- backfilling hydraulically sensitive mine workings,
- shaft sealing,
- converting some tunnels into underground drains for the backfilled open pit mine,
- construction of hydraulic barriers (dams) in order to isolate parts of the mine workings and to minimize mixing of mine waters of different qualities
- in situ treatment of acid mine drainage
- controlled collection of all contaminated waters in order to inhibit migration of contaminants into aquifers.

At the Ronneburg site the rehabilitation of surface structures and facilities is closely linked to mine flooding. Due to the interdependence of rehabilitation measures and interaction of anticipated hydrogeological and hydrogeochemical processes, an optimum solution requires a careful sequencing of waste pile rehabilitation, filling the open pit, and mine flooding. The concept must also include the disposal of materials from the demolition of buildings and facilities, the decontamination of plant areas, and landscaping of the rehabilitated mine site.

Cost-benefit analyses and multi-attribute analyses were applied to determine the most appropriate rehabilitation options for the 14 waste rock piles in the Ronneburg region. On that basis, the choice for individual piles was either relocation into the open pit or rehabilitation in situ. Regulatory approval granted in October 1993 allowed relocation of the Gessenhalde heap leach pile into the open pit, an operation that yielded valuable experience in rehabilitation technologies. In the current excavation and relocation of the Absetzerhalde pile the sequences are controlled by the acid generating potential of the material using optimization principles. Waste pile material in which minerals (e.g. pyrite) with acid generating potential (AP) are dominant over the proportion of minerals (e.g. calcite) with neutralizing potential (NP); i.e. NP<AP, are placed at the bottom of the open pit below the anticipated water table when the flooding is complete. In that area the introduction of oxygen is largely inhibited which cuts off any pyrite oxidation. Waste materials having predominantly neutralizing potential, i.e. NP>AP, are fit for placement above the water table. Once the open pit is filled, the rehabilitated former mining area will be landscaped to fit into the natural surroundings and meet with public approval.

Optimization factors with regard to waste rock piles to be left in place and covered include radon and contaminant control, long-term stability of the cover system, and their ecological integration into the surrounding landscape. Field testing of a number of different cover systems has been in progress for a couple of years.

Unconventional approaches to the treatment of heap seepage at all Wismut sites are being considered. Heap seepage occurs in relatively small (but not negligible) volumes over extended periods. For that reason, procedures using chemical technologies are not justifiable in view of cost. On the other hand, seepage is partly not fully fit for straight discharge into the receiving streams. Long-term treatment of heap seepage would therefore require maintenance-free and self-regulating treatment systems. With this aim in view, the efficiency and applicability of natural biological systems such as wetlands are currently investigated which, if suitable, would supplant treatment facilities using chemical technologies once the contamination peak is whittled down to low contamination levels in the feed water.

Seelingstaedt

A technical challenge of a particular kind is the rehabilitation of the tailings management areas (TMA) of the former mills at Seelingstaedt and Crossen involving about 150 million t of fine-grained uranium mill tailings which are up to 70 m thick and cover a total surface area of approximately 600 ha. The major part of seepage from the tailings dams is currently collected and returned to the tailings basins in order to inhibit contamination spread to aquifers in the surroundings of the TMAs.

In the strategic approach to water treatment and disposal of residues the time duration of operation of these facilities is a very important cost factor. However, it is not only the time of operation that determines the overhead cost but also the total volume of residues. This has to be considered in the long-term planning of rehabilitation sequences and disposal facilities will have to be provided at the sites for residues from water treatment in the future.

Using risk analyses and considering in addition socio-economic aspects, the approach subsequently considered as optimum rehabilitation option for those sites are:

- in situ rehabilitation including removal of water cover
- gradual covering of exposed beaches to protect them against erosion and wind-blown dust
- partial dewatering of the sludges (different wells and surcharge, respectively, in combination with geotextile materials and drains), and
- long-term inhibition of seepage as a function of the cover layer.

Finally, the embankments and basins will be graded and landscaped, and the tailings will be covered by a system of cover layers especially designed to reduce precipitation infiltration and radon exhalation. Model calculations reveal that conventional geotechnical approaches are unfit to describe settlement sequences in the tailings basin during the dewatering period which can only be assessed using a finite strain model. Slurry dewatering experiments using surcharge and textile drains or dewatering wells, respectively, have demonstrated that these technologies will considerably accelerate the speed of tailings consolidation.

The open pit mine at waste rock piles at other Wismut sites as well as the existing tailings management areas of the former mills are locations for the intermediate storage and disposal of radioactively and/or chemically contaminated soils, slurries, construction debris, scrap metals, and water treatment residues which are produced by the rehabilitation of sites. These materials are designed to be put into the tailings ponds.

4. PROJECTS FOR THE REMEDIATION OF OLD SITES

4.1 The Federal Project for the Investigation of Old Sites

According to its legal obligations the BfS has developed the investigation programmes and methods. The investigations are carried out by the BfS itself or by contractors on its behalf. In view of the large number and distribution of residues and sites under consideration, a stepwise procedure of investigation has been developed by which non-relevant sites can be excluded as early as possible and identify those which are fit for consideration as sources of serious environmental contamination and radiation exposure to the public.

In the first stage of investigations 34 areas of former mining activities were defined as "suspected areas" using information on regions where uranium ores and other ores with above-average concentrations of uranium were mined as well as regions where the terrestrial gamma radiation is higher in comparison with the average level. The total area under suspense is about 1 500 km². For these areas, all existing data relevant to the radiological evaluation of mining residues and sites were compiled. In this way about 8 000 mining relics of different kinds have been identified and registered in the data bank, most of them being waste rock piles. The total area covered by the relics amounts to about 73 km² and the area with above-average gamma radiation is about 170 km². Further investigations concentrated on these areas ("investigation areas").

A good amount of the registered data and information were obsolete and did not permit a proper radiological assessment. Additional efforts to verify and complete the registered data and information were therefore required. By field inspection the information on the state of the structures, facilities, sites etc. were updated and the data and information needed for the radiological assessment were checked, revised and completed, as required. Screening measurements were included in the verification procedure. On all sites and also the land in their surroundings not affected by mining works local gamma dose rate measurements were carried out. Soil sampling and measurements of radioactivity were resorted to additionally if contamination of soils by non-gamma emitting radionuclides were expected. Following the verification procedure, the first radiological evaluation was made on the basis of the revised data, using simple criteria derived from recommendations of the SSK for the unrestricted or restricted use of areas or dumps contaminated by uranium mining (cf. section 2). If the established criteria (Fig. 1) were not exceeded the relics were classified as "non-relevant", the others as "possibly relevant". Within the scope of the Federal Project only the last mentioned "possibly relevant" relics and sites were investigated in greater detail and were subjected to specifically evolved measuring programmes. The measuring programmes provide comprehensive information about dimensions of contaminated areas, thickness of contaminated layers, concentrations and inventory of radioactivity, radioactivity released and spread (e.g. radioactivity in seepage waters), relevant pathways and radiation exposure to the public. Land areas adjacent to the relics were included in the investigations.

Till now such programmes have been carried out for the following sites which are considered most important and relevant:

- Dittrichshuette Uranium Mining Site (DUMS):
  Uranium mining site from the early 50's, abandoned in 1954. The dumped mining wastes were graded and covered with mineral soil and subsequently used for agricultural and forest purposes.

- Aue Uranium Mill Site (AUMS):
  Traditional site for ore processing, later on used for uranium milling. When the milling was abandoned, site and plants were used for industrial purposes and for ore processing again.

- Freital Uranium Mining/Milling and Hard Coal Mining Site (FUCMS):
  Traditional site for the mining of hard coal mineralized by uranium, later on coal and wastes of coal mining and coal were processed for uranium production. When the milling was abandoned, site and plants were used for industrial purposes (steel works). The contamination of private properties by carelessly dumped coal ash/slag and surface near coal seams are special features of this site.

- Gottesberg Uranium Mining and Milling Site (GUMS):
  Traditional site for the mining of tin, silver, bismuth and uranium, later on the site was used for uranium milling. In addition heavy spar was mined. Uranium production was abandoned in the 50's and the buildings of the uranium mill were demolished. The tailings ponds and the waste rock dumps were insufficiently covered, parts of the area were used for recreation purposes.

- Johanngeorgenstadt Uranium Mining and Milling Site (JOMS):
  Traditional site for silver, cobalt, bismuth, tin, pyrite, sulphur and iron mining since the 15th century. Later on (in the 40's and 50's of this century) uranium was mined and milled. After the abandonment of mines and mills at the end of the 50's the buildings used for uranium production were demolished, the tailings ponds were used for rubbish dumping. Up to now only few waste rock piles have been graded and covered.

- Hettstedt Copper Ore Processing Site (HOPS):
  Traditional site for mining and smelting of copper ore mineralized by uranium. The mining and smelting of copper ore were abandoned. The smelting process and deposited wastes have caused contamination of soils in the surroundings of smelteries by dusts containing Pb-210 and Po-210 and spread by wind.

The kind and scope of measurements are established specifically for each site (cf. Tab. II) taking into account results and experience from pilot studies carried out before 1992 at typical sites (abandoned uranium mining and milling site and a site of copper smeltery).
For all other investigation areas the programmes are going on and shall be finished in 1997.

Estimating the contribution to the outdoor radon level from the exhalation of mining residues is a basic problem. That is why investigations were carried out within the scope of the Federal Project. Radon measurements were carried out at 480 points (on or adjacent to mining sites and affected grounds as well as at greater distance from

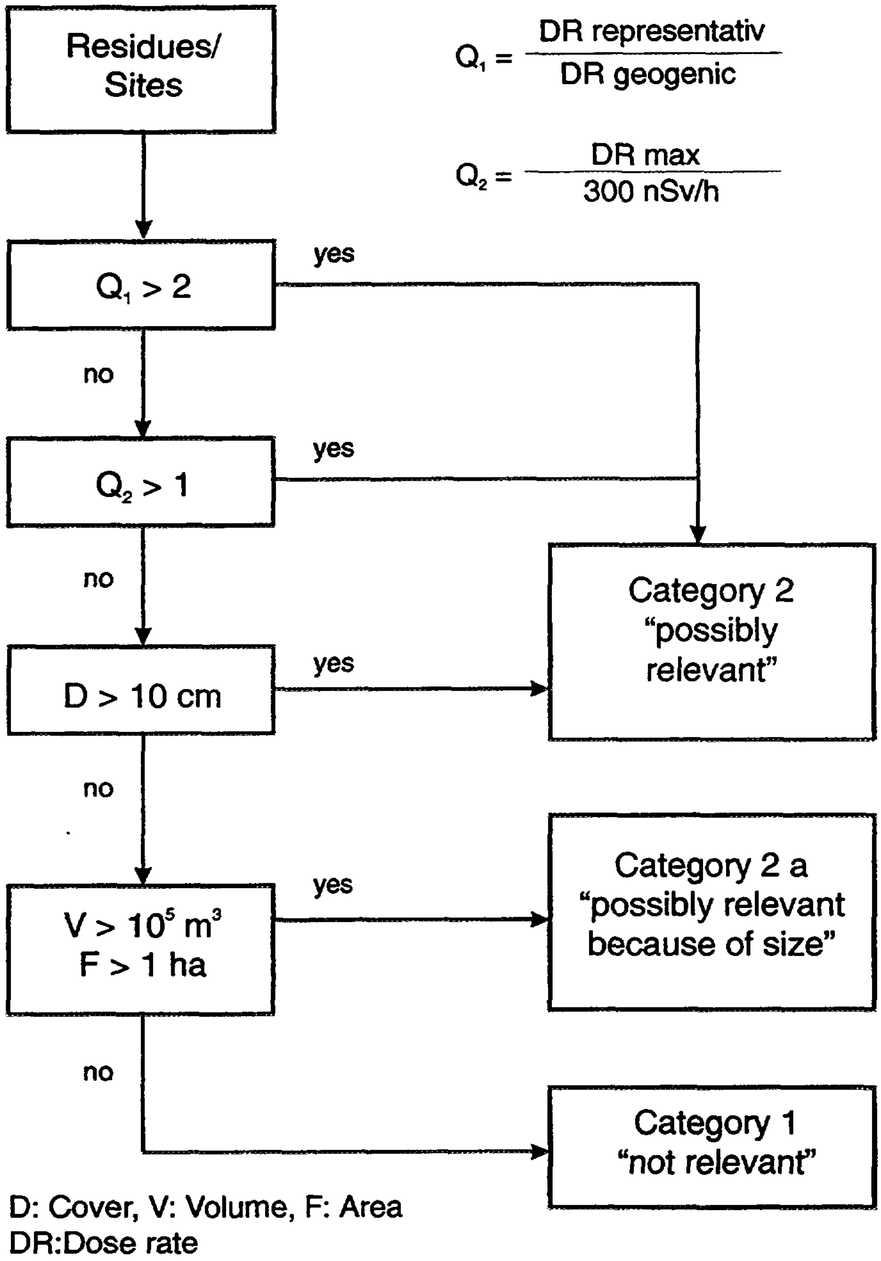

Figure 1: Classification after Verification

them) using diffusion chambers equipped with solid state nuclear track detectors. The period of exposure was about 6 months (spring/summer and autumn/winter). Generic criteria (Fig. 2) have been developed for radiological evaluation of the investigation results for this part of the project, too. They are based on a primary reference level of the effective dose (1 mSv/a) from mining relics in addition to that of the regional background and based on other recommendations by the National Commission for the restricted and unrestricted use of radioactively contaminated sites (cf. Section 2).

The results of the investigations led to the conclusion that old mining activities and their relics did not cause wide-spread radioactive contamination of the environment. Usually a significant radioactive contamination has to be assigned only to limited land

Tab. II: Scope of Investigations

Investigation	DUMS	AUMS	FUCMS	GUMS	JUMS	HOPS
Investigated area (km²)	2,4	0,78	30	4,6	18	35
Number of objects	91	11	160	91	403	347
Number of gamma-dose rate measurements	7450	5900	45500	15700	35000	5525
Number of ram drills/rall drill samples	90/311	132/346	840/1200	530/900	600/1100	24/165
Measurement of the soil air radon concentration	-	-	180	-	60	-
Sampling and radionuclide measurements of						
I. soil	43	54	340	120	150	2950
II. water (seepage waters included)	50	35	80	80	45	159
III. sediment	21	12	30	40	30	32
IV. plants	20	24	90	25	110	119
V. building material	-	40	50	-	20	-
VI. dust	-	-	-	-	-	15
Samples from the sewerage system	-	10	10	-	-	-
Assessment of the ground-water hydraulics	-	yes	yes	yes	yes	-
Number of points for outdoor radon measurements	15	36	40	8	58	46

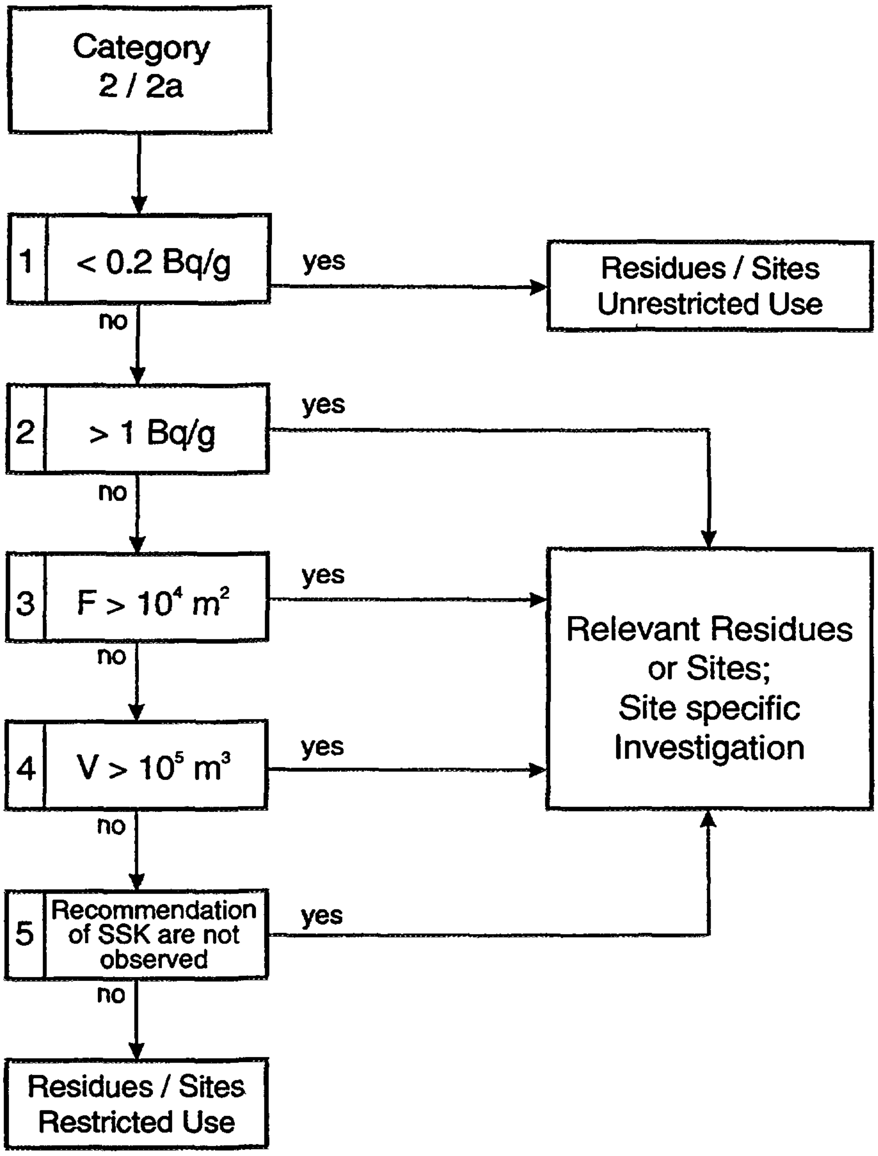

Fig. 2: Classification after Measurement Programmes

areas where waste material of mining and milling were dumped or materials were not removed in the process of former decommissioning. The highest radioactive contaminations were found at sites where uranium ores were milled and copper ores were smelted and where the waste from these processes (mill tailings, sludges and slags from copper ore smelting) were dumped, in ponds or piles. Although many tailings ponds and other dumps were stabilized and covered in the past they have to be considered as sources of hazard. The reason for this is that only the standards of mining safety have been observed in the past and the conditions are not found to be in accordance with the present standards for radiological protection and environmental safety.

Only in limited areas around sites of old copper smelteries concentrations of Pb-210 and Po-210 above the normal natural level have been found, but they do not create a serious radiation exposure problem.

The initial radiological assessment of relics and sites resulted in about 60 % of them are „non-relevant". Within the scope of the current Federal project, only the remaining relics and sites classified as „possibly relevant" were investigated in greater detail. The results of such investigations available up to now make clear that remedial measures are necessary for 10 - 15 % of the relics and sites within the „suspected areas" and restrictions on use for reasons of radiological protection should be observed for 20 to 25 % of the sites and relics. Outside these areas the number of both groups of relevant relics and sites is much smaller.

As mentioned earlier there are no regulations in Germany applicable to chronic radiation exposure from old or past practices. The above mentioned StrVG (cf. section 2) prescribes only the investigations of the environmental radioactivity to identify situations requiring intervention measures. But this law authorizes the BMU to enact regulations as a legal basis for remedial actions. The problems associated with regulations concerning sites of old or past mining activities (criteria for decision making, responsibilities, financing etc.) are currently under discussion. Nevertheless on some old sites remedial measures are already under way. That is because the owners intend to use such sites for industrial or other purposes. On the basis of the HAO (cf. section 2) a licence from the authority responsible for radiological protection is required if the specific activity of the materials on the site of interest exceeds the level of 0.2 Bq/g Ra-226. In most cases remedial measures have to be taken before the owner gets the licence and can use the site. Examples are given in the following section.

4.2 Remedial measures on old sites

Saxony:

In Saxony not only the lack of regulations but also unclarified distribution of property and responsibility is obstructing systematic remediation of old sites. Nevertheless in Saxony preparations are under way in a few old sites formerly used for uranium milling, partly individual projects are carried out.

Dresden-Coschütz:
The tailings management area is cleaned up (the materials are removed). In early 1996 the demolition of the buildings of the former mill began. The intention is to restore the site and to make it usable as an industrial area without any restrictions. Investigations are carried out for two tailings ponds belonging to this mill site. Planning for their remediation will be completed by the end of 1996.

Lengenfeld:
Remedial measures are planned. The intention is to remedy the tailings pond in situ. In the past waste (sand) from spar production (spar was mined and processed on this site after the uranium milling was abandoned) was dumped on the tailings and can be useful as a first cover. Before the final covering the residues of radioactively contaminated materials from the mill land area and tailings management area will be removed and deposited on the tailings pond.

Johanngeorgenstadt:

Waste rock piles and two tailings ponds are under consideration. In the past some waste rock dumps were remedied. They have been graded, covered, with „non-radioactive“ gravel, sand or soil and have been reafforested. One of the tailings ponds is used for rubbish dumping. This cannot be continued any further for legal reasons and for reasons of radiological protection as well. The other pond is provisionally covered. The design for the final remediation of the ponds is under way. The option preferred is in situ remediation. Measures to balance the groundwater flowing in and flowing off the ponds are already carried out.

Schlema:
Remedial measures have been carried out for a former tailings management area since the owner (Schlema municipality) intended to use this area as a car park after remediation. This remediation project was planned and carried out by the municipality, approved and supervised by Saxon authorities. The tailings (dry materials) were covered („sealed“) to prevent external exposure, erosion and the spreading of radioactively contaminated materials as well as the infiltration of water and the leaching of contaminants. The exhalation of radon is also reduced by that.

Saxony-Anhalt:

At present in the Mansfeld region (Saxony-Anhalt) remedial measures are planned for sites of the abandoned copper production (smelter sites), above all for the dumps of sludges from waste gases cleaning („Theisenschlämme“). This waste not only contains high concentrations of heavy metals and other hazardous materials but also high concentrations of radionuclides (Pb-210, Po-210 up to 20 Bq/g). First measures have been initiated, such as removing the dumped materials from separate sites and putting them together in one deposit. There the materials are provisionally covered to prevent wind erosion and spreading while the final confinement will be designed.

In addition remedial measures are under way for some slag/ash heaps which are inside residential areas and are of particular public interest.

The representative gamma dose rate level for these piles is above 1000 nSv/h without exception, the maximum figure being about 7000 nSv/h. In the last mentioned case immediatly after the observation of this dose rate level the pile was fenced off for the time being to prevent the radiation exposure of children using this heap as a playground and to gain time for the decision on the best solution for remediation.

In the other cases depending on the intended future use the heaps were graded and covered with gravel, sand, soil or asphalt surface to reduce gamma radiation. Because of the specific properties of copper slag, measures to reduce radon exhalation and leaching are not required.

5. CONCLUSIONS AND OUTLOOK

The remediation of Wismut sites will still take about 10 years. The estimation for the overall project of Wismut rehabilitation currently amounts to roughly DM 13 billion ($ 8 billion). This level of expenditure is a part of Wismut's business plan and is approved by the

German parliament. The size of the annual budget for remediation depends on certain factors, above all on the remediation projects approved by the authorities and on the changes in costs. In the beginning the individual remediation projects have concentrated on the elimination of hazard sources and on problems of mining safety, underground remediation including clearing and flooding of mine workings as well as on conceptional work, planning and pilot projects.

Underground remediation will be completed in the years to come, planning works and the design of several hundreds of individual projects for surface remediation are in progress, they have partly been approved by the authorities and main emphasis of the Wismut activities is shifted more towards surface remedial actions. The biggest project in the next few years will be the backfilling of the open pit mine at Ronneburg associated with the relocation of the Absetzerhalde and some other piles of this site.

Comprehensive investigations and evaluations of the mining areas in Saxony, Thuringia and Saxony-Anhalt will be terminated in 1997. The results of the investigations so far have given valuable information on the extent of radioactive contamination. This can be used for decisions on the remediation and restrictions on the further use of sites and for regional planning, too.

Remedial actions have to be considered also for numerous relics and sites outside the responsibility of Wismut. Such relics and sites are not limited to the new Federal States of Germany only. Hence a uniform legal basis has to be established for remedial actions on all sites that must be considered as sources of chronic radiation exposure. The approaches for the important elements of the decision process - justification and optimization - have to be included in the regulations. Intensive discussions are in progress to prepare such regulations. They have to be finalized as soon as possible.

That is why in 1996 the European Safety Standards have been passed and within a few years these Standards have to be integrated into the national system of radiological protection and control.

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ENVIRONMENTAL RESTORATION PLANS AND ACTIVITIES IN HUNGARY: 1995-1996 PROGRESS REPORT

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Abstract

After more than 35 years of operation, the uranium mining and milling activities in Hungary will be finally shut down by the end of 1997. The surveying programme on the affected area was started in 1991, and the first phase of the remediation project was launched in 1992-93. In the last few years a new concept and strategy has been prepared for the next phase of restoration tasks. The restoration will mainly follow the principle of application of step by step approach to the solution of each task. Due to lack of approved national regulations, authorization in the form of letters are obtained on specific issues of remedial action on a case by case basis. The radiological requirements for both reuse and restoration of the affected areas call for setting up radiation limits. The radiation monitoring and radiological characterization of the affected areas both during operation as well as after restoration are being systematically performed. The monitoring of water contamination is given high priority, because the uranium mining and milling sites have a lot of surface water and aquifers. So far, 3 mines have been shut down while 2 mines are still operating. After final close down the mines will be flooded, and the monitoring system will be expanded and upgraded. Major portion of waste rock piles have been restored, and a number of experiments and investigations have been performed for decreasing the contamination of heap leaching and for selection of cover layers of tailings ponds. As a prelude to decommissioning of milling facility preliminary survey of items and equipment for reuse or disposal has been started.

1. NATIONAL CONDITIONS REQUIRING ENVIRONMENTAL RESTORATION

In Hungary, owing to the economic situation, after more than 35 years of operation the mining and milling activities will terminate by the end of 1997, according to a governmental decree. The preparation for closedown and remediation works has been in progress since 1991. To start with a general survey and preliminary investigation of affected areas were carried out, based on which a remediation project has been launched in 1992-93. Since there is no system of funding by the operator for the fulfilment of restoration tasks, the national government has taken the responsibility for meeting the restoration costs. With the changes in the political situation since the 90's and revelation of information on uranium mining and milling activities there has been increasing public awareness on environmental problems and demands for carrying out more comprehensive and thorough restoration are being made as against an oversimplified remedial action by way of abandoning the operations followed by simple closedown [1, 2, 3, 4, 5, 6].

The first task was to work out by suitable practical modes of surveying the depth and extent of affected mining and milling areas to the extent possible. The survey included establishing a database which was subjected to revisions as new results on radiation levels of the affected surrounding area, and measurements of radioactivity on residues became available. The intention was to prepare reliable plans and strategy based on well-conducted surveys. In the last few years, in view of changes of circumstances and for the sake of achieving a good solution to restoration problems a more detailed version of the strategy has been prepared. This includes task based step by step approach taking into account the local conditions of the area to the maximum extent possible. The main elements of this new approach are:

- The scope and direction of each remediation task should be defined, which in effect means clear formulation of the start and end points;

- The regulations and the stipulations by competent authorities are to be complied with to the highest degree, and in case of ambiguities international practices and recommendations are to be followed with modifications as necessary and with the approval of authorities in each case;

- The creation of long term database and continuous upgradation of the same is one of the crucial points. Before starting any task the relevant data related to the actual remediation and decommissioning is updated and wherever this is not possible action is taken based on the assessment of data or by resorting to modelling. The main parameters and features of the area being restored from the point of view of long term safety are geology and hydrology. Additional investigations through research or extrapolation of existing data may be necessary in case of lack of information on parameters of interest. The environmental impact (contamination of air, soil, water) is to be assessed in such a way that the series of tasks necessary for achieving the solution should be clear;

- Planning should include alternative versions for remediation tasks to facilitate selection of the best solution at the decision making stage. These versions are to be practicable and financially viable so that they are technically feasible with available expertise and finance for the fulfilment of the remediation task. The milestones and the steps involved in the process of remediation are to be indicated, and after reaching each milestone it should be reviewed so that modifications required if any could be made;

- A well-established institutional control and monitoring system associated with restoration works is important to get immediate feedback on effectiveness against spreading of contamination not only after restoration, but also during the execution of restoration works due to any malfunctioning of engineered measures;

- Public awareness and information to the responsible media during the whole remediation process are essential factors to gain public confidence and avoid problems due to misinformation/misunderstanding;

- For successful accomplishment of the project persons responsible for each task should be identified with time schedules for each task as a prudent management practice;

- It is very important that the availability of finance, technical capability and the acceptance by the society (public, authority) should be harmonized at every step to avoid adverse effects of changes during the execution of remediation work.

2. LEGISLATION, REGULATIONS, POLICIES

Till now, in Hungary, there are no specific regulations related to the uranium mining and milling activities nor the remediation aspects. The Mining Act and Environmental Protection Act and their implementation orders deals with these issues, but only in an implicit way. Perhaps, the new Atomic Energy Act and its implementation orders will address regulatory aspects in the sphere of remediation works. In view of lack of statutory national regulations to deal with restoration, two alternatives are open for consideration pending formulation of regulations. One, after negotiations between the operators and the authorities, requirements on specific aspects may be stipulated by the authorities as official orders for compliance. Alternatively, international recommendations and practices may be adopted by both the operator and the authority which form the basis for regulation. For the radiation protection aspects of remediation and decommissioning works of mining and milling areas and facilities, the following requirements are to be complied with:

General requirements, statements:

Usage of restored area without any restriction is possible only if the radiation levels are around background and the cover layers (protection barriers) are stable and not likely to change.

Restricted reuse of area or facilities is possible only if the maximum radiation levels do not exceed 2-3 times the background, and in so doing

- parking, pasture and forest area can be established on restored waste rock piles, tailings ponds and other industrial territory,
- decontaminated facilities (buildings) can be used for storehouse or other industrial activities.

In the case of restricted reuse, the additional radiation exposure burden to workers may be 1 mSv maximum, so that the cumulative dose from different pathways (external and internal exposure, radon exhalation) should be less than 1 mSv, a small portion of 1 mSv being considered as safety reserve for unexpected future exposures.

During the restoration planning the ALARA principle should be used.

The background levels should be set up as references from measurements being carried out on or in the vicinity of the affected area.

Detailed formulation of radiological requirements:

As per the restoration plan, the background values were established for two different zones of the affected area in view of significant differences in the measurements as indicated in Table I.

TABLE I. BASIC BACKGROUND LEVELS FOR RESTORATION PLANNING

Target of measurements	South of the main road 6	North of the main road 6
Activity conc. of Rn in open air	8 Bq/m^3	12 Bq/m^3
Activity conc. of Rn in buildings	100 Bq/m^3	150 Bq/m^3
Gamma dose rate in air	180 nGy/h	250 nGy/h
Activity conc. of soil	125 Bq/kg	180 Bq/kg

For the restoration of residues (tailings ponds, waste rock piles, heaps for leaching) the values to be taken into account are shown in Table II. The measurements should be carried out and averaged over an area of 100 m^2.

TABLE II. RADIATION LEVELS FOR RESTORED PLACES

Measurements	Values
Rn flux	0.74 $Bq/cm^2/s$
Activity conc. of Rn	Bkg(1) +20 Bq/m^3
Gamma dose rate	Bkg + 200 nGy/h
Activity conc. of soil	
in upper 15cm	Bkg + 180 Bq/kg
in lower than 15cm	Bkg + 550Bq/kg

(1): Bkg = Background

In the case of contamination occurring in an industrial area the radiation levels are to be brought back to the background values and in case of uncertainties the levels should be agreed with the authorities.

In the case of reuse of facilities the prescribed radiological values regarding inside and outside of buildings as per Table III

TABLE III. RADIOLOGICAL VALUES OF REUSING OF FACILITIES

Measurements	Values	
	inside	outside
Activity conc. of Rn	Bkg + 30 Bq/m^3	Bkg + 30 Bq/m^3
Gamma dose rate	Bkg + 200 nGy/h	Bkg + 250 nGy/h
Fixed alpha contamination	0.5 Bq/cm^2	-
Rn flux	-	0.74 $Bq/cm^2/s$
Activity conc. of soil	-	Bkg + 180 Bq/kg (< 15cm) Bkg + 550 Bq/kg (> 15cm)

For the classification of radioactive waste arising from remediation or decommissioning works the limits and stipulations for handling are given in Table IV.

TABLE IV. CLASSIFICATION OF CONTAMINATED MATERIALS

Materials	Limits	Remarks
Fixed surface contamination		
on metals	< 0.5 Bq/cm^2	for metallurgy
	> 0.5 Bq/cm^2	disposal of in ponds
Mixed waste consists of		
debris, soil, rubber, plastic,...	< 0.2 Bq/g	ordinary waste
	> 0.2 Bq/g	disposal of in ponds

The discharge limits for industrial water to the environment are 2 mg/l of natural U and 1 Bq/l of Ra-226, and the canal Pecsi is the collector of surface water arising from the affected area.

3. RADIOLOGICAL CHARACTERIZATION

The radiation monitoring and control system for both operational and restored areas is being systematically applied by Mecsek Ore Mining Company (MOMC). Major emphasis is put on the monitoring of water contamination, because the water reservoir is very close to the affected area. and there are a lot of surface water in this territory (Fig. 1). In the past years on the mining and milling area there has been no detectable deterioration of the main parameters related to the radiation protection. However, continuous development of measuring system and up-to-date information about the transport of possible contamination are very important for proper planning. Surveying of water contamination on the whole industrial territory is an important task for restoration. The typical ranges of the water contamination are shown in Table V.

TABLE V. WATER CONTAMINATION OF MINING AND MILLING AREA

Component	Unit	Values at			
		mines	piles	heaps	ponds
Uranium	mg/l	0.7 - 0.8	3 - 12	3 - 5	0.01 - 0.03
Ra-226	Bq/l	0.2 - 0.6	0.02 - 0.1	1. - 1.5	0.1 - 2.0
Na	g/l	0.02 -0.2	0.1 - 0.4	3. - 4.	0.4 - 0.6
Mn	mg/l	-	-	-	0.1-200.

4. ACTIVE PROJECTS UNDERWAY

4.1 Mine closing

In the MOMC, two mines (mine 1 and mine 2) were closed down in 1971 and 1988, respectively. In the middle of 1995 the closing of mine 3 was also completed [7, 8, 9].

The closing procedure was approved by the competent authorities, and the task was performed complying with the stipulated requirements. All polluting sources such as oil, contaminated soil, chemical agents were removed first from the galleries (workings) and tunnels, and all openings leading to the surface were filled.

The alpha contamination level of the equipment saved from mine 3 was 0.05 Bq/cm^2 and only above this value decontamination is needed.

The abandoned galleries, where uranium ores could be found, were tight closed in order to immediately block radon emanation to the surface through the shaft and later the uranium leach liquid.

Because this area has a complicated hydrology the plan of the close-out of mine 3 will involve controlled flooding. At present, the mines 4 and 5 are still operating, and hence mine 3 (together with other mines) will be flooded only after the closing of these mines. According to hydrology calculations, the cavity of the mines will be filled full with water only in 30 - 40 years after which, the water will come out of the mines on to the surface with flowrates of a few hundred m^3 / day, and the uranium content in the mining water overflow will be 1 - 2 mg/l.

At present, the water from all mines is pumped (~ 5000 m^3/day) and a part of this is used for milling operation with about 3000 m^3/day discharged to the nearby streams after subjecting to a

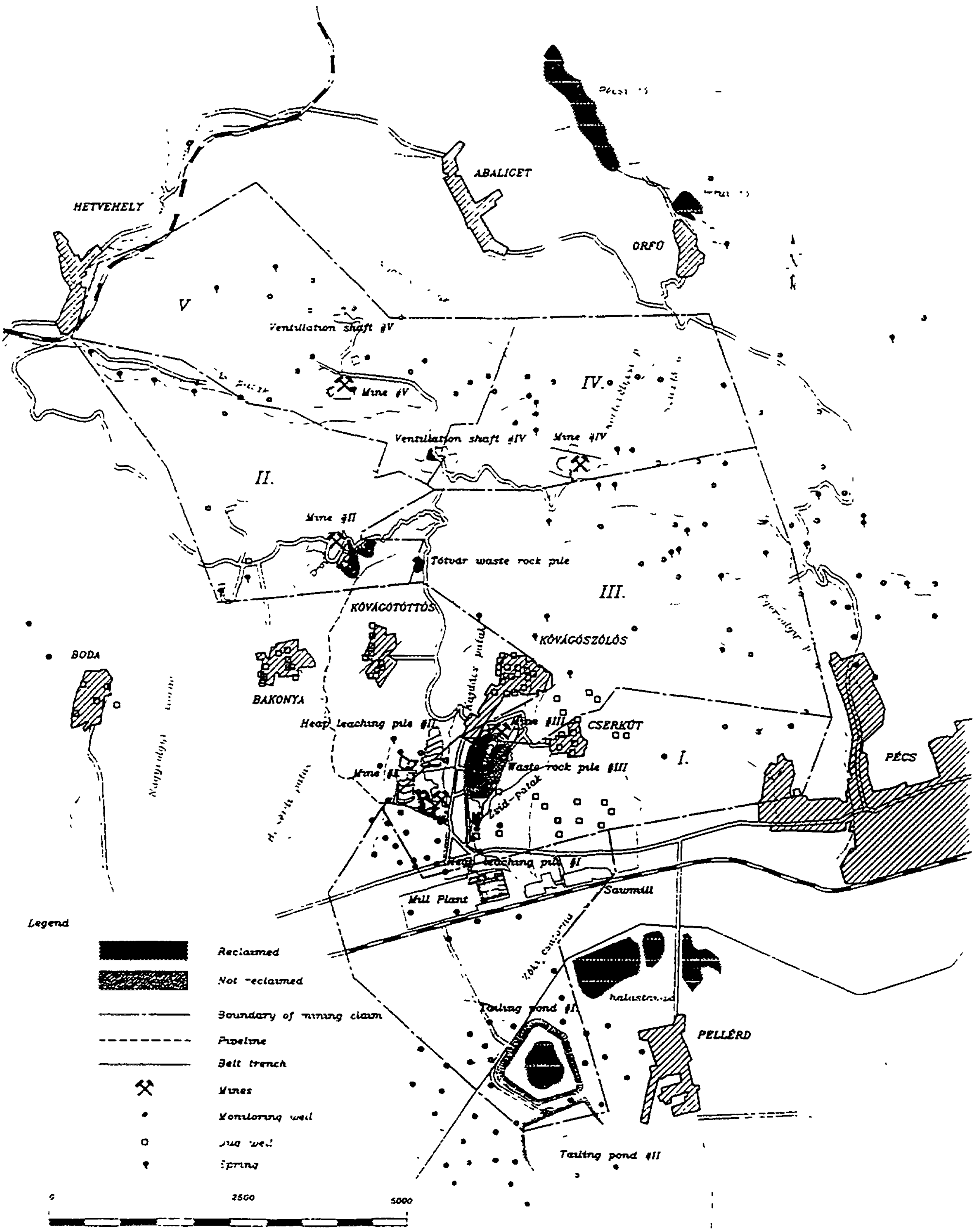

Figure 1. Map of groundwater level and quality monitoring points of hydrogeological monitoring system

cleaning process. The average uranium content of mining water is 3 - 6 mg/l and the activity concentration for Ra-226 is 0.5 - 0.6 Bq/l. Filtered water has less than 1 mg/l of uranium and less than 0.1 Bq/l of Ra-226 activity level.

Owing to the shut-down of ventilation system of mine 3, the emission of radioactivity (radon gas, uranium dust) comes to an end , which otherwise would have had the following annual environmental impact:

Radon:	3.10^{13} Bq/y
U-dust:	9.10^{9} Bq/y
Ra-226:	7.10^{8} Bq/y

4.2 Monitoring system for closing mine area

The authorities have stipulated that after closing each mine a monitoring system has to be set-up in order to control the long term impact of closing on the environment and population.

The monitoring system, some parts of which have functioned in the earlier phase, consists of the following subsystems:

- hydrology monitoring
- radon monitoring
- geodynamic monitoring
- environment data bank.

4.3 Restoration of waste rock piles

For the remediation of waste rock piles creation of new slope (with smaller degree) and construction of new water collection around piles have been carried out to reduce erosion. Because the former slope of piles in some places (above 7^o - 10^o) is somewhat high, some modification has become necessary. At the same time, the monitoring measurements show a somewhat elevated uranium content in the water collector system, owing to the larger infiltration of rainwater, because the cover layers have not been suitably compacted as yet. As a temporary solution a closed water collection has been introduced for these piles, and this water is discharged after going through a cleaning process. Otherwise, the revegetation on piles has been continued, and the systematic radiation monitoring (dose rate, radon flux, ..) is also performed. For the enhanced restoration of pile 3 a new plan has been worked out owing to the changes in the previous concept, namely the heaps P1 for leaching are to be moved to pile 3, so that the residues are handled in a compact way instead of many scattered spots, and on the other hand, the place of heaps P1 will be free for reuse.

4. 4 Heaps for leaching

On the heaps P1, a series of tests have been performed for preliminary investigation of remedial action. The aim of this investigation is to get necessary information about the content and the distribution of radioactive and chemical materials in the heap, as well as the contamination of basement soil and groundwater.

The heap P1, which is one of the oldest heaps for leaching, has 2.1 million tons of crushed uranium ores. During more than 25 years operation 11 thousand tons of solvent have been sprinkled over the heap. Presently, about 2.5 thousand tons of solvent have remained there. At the beginning, the uranium content of ore was 150-200 g/t, and now the average value is 80 g/t. The base of the heap has been lined with double plastic material.

Next a study was performed to ascertain how to remove the remaining solvent from the heap P1. This was achieved by a simple washing method using clear mine water. The washing process of the heap and the experimental pile lasted about half a year, and the amount of mine water used was 5000 m^3. The result was the average specific conductivity of 5.5 mS/cm at the beginning decreased to below 2.2 mS/cm after the washing period.

The study concluded that presently in the heap P1 the content of chemical materials after washing process is at an acceptable level and the basement soil and the groundwater below the plastic layer do not have significant contamination of either radioactive or chemical materials.

4.5 Tailings ponds

Remediation of tailings ponds is very complicated, because a lot of site specific data have to be taken into consideration. Besides, to get this data many systematic investigations have to be performed to obtain reliable information necessary for best possible restoration planning.

As a first step, a simple neutralization experiment was started to reduce salt content in the solvent by using a lime treatment at the release of tailings to the pond. At the same time, the recycled water from the pond is also treated with lime-wash.

In the next step, a programme has been launched to test different solutions for cover layers of tailings pond including the layer thickness under in-situ conditions. One meter diameter concrete rings are used for building the test layer series and different arrangements of compacted soil. Out of 11 options being studied, the first option is the uncovered tailings taken as a reference option (Fig. 2). The concrete rings are constructed in a leak tight mode and in the middle part of each layer a sampling tube is introduced in order to measure the changes of radon concentration (Fig. 3). At the same time, the radon flux is measured on the top of the column, as well as the temperature, wind speed and soil moisture (Fig. 4). On the basis of preliminary evaluation of the measurements, 2-3 options have been selected for detailed field studies planned to cover about 100m^2.

4.6 Decommissioning of milling facility

Since, by the end of 1997 the mining operation together with the milling activities will be terminated, the data collection and general survey has been started at the milling facility to prepare for the decommissioning programme.

The aim of this programme is that major portion of the milling facility (offices, laboratories, workshops, halls,..) will be rendered suitable for reuse just as other industrial activities. As the primary goal is not to demolish the facility, the survey of contamination and radiation level is carried out with the knowledge that survey results the decision on whether to reuse or not will be made. Of course, certain parts of facility will be classified as highly radioactively contaminated, so that they are disposed off into the tailings ponds, as the decontamination of these parts is expected to be difficult and expensive.

5. NEAR - TERM SCHEDULE AND PROSPECTS

After completion of mining activities, firstly the mines will be closed down and preparation for controlled flooding will be started. Together with closing down, the monitoring system will also be expanded to follow changes in the mining area. Should any deviations were to occur during closing down process, the plan has provision for resorting to additional measures.

The heap P2 for leaching will be further washed by clean water to decrease the chemical content. In addition, the solvent removal methods to be studied include reverse osmosis,

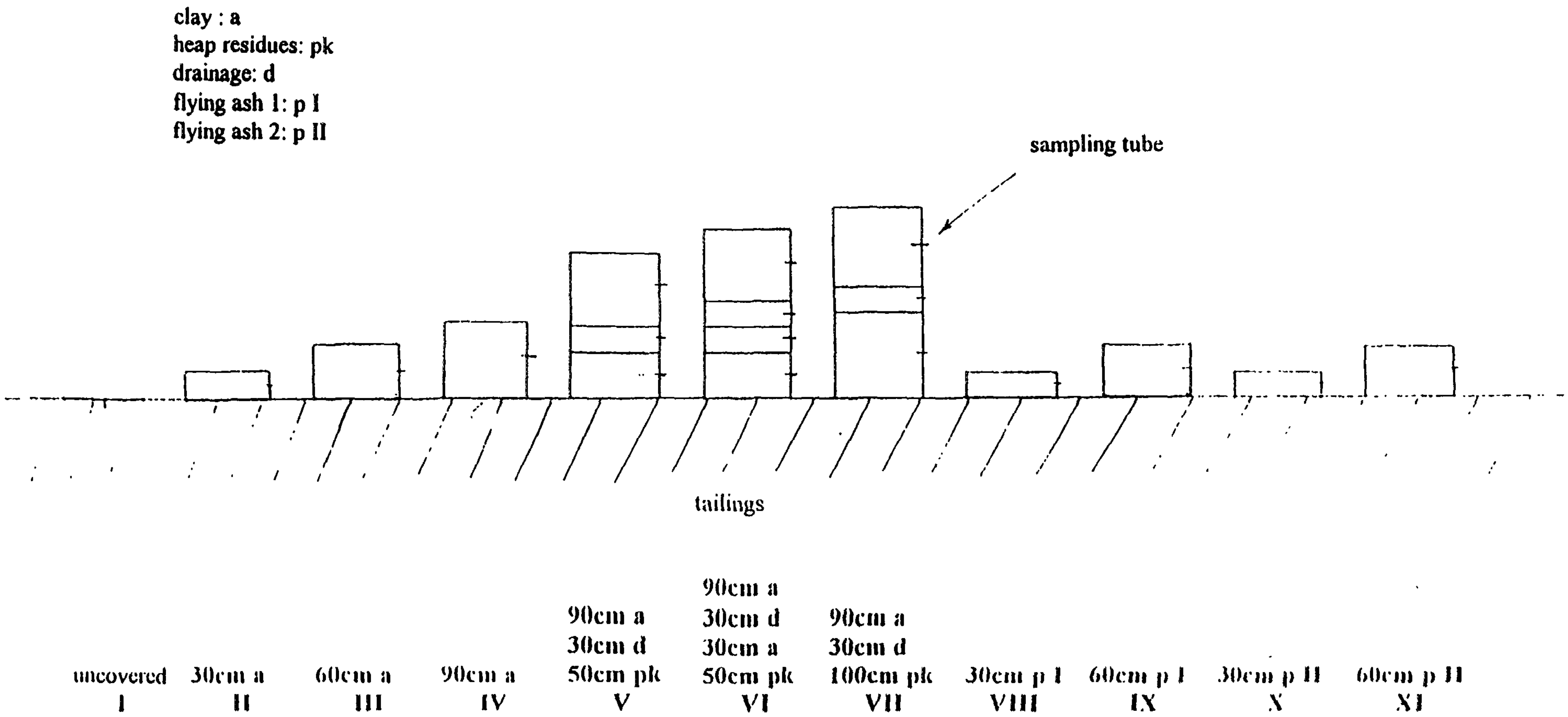

Figure 2. Arrangement of studying of cover layers at tailings ponds

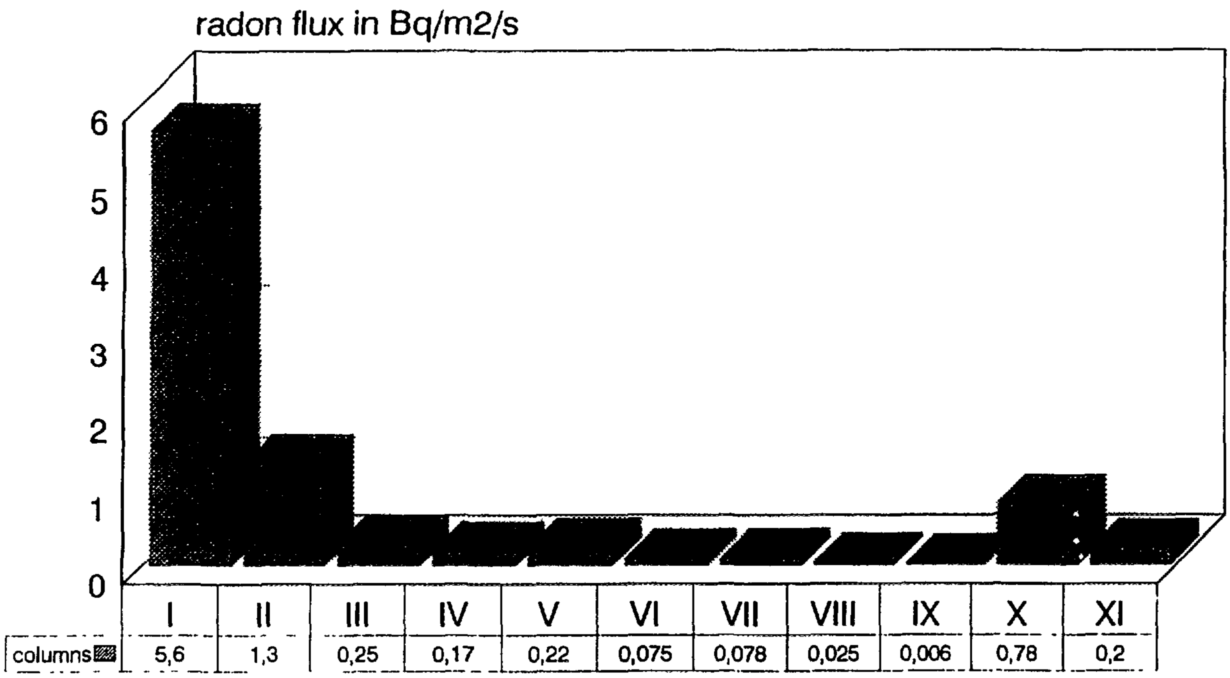

Figure 3. Measurement of radon emanation at the top of columns

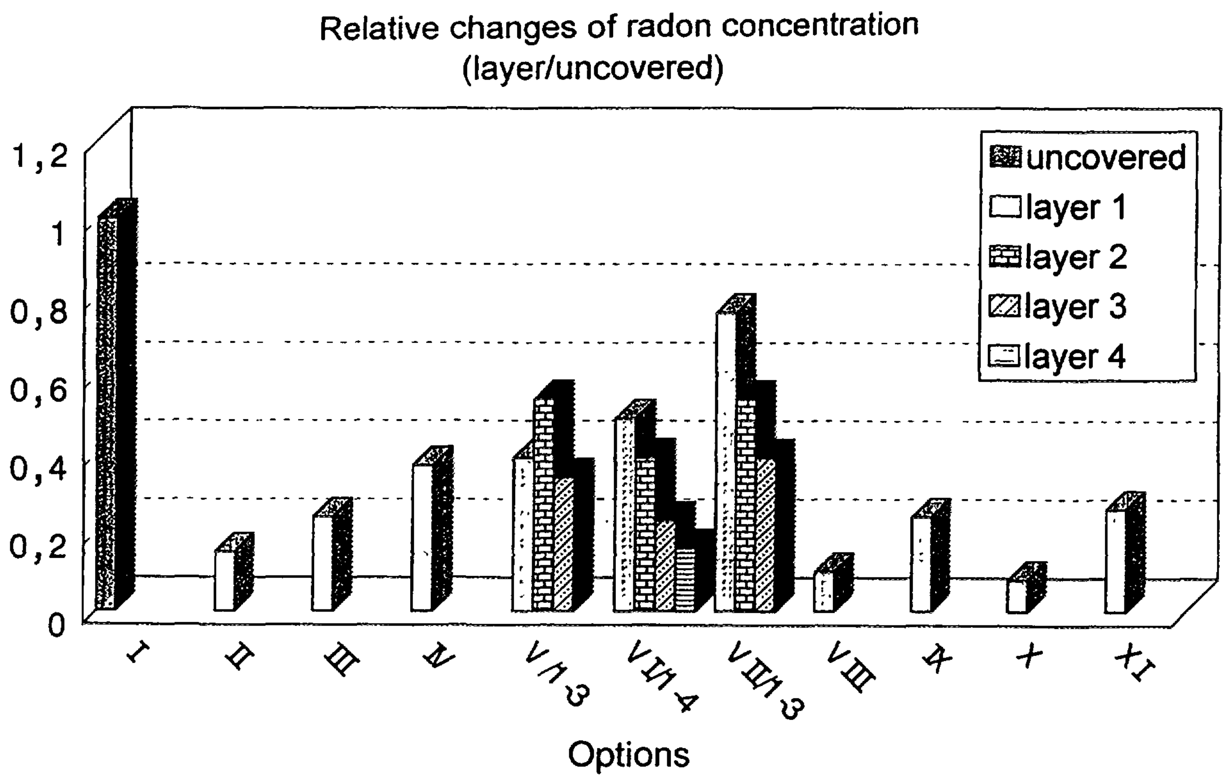

Figure 4. Changes of radon activity concentration in each layer comparing with uncovered tailings

electrodialysis and evaporation. Based on these studies a final plan of action will be worked out for the remediation of the heap P2.

At the tailings ponds, the investigation for cover layers is to be continued to reach an optimized solution. Studies have been started to examine the possibility of a unified remediation of two ponds on one place. Because one of the ponds is situated just over a water resource and in the border of an industrial area, planning may be directed towards such unified restoration effort.

6. DIFFICULTIES

The main problem of restoration works is in the treatment of water contamination. Due to occurrence of uranium, manganese and salt content in soil, discharge water will have concentrations posing difficulties in the longer term. Presently, the uranium content in industrial water is high at several discharge points (waste rock piles, heaps for leaching), but fortunately the Ra-226 concentration is acceptable almost everywhere on affected area, and the assessment indicates that this situation is likely to continue for a long time (Fig. 5, 6 and 7).

In the short term the extraction of uranium from industrial water can be adopted, but the methods of reducing uranium content in other solutions requires further studies. The pumping of mine water can be maintained for a few years, but after flooding of mines the analysis shows the uranium content of water arising from mine galleries will be below 2mg/l.

After collection the water originating from around restored waste rock piles is to be diverted into the mine cavities until the stabilization of cover layers, which may last a few years.

The restoration of the heap P2 for leaching may be solved in two ways, namely, carry out remediation works on-site using washing and removing process, or transport the main parts of heap P2 to the tailings ponds, where they will be used as a cover layer.

For the restoration of tailings ponds the higher salt and manganese content in the base give more difficulties though the method of washing through the base soil may be used to decrease the chemical components, but it will add to the cost of the remediation project making it expensive.

7. CONCLUSION

In the past two years (1995-96) the remediation tasks of mining and milling have concentrated on planning, data collection and development of institutional control. Till now, major

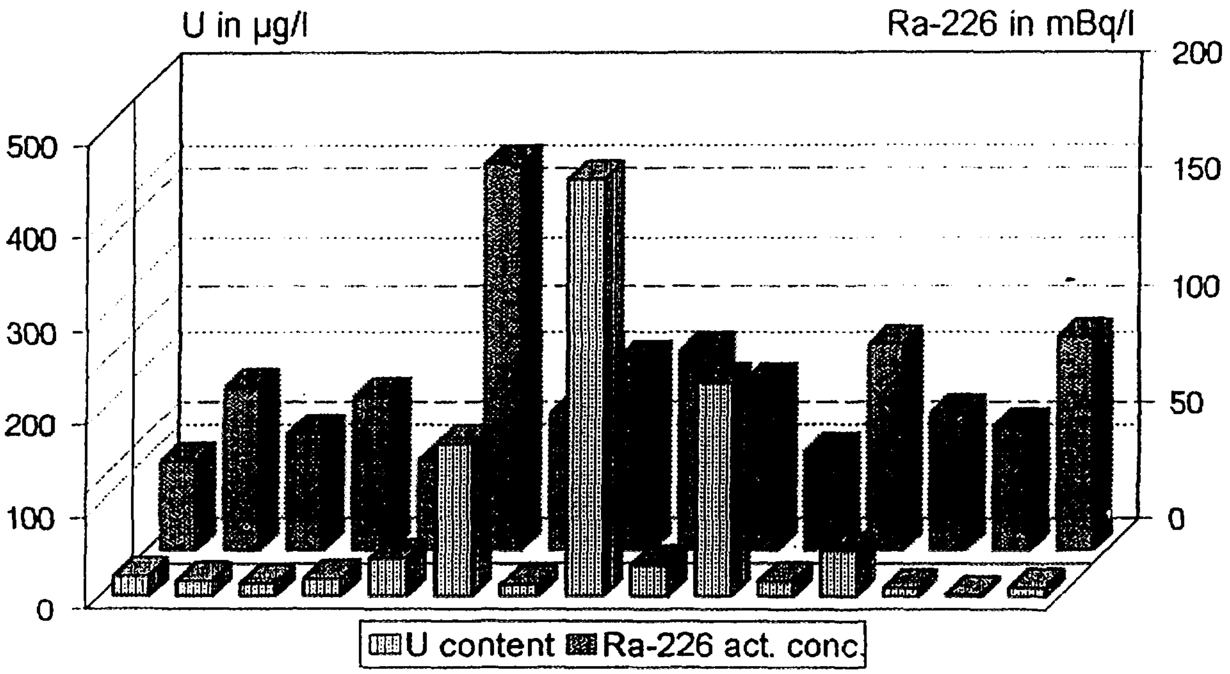

Figure 5. Water contamination on area of heaps P2 for leaching

(First half-year of 1995)

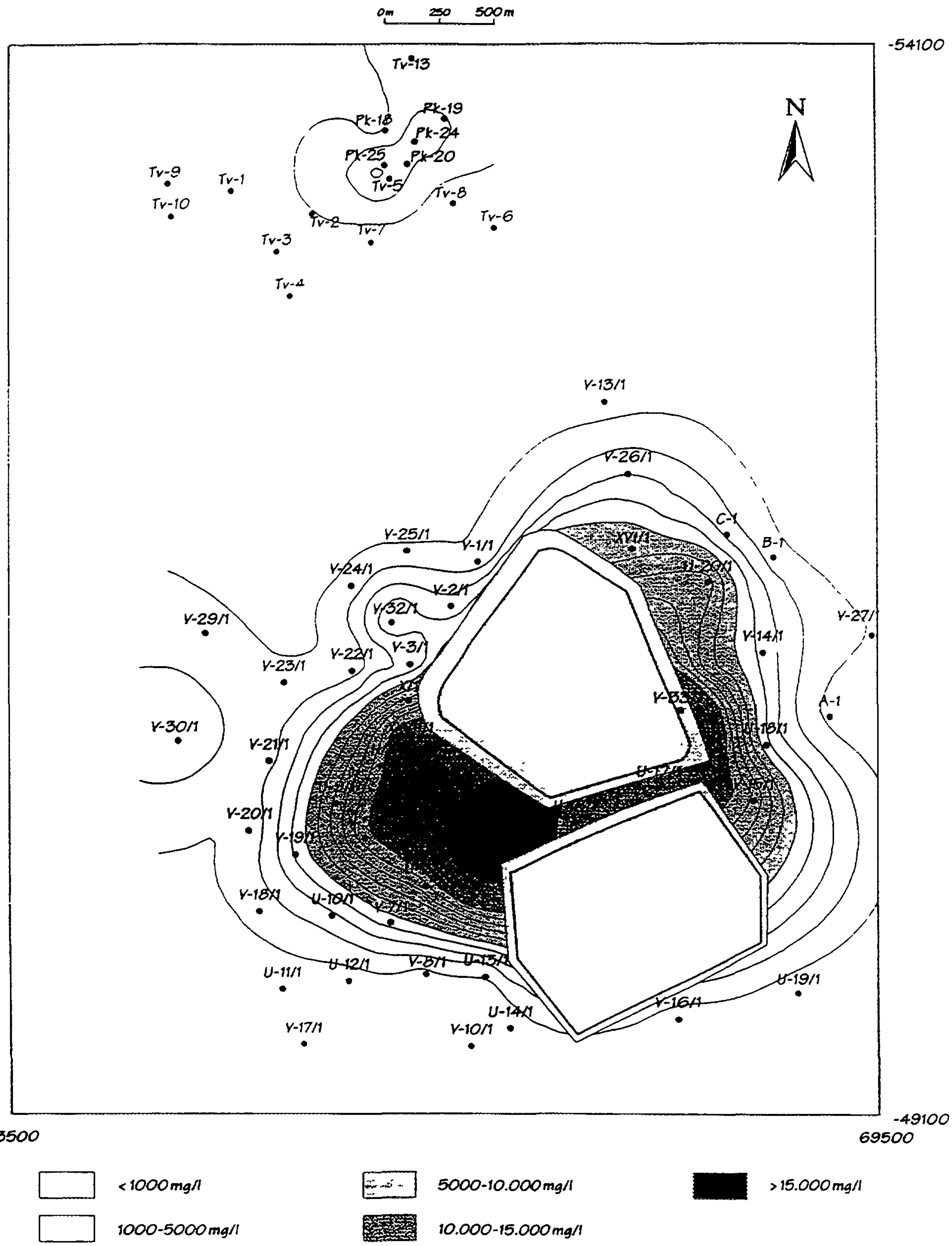

Figure 6 Total content of upper-groundwater at the tailing ponds (mg/1)

(First half-year of 1995)

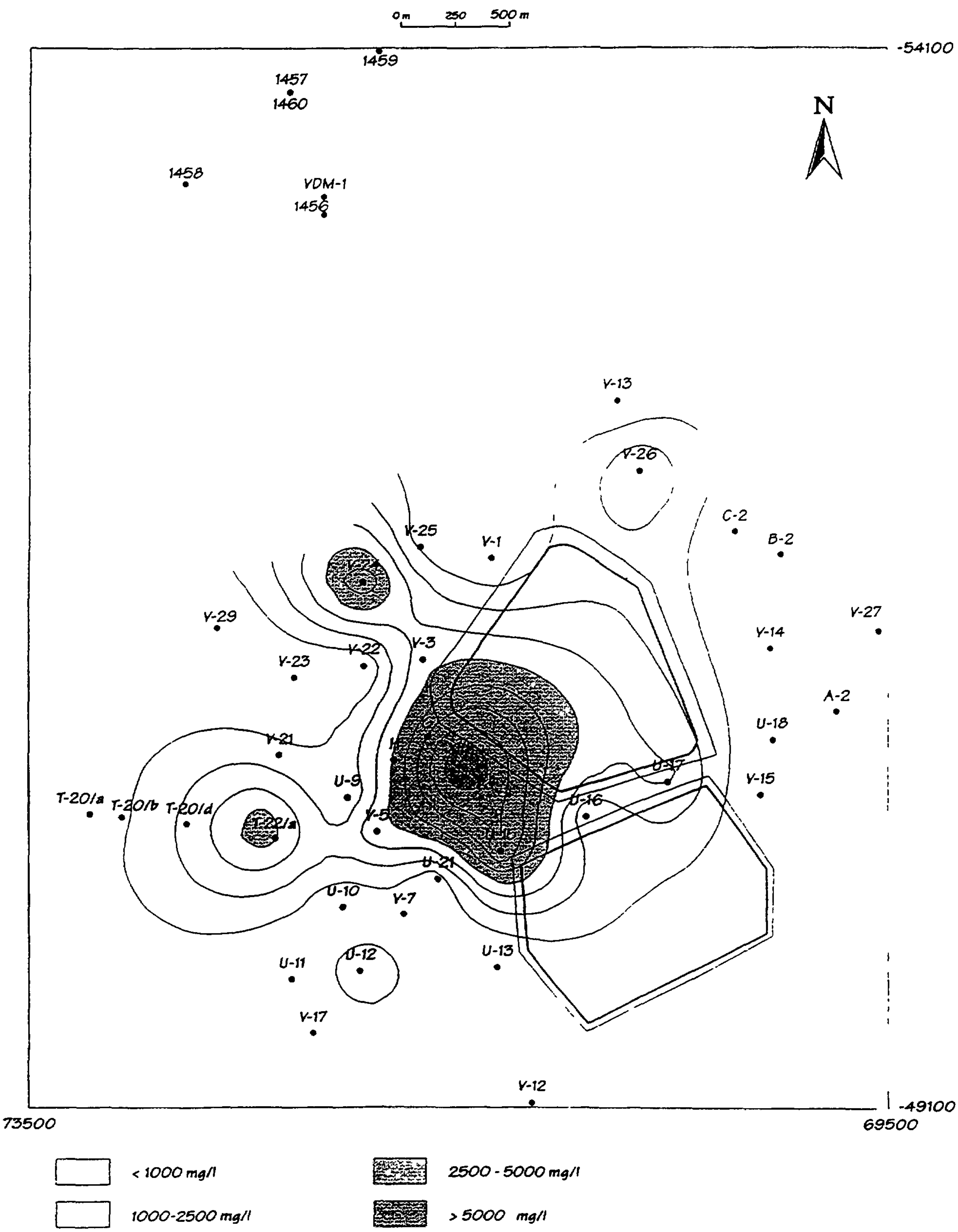

Figure 7 Total content of lower-groundwater at the tailing ponds (mg/1)

portion of waste rock piles have been restored, the monitoring system has been upgraded for close down of mines and a number of experiments and investigations have been performed for decreasing the chemical content of heaps leaching and for selection of cover layers of tailings ponds [10, 11, 12, 13]. Moreover, preparation for decommissioning of milling facility has been started. Requirements for radiological aspects of restoration are also worked out.

A strategy and a phased action plan for carrying out the remediation tasks with next phase to last about 10 years, has been worked out during which the full close out of mines, the restoration of leached heaps, tailings ponds, and decommissioning of milling facility will be performed.

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ENVIRONMENTAL RESTORATION PLANS AND ACTIVITIES IN KAZAKSTAN

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Abstract

During the period of uranium mining activities in the Republic of Kazakstan so far more than 200 million tonnes of radioactive waste with a total activity of about 250,000 Ci has accumulated. The problem of environmental restoration of contaminated uranium mining and milling sites is very topical and important for Kazakstan. This paper presents the radiological status of the situation in Kazakstan, the characteristics of the uranium mining and mill tailings and the approach to the tailings management for stabilization and isolation from the human environment. Legislation in the field of atomic energy including radwaste management has been established in Kazakstan through a structure of State Bodies such as Ministries of Science, Ecology, Bioresources, Health and Atomic Energy Agency. An organization for radiation safety regulation has also been created. Studies regarding stabilization of radiological situation have been started in Kazakstan with the support of IAEA and EU. This paper deals with the regional project for assessment of immediate measures to be taken for remediation of uranium mining and mill tailings sites.

1. INTRODUCTION

The general guiding principle purpose in the field of atomic energy and radioactive waste management in the Republic of Kazakstan is to ensure safety of the present and future generations and protection of the environment from radioactive contamination by normal and extraordinary situations.

Major factors responsible for the generation of radioactivity in the Republic of Kazakstan are:

- uranium mining and milling activity, including geological exploration of uranium;
- mining and milling of commercial minerals containing radioactive elements;
- underground and atmospheric nuclear explosions for military and peaceful purposes;
- power and research reactors;
- use of radioisotopes in medicine, industry and scientific research.

The problem of radwaste management and environmental restoration in Kazakstan are very topical and important.

In line with the subject of this Workshop the radioactive waste situation as it exists in the uranium mining and milling industry of Kazakstan is dealt with. The radwaste in this category comprises about 90 % of the total volume of radwaste generated in the country.

2. THE CHARACTERISTIC OF THE URANIUM MINING INDUSTRY WASTE

Kazakstan is one of the first countries in the world with explored uranium resources (about 50% of the total stock of the former Soviet Union). During the long history of development (from the 40's) of uranium mining and milling industry in the country more than 50 uranium deposits have been exploited. In the North, West and South of Kazakstan three large combines were mining uranium ores, and one plant (on the East of Kazakstan) produced fuel pellets from enriched uranium received from Russia. At present, only two combines are operating: Ulba combine in the East, and Tselinny mine and chemical company in the North of Kazakstan.

TABLE I. THE DISTRIBUTION OF RADIOACTIVE WASTE FOR THE REGIONS OF KAZAKSTAN

Region	Name of district	Low-level waste, Type 1 thousand tonnes/Ci	Low-level waste, Type 2 thousand tonnes/Ci
West	Mangistau	120,000/24,000	8/4,000
North	North-Kazakstan	1.6/0.5	-
	Kokshetau	2,957.3/3,012.7	-
	Akmola	54,982.3/154,197.9 L*. 28/0.11	6/9,000.
	Turgay	1,262.6/867.8	-
	Zheskasgan	4.6/25.1	-
	Karaganda	7.4/8.0	-
South	Kzyl-Orda	4.0/2.3	-
	South- Kazakstan	2.5/1.4	-
	Zhambyl	33,125.7/36,202.7	-
	Almaty	0.8/0.7	-
	Taldy-Korgan	21.9/16.6	-
East	East-Kazakstan	889.1/298.3 L. 453.53/2,810.6	1,142/12,358 L. 11/5,550
	Semipalatinsk	15.7/12.7	-
Total		217,839/221,457	1,167/30,908

L* - liquid waste.

Now, uranium extraction in Kazakstan is carried out mainly by In-Situ Leaching, which does not lead to significant volumes of radioactive waste arisings. As a result of carrying out exploration and mining works as well as milling operations more than 200 million tonnes of radioactive waste with total activity of about 250,000 Ci have accumulated in Kazakstan. They are mainly of two types: dumps of mine rocks and very low-grade ores, and mill tailings.

The type 1 low-level waste is disposed in situ during recultivation of land after closing of the mines. Since the technologies of ore processing and pellet production do not generate intermediate-level waste, the type 2 waste is also of low-level but of slightly higher activity than type 1 and collected in special ponds and disposed by fixing without removing from the ponds.

Regional concept is followed for radioactive waste disposal in the Republic of Kazakstan [1] according to which the country is divided into four regions based on transport connection infrastructure, as North, East, South and West (Fig. 1).

The regionwise distribution of radwaste in Kazakstan is shown in Table I.

The uranium mining and milling wastes are disposed in as many as 127 locations and are of three types:

- piles and embankments (dumps);
- tailings ponds;
- special disposal facilities.

The first two types of disposal were created at the time of the start of the development of uranium mining industry. Therefore some of them do not correspond to the modern standards of radioactive waste management. Now the industry has to dispose the low-level waste by itself in the near surface disposal facilities after they are constructed.

The following aspects need to be addressed to achieve a solution to the environmental restoration problem of the uranium mining and milling industry:

(i) Creation of necessary legislative base.
(ii) Implementation of environmental restoration activities.

These two aspects are considered in more detail.

3. LEGISLATION AND STATE BODIES

3.1. Legislative structure

Before the disintegration of the former Soviet Union, Kazakstan did not have its own legislative base dealing with utilization of nuclear energy and radioactive waste management nor was there any organizational set up to carry out the regulatory and control functions in this field of activity. The basic safety regulation documents in the field of nuclear energy were Standards of Radiation Safety NRB 76/87, Basic Sanitary Rules OSP 72/87 [2] and different departmental documents. The State Committee of Atomic Inspection was responsible for nuclear safety and control.

After Kazakstan became an independent Republic, work has been started on the creation of a legislative base in the field of utilization of nuclear energy and radioactive waste management. The experience of leading countries in this field, such as Germany, Finland, Russia and Ukraine is being used.

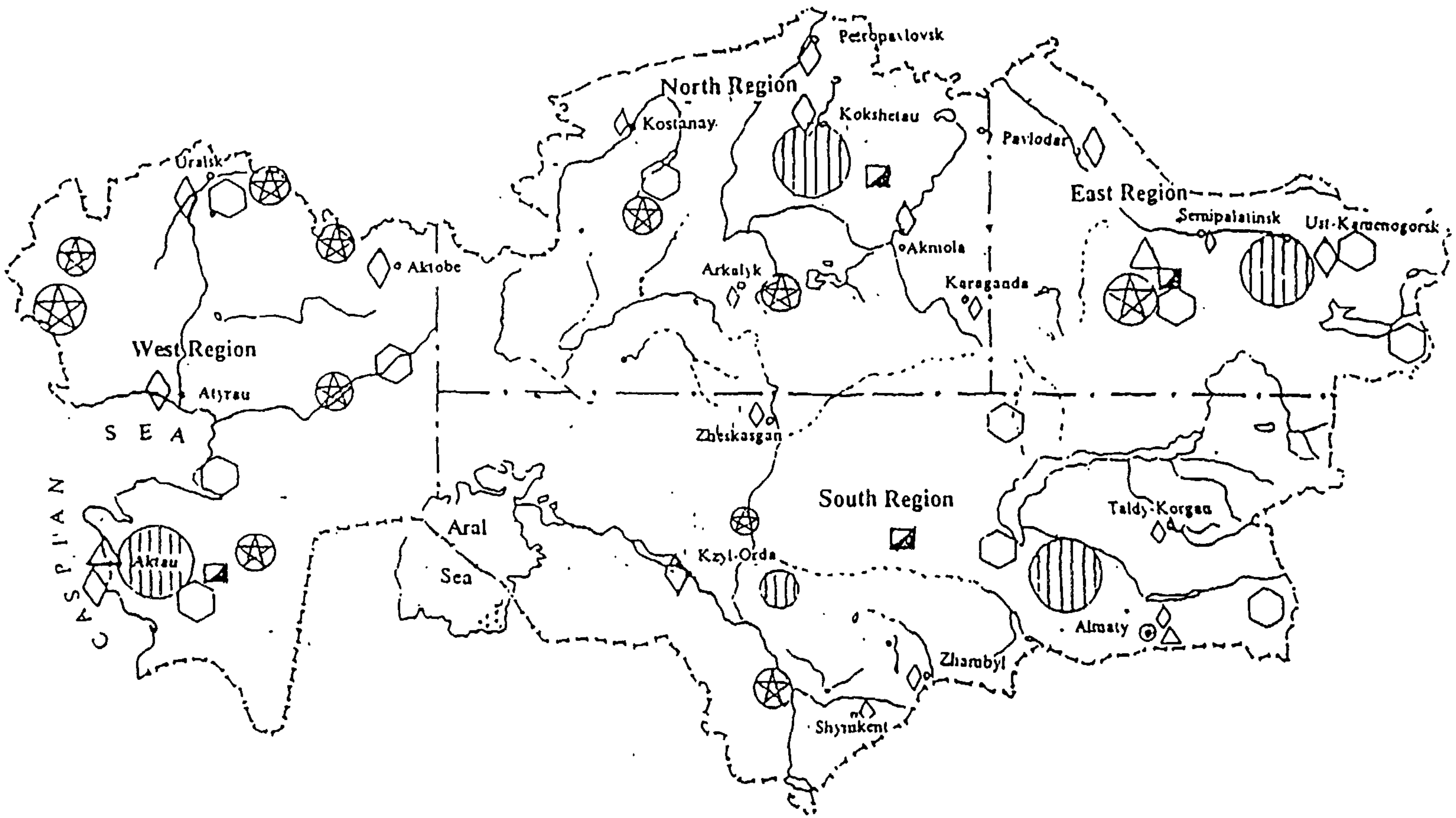

Fig. 1. Scheme of the radioactive waste disposition in Kazakstan

Waste from uranium mining and milling enterprises

waste from non-uranium mining and processing plants

Nuclear explosions

nuclear power and research reactors

sealed sources

proposed points for radwaste disposal creation

At present in the Republic of Kazakstan the authority for regulatory functions is drawn from:

- Laws, defining basic principles for regulation of activities in the field of atomic energy;
- Presidential decrees, Decision of Parliament and Government;
- Authority vested with the State Bodies for regulation and inspection;
- Nuclear and Radiation Safety Standards and Rules;
- State Standards and Construction Norms and Rules;
- Ministerial Regulatory Documentation;
- International Treaties, Agreements and other International Conventions to which Kazakstan is a member.

Currently in the Republic of Kazakstan the laws pertaining to the utilization of atomic energy and radioactive waste management are applicable to the following areas:

- on environmental protection;
- on bowels and bowels use;
- on licensing [3-5].

These Laws are used for regulation to bring social benefits:

- by environmental protection to prevent health detriment due to adverse effects of economic activity in the field of atomic energy including radwaste management;
- by bowels use including extracting and processing of commercial minerals which contain radionuclides;
- by licensing of activities connected with utilization of atomic energy and radwaste management.

To deal with the problems in the field of atomic energy in Kazakstan and development of nuclear power it has become necessary to create Acts of legislation which can directly permit regulatory functions to be carried out by authority.

Kazakstan is now in the process of drafting a Law on "Atomic Energy Use" drawing from the experience of Germany, Finland, Russia, Ukraine [6-9] and others based on main principles of International Basic Safety Standards (BSS) [10] to create similar Acts. Being the first one, this will be the basic Law pertaining to nuclear legislation in Kazakstan.

The draft of the above mentioned Law was examined by IAEA experts, was discussed during the meeting of an International Group of Legal Experts and is being updated and processed by governmental agencies. After going through the internal procedures it will be passed on for approval to the Government and Parliament of Kazakstan, before enforcement.

At present draft laws on "Radioactive Waste Management" and "Radiation Safety of Population" are being developed. In the near future these laws along with the law on "Atomic Energy Use" will form the full package of nuclear legislation of Kazakstan in this field.

Except the above mentioned laws, in the Republic of Kazakstan there are now more than a hundred regulatory documents, including the documents of the former Soviet Union which were being used so far, in addition to the new ones developed in Kazakstan and also Standards of Radiation Safety NRB-96 developed and established in the Russian Federation in 1996.

3.2. Structure of State Bodies

President and Government of Kazakstan, realizing the high national responsibility in discharging the functions took a decision to create a State Body in 1992 called Atomic Energy Agency and a system of State Radiation Safety Regulation. This Agency along with various Ministries is responsible for the following functions (Fig. 2):

Atomic Energy Agency is responsible for issue of licenses pertinent to all nuclear activities, state control over export and import of nuclear materials and nuclear technologies, accounting and control of nuclear materials, physical protection of nuclear materials and to carry out overall supervision of nuclear and radiation safety at the nuclear plants and on the use of radioactive sources.

The following Ministries of the State of Kazakstan within the framework of their competence maintain the state control and supervision:

- Ministry of Science-Academy of Science coordinates all scientific activity in the field of atomic energy including radwaste management and provides scientific expertise for projects.

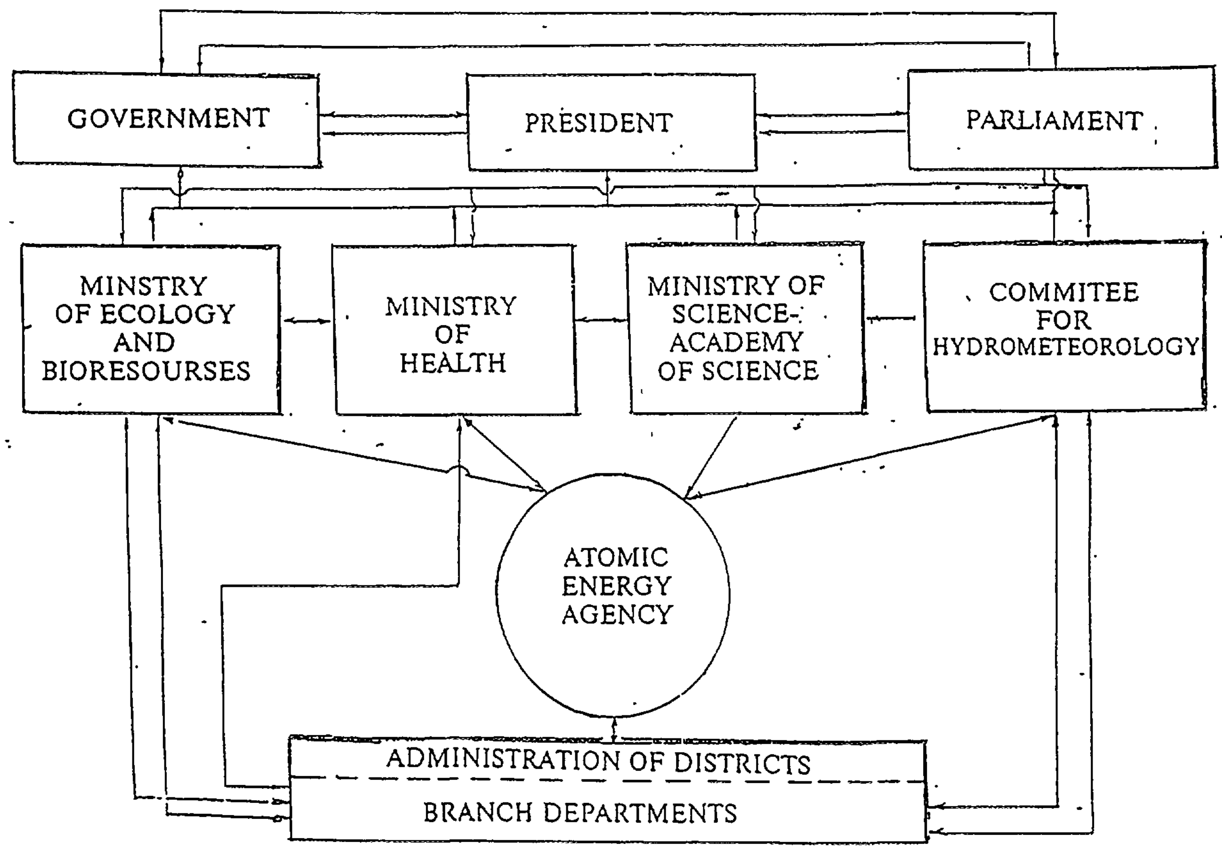

Fig. 2. Organization system of State regulation of radiation safety

- Ministry of Health in the sphere of its competence is responsible for regulation and inspection of production, use, storage, transportation of nuclear materials and radioactive sources, radioactive waste disposal, maintenance of inventory of all radioactive sources and for the issue of license to work with radioactive sources, and render medical assistance to personnel working with nuclear materials.
- Ministry of Ecology and Bioresources maintains control on protection of the environment from radioactive pollution and on the disposal of radioactive waste, coordinates measures to assess radiological situation in Kazakstan and provides ecological expertise to projects.
- Department of Hydrometeorology keeps control on radioactive fall out on the territory of Kazakstan with the help of a national network of meteorological stations.

Other State bodies with their responsibility are:

- State Committee for Work Safety in Industry and Mine exercises control on exploitation of industrial equipment.
- State Committee for Extraordinary Situations is responsible for the implementation of measures for prevention of emergency and measures for dealing with emergencies if they were to occur.
- Ministry of Geology is responsible for licensing activities connected with mineral exploration and exploitation (Bowels use).

Also, control of external radiation dose and monitoring of radionuclides content in soil, in foods and drinking water is carried out by different national laboratories under the Ministry of Industry, Ministry of Power Engineering and Oil Industry, Ministry of Agriculture and different scientific laboratories and research institutions of repute.

4. DIRECT ACTIVITY ON THE ENVIRONMENTAL RESTORATION

The waste producers were responsible for the disposal of radwaste and environmental restoration in the past. However, in view of the present economic conditions, unfortunately the waste producers have stopped taking this responsibility. Therefore, during the last two years Kazakstan, in cooperation with International Organizations like IAEA and EU is taking part in various projects to work out possibilities of stabilization of the radiological situation in the country.

One such project is TACIS Regional Project G4.2/93-NUCREG 9308 for assessment of urgent measures to be taken for remediation of the uranium mining and mill tailings. Main thrust of the project is to carry out investigation of the influence of radwaste on environment and make recommendations.

The project plan consists of four phases:

1. Identification of sites and installations.
2. Radiological survey of the selected sites and installations
3. Geochemical and hydrogeological modeling and computation of radiological consequences.
4. Assessment of remediation options and ranking.

The first phase has the following objectives:

- Consensus on outline and organization of work;
- Common understanding on remediation objectives;
- Preparation for data collection and site investigations, assignment of responsibilities and bilateral interfaces for cooperation;
- Consensus on the criteria to be used for site selection.

Based on outcome of this phase fine tuning of programme planning and a list of selected sites or district for site investigation will be decided.
Data collection will be through use of prepared data sheets for each criteria and major data category to establish a data base.

Site investigation together with CIS experts will include scrutiny of data presented by local authorities and operators. Additional requirements for data and measurements will be clearly defined as well as relevant methodologies for acquisition.

- Definition of criteria for selection, measurements and modeling;
- Definition of criteria for site prioritization.

The main outcome of site investigations and data evaluation will be:

- Characterization of source terms;
- List of selected sites for measurements and sampling;
- Outline, equipment and methodology of sampling and measurements programmes and analytical procedures.

The second phase includes:

- Definition of needs of instruments and measuring equipment, and their procurement;
- Preparation of training programme;
- Definition of required data for measuring programme;
- Measurements (aerial, aquatic pathways and biota);
- Calculation of effective dose from source term data using appropriate codes, from all pathways;
- Use of codes for atmospheric dispersion and transfer;
- Standards to be met for compliance with international regulations;
- Outline of tools and methodology for an environmental monitoring network..

The third phase includes:

- Definition of objectives and strategy for modeling;
- Selection of sites for monitoring according to criteria defined in previous phases of project;
- Use of simple models and codes on selected sites;
- Use of detailed modelling on one priority site;
- Introduction to appropriate software and training for continued use of modelling methodology

The fourth phase includes:

- Categorization and prioritisation of sites and facilities according to degree of risk and environmental damage, definition of criteria to be used;
- Assessment and ranking of remediation options as specified for each investigated site;
- Ranking of remediation measures according to degree of urgency;
- Definition of urgent measures;
- Use of decision making techniques;
- Evaluation of current remediation measures;
- Suggestions for optimization and improvements.

The first phase of the project has been completed. 30 sites with mining and milling radwaste in Kazakstan are listed based on answers to project questionnaire. However 70 sites are listed based on response to short questionnaire.

All sites are located in different parts of a huge area in Kazakstan and are characterized by various features. For definition of degree of hazard radwaste is divided into 3 main groups:

1. Distance from the nearest populated area - possibility of direct influence on population

- Class A - up to 1 km;
- Class B - up to 3 km;
- Class C - more than 3 km.

2. Grain size distribution - possibility of dust getting air-borne from surface of tailings pond

- Class I - Tailings after hydrometallurgical process (grain size less 1 μm);
- Class II - Radwaste after radiometric enrichment (grain size less 30 μm);
- Class III - Radwaste after mining (grain size less 300 μm).

3. Climate - possibility of contamination of surface and underground waters by way of infiltration of precipitation (atmospheric)

Class a - moderately continental, steppe, foothills (precipitations over 300 mm/y and altitude over 1,000 m).

Class b - sharply continental, semidesert (precipitation less than 300 mm/y and altitude less than 1,000 m).

The results of data are shown in Tables II-IV.

TABLE II. RADWASTE DISTRIBUTION AS PER DISTANCE FROM NEAREST POPULATION AREA

Class	Distance from, km	Number of sites	RW quantity, million. tonnes	Activity thousand Ci
A	≤ 1	7	2.2	1.4
B	1 - 3	15	19.3	214.9
C	> 3	78	2.4	15.0
Total		100	222.9	231.3

TABLE III. RADWASTE DISTRIBUTION AS PER GRAIN SIZE

Class	Grain size, mm	Number sites	RW quantity, million. tonnes	Activity thousand Ci
I	≤ 1	3	165.0	170.0
II	≤ 30	4	22.4	21.9
III	≤ 300	93	35.5	38.8
Total		100	222.9	231.3

TABLE IV. RADWASTE DISTRIBUTION AS PER CLIMATE

Class	Precipitation, mm/y Altitude, m	Number of sites	RW quantity, million. tonnes	Activity, thousand Ci
a	> 300 and > 1000	20	13.6	12.5
b	< 300 and < 1000	80	209.3	218.8
Total		100	222.9	231.3

Based on these results the second phase of the project will be started.

5. CONCLUSION

The status of restoration project in the Republic of Kazakstan is as follows:

1. An analysis of conditions of formation and disposition of radioactive waste has been performed. Major part of radwaste was generated from uranium mining and milling activities.
2. In the field of nuclear legislation the draft of the Law on "Atomic Energy Use" has been prepared. Now it is going through internal procedures towards enforcement by the Government and Parliament. The drafts of Laws on"Radioactive Waste Management" and on "Radiation Safety of Population" have also been prepared and are going through review process.
3. A State System which includes a number of Ministries in Kazakstan was created for the organization of the Radiation Safety Regulation.
4. The work on TACIS Project for studying the possibilities of stabilization of radiological situation in Kazakstan has been started. Now the first phase of this project is completed and the conditions for starting subsequent phases have been created.

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ENVIRONMENTAL RESTORATION PLANS AND ACTIVITIES IN POLAND (LIMITED TO URANIUM CONTAMINATION ONLY): 1995-1996 PROGRESS REPORT

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Abstract

The current status of remedial action in uranium mining areas of Poland has been presented. Environmental significance of radiological risk has been discussed on the basis of recent investigations. However, the most significant direct risk seems to be connected with human intrusion. The role of geotechnical safety measures has been stressed. Geotechnical safety should cover not only intrusion prevention, but also stabilisation of dumps and tailings ponds in the area of intensive erosion. Priorities, plans and difficulties connected with their realisation have been described.

1. NATIONAL CONDITIONS REQUIRING ENVIRONMENTAL RESTORATION

Exploration for uranium in Poland started in the late 40's. Sudetes located in the south-western Poland were the main area of exploration, although minor prospecting has been carried out in the Holy Cross Mts. and Carpathians in central and south-eastern Poland. At the beginning prospecting and mining were conducted under close Soviet supervision but later the Polish company Zakłady Przemysłowe R-1 took over the mining and most of the prospecting activities. Some prospecting works have been carried out also by Geological Institute. In the early 70's all mining activities were stopped and no legal descendant of the uranium mining company exists now.

Prospecting stage was often associated with mining minor amounts of uranium ore. However, serious mining activity took place only in the environs of Kowary Podgórze, Radoniów, Kopaniec, and Kletno. Uranium mineralization is associated mainly with the hydrothermal processes of the late- and post-Variscan stage. Mineralization of the vein character has been superimposed on the metamorphic rocks of the Karkonosze Izera Block, Kaczawa Mts, Sowie Mts. Block and the Śnieznik Metamorphic Massif and the Holy Cross Mts.. Some exploration works have also been done within sedimentary series of the IntraSudeticBasin, North Sudetic Basin and Carpathians.

Not only mining, but also significant amount of prospecting was done underground as a result of which, numerous remnants of adits, tunnels and shafts accompanied by dumps are widely dispersed in the mountainous region. In the town of Kowary the only uranium tailings pond of Poland exists. Shafts have been provisionally covered with concrete covers and some of the entrances of the tunnels have been blasted. Because of the poor quality of closing works they cannot be regarded as permanent. Recently some of the shaft entrances have got reopened due to erosion caused by intensive washing out of soils into the shaft. It became possible because shaft covers have not been made on solid rock but on weathered debris. Some dumps are getting heavily eroded, especially the dump located downstream in the Jedlica valley. (Figs. 1,2).

Fig 1 - Shaft entrance exposed by erosion, with provisional safety measures (Kowary Podgórze)

Inventory works [1] in the Jelenia Góra district resulted in the accounting of

- 6 862 m of vertical shafts,
- 276 334 m of horizontal adits and galleries,
- 446 295 m^3 of tailings on the area of 297 730 m^2,
- 1 5 ha tailing pond with 12 m infill of post hydrometalurgical wastes consisting of disintegrated gneisses of 30 ppm uranium and 3-8 10^8 g/kg radium content

In the case of the Wałbrzych district similar range of uranium mining remnants can be expected

Some remnants of mining works can be expected in the Holy Cross Mts area while in the case of the Carpathian region probably no mining works were done

Fig 2 - Erosion of dump at the entrance of the adit 19 resulting from heavy rainfalls in the summer of 1996

2. LEGISLATION, REGULATIONS, POLICIES

Responsibility of the activities of uranium mining operator has been inherited in 1973 by ZZTJ POLON and later transferred to the National Atomic Energy Agency According to the Mining Law of 1978 any claims connected with mining impact should be made within 3 years of the start of the harmful effect. According to the new Mining Law (1994) if the mining company is not existing any longer the State Treasury represented by the Ministry of Environment Protection is responsible for the remediation actions.

3. RADIOLOGICAL CHARACTERIZATION

Environmental studies of the uranium remnants revealed radioactivity levels up to 2000 μR/h in Radoniów and up to 1500 μR/h in Kowary Podgórze dumps [2].

Uranium content of 1500 ppm has been found in some dump samples, and in clay fraction of stream sediments values as high as 0.11%U have been detected [2] Mining waters flowing out from the No 19 adit contain 1 x10^4 g/ℓ U [2].

In the year 1996 comprehensive environmental study was completed [3]. Investigations covered

- outdoor gamma dose measurements with MM900GL monitor and thermoluminiscence detectors
- radium in water analyses

- radionuclide contamination in soil
- radon daughters in air by means of RGR-13
- outdoor and indoor concentrations of radon by means of solid state nuclear track detector LR115

Gamma dose in the environs of dumps has been found [3] to be two times greater than the average for the region but it can be at least partly explained as natural variation of radioactivity in granitic area. Radium content in waters was within natural limit for granitic aquifers Radium content two times greater than average for the region has been found in the environs of dumps which is also a natural variation. Significant increase in radon content is restricted only to the close neighbourhood of dumps and entrances of mining works.

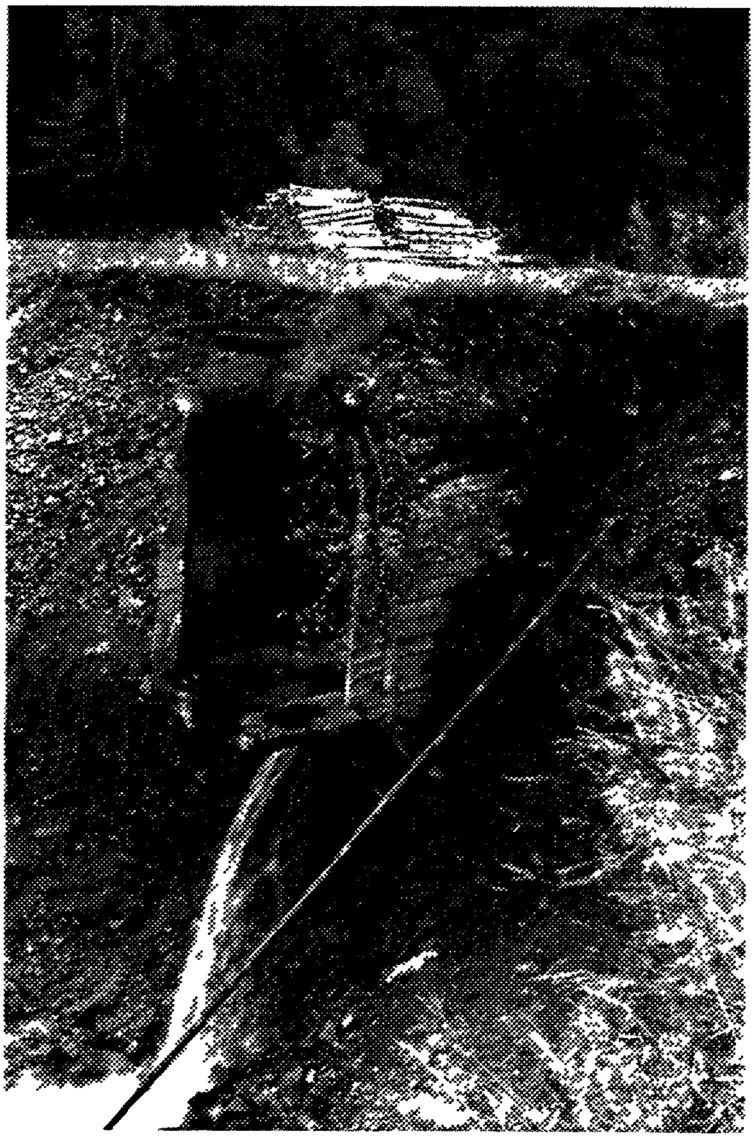

Fig. 3 - Temporary channel of mining water outflow and natural stream through the dump below the adit 19

4. ACTIVE PROJECTS UNDERWAY

The year 1996 saw a spurt of activities. It was the year when extensive environmental study on "*Effects of Uranium Mining on the Contamination of some areas in Poland*" was completed [3]. In the beginning of the year bidding for the *Technical project on safety measures in the uranium mining areas of Jelenia Góra district* started. In September 1996 monitoring of uranium mining areas in Jelenia Góra district conducted by IMGW commenced. It was also the first year of the European Commission's Phare project: *Remediation Concepts for the Uranium Mining Operations* In *CEEC*, covering in the first stage (1996-97) inventory of uranium mining and exploration areas, not only in Sudetes, but also in Holy Cross Mts. and Carpathians. Preliminary inventory works within the framework of the Phare project revealed the existence of seven exploration and five mining districts of uranium covering not only Sudetes but also Carpathians, the Holy Cross Mts. and also Polish lowlands. Since the beginning of 1996 MSc environmental research focused on uranium mining remnants, is being carried out in the Kowary area.

5. PRIORITIES AND PLANS

Following priorities seem to be important for the immediate future:

- Closing entrances of shafts and galleries to prevent intrusion.
- Geotechnical safety measures for other mining works to prevent development of surface damages
- Stabilisation of tailings pond in the town of Kowary.
- Stabilisation of the dump in the Jedlica valley
- Creation of information centre on the history of uranium mining in Poland to improve public relations and awareness
- Control and monitoring of mining water outflow.

6. NEAR -TERM SCHEDULE AND PROSPECTS

Taking into account the above listed priorities in the Jelenia Góra district commercial bids for preparing the *Inventory of the shallow mining works of the uranium mining in the Jelenia Góra district* are being invited. Creation of the inventory data base is planned to be completed within the Phare project by June 1997.

7. DIFFICULTIES ENCOUNTERED OR ENVISIONED

Three kinds of difficulties exist in the case of reclamation works namely legal, financial and technical. Problems result from the fact that all industrial activities connected with uranium industry have been stopped in the early 70's. At present there is no system of legal continuation of the operator with the result dispersed character of ownership of affected areas prevails. However, the most important is the lack of legal investor. Even in the case when funds are donated by central administration legal problems in managing arise.

8. CONCLUSIONS

Environmental impact of uranium mining in Poland is mainly of non radiological character. The most important problem is connected with the stability and geotechnical safety of abandoned mining works. In many cases their closing can be regarded as only temporary and cannot prevent human intrusion. Majority of works is located in the Sudety Mts. an area with significant risk of heavy rainfalls and rapid erosion. Erosion of abandoned mining works can result in emergence and migration of new radiological contamination. Especially unstable is the situation in Jedlica valley where rapid outflows of mining waters occur. These outflows are provisionally channelled (Fig.3) and flow through the dump and later along the valley across the town of Kowary. In the same valley the tailings pond with high risk of flooding exists.

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ENVIRONMENTAL RESTORATION PLANS AND ACTIVITIES IN THE ZONES OF URANIUM ORE EXTRACTION AND MILLING IN ROMANIA: 1995-1996 PROGRESS REPORT

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Abstract

The objective of this paper is to present the ecological impact on environment as a consequence of more than 30 years of activity in the field of uranium exploration, mining and ore processing in Romania and a brief description of the measures taken for limiting the effects of contamination on the affected zones including the proposed restructuring and rehabilitation programmes The Autonomous Regie for Rare Metals (RAMR), the coordinator of the activities in the uranium field is responsible to implement the provisions of the IAEA Technical Cooperation Project on Environmental Restoration in Central and Eastern Europe joined by Romania in 1993. The Autonomous Regie, through the Research and Designing Institute for Rare and Radioactive Metals and its production units has so far been successful in identification and characterization of radioactively contaminated areas with a view to preparing a restoration and rehabilitation plan The characterization of radioactively contaminated areas is dealt with broadly under two categories, one pertaining to sites where the mining and milling activities have already ceased and the other where the units are still operational but are going to be closed down in the near future and will be placed under surveillance So far, RAMR has performed activities specific to limiting the effects of radioactive pollution on environment and people through execution of antipollution measures for the mine and industrial waters, installations for dust removal, improved ventilation in underground mines, provisions for washing safety and transport equipment, washrooms for the personnel, health care and control, etc. Generally speaking, the activity in the uranium field is developed by observing the national Norms of Nuclear Safety for the Activity of Geological Investigation, Mining and Milling of Nuclear Raw Material. A feasibility report "Environmental Protection Works and Ecological Remediation in the Areas with Activities of Geological Investigation, Mining and Milling within the Autonomous Regie for Rare Metals" was drawn up in 1995 and approved by the Government of Romania. This report includes an evaluation of the necessary investments for the first stage of the programme dealing with the environmental restoration and the necessary research activities This will be followed by studies for closing down and surveillance of the mines with special problems taking into account their depth and complex hydrology. In order to provide the funds necessary for the studies and execution of works on environmental protection and ecological remediation, besides funds of RAMR and from the state budget it is very essential to attract co-financing through international bodies.

1. BRIEF HISTORY OF THE ACTIVITY OF URANIUM ORE PROSPECTING, MINING AND MILLING

Uranium research in Romania started in 1950, and underwent a process of evolution in three distinct stages of organizational set up. The founding of the Romanian-Russian joint venture SOVROM-CUARTIT marked the beginning of the first stage which ended in 1961 when the Soviet consultants left the country. During the second stage, spanning the period 1961-1989, the activities in this field were organized under the Rare Metals Enterprise, a state organization with industrial profile. Since 1990, with change towards conditions of free economy, the entire uranium exploration and production activity has come under the purview of Rare Metals Autonomous Regie.

2. GEOLOGICAL CHARACTERISTICS OF THE URANIUM MINING AREAS IN ROMANIA

2.1. APUSENI MOUNTAINS

The **Băita-Bihor** is a representative type of uranium deposit in Permian sandstone. It is located in the hydrographic basin of Crişul Mic river, 5 km north-west of the Bihor Mountains peak (1851 m). The mineralization of this deposit, represented by pitchblende is in the gray striped sandstone with bands of black sandstone belonging to the Permian age.

Avram Iancu deposit is one of the most important deposits in operation in Bihor Mountains and it is located in the southern part of Bihor Peak in Gruiul Dumii summit which is the cut-waters between Arieşul Mic basin and Crişul Alb basin. It is situated in the average carbonatic horizon of crystalline schists of Biharia unit which as age, is attributed to Silurian, Biharia Series and consists of chlorite schists with porphyroblasts of albite, quartz-chlorite-albite schists, mica schists with chlorite, crystalline limestones and of metamorphosed rocks originating from the intrusive products of initial magmatism, represented by metadiorites and metagabroes.

2.2. BANAT MOUNTAINS

Exploration conducted in the Banat Mountains also yielded exceptional results. In this area are discovered and later explored mineralizations hosted in sedimentary rocks: micro conglomerates, sandstones and shells of upper Permian age. For uranium of particular importance is the fine granulation facies within the Ciudanoviţa sedimentation series. The most complete development of this series is in the eastern part of the Natra-Gârlişte anticline. In this area five sedimentation rhythms are recognized within a 350-400 m thickness. Starting with the bottom they are named: Dobrei, the Mezorythm of the conglomerates, Lişava, Natra, Ciudanoviţa. The Ciudanoviţa deposit, a representative type for this metallo-genetic province, is situated 18 km north-east from Oraviţa town. The Ciudanoviţa sedimentation rhythm has generally, fine grain sizes and an average thickness of 30-40 m. From the lithological point of view this sedimentation rhythm has basically gray and red sandstone shaped lenses over which other fine, gray-greenish carbonate sandstone is located. In the Eastern Banat the recent surveys outline a new uranium metallogenetic sub province characterized by mineralization without bitumen support, formed probably due to the hydrothermal implications.

2.3. EASTERN CARPATIANS

2.3.1 Crucea deposit

The uranium concentrations forming Crucea deposit are hosted in the complex of mesometamorphic rocks (Rarău Series) more or less affected or less intensely by retromorphism.

Rarău Series consists of a facies with high crystalinity, including a complex of rocks of the type of micaschists, amphibolites, quartz-mica schists, feldspar quartzites and gneisess of Rarău type.

The uranium mineralizations are located either directly on the lateral fractures approximately according to the structure NNW-SSE or next to support fissures.

2.3.2 Tulgheş deposit

In the Tulgheş deposit, typical for this area in a geological section, four mineralized zones can be distinguished, all having almost the same direction NNW-SSE. In the first zone, situated in the West of the deposit, mineralization occurs about 2 km along the main fracture oriented NNW-SSE, with an eastern dip of 60-70 degree.

In the second period of research in the Oriental Carpatian metallogenetic province mineralizations at Bicazu Ardelean, Pârâul Leşu, Holdiţa and Hojda have been identified. Additional exploration is required to establish the economic potential of these uranium occurrences.

3. METHODS USED FOR MINING URANIUM DEPOSITS

The uranium deposits under mining (Bihor, Banat, Crucea) generally have a discontinuous structure of mineralization, with tectonic fractures produced by a lot of faults and microfaults with reduced thickness, with inflections on inclination and direction and a reduced stability of the surrounding rocks.

The geological and mining conditions of the uranium deposits under mining (Bihor, Banat, Crucea) corroborated with the existence on the surface of the mines of water flows, sites, communication means as well as of the location of the main development works of the mines with pits and roadways, which contain important reserves in the pillars. This has led to the utilization by about 85-90% of the area with filling in the excavated space.

Although with reduced productivity, and high costs per ton of ore with reduced capacity per panel this has provided opportunities and valuable information for selective excavation of the mineralized zones; for example:

- mining parallel zones of mineralization found by cross channels at the level of the face strip;
- evidence of zones with discontinuity of mineralization or of tectonic fractures produced by a number of faults and microfaults;
- variable thickness ranging from some centimeters to meters, the inflection on inclination and on direction of the ore bodies, the display in scales of the ore lenses, imposed step by step extraction at the level of each strip of 2.5-3 m.

3.1. BIHOR MINING BASIN

Between 1952-1964, at Bihor Mining Complex, open-pit mining was adopted on a deposit of about 20,000 t U with grade over 1.4 % which at that time was considered the richest deposit in the world. At present mining is carried out only in underground.

3.2. BANAT MINING BASIN

The geological conditions of Banat Mining Complex, with unstable surrounding rocks, of average hardness, fissured and inconsistent led to the utilization of mining methods with filling in the excavated space.

3.3. CRUCEA MINING BASIN

Due to the geological and mining conditions, the mining of Crucea and Botuşana deposits of Crucea mining basin is carried out only using mining methods of horizontal, ascendant strips, with filling in the excavated space, and mining in directional chambers or staggered flanks.

3.4. TULGHEŞ MINING BASIN

For mining Tulgheş deposit, which will start after the year 2000, besides the mining method with filling in the excavated space in those parts of the deposit having small inclination, slightly consolidated surrounding rocks, and high loosening coefficient, application of mining method with caving in directional chambers can be resorted to, to avoid the danger of undercutting the close deposits.

4. MILLING OF URANIUM ORES

4.1. EXTRACTION AND PURIFICATION TECHNOLOGIES FOR THE URANIUM ORES

The Romanian uranium ores originating from the 3 mining units are processed using the same technology in Feldioara milling plant, located at about 30 km from Braşov town. The technology used is based on alkaline attack. The main technological operations in Feldioara plant are the following:

- crushing the ore to 20 mm;
- grinding in ball mills at 95% - 0.1 mm;
- slurrying the ground ore;
- carbonate eaching in horizontal autoclaves with mechanical agitation;
- sorption of uranium with resin in pulp (RIP procedure);
- evacuation of the waste pulp to the settling pond;
- washing followed by elution of the saturated resin;
- precipitation of the sodium diuranate ($Na_2U_2O_7$) from the uranium eluate;
- drying of the uranium concentrate.

The uranium concentrate from "R" Plant is present in the form of sodium diuranate (DUNa) with minimum 62% U.

The type "E" plant is located in the same site of Feldioara and is meant for purification of uranium to nuclear purity and convertUO_2, powder of sinterable quality.

The purification of uranium is mainly carried out by extraction using the solvent 30% 7BP in kerosene and the resulting uranyl nitrate is further processed to pure ammonium diuranate and then to pure nuclear grade UO_2.

4.2. EVIDENCE OF THE SOLID AND LIQUID RESIDUES

From the technological flow-sheet of type "R" plant which produces the uranium concentrate the following residues are formed:

- waste pulp which settles in the pond;
- technological waters from slurrying of the ore after grinding (part of which is recirculated);
- solutions of liquors after uranium precipitation;
- waters from technological process washing;
- rain waters collected on the surface of the plant.

"E" type plant has as main effluent "depleted" stream from solvent extraction, characterized by a free acidity of 2-3 N-HNO_3, low uranium content and other impurities. At the same time, there are supernatant liquors resulting from uranium precipitation and washing solutions. As solid product, the filtering residue is discharged. The uranium solutions pass through neutralization and precipitation steps in the plant and they are then discharged to the settling pond. These solutions have a rather high content of nitrate ions and ammonium ions. From the settling pond of the plant the top clear watery layers of composition 10-12 g/ℓ sodium carbonate and bicarbonate, 2-4 g/ℓ sodium sulphate and 1-2 g/ℓ chlorine are discharged. The residual waters from the settling pond are discharged after passing through the recovery station which separates the residual uranium using resin bed ion exchange method.

5. EVALUATION OF THE IMPACT OF THE ACTIVITIES OF EXPLORATION, MINING AND MILLING OF THE URANIUM ORES

The specific activities of the Autonomous Regie for Rare Metals in the field of uranium include generating information and knowledge on the modifications of the natural factors of the environment causing risks of contamination with radioactive elements belonging to the family of uranium and its disintegration products. Risk factors are:

- natural uranium, present as powders can pollute the atmosphere, while dissolved or in suspension it contaminates the surface and underground waters and thereby the vegetation and man;
- radium-226, can contaminate the environment in the same way as natural uranium;
- radon-222, the radioactive gas formed by the disintegration of radium-226 can contaminate the atmosphere together with its active alpha descendants.

Among the activities of Autonomous Regie for Rare Metals having potential for environmental radioactive pollution the following are relevant:

- geological and technological research;
- development studies on the uranium deposits;
- preparatory and mining works;
- industrial and social constructions on the surface of the mine;
- uranium ore milling and concentration plants;
- plants for uranium recovery by non-conventional methods;
- transportation of uranium ore and concentrates.

The followingare the pollution sources from the above mentioned activities:

- mine waters containing natural radioactive elements;
- settling ponds of waste resulting from milling process;

- sterile rocks stock-piles with low uranium content resulting from exploration and mining, as well as poor ores with 0,02-0,05 % U stored in the neighborhood of the mines;
- solid radioactive residues and used ion exchange resins, resulting from concentration process;
- uranium ores and concentrates under transportation.

5.1. IMPACT OF DISPERSION OF NATURAL URANIUM AND RA-226 FROM MINING ON THE ENVIRONMENTAL FACTORS

In order to have a more comprehensive image on the impact of the uranium ore extraction on the environment, the results of the measurements made in the last 20 years were statistically processed. Measurements were usually made on samples, collected half yearly and focused on dispersion of natural uranium and radium-226 in water, sediments, soil and vegetation.

From the interpretation of these data some specific aspects emerge, namely:

- the surface waters in the mineralized zones can have uranium concentration exceeding by 5 to 15 times those existing normally in the surface waters and 2-3 times higher as far as radium -226 is concerned; even upstream of entrance in the industrial areas there are recorded average uranium concentration 3 times higher than CMA for the drinkable water;
- the surface waters crossing the industrial areas are contaminated with uranium and radium reaching at the exit from the respective zones with concentrations 3-4 times higher than upstream;
- the discharge waters from the roadways-the most contaminated (0.867 mg U/dm^3) are at Banat Mining Complex;
- the contamination with uranium and radium is evident in the samples collected from the mining sites and even in their neighborhood up to a distance of about 50 m; at longer distances, the contamination in soil of the two radioelements are comparable with the reference values;
- the contamination of vegetation is higher at Banat Mining Complex and Bihor Mining Complex (4-5 times as compared to the reference values) and lower at Crucea Mining Complex; in the neighborhood of the mines this contamination is very reduced;
- significantly, radioactive contamination is absent in all drinking water sources in the mining areas.

A suggestive image of the distribution of natural uranium in the hydrographic basins of several mining sectors was obtained based on measurements taken weekly on water samples collected from different significant points. Based on a correlation between the geological and mining characteristics specific to the different mining units and the corresponding industrial activities, a detailed analysis regarding the degree of radioactive pollution in the respective zones is presented. At Bihor Mining Complex, the mineralized zones targeted for mining are located above the level of the basic roadway, at 720 m level and are comprising of metamorphic rocks of Bihor and Muncel series placed in the middle carbonatic level of the first series. The carbonatic level is made up of metamorphic chloritous schist rocks with porphyroblasts of albite, quartz-albiotic schists and lenses of crystalline dolomites, non-uniformly spread out both on the surface of the carbonatic level and in its thickness. The area is furrowed by lots of faults and microfaults (concordant or discordant with the inclination of the mineralization). The mine waters which wash the deposit and the mined and filled in areas are collected at the level of the basic roadway and evacuated on surface by free discharge into Poiana brook The waters having a concentration of 0 1-0 2 mg U/l are not treated before discharge The situation is identical for the waters collected on 23 roadway (continuation of "Noroc bun" ⟨good luck⟩ roadway) which are discharged into Băiţa brook, their uranium concentration ranging between 0 1 and 0.3 mg U/l Before reaching the entrance to Băiţa Plai village the uranium concentration of Băiţa brook decreases to below 0 02 mg/l Within the sites of Avram Iancu mines there are two other radioactive sources of environmental pollution for which measurements have indicated the following average values

- radiometric sorting station 0 2-0 5 mg U/l,
- old ore deposit 0 05-0 2 mg U/l

Banat Mining Complex has two productive sectors

- Ciudanoviţa having the same name,
- Lişava with the mines Dobrei Sud, Dobrei Nord, Dobrei Est and Natra

The hydrographic network of the region is represented by the basin of Caraş river, which takes over the main brooks Jitin, Gârlişte a and Lişava whose flow-rates are varying depending on the precipitations during the year, average flow-rates being in the range 0 2-0 98 m^3/sec From the examination of the general conditions and geographical events in the mine areas the presence of two types of aquifers results·

- the aquifers of carstified limestones;
- the aquifers of quaternary deposits

The most important aquifers is that of Upper Jurassic age which is larger and has a thickness of about 600 m. Limestones have an accentuated carstic permeability, due to a developed system of fissures, funnel channels and sink holes formed as a consequence of a long chemical process of dissolution The aquifers of the quaternary formations is located in diluvial formations with thickness up to 10 m

The degree of porosity of the diluvial is relatively high and allows an intense circulation of freatic waters The living rock under this cover is limestony or contains a large quantity of clay in cement, making it unpenetratable for infiltration waters
In the areas of the deposits there are 3 types of underground waters

- waters connected to faults and crushing areas;
- carst waters,
- waters from quaternary deposits

Among them, the most important contribution is that of the waters originated from faults or from the crushing areas which are also affecting the limestony or quaternary deposits Evacuation of underground waters is made by the pumping stations from

- level -250 m, -140 m and±0 blind pit no.1. Ciudanovţa and further from level +155 m on the auxiliary adit level +330 m to surface where a decontamination station is located;

- level -400 m, blind pit no.4 Dobrei Sud and further at level -200 m, -60/70 m and +143 m and of pit no.3 on surface where the second station for mine waters decontamination is located.

As compared to CMA (0.021 mg U/l) the treated and discharged waters have natural uranium concentrations ten times higher, leading to the pollution of Jitin and Lişava brooks at a distance of some kilometers. Crucea Mining Complex develops its productive activity in two distinct sectors: Crucea and Botuşana. The contaminated waters from Crucea area are evacuated to surface by the pumping station from pit no.1 and taken to the radioactive decontamination station in which uranium as DUNa is recovered. The weekly measurements on water samples collected from the exit of the station, for uranium and radium concentration have demonstrated their efficiency, the determined values being in the permissible limits, thus:

- average content at station inlet = 0.45 mg/l;
- average content at station outlet = 0.04 mg/l.

Rain waters and some accidental mine water discharges from the stock-piles represent a pollution factor for Troaca Găvanului brook, accidentally recording excessive natural uranium concentration of about 3 times as compared to CMA until the discharge in Crucea brook. Further downstream from the confluence up to the discharge into Bistriţa river, the water of Crucea brook has a natural uranium concentration exceeding twice CMA, this phenomenon being no more noticed upstream taking into account the ratio of the flow-rates. In Botuşana sector, water flowing into the environment with a concentration of about 0.35 mg U/l leads to pollution of Ion brook on the portion upstream of roadway 1/30 till the stock-pile confluence with Stoluri brook and further on for about 1 km. For eliminating this situation, it is envisaged to collect the entire quantity of mine waters from Botuşana sector in a catchment area and bringing to Crucea decontamination station whose capacity is going to be doubled. At Tulgheş deposit and at the other geological research sites, the mine waters are evacuated in rivers and no decontamination station is provided. When evaluating the impact of the uranium ore exploration-mining activities on environment, special attention was given to the waste and low grade ore stock-piles existing in the site or in the mining areas. An inventory was made of 160 stock-piles with a total area of 1,382,330 m^2 as shown in Table 1.

TABLE 1. STOCK-PILES WITH LOW U CONTENT

Unit	No. of stock-piles	Occupied areas (m^2)
Banat Mining Complex	17	210,000
Bihor Mining Complex	8	529,330
Crucea Mining Complex	30	364,000
Tulgheş II sector	74	157,000
Alba Iulia V sector	31	122,000
TOTAL	160	1,382,330

The evaluation of the radioactive contamination potential of the waste stock-piles existing in the mining zones was made by: measurement of the external gamma radiation dose level on stock-piles and in their neighbourhood and analysis for uranium and radium in water, sediments, soil and vegetation up to distances of 30-50 m and in case of water flows, downstream of the stock-piles. For the interpretation of the external gamma radiation dose level the natural gamma background levels of the zones and the maximum permissible exposure to persons from general population (0.60×10^{-6} Sv/h) were taken into account. The variations of the limits in the external gamma radiation levels measured in the investigated areas (the values of the natural background and those measured on surface of the stock-piles and at distances of 10-50 m) are shown in Tables 2 and 3.

From the interpretation of the results shown in these tables it can be noticed that values exceeding up to 2 times the gamma natural background level can be present up to 50 m from the stock-piles. From the measurements made at contact on the surface of the stock-piles it is noticed that on 14 stock-piles (16%) the measured values were within the limits of gamma natural background. On 18 of them (20%) the measured values were up to the level of Effective Dose Equivalent (EDE) for persons from population (0.60×10^{-6} Sv/h) while on 7(8%) stockpiles doses exceeded this limit. All measurements made in the neighborhood of stock-piles have indicated external gamma radiation dose levels lower than EDE for persons from population.

TABLE 2. LIMITS OF EXTERNAL GAMMA DOSE LEVELS AT THE WASTE STOCK-PILES (10^{-6} Sv/h)

Unit	No. of stock-piles	No. of measure-ments	External gamma radiation dose (10^6 Sv/h)			
			Background non-influenced zone	Background non-influenced stock-piles	Background neighbouring stock-piles	
					10 m dist.	50 m dist.
Bihor Mining Complex	17	185	0.10-0.12	0.08-2.40	0.10-0.40	0.10-0.25
Banat Mining Complex	7	166	0.08-0.12	0.13-2.50	0.08-0.30	0.08-0.18
Crucea Mining Complex	17	210	0.09-0.13	0.12-0.50	0.10-0.20	0.09-0.17
Tulgheş Section	39	360	0.07-0.14	0.09-0.40	0.11-0.30	0.09-0.25
Alba Iulia Section	9	70	0.08-0.11	0.10-0.22	0.10-0.16	0.11-0.13

TABLE 3. CLASSIFICATION OF STOCK-PILES ACCORDING TO RADIATION LEVEL ON THEIR SURFACE(10^{-6} Sv/h)

Unit	No. of stock-piles	Limits of external radiation (10^6 Sv/h)			
		0.07-0.14	0.15-0.30	0.31-0.60	> 0.60
Bihor Mining Complex	17	5	3	5	4
Banat Mining Complex	7	1	3	-	3
Crucea Mining Complex	17	1	11	5	-
Tulgheş Section	39	5	26	8	-
Alba Iulia Section	9	2	7	-	-
TOTAL	89	14	50	18	7

It can be stated that the risk of external radiation for the population is not significant even in conditions of occasionally staying close to the stock-pile. As far as the soil and vegetation samples are concerned, there was evidence of contamination with natural uranium and radium only on the sloped lands that too up to 30-50 m distance from the stock-pile, exceeding by 1-2 times the natural background. These stock-piles are in different stages of development, lacking in general of safety measures (guarding trenches, ditches, sewage of the water flows, grass plantations, afforestations etc.). As far as the ore transportation from the mines to Feldioara milling plant is concerned, by trucks or in wagons, radioactive pollution of soil and vegetation on the respective routes was noticed only at the stations where shunting and reformulation of wagon trains were carried out. At the same time, on the transportation routes, inside the mining site there was no evidence of natural uranium contamination beyond the admissible values.

5.2. EVALUATION OF IMPACT IN THE AREA OF THE MILLING PLANT FELDIOARA "R"

In the uranium ore processing and hydrometallurgical concentration plant, the main source of environmental pollution is the powders of ore or of uranium concentrates getting airborne during their handling. These powders can be dispersed over long distances indicated by the contamination of soil and vegetation. Another source of contamination is radon with its daughter products, which if not diluted by atmospheric air, can be hazardous in closed spaces. But the highest potential for environmental pollution is from the liquid effluents generated during ore processing which contain all the radionuclides belonging to uranium family the smallest constituent being the technologically retained uranium.

The "R" plant discharges daily on an average 4,500 m^3 of residual waters as pulp of density 1990 kg/m^3 to which is added about 250 m^3 of used waters. Settling is made in Cetăţuia settling pond, with an area of about 70 ha in which 6,800,000 tons of waste (3,580,000 m^3) and more than 1,000,000 m^3 of used water are stored. After settling in this pond the effluent overflows into the Mitelzop pond, with an area of about 17 ha. For recovering the residual uranium, water from Mitelzop pond passes through a process plant at an average rate of 2,880 m^3/day. The resultant effluent is then discharged into Olt river with the help of a distribution station (basin).

The waste has high concentrations of uranium and radium-226. When it is not covered with water, as it happened in 1994 when approximately 30% of the area was in direct contact with air, it can become a strong source of environmental contamination. An evaluation criterion for the pollution potential of the residues from the uranium ore concentration plants is the radon emission. Measurements made in 1994 at Cetăţuia settling pond have indicated a radon release of 8.81 $Bq/m^2/s$. In such cases it is necessary to take steps for decreasing the radon release by a factor of 12.

The residual water of Cetăţuia settling pond also has high concentrations especially of natural uranium. In the last 15 years the concentration somehow remained steady within limits and settling is not causing significant changes regarding radionuclide concentration in water with Mitelzop pond showing values close to those of Cetăţuia pond (Table 4).

In the basin, before discharge into the Olt river, the natural uranium and radium-226 content in the effluent is low, the lowest recorded was in 1994. The main reason for this can be the increase in the volume of water passing through the uranium recovery facility (Table 5).

In the Bazinet as well, before discharge into the Olt river it is noticed that the non-radioactive pollutant values are lower than the limits permitted by the authorization issued for "R" plant (Table 6).

TABLE 4. CONCENTRATIONS OF NATURAL URANIUM AND RADIUM-226 IN WATER AND WASTE COLLECTED FROM CETĂŢUIA SETTLING POND

Collecting year	Water		Waste	
	Natural U mg/dm^3	Ra-226 Bq/dm^3	Natural U mg/dm^3	Ra-226 Bq/dm^3
1978	5.163	6.852	-	-
1979	0.950	0.696	26.0	444.0
1980	4.887	0.793	9.6	63.0
1983	5.194	1.055	23.8	3518.0
1986	8.078	0.504	-	-
1994	1.667	0.086	-	-

TABLE 5. NATURAL URANIUM AND RADIUM-226 CONTENT IN SAMPLES FROM THE BAZINET

Collecting year	Natural U (mg/dm^3)	Ra-226 (Bq/dm^3)
1978	0.612	2.012
1979	0.708	1.778
1980	14.130	1.693
1983	4.843	0.533
1984	5.540	0.496
1985	3.111	0.330
1986	4.888	0.759
1987	5.700	0.481
1988	0.297	0.092
1989	2.988	0.537
1990	1.064	0.230
1994	0.078	0.049

TABLE 6. CONTENT OF NON-RADIOACTIVE ELEMENTS IN THE BAZINET

Non-radioactive elements	Content in Bazinet	Admitted limit
SO_4^{2-}	1.154 mg/dm^3	3.500 mg/dm^3
Cl^-	1.333 mg/dm^3	1.000 mg/dm^3
Na^+	2.888 mg/dm^3	4.000 mg/dm^3
NH_4^+	5.2 mg/dm^3	25 mg/dm^3
Ca_2^+	6.63 mg/dm^3	40 mg/dm^3
Mg_2^+	2.26 mg/dm^3	10 mg/dm^3
pH	10.0	8.6
Suspensions	73 mg/dm^3	300 mg/dm^3

As a conclusion, in the residual waters from the settling ponds of "R" plant, the main polluting element is the natural uranium which reaches concentrations of up to 5.20 mg/dm^3 in Cetăţuia pond and up to 1.67 mg/dm^3 in Mitelzop pond as against radium which in Cetăţuia pond is 0.021 Bq/dm^3 and in Mitelzop pond 0.086 Bq/dm^3. By settling, and especially by recovering uranium through modules from Mitelzop pond this decreases to very low values with the effluent discharging into the Olt river having 0.078 mgU/dm^3 and 0.049 Bq Ra/dm^3.

Water and sediments of Olt river are not polluted radioactively, the concentrations of uranium and radium downstream of the effluent discharge being lower than CMA for drinkable water.

The waste not covered with water in the ponds is a source of environmental pollution due to carry over of the powders by air currents, with concentrations of uranium up to 1,544 g/t and of radium 8,818 Bq/kg. High radium content in the waste is also indicative of a high release of radon which is as much as 8.81 $Bq/m^2/s$ with significant potential for atmospheric pollution. The waste in the ponds, being regularly covered by water, has not contributed to soil and vegetation contamination in the neighbourhood of ponds, the uranium and radium content in the analyzed samples being comparable with those in the areas not exposed to contamination.

6. MEASURES TAKEN FOR LIMITING THE RADIATION AND CONTAMINATION EFFECTS IN THE ZONES WITH MINING ACTIVITIES AND URANIUM ORE PROCESSING

Environmental radioactive contamination in the zones of uranium exploration, mining and milling has been controlled for more than 30 years as one of the main tasks of the Research and Designing Institute for Rare and Radioactive Metals (I.C.P.M.R.R.). This is achieved through the following measures:

- systematic monitoring of the environment in all the units of Autonomous Regie for Rare Metals through fixed points of surveillance and periodical collection of samples;
- a ventilation and dosimetry unit follows the radiation exposure of the employees in the working area;
- control of the health status of the people both in the working environment and in the neighboring zones;
- installations for dust removal at the ore crushing, sorting and processing operations;
- each unit is equipped with washrooms for personnel and installations for washing the safety equipment and transport vehicles;
- the general ventilation of the mining units is provided through ventilation stations sized so as to ensure the radon concentration in the mine air is below the authorized maximum permissible limits through dilution;
- each working place with dead-end is equipped with partial air circulation fans which operate during the shift;
- for decontaminating the mine waters treatment plants were provided for Banat and Crucea mines;
- for treatment of water from "R" plant settling pond, a decontamination facility was provided.

The technological flow-sheet for the decontamination facility is based on retention of uranium on ion exchange resin bed (sorption) followed by regeneration (elution) with sorption of sodium chloride and sodium carbonate (eluant).

A special problem which has not yet been faced but will become a reality very soon is related to the cessation of underground activities and abandonment by flooding of some sectors of mines (Natra, Ciudanoviţa). The following aspects needs attention:

- accumulation of considerable volume of static water in the development, preparatory and underground mine workings;

- loading of the natural waters with uranium and decay products of its family, agravated by conditions prevailing underground;
- depth of formulation of the rocks, their porosity, numerous fractures and microfaults which facilitate uncontrolled circulation of water deep underground with the existence of the risk of contamination of underground water table;
- lack of hydrogeological studies and systematic analysis pertaining to circulation of the underground water;
- lack of experience in the settlement of all the problems connect with closure of a mine in compliance with international regulations.

7. RESTORATION PLANS FOR THE ENVIRONMENT IN THE IMPACT ZONES OF THE URANIUM EXTRACTION AND ORE PROCESSING ACTIVITIES IN ROMANIA

7.1. TECHNICAL ASPECTS

The problems regarding environmental restoration have at present other dimensions as compared to those of the past decades when the maximization of product output was of priority and the aspects connected with environmental protection were treated as less important. In order to eliminate the risk of radioactive contamination with long term effects in the field of uranium extraction and processing it is necessary to intensify the efforts and to use appropriate technologies for diminishing these adverse effects. In this connection elaborate short and long term plans or programmes need to be drawn up, to be financed both from Romania's own resources and more importantly from some international bodies who have commitments to the aim of such programmes.

Taking into account the complexity of the problem and the incipient stage of this activity in the field of uranium ore mining and milling in Romania it is proposed to carry out studies and prepare documentation to help develop a suitable strategy recognizing the ground realities and in compliance with international norms, in the following lines:

- technological studies and research for establishing the most effective methods of decontaminating the radioactive liquid effluents (mine waters, waters from the plant);
- studies for environmental rehabilitation of all the mines and geological research with the objective of identifying the tasks to be executed (a feasibility report was drawn up in 1995);
- analyses on environmental impact for all the rehabilitation programmes with characterization of each zone (mines closure, removal of installations, preservation of the stock-piles, etc.);
- research on the evaluation of the exposure to population in the rehabilitation zones: sources of contamination or radiation, radionuclides of relevance, transportation pathways and affecting environmental factors;
- delineation of critical groups of the population;
- establishing criteria for selection of the objectives and the zones to be rehabilitated;
- experiments for establishing procedures for covering the stock-pile and soil studies on the migration of the radionuclides and other pollutants to the underground water table;
- studies for establishing the conditions for utilization of waste, buildings, equipment and material originating from the uranium mines;
- establishing the criteria for ecological rehabilitation of uranium ore extraction and processing facilities;

- establishing the maximum permissible limit for the exposure to nuclear radiations of the population from the critical group in the zones where environment is to be rehabilitated,
- establishing the permissible limits for decontaminating different soils - agricultural soil, pastures, forests;
- establishing the concentrations permissible in the underground water table for radionuclides belonging to uranium and thorium family as well as other pollutants accompanying the radioactive ores;
- establishing the criteria for radiological and chemical characterization of the zones affected by radioactive and other pollutants (As, Cu, Zn, Pb, Ni);
- drawing up of the control and monitoring methodology for the activities in the uranium field, at the units in operation and at the units which are or being closed;
- working out value of investment necessary for achieving the new objectives on environment protection and rehabilitation.

For the implementation of the environmental rehabilitation programmes, a lot of technical and administrative support measures are necessary, such as:

- setting up within RAMR structure of a workshop for executing environmental restoration operations (Fig. 1);
- setting up laboratories for specialized technological studies, research and for the environmental control (monitoring) including the equipment for radiological protection;
- necessary equipment and ecological rehabilitation techniques, decontamination facilities, transport means, etc.

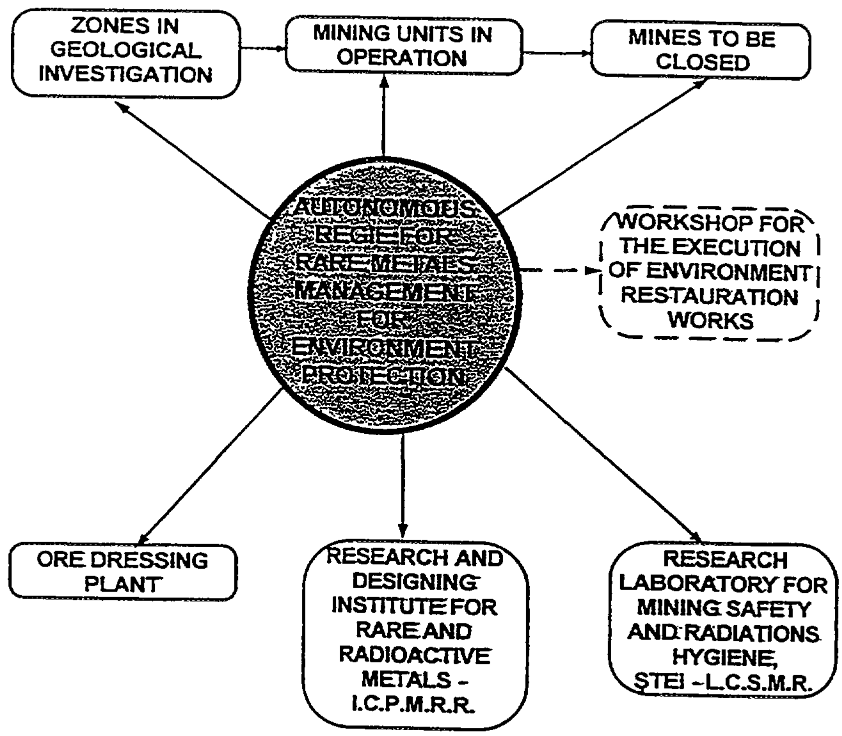

Fig. 1 Implementation system of the programme for environment restoration to Autonomous Regie for Rare Metals

Taking into account that the main sources of pollution are the radioactively contaminated waters, the mill tailings, low grade ore stock-piles and the settling ponds from the sites of the ore processing plants, the environmental protection and rehabilitation works in the areas affected by the activities of RAMR's units, should consist of:

(a) Mining sites

- collection of rain waters from the low grade ore stock-piles and of the mine waters and their joint decontamination in suitable facilities;
- protection of the mill tailings and low grade ore stock-piles;
- land reclamation;
- closing some sectors of mines.

(b) Platform of "R" Feldioara plant

- strenghtening of the protection dams (impermeabilization) and settling ponds;
- improvements in the efficiency of decontamination facility for residual waters, including retention of Ra-226;
- reduction of the contamination potential of the existing settling pond after removal of uranium contained in it;
- restoration (covering, plantation, etc.) of the waste stock-pile after removal of uranium from the existing settling ponds.

Along with the above, medium and long term monitoring of the respective areas after completion of the restoration works is envisaged. In the framework of the rehabilitation plans for the environment related to the mining zones it is proposed to examine the possibility for utilizing the wastes of uranium ore, especially those with radioactive elements at natural background level (development of roads, railways, open or closed constructions, etc.) and find solutions for implementation. Taking into account the actual situation regarding uranium mining in Romania, the programme of environmental protection and rehabilitation has as top priority, two components of highest importance namely:

- programme of development for restoring the land of the former uranium open pit from Bihor Mining Complex to the original condition, and
- programme of closing some sectors of the mines belonging to Banat Mining Complex, Dobrei-Sud, Ciudanoviţa (Fig.2).

7.2. ECONOMIC ASPECTS

In the framework of the feasibility report drawn up in 1995 by the Design and Research Institute for Rare and Radioactive Metals-Bucharest concerning environment protection and ecological works in the areas with geological, mining and milling activities of the Autonomous Regie for Rare Metals costing of these activities were carried out based on which the total financial requirement is estimated at USD 11.7 m. The breakdown is indicated in Table 7.

The physical works taken into account in this stage include the following:

- support walls: 6,400 m;
- rain water collecting trenches: 48,675 m;

- stock-piles consolidations: 10,850 m;
- arrangements of brooks: 1,300 m;
- absorption shafts: 940 m;
- resin plantations: 142,450 m^2;
- plantations of trees: 5,600 m^2;
- grass plantations: 378,810 m^2;
- radioactive decontamination stations-module: 6 numbers.

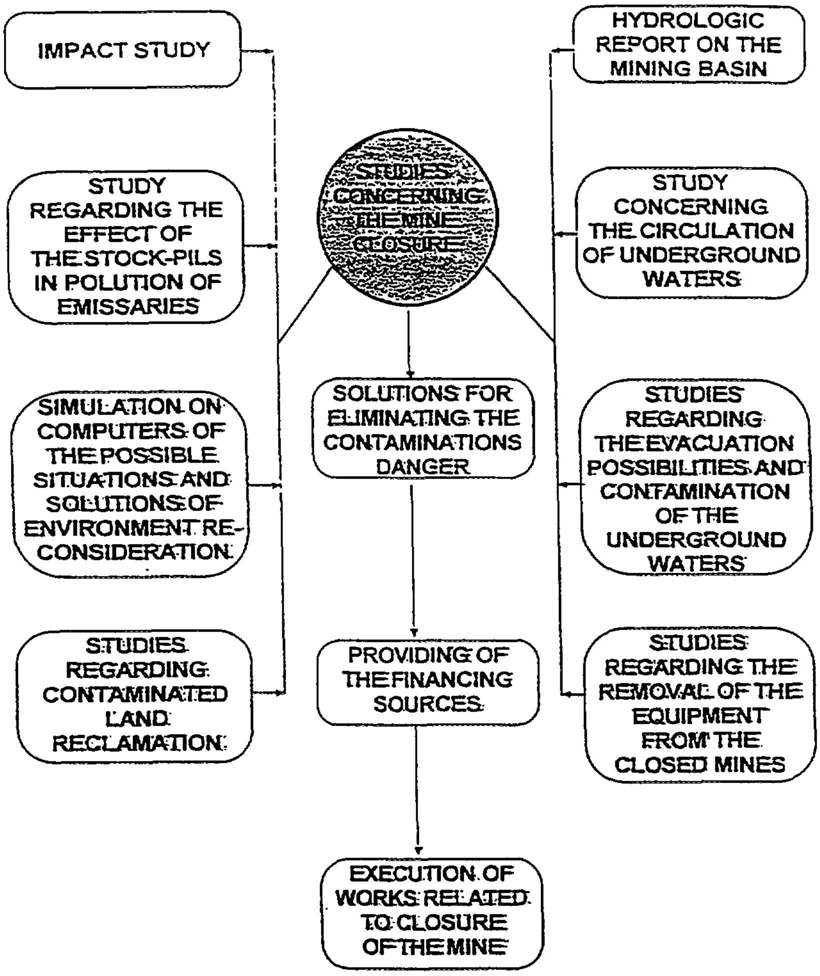

Fig. 2 Programme for closing an uranium mine

TABLE 7. EVALUATION OF INVESTMENTS NECESSARY FOR ENVIRONMENT RESTORATION WITHIN R.A.M.R. (THOUSAND USD)

Time-schedule	Unit						
	Crucea M.C.	Bihor M.C.	Banat M.C.	Tulgheş	Alba Iulia	"R" Plant	TOTAL
Year 1	1,000	1,178	1,430	715	160	285	4,768
Year 2	1,036	1,250	1,430	715	178	357	4,966
Year 3	342	442	575	370	30	198	1,957
TOTAL	2,378	2,870	3,435	1,800	368	840	11,691

8. CONCLUSION

From the situation described, regarding the environment pollution level in the areas affected by more than 30 years of activities pursued by RAMR in the field of uranium which included geological investigation, mining and milling of uranium ore, the following activities and their priorities for the programme of environmental remediation are identified:

a) Activities where the operations have ceased among which we mention could be made of:
Natra mine belonging to Banat Mining Complex with a depth of more than 750 m;
Băiţa open -pit within Bihor Mining Complex;
about 160 waste stock-piles or low grade ore located in 10 counties;
geological investigation and mine workings, abandoned or placed under surveillance in 3 basins, Banat, Bihor and Eastern Carpatians.
b) Activities where the operation is on with high potential for environmental pollution, include among others:
Feldioara milling plant, with a settling pond of about 5 million tons and approximately 1 million cubic meters of used water;
Bihor Mining Complex with its 2 mines Avram Iancu and Băiţa;
Banat Mining Complex with its 3 mines in operation;
Crucea Mining Complex with 2 mines in operation;
Geological investigation and mine workings located in Eastern Carpatians, Apuseni Mountains and Banat Mountains.
c) -Activities in which the prospects of reduction or cessation of operations is visualized for the near future, which include among others:
closing of Ciudanoviţa and Dobrei mines with depths of over 700 m within Banat Mining Complex;
closing or reduction of activity of the mines located in Bihor basin.

Regarding the strategy for reducing environmental pollution and implementing environmental restoration measures in the near future a programme for the next 3-5 years has been drawn which includes the following:

- continue to identify the affected zones and evaluate the radiological risk of pollution sources;
- establish the conditions to be created when closing major nuclear activities (mines, plants, geological investigation roadways);
- evaluate the quantities of ore existing in various stock-piles and storages and establish procedures for recovering uranium in case it is economical;
- develop schemes for decontamination of radioactive liquid effluents;
- establish compatability of safety norms with international norms and practices;
- take steps for implementing concrete measures for environmental rehabilitation and landscape restoration;
- organize special task groups within RAMR, specialized in execution of environmental restoration works;
- monitor to maintain continuous control on environmental pollution both for radioactive and other pollutants with a view to take steps to reduce the ecological impact.

The first stage of the feasibility study confirmed the concerns and the role of RAMR which was elaborated in the report "The works for environmental protection and ecological restoration in the areas with geological, mining and milling activities within RAMR" which was approved by the Government and estimated at about 12 million US$. The necessary funds will be provided by financing from the state budget and from RAMR's own sources as well as by attracting foreign sources (PHARE programme).

The works envisaged mainly consist of:

- setting up radioactive decontamination facilities for the mine and industrial water wherever they exist;
- stock-piles consolidation;
- impermeabilization;
- water channeling;
- land levelling, covering with soil, plantation and reclaiming for the forest cultivation;
- extension of the settling pond of the milling plant and safety upgradation for the existing pond;
- setting up laboratory for studies and research in the field of radiological protection;
- mobilize units specialised in environmental restoration with equipment and facilities specific to decontamination and transport;
- preparation of design documentation for the execution on site of the proposal.

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ENVIRONMENTAL RESTORATION PLANS AND ACTIVITIES IN THE RUSSIAN FEDERATION

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Abstract

The report deals with the status of environmental restoration of uranium-contaminated sites and the methods to reduce radionuclides concentration in the solid and liquid wastes as well as their utilization potential. Attention is given to the waste utilization in agriculture and civil engineering construction. With this in view, the paper deals with waste water purification and applicable standards for natural radionuclides content in solid waste for utilization in construction activities. All works are carried out in accordance with the Special Complex Programme for environmental restoration of contaminated uranium mining and milling sites caused by the activities of the industries engaged in nuclear materials production for the Ministry of Atomic Energy of the Russian Federation. The Programme is an integral part of the Federal Programme "Conversion of Russian Defense Industries in 1993-2000 ".

1. INTRODUCTION

The Special Complex Programme for environmental restoration of contaminated uranium mining and milling sites includes seven sub-programmes. Two of them are general for the industry and relate to the development of standards and methodology applicable to rehabilitation as well as to radiation, health and environmental monitoring of the areas under rehabilitation. The other five sub-programmes cover focused research, design and production activities at the Minatom sites of the Russian Federation to be rehabilitated.

Rehabilitation of contaminated land areas calls for a system of management, science and engineering, social and medical measures directed for restoration to environmentally normal conditions for living and production activities. It includes decontamination, removal of radioactive and toxic materials from the sites to be restored (land, water, equipment, building, constructions) and recultivation of disturbed land (restoration of landscape, productivity and agricultural value of disturbed land). An indispensable part of the rehabilitation system is radiation/environment monitoring over the land and other entities to ascertain conditions before and after rehabilitation, thereby making it possible to evaluate the adequacy and effectiveness of rehabilitation measures.

2.CLASSIFICATION OF CONTAMINATED AREAS

Within the sites contaminated with radionuclides, the environmental safety criterion for humans is the extent of admissible risk. The basic dose limit for population is the effective dose equal to 1 mSv per year, which corresponds to the individual risk level 7×10^{-5} per year. The environmental assessment of radioactive contamination of soil is to be carried out for two indices: the exposure dose rate at 1 meter from the soil (mR/h) and radioactive contamination by single isotopes (Ci/km^2). The situation is considered relatively satisfactory at an exposure dose rate up to 20 μR/h and radioactive contamination due to caesium-137 up to 1 Ci/km^2 and with strontium-90 up to 0.3 Ci/km^2. The environmental situation is considered as extraordinary at the exposure dose rate 200-400 μR/h and radioactive contamination by caesium-137 at 15-40 Ci/km^2 , strontium-90 at 1-3 Ci/km^2 and total plutonium at more than 0.1 Ci/km^2 .

The lands with a population dose exceeding 1 mSv per year require decontamination and recultivation is to be resorted to for further productive use. The sites with the annual dose 1-3 mSv per year(hazardous sites and areas) require certain protection measures to be taken. The sites with the effective radiation doses exceeding 5 mSv per year (over background values) present an extraodinary ecological situation. These areas are subject to first order priority in rehabilitation. The areas with the annual dose over 5 mSv are prohibited for living. The criteria chosen for assessing the ecological condition of soil depend on its locality, genesis, buffer state as well as on its utilization plan.

3. PRIORITIES AND PLANS

Priority rehabilitation order applies to the following areas:

- those with effective annual dose over 1 mSv;
- those with exceeding maximum permissible concentration of toxins in soil, water and air;
- those contaminated sites situated in densely populated areas;
- those with old radioactive waste burial sites, requiring reburial due to non conformance with present Sanitary Standards;
- those under risk of damage due to potential adverse effect from nuclear facility to be phased out or decommissioned;
- those where social and productive activity are worth the rehabilitation efforts, based upon adequate feasibility study.

The total area contaminated with radionuclides and toxins from the Russian Federation Minatom facilities and institutions previously engaged in nuclear weapon production comprises 72,000 hectares. The figure includes 12,400 hectares under production sites, 37,300 hectares under sanitary protection zones and 22,300 hectares under surveillance zones. There are 48,600 hectares of contaminated land, 23,400 hectares of water reservoirs (including 9,500 hectares of underground burial sites). More than 5,000 hectares are contaminated with radionuclides, the exposure dose intensity being over 200 μR/h.

The uranium mining and milling contaminated sites subjected to rehabilitation are the following:

- production sites of pits and mines under working or phasing out conditions, or decommissioned ones;
- production sites of uranium in-situ leaching;
- production sites of operable, reconstructed and decommissioned dressing mills and hydrometallurgical plants;
- sites occupied with tailing dumps, ore stores, barren rock and off-grade ore stores, sites of heap leaching;
- surface areas contaminated with dumped mine waters and technological solution leakages from pipe-lines.

From the total allotted land area which was 22 000 hectares, 32 % were disturbed by dumps, 25 % - by open pit excavation, 21 % - by production sites, 12 % - by tailing dumps and 10 % - by other kinds of waste generating facilities. Regardless of the fact that the disturbed land areas are not very large in comparison with other branches of mining facilities, rehabilitation measures should be undertaken for the reasons of threat that radiological contamination could spread to the adjacent areas. The growing land cost should also come into consideration.

4. REHABILITATION PROGRESS

4.1. Restoration works on uranium plants

In 1993 1,042 hectares of contaminated areas were rehabilitated, in 1994 - 800 hectares, in 1995 - 985 hectares and in 1996 - 763 hectares. Special attention was given to restoration works on largest uranium plant in Russia now, "Priargunskyi mining-chemical enterprise"(Krasnokamensk city, Siberia). Area rehabilitated was 24 hectares and the unit for purification of mine waters was commissioned during this year. At the old closed uranium mining-chemical enterprise "Almaz" (Lermontov city, Stavropolskyi krai) all rehabilitation works on mine and tailing dump have been completed.

4.2. Decontamination and utilization of wastes

4.2.1. Solid Wastes

All technological operations in mining and processing uranium ores leave solid, liquid and gaseous wastes liable to enter the environment. At present, uranium is obtained by mining uranium ores followed by processing in hydrometallurgical plants or by recovering it by underground (in-situ) leaching of uranium ores. In the first case, the ensuing wastes are solid rocks with uranium concentration below economically viable treatment level and mine water. The activity of solid rock is mainly determined by uranium. The impact of solid wastes on the environment in uranium mining is due to the fact that they are usually stored in open dumps or heaps. The natural radionuclides (NRN) migrate as ore dust or can be washed out from the dumps by atmospheric precipitation. In spite of the fact that uranium content in the dumped waste comprises mere hundredth fractions of one per cent, its concentration in the wash-out waters can still exceed the permissible concentration value.

Solid wastes originating from mining operations are recommended for recycle in the following ways thereby reducing the chances of radioactivity entering the environment and causing environmental impact:

- utilization of the wastes for grout fillings, embankments, etc.;
- filling holes in disturbed surface of lands, ravines, etc. followed by recultivation of land;
- construction of ore storage, industrial buildings foundation;
- construction of motor roads and railways.

In Russia, the specific activity of NRN in construction materials used for residential community buildings should not exceed the values: ^{226}Ra - 0.37 Bq/g, ^{232}Th - 0.26 Bq/g, ^{40}K - 48 Bq/g. The solid wastes can be recycled in industrial and civil construction without limitation if the uranium concentration is below 0.003%, the radium equivalent below 0.37 Bq/g or total alpha activity less than 22.2 Bq/g.

This classification is a reliable basis for the development of reasonable reuse criteria of wastes. However, this will require changes in the mining technology for more precise separation of the rocks according to their activity level and separate storage. Still, the expenditure on technological changes to achieve radiometric separation will pay off, since the solid waste storing is rather expensive. Large quantities of solid wastes can be utilized as filling. The main problem here is the selection of grouting materials and abatement of radon emitted into the mine atmosphere.

The All-Russian Research Institute of Chemical Technology has developed a unique technology for treatment of solid uranium waste (dump fields) generated as a result of uranium-processing. This has been tested on commercial scale. The end results of this development are construction materials and decontaminated and recultivated land are suitable for further civil use.

4.2.2. Liquid Waste from Uranium Mining and Milling Facilities

Recycling of waste water from uranium mining and milling activity has proven to be economical and a means of saving resource in support of environmental preservation. The water recycling systems installed at an uranium processing facility is on an average 10 times cheaper than a set-up for sanitary water cleaning of similar capacity. The fresh water required by a facility that has changed to water recycling system would be 8-10 times less. The mine liquid wastes can be cleaned by the adsorption method in plants with a capacity of 100 to 3600.m^3/h. The uranium concentration in mine water reaches several mg/l, and that of radium and other NRN - about 3.7 Bq/l, which is much higher than permissible concentration level and hence requires decontamination. The major factors having influence in decreasing the mine water impact on the environment are the local decontamination and control over its use in industrial and community water supply. The uranium can be recovered from water using various types of ionites. The ionites are characteristic of high capacity for uranium in low concentration range. AM-10XП anionite is preferable. At the uranium concentration of 5 mg/l in 2 g/l sodium sulphate solution, the AM-10XП capacity reaches 25-30 mg/g, exceeding the AM and AMП capacities by 1.5-2 times. The increased selectivity of these anionites for uranium leads to some deceleration of adsorption rate, but the adsorption front remains still active enough for effective recovery of uranium under dynamic conditions up to a residual concentration level of 0.1 mg/l. Utilization of carboxyl cationites of CГ-1 type from water with pH=7.0-7.5 and calcium content 100 mg/l seems hardly expedient, since these cationites absorb large amount of calcium and magnesium, which transit into regenerants and an additional cleaning of the same would be required. On the basis of data obtained, integrated schemes have been developed for cleaning mine water from uranium deposit with complex salt content, the NRN cleaning efficiency reaching 90%. The technological schemes have been developed taking into account the mine water type and the NRN form present. The major operations of the developed schemes and the sequence of steps are as follows:

- cleaning from suspensions, NRN and bacterial impurities in a mixer and thickener using barium chloride, polyacryl amide, aluminium sulphate and tri-sodium phosphate, followed with recleaning from suspended particles on filters;
- treating mine water with barium chloride, surfactants, followed by recovering of uranium from the suspension filtrate on AMП anionite;
- treating mine water with barium chloride or pyrolusite, surfactants with ferrous aluminium sulphate, followed by the recovery of uranium via ion-exchange on a vinylpyridine anionite BP-1AП.

The above schemes have been introduced at the facilities. To sum up, at the present there have been technological schemes developed suitable enough for cleaning mine water from uranium, radium and other nuclides. Therefore recycling of this water for further utilization is an essential condition for preventing the impact on the environment.

4.2.3. Decontamination of equipment

A tangible achievement in nuclear fuel cycle is the feasibility to decontaminate and utilize to a limited extent construction materials contaminated with radioactivity. The process of complex decontamination and retreatment of decommissioned equipment of nuclear power stations, uranium plants and mines, radiochemical and other facilities of the nuclear fuel cycle include one or more of the following operations (Fig.1):

- decontamination of equipment at the working area prior to dismounting;
- dismounting, air-plasma cutting, mechanical dismembering;
- liquid decontamination of the metal scrap;
- thermal decontamination of the metal scrap and its remelting;

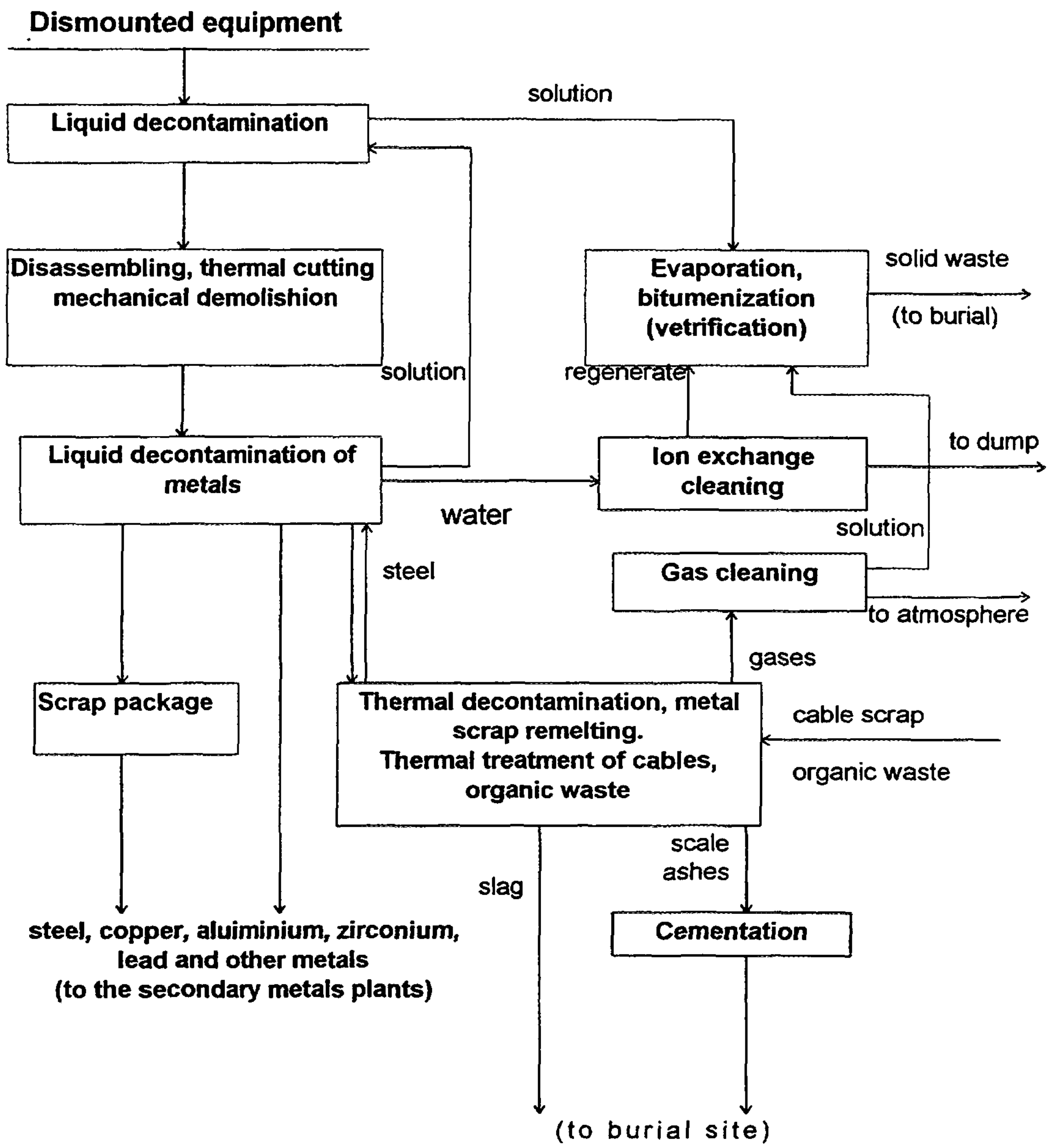

Fig.1. Complex treatment of radiatively contaminated equipment, metal and organic wastes

- processing of ensuing secondary solid, liquid and gaseous radioactive wastes (decontaminating solutions, released gas, cinders, slurries, ashes).

In liquid decontamination techniques nitric acid solutions are widely used. But some surface etching takes place there and the base metal enters the decontamination solution along with radionuclide contaminants. Therefore some other reactant which would have much less capacity to dissolve the base metal and selectively disintegrate the radionuclides adsorbed on the surface will be more appropriate. Such properties are characteristic of fluororganic acids (trifluoro-acetic acid), freons doped with alcohols, alcohols as well as certain products of E.S.Decon Co., (Holland), presenting low-toxic water-soluble compounds: mono-ethyl amine, mono-substituted ethers of diatomic alcohols, alcohols and sulpho-acids. Accordingly Decon-375, a product demonstrating the best test results, containing mono-ethyl amine, mono-methyl ether of dipropylene glycol and sodium alkyl benzosulphonate was selected.

Later on, the decontamination was done with domestically produced cleaning products of the KÓK series, similar to the E.S.Decon's preparations and with approximately same chemical composition. The products of the KÓK series are easily decomposed by biological means. The compounds within the blend composition contain ether and ester groups, carboxylic, oxy- and amine groups, aliphatic radicals. Their structural peculiarities make them easily digestible by micro organisms.

Under the actual condition of the Chernobyl power station, the best equipment decontamination results were attained with the E.S.Decon (Holland) and KÓK (Russia) products, though other compositions also satisfactorily removed radioactive contaminants. The main nuclides causing radioactive contamination of metal scrap are potassium-40, radium-226, thorium-232, uranium-238. The specific activity of the radionuclides is as follows: potassium-40 - $2.6 \cdot 10^2$ Bq/kg , radium-226 - $1.5 \cdot 10^2$ Bq/kg, thorium-232 - 5.6 Bq/kg, uranium-238 - 21.1 Bq/kg. The metal wastes are subjected to a one-stage thermal decontamination in electric furnace at 800-1050°C for 5 hours. The thermal treatment over, the metal wastes are cooled in the electric furnace and directed to the descaling operation. The residual activity on the metal surface is typically $9.9 \cdot 10^{-2}$ Bq/kg and that of the scale - $4.4 \cdot 10^{-1}$ Bq/kg. After the thermal decontamination, the metal wastes are directed to the remelting operation. The purified metal is shipped to metallurgical facilities as fused ingots.

5. CONCLUSION

To sum up, at the present time the harmful impact of uranium mining and milling complexes on the environment and rational utilization of natural resources require large-scale research carried out within the framework of target national programmes aimed at handling radioactive wastes. The programmes should be implemented by introduction of scientific and management/ engineering decisions at different levels and scale. The effectiveness of the decisions must be determined on the basis of economic viability taking into account the ground realities of the country. The ecological strategy of the uranium production industry must be enunciated on the basis of reducing the radiological impact on the environment. The cleaning of mine waters from uranium, radium, polonium with co-precipitants and coagulants, recovery of uranium by using highly selective ionites, collecting the mine waters in special ponds prior to further utilization in industry and agriculture - an approach which will facilitate a decreased freshwater consumption and prevent radionuclides entering the environment needs careful consideration. Science and technology measures for the equipment decontamination and recycling of metal scrap as raw material for certain applications have been developed and can be applied in practice.

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ENVIRONMENTAL RESTORATION PLANS AND ACTIVITIES IN SLOVENIA: 1995-1996 PROGRESS REPORT

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Abstract

This report gives a brief status and description of new developments in the remediation activities which are going on at Žirovski Vrh Uranium Mine site during the last two years. The progress of the implementation has slowed down compared to the plans. Reasons for that are: (a) legal problems (responsibilities between two authorized governmental agencies) in the procedure for obtaining location permit for the long-term site remediation of the wide exploitation area, particularly for the mill tailings disposal site; (b) lack of funding. However, some tasks have been performed during this period in the field of investigations, reporting to the authorities, design and to a lesser extent actual implementation. The investigations have concentrated on the hydrology of the site underground waters, radiological site characterization and investigation of locally available materials for constructing the cover of the waste disposal sites. On the basis of RŽV's Environmental Impact Report, Slovenian Health Inspectorate has officially set authorized limits for radioactive pollutants emission for mine water and mill tailings and mine waste disposal sites. Detailed drawings of the mill site decommissioning have been presented to the authorities. Approval by the authorities is expected to be granted soon. This represents the last stage in the procedures for obtaining permissions before the field work at the mill site can be formally started. The problem of the mill tailings earth slide has been successfully solved by constructing geotechnical underground water drainage structures including vertical dewatering wells.

Some research and investigation projects are in progress to promote knowledge on radiological site characterization, water pathway emission of the pollutants and to identify required materials locally available for the mine waste and the mill tailings cover construction. Measurements of the radioactivity in Žirovski Vrh Uranium Mine environment and assessment of its environmental impact are being continued.

1. INTRODUCTION

The Project on Environmental Restoration in Central and Eastern Europe started with the first workshop in Budapest in 1993 to identify radiologically contaminated sites in those countries. Four workshops have followed with different topics closely linked to the environmental restoration of the uranium production sites, problems connected with radiological characterization of the sites and implementation of the sites remediation as well. Thanks to the efforts of the participants a good picture about the status of the uranium production and broad plans for future development in the participating States has emerged.

Compared to the large extent of contaminated sites in some other countries, the situation in Slovenia is rather small, with only one closed down uranium mine. Extensive exploration works in the mine area started in 1968 and the production of yellow cake which commenced in 1984 ended in 1990. The whole project was conceived in the time frame which enabled taking advantage of the accumulated experience in the implementation of environment protection principles. During the period of operation 620 000 tons of ore had been extracted and 452 tons (U_3O_8) of yellow cake produced. Quantities of waste materials - 700 000 tons of mill tailings and 1 600 000 tons of mine waste - on two disposal sites are still awaiting remediation. In the production phase there were 500 employees in the company. The Slovenian parliament passed the Law on Permanent Close-out of Uranium Ore Exploration in 1992 , two years after the decision of the Slovenian Government to stop production of yellow cake [1, 2].

At present there are 115 employees in the company. The main task of the company is management of the mine site remediation in a safe and environmentally sound way. Parallel activities are maintenance of the mine and its surface structures, mill buildings and waste sites maintenance as well as protecting the equipment against damage and avoid additional burden to the surroundings. The company is also engaged in contracting the design and engineering works, research and investigations, construction, drilling works etc. The control of environmental impact of the emission of radioactive and chemical pollutants is being continued. The air and water pathways of radioactive pollutants are measured, sampled, analyzed and evaluated.

The whole area of the company owned land amounts to 74 ha, out of which 60 ha are operational areas. Business and storage buildings areas cover 10 000 m^2 and 8 000 m^2 cover roofed production areas. During the exploitation 60 km of mine tunnels of cross section from 4 m^2 to 17 m^2 were built. The location of the mine and mill facilities is shown in Fig. 1., and the underground structure of the mine in an area of 1.5 km^2 is given schematically. Vertical elevation of the mine is from 430 m to 580 m which is the highest level.

2. NATIONAL CONDITIONS REQUIRING ENVIRONMENTAL RESTORATION

The territory of the Republic of Slovenia is not considerably polluted with radioactivity. The general public opinion is to keep this condition on the low side as much as possible and the use of nuclear energy, ionizing sources and production of radioactive source materials should be minimized in future. The same attitude prevails towards the Uranium Mine Žirovski Vrh. In this case, without doubt, the site remediation must be done professionally and in an environmentally sound manner. The objective is to bring down the equivalent dose commitment from 0.35 mSv to 0.15 mSv or lower for the critical group. Regardless of the small contribution to the equivalent dose commitment the impact on the water environment must be minimized[3].

One of the objectives of site remediation is to return as much of the land as possible back to public use without any institutional control for the long-term future. Active institutional control (long-term maintenance and monitoring of the effluents) has been foreseen for the mine waste disposal site and mill tailings.

3. LEGISLATION, REGULATIONS, POLICIES

Three authorized governmental regulatory agencies exercise control over the uranium mine and its remediation plans from radioactivity point of view: Slovenian Nuclear Safety Administration since 1992, Mining Inspectorate and Health Inspectorate since the start of the mining and milling. Other inspectorates involved are Water Management Inspectorate and Fire Inspectorate. Since the mine and mill operation permits were issued years ago (exploitation permit), and did not include remediation plans, it is clear that the site remediation plans must pass the current procedures applicable to obtaining permit for location and construction. It is also valid for the Uranium Mine Žirovski Vrh. There are also differences of opinion regarding responsibility and interactions of the two governmental administrative agencies: the Slovenian Nuclear Safety Administration and the Mining Inspectorate.

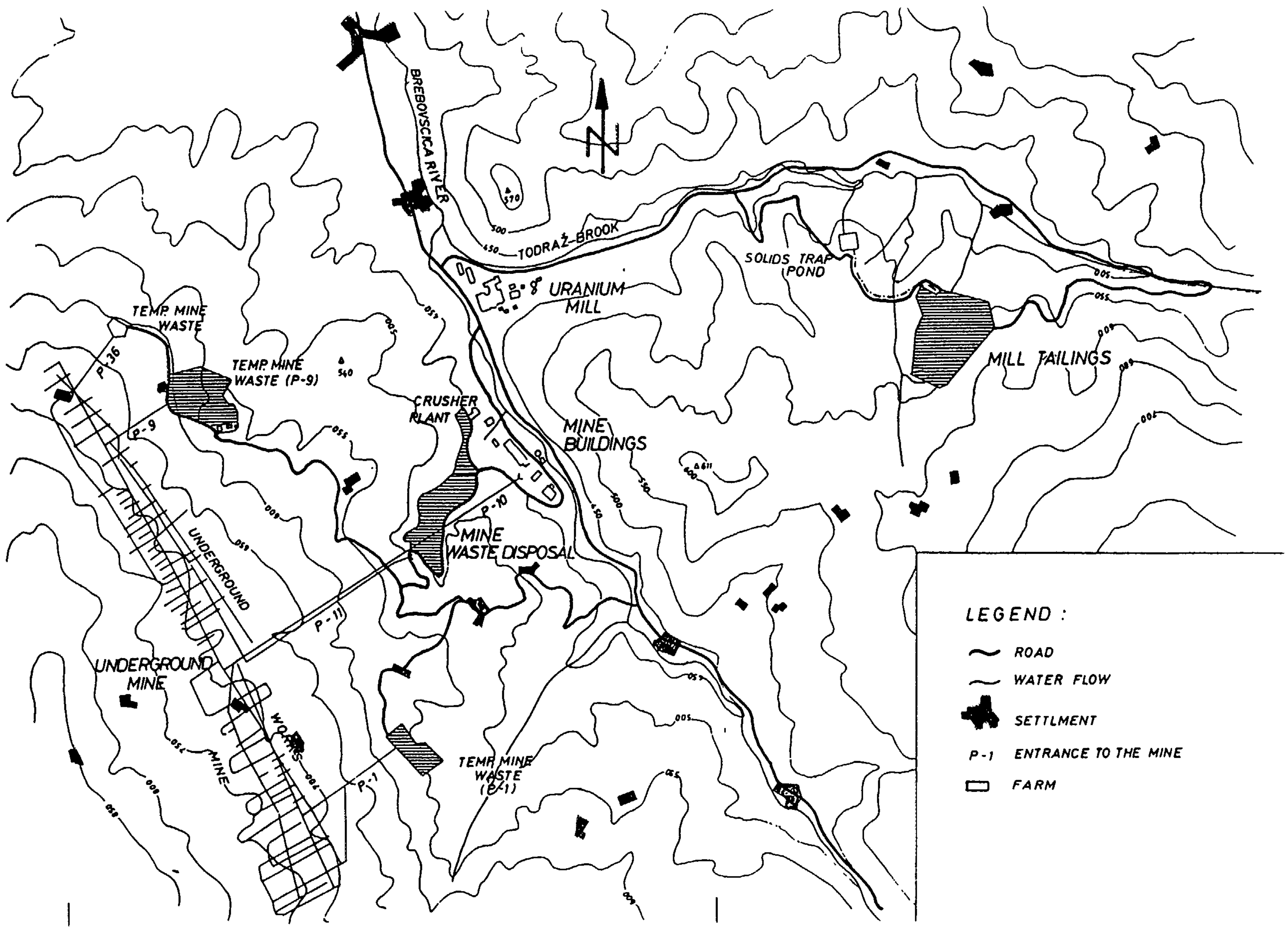

FIG. 1. Uranium Mine Zirovski Vrh Production Site.

As reported previously the mill site location permit (the decommissioning part for some process buildings) was granted in September 1995 [2]. The construction permit (the decommissioning of the equipment and demolition of some buildings) is expected to be granted in October 1996.

Application for location permit for the whole mine exploitation (production) site remediation including Environmental Impact Report had been addressed to the authorities almost a year ago [4]. This permission has been held up since the Slovenian Nuclear Safety Administration questioned the proposed mill tailings siting solution, e.g. the existing place. They have asked for additional safety evaluations on the long-term location of the mill tailings [5]. However, a limited location permit for all mine exploration area was granted very recently. The exemptions are the mill tailings and the mine waste disposal sites.

Authorized limits for different points of emission were officially granted to the Žirovski Vrh Mine by the Health Inspectorate. Some of them are given as maximal concentration limits and also as yearly maximum limits. Table I indicates authorized limits. Radon-222 exhalation rate must be below 0.7 $Bq/m^2.s$ for mill tailings disposal site and below 0.1 $Bq/m^2.s$ for mine waste disposal site. Two different numbers are given due to different contribution to the equivalent dose commitment from these two sources by the air pathway. Mill tailings are located above the average winter temperature inversion layer and mine waste disposal site is located under the temperature inversion layer. Due to laminar air flow movement the impact of the lower site is much larger than that from the mill tailings. Gamma dose rate must be below 0.2 μGy/h for all remediated areas. Annual effective dose to a member of a critical group must be below 0.3 mSv [3].

TABLE I. AUTHORIZED LIMITS

	Uranium		**Radium 226**		**Other**
	μg/L	**kg/year**	**Bq/m^3**	**MBq/year**	**Bq/m^3**
ENTRANCE CONTROL POINT					
Run off mine water	250	170	60	50	
Mine waste disposal drainage water	510	85	40	25	100 [a]
Mill tailings ^{222}Rn exhalation rate					0.7 [c]
Mine waste disposal site ^{222}Rn exhalation rate					0.1 [c]
EXIT CONTROL POINT					
Todraž Brook - collector of all mill tailings waters			60	50	
Brebovščica River - collector of all Žirovski mine area waters	50 [b]		40		

a - Sum of Th-230, Pb-210, Po-210

b - Regulation on Hygienic Irreproachability of the Drinking Water[9].

c - $Bq/m^2.s$

4. RADIOLOGICAL CHARACTERIZATION

Corresponding radiological characterization of the Žirovski Vrh Uranium Mine site was given in Environmental Impact Report [4]. Annual effective dose for a member of a critical group was estimated to be from 0.3 to 0.37 mSv/year [6, 7, 8]. Uranium and Radium-226 average concentrations in Brebovščica River are 13 μgU/ℓ and 7 Bq $^{226}Ra/m^3$ respectively. Uranium concentration in Brebovščica River swings up to 25 μgU/ℓ due to the Brebovščica River flow changes. The mass flow of Uranium with the run off mine water is quite regular. Gamma dose rates in the region range from 100 nGy/h to 200 nGy/h as background. Exceptionally, uranium ore bearing surface rocks with gamma dose rates up to 5000 nGy/h can be detected as a natural occurrence.

In the last two years additional bore holes were drilled for underground water quality investigation at mill site, the mine waste disposal site and at the control point below the whole mine facilities site (borehole BS 26), Fig. 2 [6, 9]. The table II shows the comparison of the obtained results for the mill site and the control point of the underground water against the maximum concentration of constituents for ground water protection stated in the US NRC report [10]. Also the borehole No. 3 disclosed some solid uranium contamination under the yellow cake precipitation site. The area is limited to a few tens of square meters, certainly, this is the source of uranium contamination of the mill site underground water.

Generally the surfaces of the mine area are less contaminated than the mill areas. Gamma dose rate is up to 1000 nGy/h (background 160 nGy/h), Alpha surface contaminations are from 0 to 18.3 Bq/100 cm^2 (average 0.7 Bq/100 cm^2), Beta surface contaminations from 0 to 330 Bq/100 cm^2 (average 7.8 Bq/100 cm^2).

Areas and process buildings are radioactively contaminated as follows. Gamma dose rates are from 30 to 1 600 nGy/h, Alpha surface contamination from 0 to 37 Bq/100 cm^2, Beta surface contamination from 0 to 6 000 Bq/100 cm^2. Radon-222 concentrations are from 50 to 13 000 Bq/m^3 of air (one case), average under 250 $^{222}Rn/m^3$ [3].

5. ACTIVE PROJECTS UNDERWAY

As mentioned in earlier papers Uranium Mine Žirovski Vrh site remediation is progressing very slowly [2, 6] for the reasons already mentioned. Irrespective of this, some activities are in progress. Details are given below.

5.1. Investigations and design works

(a) Chemical and radiological monitoring of the entrance and exit points is continued for air and water pathways on previously determined schedule.
(b) New bore holes have been drilled for underground water investigation in the vicinity of the mine waste disposal site and mill tailings. The results have not been studied yet, radiological contamination has been detected [9].
In some cases radioactive contamination of ground water have been detected such as at the mill site. Old borehole (VPO-1 drilled in 1993) was contaminated by the movement of the plume of contaminated ground water (detected in 1996), lower concentrations have been observed in the second borehole (VPO-2 drilled in 1993) than in the observing year 1994. This was possibly due to migration and dilution processes[9, 12].

(c) Locally available materials (tuffs, loamy sandstones, clays and bentonites) for engineered cover of the mill tailings and mine waste are investigated as well Their permeability and confinement of Radon-222 are studied as well as the mechanical properties

(d) Case studies for mill tailings and mine waste site emission of radioactive and chemical pollutants have been carried out, including some modeling and calculations to forecast long-term impacts by water pathways

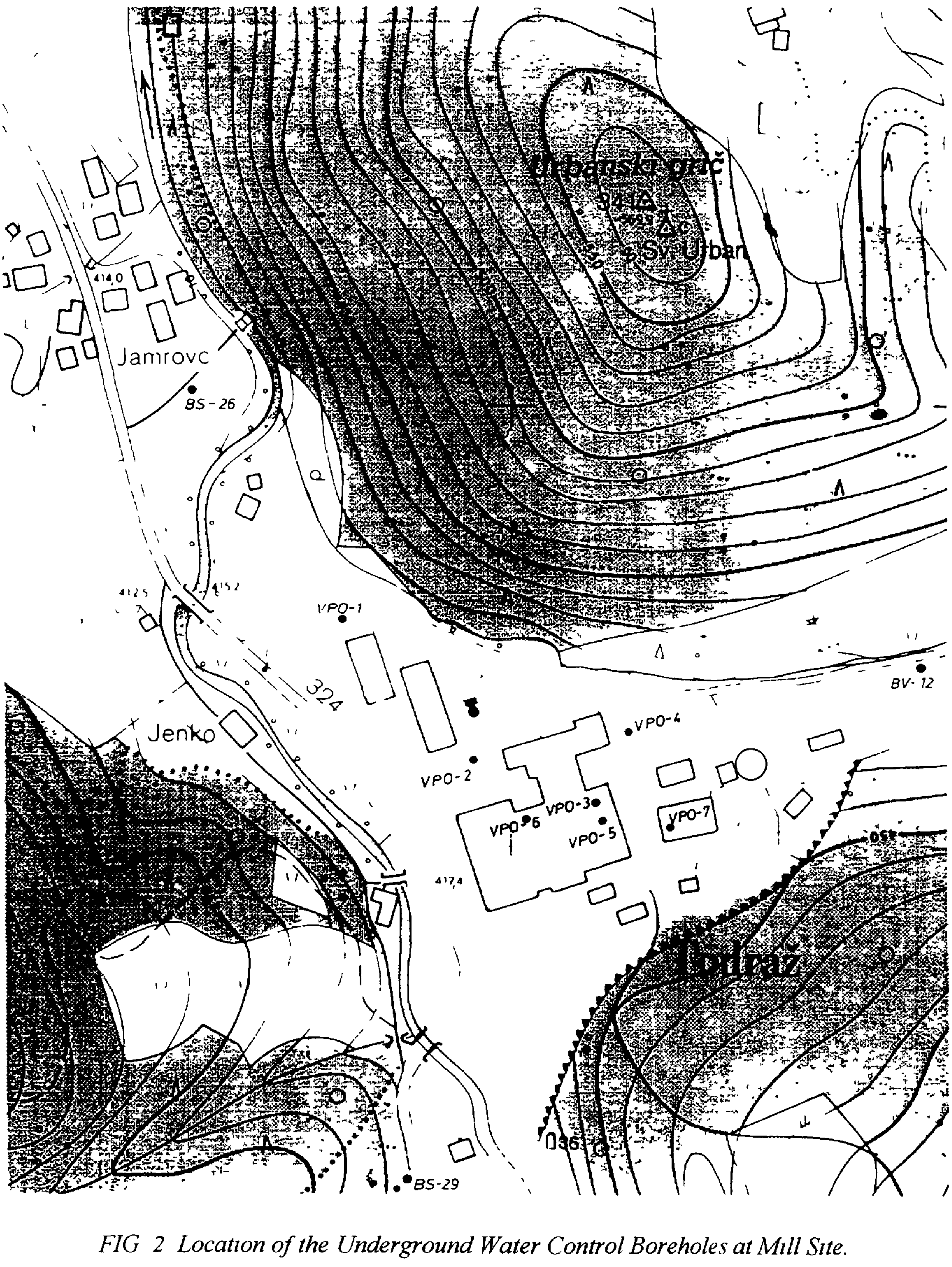

FIG 2 Location of the Underground Water Control Boreholes at Mill Site.

TABLE II. CHEMICAL COMPOSITION OF THE UNDERGROUND WATER FROM THE MILL SITE BOREHOLES

CONSTITUENT	UNIT	VPO-1 2/2 Sept. 96	VPO-2 2/2 Sept. 96	BS-26 Jul. 96	Max. Conc. of Constituent [a]
Conductivity	mS/cm	0.359	0.555	-	-
pH		8,0	8.0	8.2	-
Ammonia	mg/L	0.11	0.13	<0.1	-
Uranium	mg/L	<0.0005	0.044	<0.009	0.044
Arsenic	mg/L	<1	<1	-	0.05
Barium	mg/L	<0.1	<0.1	-	1.0
Cadmium	mg/L	<0.02	<0.02	-	0.01
Chromium	mg/L	<0.1	<0.1	-	0.05
Lead	mg/L	<0.2	<0.2	-	0.05
Mercury	mg/L	-	-	-	0.002
Selenium	mg/L	-	-	-	0.01
Silver	mg/L	<0.05	<0.5	-	0.05
Nitrate (as N)	mg/L	-	-	-	10
Molybdenum	mg/L	<0.2	<0.2	-	0.1
Zinc	mg/L	0.8	0.03	-	-
Sulphate	mg/L	11	12	4.4.	-

a - Subpart A Standards for the Control of Residual Radioactive Materials from Inactive Uranium Processing Sites [10]

(e) Detailed decommissioning design of the mill site is being continued. The drawings were finished for decommissioning of some mill buildings. It is expected that the construction permit will be granted soon. Then, the field works like demolition of structures can officially start.
(f) Detailed drawings for mine waste disposal site improvement of the underground dewatering pipelines have been submitted for approval.
(g) The reasons to initiate activities by the company for obtaining the quality assurance (ISO 9001) certificate have been reviewed. The management believes that the introduction of limited quality assurance procedures will be the most important and demanding long-term task. There is no point in obtaining the quality assurance certificate for the company, because the company will be liquidated when the site is rehabilitated.
(h) Detailed study of the mine waste disposal drainage water flows has been done to determine remediation actions.
(i) The bidding procedure is going on to find a contractor who will design the waste management steps and underground disposal of the wastes from decommissioning of the mill in a part of the mine.

5.2. Implementation activities in the field

(a) The mill tailings drainage tunnel construction was finished along the whole length.
(b) Geomechanical works are being continued to stabilize the mill tailings site. The contractor is drilling the next eight vertical boreholes (wells) to drain underground water via drainage tunnel in order to lower the existing underground water table. There will be 11 out of 21 drainage boreholes installed till the end of the year.

(c) At the lowest point of the mine some mine dewatering structures were remediated.
(d) Almost 50 tons of the mill equipment have been dismantled, decommissioned and has been sold for reuse at steel mills. For long-term disposal in the mine, the waste material and equipment are packed into 2 m^3 containers and temporarily stored at the mill site.

6. PRIORITIES AND PLANS

The main and most urgent priorities are to obtain all the missing location and construction permits for the exploitation area including the mill tailings and the mine waste disposal sites. This would enable continuation of the rehabilitation works for the whole exploitation area. The key to this is to reevaluate the decision making procedure all over the mill tailings location referring to the three existing possibilities as it has been requested by the Slovenian Nuclear Safety Administration. Then the state has to provide the funds for tailings and mine waste remediation works to be carried out in 1998 and beyond. Steady cash flow as planned is necessary for proper execution of the activities to avoid interruptions after they are started. The financial structure for the next year has already been worked out[13].

7. NEAR -TERM SCHEDULE AND PROSPECTS

The plans for remediation works at the site for the year 1997 are:

- Total decommissioning of the mill equipment.
- Demolition of some process buildings.
- Long-term reinforcement of the mill tailings drainage tunnel.
- Relocation of the mine waste materials from the temporary storage areas.
- Obtaining all the necessary drawings.
- Continuation of the studies and investigations in the field.

8. DIFFICULTIES ENCOUNTERED OR ENVISIONED

Problems expected are the following:

- funding of the project activities in the field of mill tailings disposal and mine waste disposal remediation. These are demanding projects and require steady funding. When the activity is started it is difficult to stop without severe consequences;
- maintenance of the mill tailings surface to keep integrity of the tailings against erosion due to the storm fallout.

Part of the remediation works will be done by contractors in the future, because the skilled workers are leaving the company. The main reasons are limited personnel development and uncertain social status of the employees.

9. CONCLUSION

The delays due to poor funding and planning will make the whole project of Žirovski Vrh Uranium Mine remediation more expensive than it was expected. As side effects of delays problems arise due to lack of trained specialists, maintenance of the mine and mill structures, project and company management, last but not the least the public opinion, etc. Efficient remediation of the uranium production site is as important as the construction.

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RESTORATION ACTIVITIES IN URANIUM MINING AND MILLING FACILITIES IN SPAIN

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Abstract

From the end of the 80's up to now, several tasks have been carried out in Spain on restoration in the field of uranium mining and milling, significant among them being Andújar Uranium Mill (FUA) closure and La Haba closure. Also, a study has been carried out on restoration of inoperative and abandoned uranium mine sites. At present, detailed plans are being worked out for the project on the closure of the Elefante plant. All activities have been developed in the common framework of national standards and regulations which are generally in compliance with the standards, regulations and recommendations of international organizations. This paper describes briefly the standards and the criteria applied to the restoration tasks at various sites of the uranium mining and milling facilities in Spain. The restoration activities have different characteristics: La Haba facility is an isolated and conventional facility to produce uranium concentrate; in the case of old and abandoned uranium mines the intervention criteria is more relevant than the activities to be carried out; the closure (the first phase of licensing) and restoration activities of Elefante plant have to be developed taking into account that it is sited within the area of Quercus plant which is currently in operation.

1. INTRODUCTION

From the end of the 80's up to now, Spain has been carried out several works on restoration in the field of uranium mining and milling, such as Andújar Uranium Mill (FUA) closure and La Haba closure. Also, a study has been carried out on restoration of inoperative and abandoned uranium mines. At present, details of the project for closure of the Elefante plant which was built for producing uranium concentrates are being worked out. Also, under development is the closure plan for Quercus plant, which is currently in operation. This closure plan includes a study on the safety and security of the plant.

All these installations (excepting the FUA) belong to the company "Empresa Nacional del Uranio S.A. (ENUSA)", responsible for the preparation of closure plans and facilitate licencing. This company is also responsible for managing the radioactive wastes during the operational phase. Once the operational phase ends the company "Empresa Nacional de Residuos Radiactivos S.A. (ENRESA)" takes responsibility for the management of radioactive waste as per the closure plan. The company "Empresa Nacional de Ingeniería y Tecnología S.A. (INITEC)" provides engineering support to ENUSA and ENRESA in the design and licensing aspects of the closure plans. All activities have been developed in the common framework of national standards and regulations which are in general compatible with the standards, regulations, recommendations and practices followed by international organizations.

The standards and general as well as specific criteria applied to individual sites, and the details of various restoration works developed are described in the following section.

2. STANDARD USED

The regulations and standards applicable have been established by the Spanish Nuclear Council (CSN), taking into account the recommendations of international organizations (ICRP, IAEA and OECD/NEA).

The following is the order of priority for the application of Standards and Regulations:

1.) Spanish Nuclear Safety Council stipulations described in the document "Radiological criteria for the closure of uranium mining and milling installations", (April 1995, draft)
2.) Spanish standards, except in cases where it is obligatory to fulfil the European Union Standards on Security Criteria for specific facility.
3.) ICRP, IAEA, OECD standards in this order.

The following table summarizes the applicable Standards classified under two groups. The first is basically related to all aspects of Radiological Protection of workers and the public in general and includes European Union, ICRP, IAEA and OECD Regulations and Standards. The second includes the US legislation with quantitative and qualitative aspects specific for this application.

COUNTRY/ ORGANIZATION	STANDARD	RESPONSIBLE ORGANIZATION	CONTENT SUMMARY
SPAIN	R.I.N.R.	M.I.E.	- Administrative Authorizations Rule - Requirements for the Facility Classification
	R.P.S.R.I.	Presidencia del Gobierno	- Standards for Radiation Protection
	Drinking Water Regulations	Presidencia del Gobierno	- Maximum concentration in drinking water
	Law about ENRESA creation	Presidencia del Gobierno	- ENRESA responsibility
USA	10 CFR 40 Appendix A	NRC	- General Design Criteria to assure stability without maintenance
IAEA	SS-44		- General Criteria for stabilization and surveillance of tailings - Waste Management
	SS-43		- Radiological Safety
	SS-26		- Radiation Protection of workers
ICRP	N° 24		- Radiological Protection
	N° 30		- Limits for intakes of radionuclides by workers
	N° 60		- Radiological Protection

The Radiological Protection aspects are common to Nuclear Industry and are generally well known. On the other hand the requirements for a Stabilization Project concerning protection and long term durability are as follows:

1.) The protection will be designed as reasonable and practical, to be effective in any case for 200 years.
2.) The project will offer adequate guarantee for Rn-222 emission rate not to exceed 1 Bq/m^2s averaged over the whole surface of the cover.

3.) The concentration of radionuclides more significant from the radiological impact viewpoint in the soils next to the site, will be less than 1 Bq/g over natural background concentration.

3. GENERAL DESIGN CRITERIA

The general criteria which apply in the execution of closure and restoration operations are as follows:

- *Long term stabilization:*
  The final design will be carried out in such a way that guarantees for long term stabilization have to satisfy external intrusive factors.

- *Postclosure impact:*
  The final design will be carried out in such a way that the radiological and environmental impact is kept to the minimum. The radiological impact will be as near as possible to natural background values of the area. With the aim of achieving this, the release of radon and radioactive particulates as well as surface and ground water runoff will be closely controlled.

- *Minimization of visual impact:*
  The final design will have technical features which allow, wherever possible, integration of the affected areas into the environment.

- *Minimization of maintenance:*
  The final design will be carried out in such a way that requirement of extensive maintenance and elaborate control measures are avoided.

- *Minimization of storage:*
  The number and volume of storage requirements will be as low as possible.

- *Minimization of the rainfall collecting area:*
  The size of the rainwater collecting areas will be kept as low as possible to minimize the effect of erosion and inflow.

- *Protection against wind and erosion:*
  The topographic features of the land will be such that the gradients will be small and suitable for protection against wind. The land will be covered with a cover of vegetation.

- *Minimization of the risks:*
  The remediation activities will be carried out in such a way that they do not cause unacceptable risks to the public or the environment.

4. CLOSURE OF SPANISH FACILITIES

Examples of application of Criteria and Standards specified above are:

4.1. Closure of "La Haba" facility

The experimental plant for uranium ore treatment "Planta Lobo-G" is sited in "La Haba" township (Badajoz).

4.1.1 Facility description

The objective of this facility was to produce uranium concentrate as final product, with a content of approximately 90% of U_3O_8. The facility had a treatment capacity of 103 000 tons per year of ore capable of producing 32 tons per year of U_3O_8 maximum.

Hydrometallurgical treatment using acid was adopted for producing uranium ore made up of pitchblende, coffinite, phosphouranolite, autunite, sabugalite and copper uranita, the last two being the most plentiful.

The process developed in this facility consisted of the following steps:

- Ore preparation: reception and storage in heap (low-grade) and in ore-yard (ore); grinding (ore); and classification (fine and coarse fraction ore)
- Leaching: "in situ" leaching for low-grade ore; "in situ" leaching for coarse fraction ore; and conventional leaching for fine fraction ore
- Solid-Liquid separation and preconcentration (fine and coarse fraction ore)
- Concentration (coarse and fine fraction of ore and low-grade ore)
- Final product (precipitation, dried and packed)
- Neutralization
- CIX plant: pilot facility to demonstrate the continuous ion change in fluidized bed column, with the object of studying the recovery of uranium contained in low concentration solutions.

In the first years of plant operation, a small dam was built to deposit the exhausted heap or old heap. When this dam was filled, a new dam with higher capacity was built. This dam is 20 metres high, 277 metres long and has a capacity of 101 000 m^3.

In the mineral extraction and treatment operations the following types of waste have been generated:

a.) ***Rock wastes (overburden waste piles)***: coming from open-pit operations in the burrows carried out to have access to the ore. These materials were initially stored in overburden waste piles and later transferred to excavated mine holes (transfer mining).

The volume of rock wastes depends on established threshold cut and the mining activities carried out in the open-pit mine. The lens has been worked with a threshold cut of 200 ppm until 1986 and later of 300 ppm, based on which a conservative estimate indicates that the average content of uranium in the heap is 200 ppm.

The specific activity of all radionuclides in the U-238 chain (U-234, Th-230, Ra-226, Rn-222 and Pb-210) in this heap is 2.1 Bq/g in secular equilibrium. Similarly, the specific activity of each radionuclide in the U-235 disintegration chain is only 0.1 Bq/g, and as such its contribution to the overall radioactive inventory can be disregarded.

b.) ***Leached waste (heap leaching)***, exhausted poor mineral coming from "in situ" leaching operations. The volume depends on the initial ore grade and the treatment capacity of the plant.

The average specific activity of radionuclides in the U-238 chain present in the exhausted ore is: 2.1 Bq/g for U-238 and U-234 each and 4.2 Bq/g for Th-230, Ra-226 and Pb-210 each, assuming a leaching efficiency of 0% for these nuclides.

c.) ***Tailings (tailings piles)***, coming from the dynamic leaching facilities. Stored in dams or buildings in the vicinity of the plant.

The specific activity of the radionuclides in the disintegration chain of U-238 present in these tailings is 2.4 Bq/g for U-238 and U-234 and 12.5 Bq/g for Th-230, Ra-226 and Pb-210, assuming a leaching efficiency for these nuclides of 0%.

The following table summarizes the inventory of leached wastes existing in the facility at the beginning of 1990 and the surface area occupied by the rock wastes:

Heap leaching number	tons (piled ore)	Overburden piles	Surface (m^2)
3	53 437	Current	139 169
4	39 992	Old	76 402
5	72 261	Mª Lozano	53 616
6	30 190		
6 (coarse)	26 000		
7	93 477		
8	23 000		

The quantity of tailings is 80 284 tons and are stored in tailings pile.

4.1.2 Specific criteria applied in the closure and restoration

4.1.2.1 Structures, Buildings and Equipments

The criteria for exemption of material generated from uranium mill dismantling are the following:

- Beta and gamma emitters and low toxicity alpha emitters: < 0,4 Bq/cm^2
- All other alpha emitters: < 0,04 Bq/cm^2

These values have been obtained from SS n°6 "Regulations for the safe transport of radioactive material", IAEA Vienna.

4 1.2.2 Tailings pile

The stabilization of the tailings pile will be carried out in such a way that the following criteria are fulfilled

- The stabilization works will reduce the radon flux values to lower than 1 Bq/m^2s, averaged over the entire dam surface, taking account of the radon flux in the site

- The stabilization works will be executed according to the closure criteria based on the eventual objective of conservation and maintenance

- Generation of liquid effluents due to the circulation of runoff water in rainy times is avoided

- Reuse of exhausted ore that involves an undesirable risk to the public and the environment (e.g. housing construction) is avoided

4.1.2.3 Rock waste and mine site

The criteria applied will be those established in the Royal Decree 2994 about Restoration of Natural Space affected by Mining Activities.

4.1.3 Closure programme characteristics and closure operations

4.1.3.1 General Aspects of the Programme

- "In situ" stabilization of tailings pile, consolidating and protecting it against atmospheric attack by construction of a cover which also fulfils the relevant requirements in the basic criteria
- Site restoration to the conditions as they originally existed before the activities pertaining to the facilities started

- Decontamination of buildings and equipment to levels specified in the criteria for free or unrestricted use In case such levels are not reached the items will be incorporated into the tailings pile Another alternative is reuse in another similar installation.

- Incorporation of the contaminated soils into the tailing conforming to the relevant criteria

4.1.3.2 Description of the closure programme

The closure activities are summarized in the following paragraph

Structures, Buildings and Equipments

There are three possibilities (not mutually exclusive)

1) Decontamination of materials, subjecting to storage without protection or transfer to other installations,

2.) Moving reusable equipments as "contaminated material" to another similar installation, taking into account the applicable Standard on Transportation of radioactive materials; and

3.) Dismantling and demolition of the plant and incorporating the generated wastes into the tailings.

The alternative 1) requires an analysis of the techno-economic viability of decontamination. The alternative (2) is likely to be carried out only with a limited number of equipment. In the case of alternative (3) it would be necessary to determine the volumes which could be incorporated into dam like contaminated waste dumps and the definition of cut-off level of the previous volumes.

Tailings pile

The first tailings pile which contains the process coarse fractions, has been conditioned through levelling of the "in situ" leach heap, closing it and also making suitable natural drainage systems.

In the new dam, water is getting evaporated and is being forced through sprinkler irrigation over the water-collecting area of the dam.

For the attenuation of radon emission caused by Ra-226 disintegration, a layer of clayey material coming from the overburden waste pile will be placed with adequate thickness to reduce the external dose to the level stipulated in the criteria. In the case of tailings pile, besides sterile materials layer, a layer of leaching heap is placed over it. The actions related to the new dam will be carried out when the water which partially fills the dam, gets eliminated.

In order to protect the clayey material of possible demoisturizing, it will be covered with a sand layer. Finally, the whole pile will be protected with a layer of soil that makes easy the implantation of the roots of vegetation in order to integrate with the environment (Fig. 1).

Natural Land

The extent of soil cleaning will depend on the contamination level and the criteria stipulation. First a sampling will be done to determine the Ra-226 concentration and the cleaning need. The contaminated soils will be incorporated into the tailings pile and the excavated area will be filled with fresh soil.

Mine Site

Once the Open-Pit Restoration Plan is implemented the area will be covered with consecutive layers of sterile dense material, coming from the heap Mª Lozano, until the foreseen level of land restoration is reached. This will act as a barrier against the radon emission with adequate thickness to fulfil the design criteria for shielding.

Rock waste (Overburden waste piles)

Some of them do not require special treatment since from the beginning, cell covers and bench covers have been carried out thereby strengthening their stability and decreasing the effects of erosion.

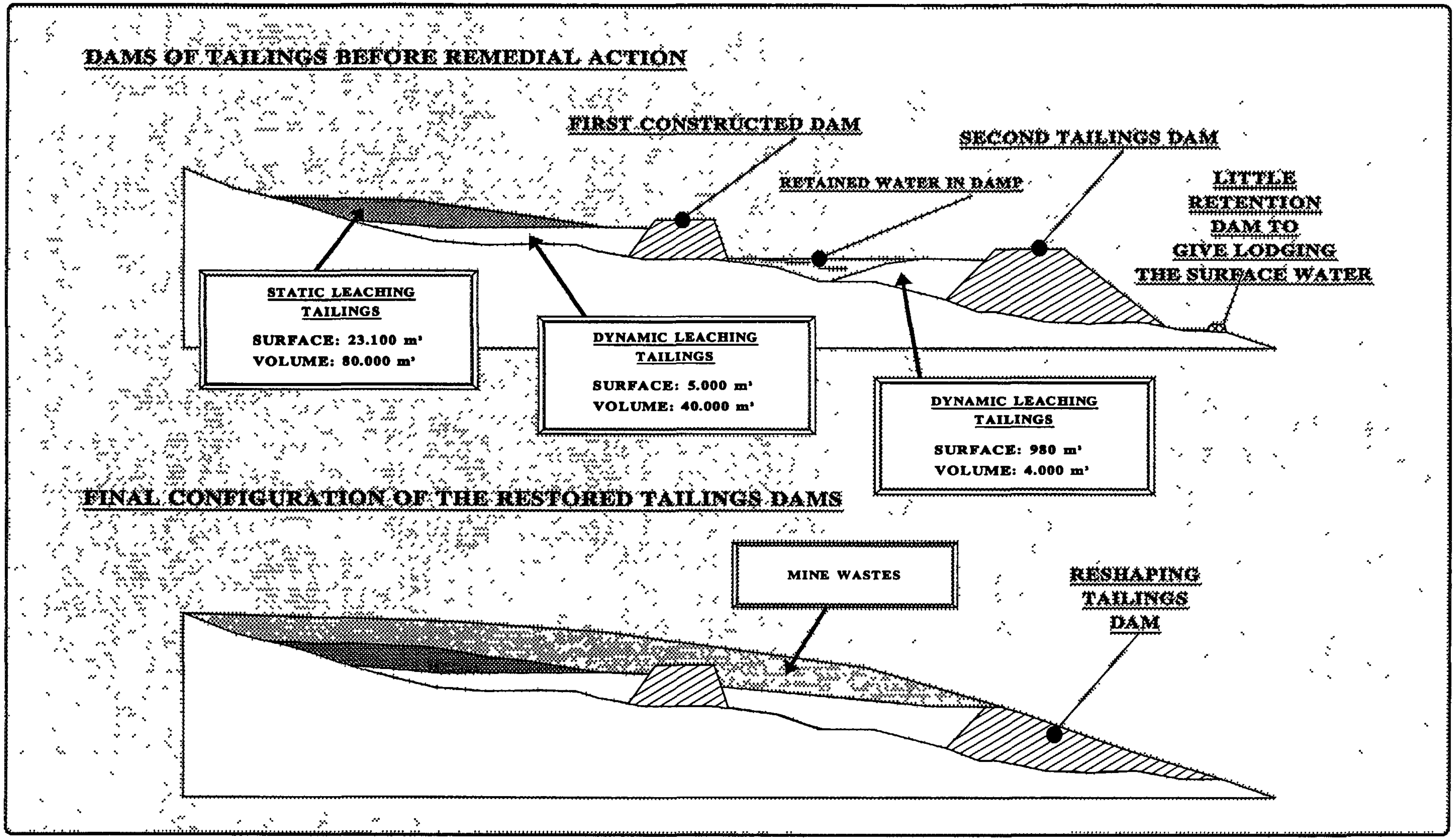

FIG.1. LA HABA. DAMS OF TAILINGS, BEFORE AND AFTER RESTORATION WORKS

4.1.4 Restoration carried out

To carry out the closure and restoration of a site, the following tasks are involved:

1.) Radiometric evaluation of the site:
   - Structures, Buildings and Equipments
   - Natural Land
   - Tailings pile
   - Heap leaching
2.) Decontamination and/or dismantling and demolition of treatment plant
3.) Decontamination of the natural land
4.) Stabilization works of tailings pile
5.) Restoration of the open-pit
6.) Stabilization of the overburden waste piles
7.) Implantation of the autochthonous vegetation species or hydrosowing

These tasks are carried out according to the general design criteria developed based on the above.

4.2. Restoration plan for inactive and abandoned uranium mines

Environmental Analysis of 26 shut down uranium mine sites, located in the West and South of Spain has been carried out.

4.2.1 Main features of the sites

The mining activities, carried out from 1950 to 1975 have resulted in the following site conditions having environmental impact:

1.) Underground ore extraction structures: unsealed pits and open shafts.

2.) Topographical and environmental alterations (Aesthetic impacts): pits, trenches, cavities, gradings, scarfings, loss of vegetation, soil, etc.

3.) Land occupied by waste rock piles and mining structures becoming unproductive.

4.) Mine and support buildings in bad condition.

5.) Radiological impact on the sites in two exposure pathways: air (radon flux, direct radiation and particle emission) and surface water and ground water (natural leaching of waste rock piles, particle releases and ground water flow distribution variations).

The mining sites show wide variation in their condition. For example:

- While in some sites there is hardly any trace of mining works, others have large waste rock piles and surface excavations.

- There are 24 sites where underground operations were carried out and only two are open-pit mines.

- The average radiation levels at contact on the existing waste rock piles range from 50 to 250 μR/h with an average background contact level in nearby sites at 45 μR/h.

- The average Radium concentration in wastes rock piles range from 1 184 Bq/kg to10 360 Bq/kg.

4.2.2 Assessment criteria

To identify the relative impact due to the mining works, an analysis was performed by comparing the situation which existed previous to mining with the current situation. Prior to mining works, the main features for radiological pathway were:

Land: Undisturbed geology typical of a mineralized area, modifications in radon flux, external radiation

Air: Existence of Rn-222, external radiation, low particles emission

Ground Water and Surface Water: natural contamination (radiological and chemical)

4.2.3 Intervention criteria for the different exposure scenarios

The final results of the detailed radiological and environmental assessment, are analysed according to the following criteria (Fig. 2):

- Nowadays, the intervention is justified when the maximum individual effective dose is greater than 0.1 mSv/y. When the individual effective dose is less than 0.01 mSv/ intervention is not required and it is necessary to evaluate other risks to justify any action.

- When a potential scenario is assessed to result in an effective individual dose greater than 1 mSv/y, the intervention is considered as justified.

- With regard to non-radiological risks, the intervention is justified in the following cases: risk of inadvertent animal and human intrusion, major topographic alterations and major visual and landscape impacts, concentration of toxic compounds in water above regulatory limits and if the area has a special ecological value and relevant impacts to the environment exist.

The doses were calculated for workers and for two classes of critical individual, with the following characteristics:

- *Real Critical Individual:* individual who permanently lives in a real locality near the mining site (8769 h/y) (air pathway) and who consumes off-site near mine water from well (water pathway)

- *Potential Critical Individual:* adult who permanently lives in a hypothetical locality near the mining site (150 metres from a mining pile) (air pathway) and who consumes on-site water from well (water pathway)

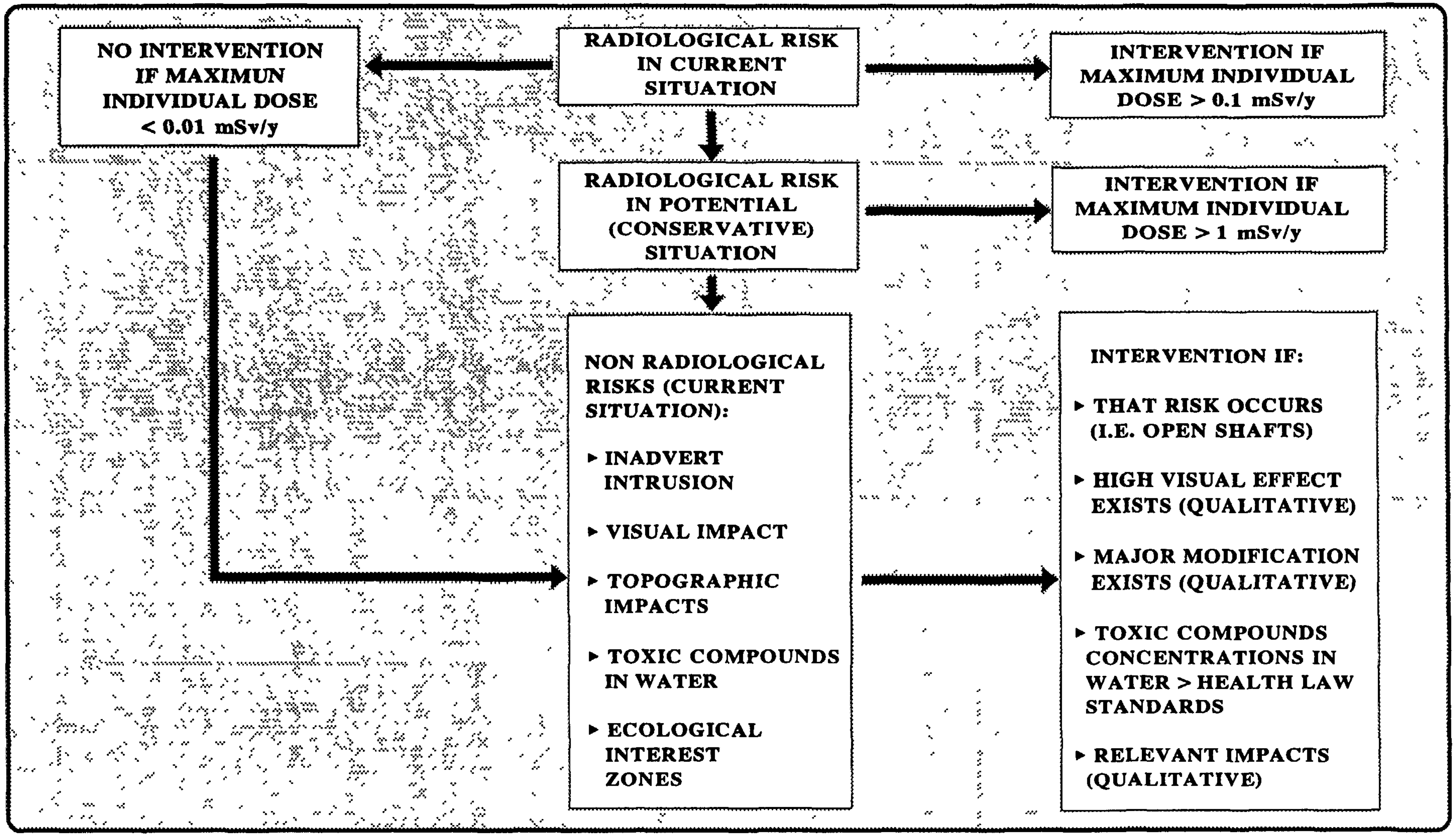

FIG.2. INTERVENTION CRITERIA

For both cases the following assumptions are made:

- Air: inhalation of radon gas and particles, ingestion of food contaminated by deposited activity and inhalation of radioactive materials air-resuspended;
- Water: drinking water, ingestion of irrigated vegetables with well water and ingestion of food made up of animal which has consumed of well water;
- Direct Radiation: on-site occasional exposure with mine-specific factors.

- *Worker (in restoration activities):* individual who inhales radon gas and particles during restoration works, receiving direct radiation for 170 hours per month by working 80% of the time over the mining pile using machinery of civil works.

4.2.4 Radiological evaluation

The results of the environmental assessment concluded that in 21 of the 26 sites, the effective dose to the most exposed individual by all exposure pathways in the real situation is less than 10 μSv/y. For this reason in 21 sites there is no justification for intervention due to radiological risks.

The sites where effective doses slightly exceed lightly 0.1 mSv/y are, Cano, Ratones and Gargüera. For the remaining two sites namely, La Virgen and Pedro Negro, the intervention is justified based on a scenario of the potential situation.

4.2.5 Classification

According to the Impact Assessment of the sites and the above criteria, the mines were classified into four groups:

- Group 1 Sites to be restored based on radiological risk in real situation: 3 Mines
- Group 2 Sites to be restored based on radiological risk in potential situation: 2 Mines
- Group 3 Sites to be restored based on non radiological risk in real situation: 14 Mines
- Group 4: Sites not to be restored because of the situation that the negative impact of restoration might outweigh the advantages to the public and improvements in environmental conditions 7 Mines

4.2.6 Objectives and design elements

To remedy the radiological and non radiological impacts and risks, a set of design elements were developed in order to establish the different design approaches for each site:

1.) To control the direct radiation and radon flux by providing a protective cover system.
2.) To prevent the mining debris and rock wastes dispersion by stabilization of waste rock piles, disposal of mining debris in open pits, and by placement of a cover.
3.) To protect the water quality by dewatering of open pits, treatment/evaporation of contaminated waters and backfilling and sealing of shafts.
4.) To control the collapse and instability of underground mines by backfilling and sealing shafts and mine openings.
5.) To restore the affected sites by grading, reshaping and revegetation of disturbed areas.

4.3. "Elefante" plant

The uranium concentrate production plant "Planta Elefante" is sited in Saelices el Chico township (Salamanca) in the same area as "Quercus" plant which at present is still in operation.

During its period of operation the Plant has produced 3 430 tons of U_3O_8 generating 7 150 000 tons of waste from heap leaching and 372 000 m^3 of tailings stored in tailings pile: dam 1 (90 000 m^3), dam 2 (126 000 m^3) and dam 3 (156 000 m^3). The dams 2 and 3 are at present closed down.

4.3.1 Facility description

The production process consist of direct acid attack of the uranium ore made up of pitchblende, coffinite, phosphouranolite, autunite, sabugalite and copper uranita, the two last being the most plentiful.

The process developed in this facility consisted of the following steps:

a.) Ore preparation
b.) "In situ" leaching
c.) Extraction-Reextraction
d.) Precipitation and Filtration
e.) Drying and packing
f.) Tailings pond

4.3.2 Current status of facility

The situation with respect to structures, buildings and equipments is as follows:

- Equipment and materials which are operable are incorporated into Quercus Plant
- Short and long term reuse of materials identified
- Materials generated from structures, buildings, equipments and sterile materials are classified and disposed as appropriate.

The contaminated materials to be dispersed belonging to structures, buildings and equipments can be grouped under equipments, and dismantled structural debris. The disposal of these wastes will be carried out "in-situ" and they will be covered with the exhausted ore proceeding to the heap leaching ("in situ" leaching). Later according to the selected alternative for the heap leaching closure, a multi layer 3 metre thickness of sterile materials is dumped and clayey vegetation soil covered to restore the site radiological conditions similar to the background.

The two classes of sterile materials generated during the process are: solid (heap leaching wastes), and sludges generated during the neutralisation (tailing ponds). Qualitative and quantitatively the two sterile classes are different and have to be handled, stored and disposed by closure in distinct ways.

Heap leaching:

All uranium minerals treated in the Elefante Plant have undergone in-situ leaching. The heap leaching wastes were conditioned resulting in truncated pyramidal shape with a height in the range of 6 to 9 metres (Fig 3) During the operational phase 2,2 million tons of high-grade ore (initial grade 1225 g U_3O_8) and 5 million tons of low-grade ore (initial grade 442 g U_3O_8) were treated The efficiency of recovery after treatment was 80% in high-grade ore and 67% in low-grade ore and as a whole the recovery was 74%

FIG.3. ELEFANTE SITE BEFORE REMEDIATION

The wastes of exhausted mineral in heaps are 7.2 million tons with an average content of 0.18 kg U_3O_8 per ton. In spite of the uranium content in the exhausted ore being low, about 99.5% of Th-230 and 99% of Ra-226 remain in the exhausted ore due to poor solubility during in-situ leaching. This situation affects the heap closure concerning confinement and long term stability due to dispersion of these nuclides.

Tailings ponds:

The technical characteristics of the Tailings Pond number 3 (the dams 1 and 2 are already closed down) are: maximum height 12.5 metres, total length 163 metres, maximum capacity 150 000 m³. Ra-226 present in the sludges is minimum (specific activity 29.6 Bq/kg), as also the U-238 content (< 1 ppm). Practically the whole of the solid fraction of the sludges is mainly made up of calcium and barium sulphate and chloride. For this reason, the closure of the dams is carried out not only to avoid the dispersion of radionuclides, but also to seal the surface at the top of the pile, improving its stability.

4.3.3 Specific design criteria

The main objective of the dismantling and closure operations of Elefante Plant is that once completed, the radiological condition of the site will be similar to the original background level.

4.3.3.1 Site criteria

a.) The closure and stabilization in situ of the heap leaching and tailings pond, favour the criterion of storing all generated wastes in an only site to reduce and make easy the operations of post-closure surveillance. In the same basin will be sited the tailings pile of Quercus Plant, at present operating, whereby in the future, the entire waste will stay integrated in the same structure of waste storage.

b.) The objective of the closure works is to achieve maximum possible isolation of the wastes to avoid dispersion due to natural phenomenon without need for major maintenance. The tailings pile of Quercus Plant which collects all possible filtrates of the basin, has a waterproofing to isolate the waste site from the ground water circulation.

c.) The water drainage area is small (4.4 km²) and to isolate the waste storage area, a perimetral channel has been built which collects the natural waters of the drainage area and divert them to Agueda river. This channel minimizes the flooding and reduces the potential to erode or move parts of the waste area.

d.) In the storage area there is no break which could cause a design earthquake intensity of 7 (Richter Scale) to be exceeded.

4.3.3.2 Radiological Protection Criteria

a.) With a view to render closured sites suitable for use as forest or unirrigated agricultural land, it is to be ensured that the added residual activity is less than 1 Bq/g for U-238 and its descendants. Additionally, the radiation exposure is kept lower than 0.3 μGy/h, measured at a point 1 metre over the soil surface.

b.) The annual individual dose to public as a consequence of the closure, will be lower than 0.3 μGy/y. To establish this value, the operational limit fixed for Quercus Plant is taken as reference.

4.3.3.3 Criteria for classification and storage of materials and equipment

a.) The dismantling and closure operations of Elefante Plant are carried out within the framework of operations of ENUSA Centre in Saelices el Chico, where the productive operations at Quercus Plant are going on.

b.) The dismantling and closure operations of Elefante Plant will be carried out in two phases. First, in the short term, developments specific to the plant which will be developed in short term and will include the dismantling of the sections which have not been incorporated into the Quercus Plant, the closure of heap leaching and tailings pond. In the second phase, the equipment and systems that have been reused in Quercus Plant and the sections that have been incorporated in it will be integrated within the general closure programme of Quercus Plant.

c.) The equipment and systems from Elefante Plant dismantling, such as dust collection systems, radiological survey systems, fire protection systems, etc., as well as other useful process equipments, will be used at Quercus Plant.

4.3.3.4 Criteria for post-closure survey

a.) Once the dismantling and closure operations are completed a survey system of closured areas (heaps and tailings) will be established to check the fulfilment of all conditions.

b.) The survey programme will have two phases, one specific to the first five years and the other for a longer duration. Finally, the survey programme will stay integrated to the overall Survey Programme of Quercus Plant.

4.3.3.5 Economic Criteria

a.) According to the techno-economical study vide BOE number 51 of 28, February 1987 condition 3.5, during the operational phase, a Restoration Fund was established to cover the Closure Phase.

4.3.4 Closure

Three possible alternatives of closure have been studied: In-situ closure, closure in the mine hole and closure in a suitable geomorphological structure.

In-Situ Closure is considered a more suitable alternative due to technical (mainly that the closure could be simultaneous, partly, with the production labour of Quercus), economical and safety (mainly the reduction of the post-closure survey due to the integration of heap leaching and tailings pond into a common structure) considerations.

In-situ closure basically consists of spreading the exhausted ore stored in tailings pile on a previously prepared land to get a slope of 5:1 to guarantee their long-term stability. Subsequent waterproofing, if necessary, with clay layer and surface overlap of the new structure made with arkose, sterile mine and vegetation soil will reduce the radon emanation and protect the pile against wind and water erosion (Fig 4)

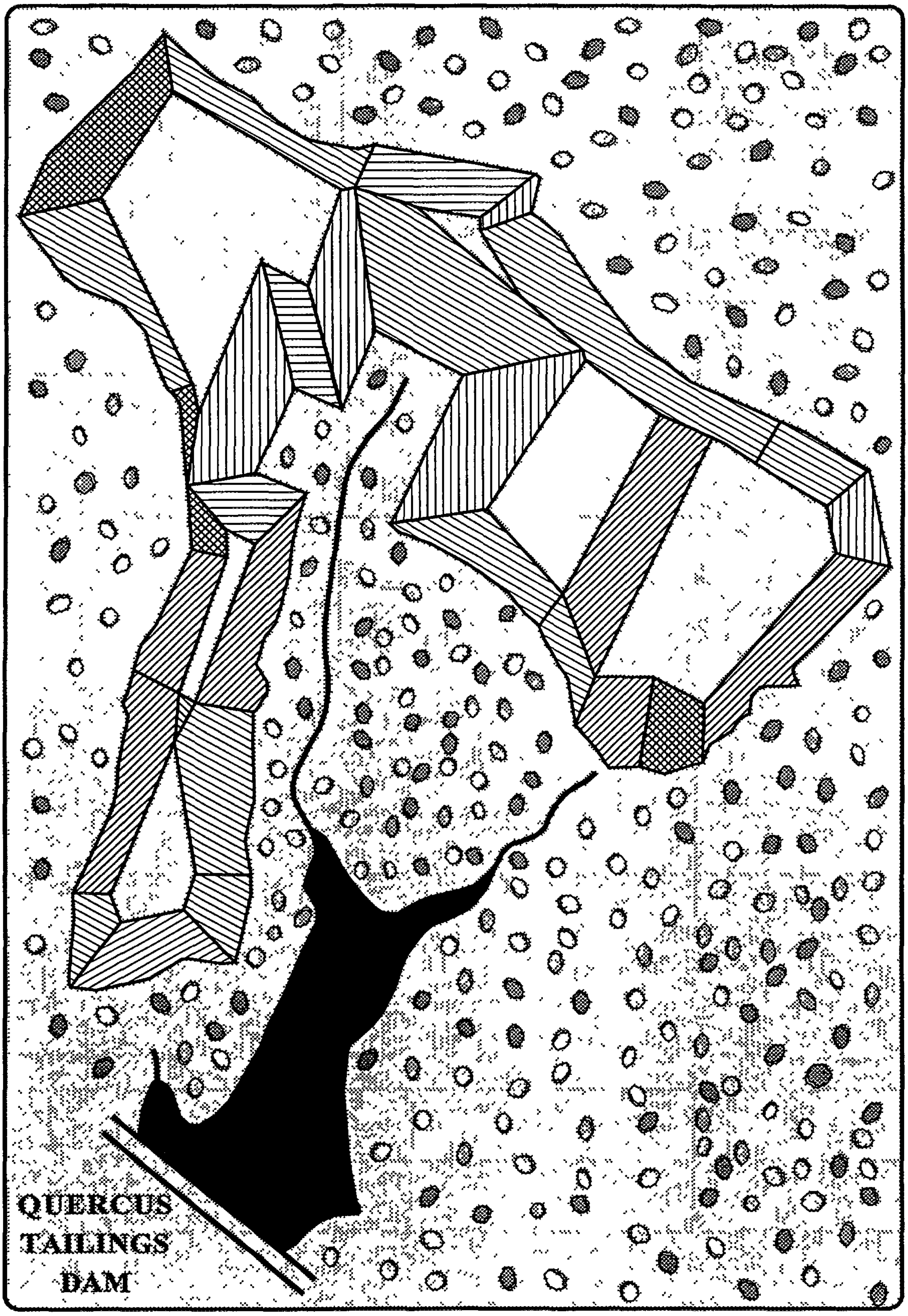

FIG.4. ELEFANTE SITE AFTER REMEDIATION

The spread of the tailing pile will also be useful to cover the materials and wastes from closure of Elefante Plant, as well as the dams 2 and 3 will be covered with the exhausted ores. With the aim of minimizing the radon emissions, the highest grade ore will stay in the lower layer, covered with the low-grade ore.

5. CONCLUSION

1.) In Spain there are Standards and Regulations to develop site remediation tasks in accordance with the Standards and Regulations of International Organizations.

2.) There exists an overall restoration methodology applicable for a whole site. The methodology has adequate flexibility for application to different restoration scenarios.

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ENVIRONMENTAL RESTORATION IN REGIONS OF URANIUM MINING AND MILLING IN UKRAINE: PROGRESS, PROBLEMS AND PERSPECTIVES

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Abstract

Uranium exploration activities in Ukraine were initiated in 1946 by a special Decree of the Soviet Union Counsel of People's Commissars, which established a number of industrial enterprises for Uranium mining and milling, as a part of an urgent and top-secret project on nuclear weapons development in the former Soviet Union. So far 21 uranium reserves have been identified in the Southern regions of Ukraine. Industrial scale mining has been undertaken in two main areas - ZhovtiVody (Dnipropetrovsk region) and more recently - near the city of Kirovograd. Uranium milling capabilities were created in ZhovtiVody and Dniprodzerzhinsk. At Dniprodzerzhinsk Prydniprovsky Chemical Plant uranium milling started in the late 40's, initially using ores from the countries of Central Europe. During the early practice of uranium mining and milling hardly any ecological and radiological factors were taken into account. Lack of relevant environmental standards and appropriate technologies for uranium extraction contributed to contamination of both industrial and residential areas. As a result, about 1340 ha of industrial areas were contaminated and ecologically affected. Extensive utilization of waste rock pile for road and building construction in the 50's and 60's resulted in contamination of residential areas in the region. Town of ZhovtiVody located in the very centre of the uranium mining and milling industrial area represents a typical case of radioecological risk. To provide a comprehensive solution to the radioecological problems of the ZhovtiVody area a State Programme of Actions up to the year 2005 was adopted by the Ukrainian government in 1995. Main difficulty in the implementation of the programme is lack of financing. Mining and milling industry belongs to the nuclear energy sector of the Ukrainian government which is now undergoing restructuring. It is expected that the reforms would change the elements of the nuclear programme in Ukraine and principally the financial aspects. A timely methodological and information support for national activities on environmental restoration in Ukraine was provided by IAEA regional project RER/9/022. In April 1996 under the framework of the RER/9/022 project, seminar on environmental restoration in regions of uranium mining and milling took place in the town of Zhovti Vody, that allowed involvement of local experts and organizations into the project activities directly. The proposed paper is based on the vast amount of data accumulated in Ukraine during RER/9/022 covering the period 1993-1996. Severe lack of finance adversely affected all activities within the nuclear sector, environmental restoration implementation being the most affected. In such circumstances RER/9/022 remained as one of the most valuable contributing factors in the development of regulations, guidance and practices in the area of environmental restoration.

1. NATIONAL CONDITIONS REQUIRING ENVIRONMENTAL RESTORATION

1.1. Current Provisions

Ukraine as a newly independent state inherited the regulations of the former Soviet Union (FSU) in the area of radiation safety and environmental restoration of uranium mining and milling industry. As for the upper legislative level, there was no nuclear legislation in the FSU. Radiation Protection Norms (NRB76/87) is the upper level radiation protection regulation that established the general occupational and public exposure principles and limits. Until 1975 there were no separate regulations addressing environmental restoration issues. "Special Sanitary Regulations СП-1324-75" adopted in 1975 was the first document containing definite provisions on environmental restoration of areas affected by uranium mining and milling practices. This document was updated in 1991 and is in effect now under the title of "Sanitary provisions on decommissioning, conservation and release of radioactive ore mining and milling enterprises"(СП-ЛКП-91). According to these provisions, the final contamination after finishing restoration activities should not exceed background level by more than 2 times. In a limited portion of the restored area (20% of total restored area) residual contamination could exceed background level by 3 times. Another standard "Regulation on the Radiation Control at Buildings and Building Industry of Ukraine PCH 356-91" establishes limits for equivalent equilibrium radon concentration in the air of industrial and residential buildings, beyond which regulatory intervention is required. Though, in the former Soviet Union there were no policy requirements for environmental restoration on a regular basis, as a rule, ad hoc decisions were taken by the Government or local authorities on case by case basis.

1.2. Newly adopted and planned Legislation, Regulations and Policies

During the last two years Ukrainian Parliament adopted two laws on nuclear legislation - the basic law "Act on utilization of nuclear power and radiation safety" and "Act on Radioactive Wastes and Radiation Protection". General provisions of these laws establish priorities of population protection and ecological safety in the utilization of nuclear power and radiation technologies, as well as set responsibilities of all parties involved. In addition, another legal Act that is supposed to influence the environmental restoration decision making - "Radiation Protection Act" is currently under development.

Chernobyl accident pushed forward environmental restoration problem in Ukraine, within the mitigation and remediation activities. Though this issue is not directly applicable to remediation of the uranium mining and milling consequences, some approaches, like, the overburdening of social mitigation activities in the planning of countermeasures, negatively influenced the projects for environmental restoration in uranium mining and milling regions, the aspect highlighted in more detail in section 3.

At the moment a number of regulations and practices on environmental restoration are under development.

2. RADIOLOGICAL CHARACTERIZATION OF THE URANIUM MINING AND MILLING REGIONS

2.1. General

Ukrainian uranium mining and milling industry is concentrated in the Southern regions. This area is densely populated and has highly productive agriculture and developed mining and metallurgical industry, being rich in various mineral resources (iron, titanium, magnesium, coal etc.). Uranium exploration activities started as early as in 1946 by a special Decree of the Soviet Union Counsel of People's Commissars, which established a number of industrial enterprises for uranium mining and milling in Ukraine. Since then 21 uranium reserves have been identified in the southern regions of Ukraine. Industrial scale mining has been undertaken in two main areas - ZhovtiVody (Dnipropetrovsk region) and Smolino and Ingul deposits near the city of Kirovograd. Uranium milling capabilities were created in ZhovtiVody and Dniprodzerzhinsk.

As a result of this activity total area exceeding 8,000 ha of highly productive agricultural land was occupied with uranium mining and milling industry, producing different levels of a radioactive contamination and general ecological damage in the region.

The main sources of contamination are:

- mill tailings (Zhovti Vody, Dnieprodzerzhinsk);
- waste rock piles (Kirovograd, Smolino, Zhovti Vody)
- uranium ore and waste rock transportation routes (Dniepropetrovsk and Kirovograd regions);
- residential areas with waste rock used as building material for construction of foundations, fences, roads, etc. (towns and villages in the region);
- mining drainage water discharges (Kirovograd, Smolino, Zhovti Vody);
- mining venting air discharges (Kirovograd, Smolino, Zhovti Vody);
- in-situ leaching sites (Devladovo, Bratske, Saphonovo).

General characterization of the radioecologically affected areas for the whole uranium industry of Ukraine is given in Table I.

Table I
Characterization parameters of the affected areas of uranium industry in Ukraine

Mining site	Area, licensed for industrial application, ha	Affected area, hectares					
		Total Affected	Types of damage				
			Waste rock pile	Open casts	Industrial sites	Mill tailing	
Zhovti Vody	4050	970	19.1	50.6	202	645	
Ingul Site	500	52.1	44.7	-	7.4	-	
Smolino Site	644.5	43.3	5.3	-	38	-	
In-situ leaching: *							
Devladovo site	150.5	123	-	-	-	-	
Bratske site	182.5	153	-	-	-	-	
Saphonovo site	5	-	-	-	-	-	
Prydniprovsky Chemical Plant (Uranium milling)	2500	-	-	-	-	577	
Total:	8032.5	1341.4	28.9	50.6	285	1222	

* for in-situ leaching sites the area of underground ore deposit is given

The Novokostiantynivske deposit located 42 km to the east from Kirovograd is in an early stage of industrial exploitation and it's full-scale utilization is planned to be licensed with new ecological regulations.

2.2. Zhovti Vody Area

Town of ZhovtiVody is located in the very centre of the industrial area of uranium and iron mining and milling and represents a typical case of technogenic and radioecological risks.

There are two uranium mines, two open quarries, uranium milling plant and 3 mill tailings dumps with a total area of 646 ha, one of which is not in operation and partly restored, the other is in operation. Third one is an iron ore milling sludge tailing used as a deposition pond for uranium mining drainage waters. Characteristics of their inventory are given in Table II.

Tailing "КБЖ" is located in the old iron ore quarry, filling was completed in 1989, and is partially restored. Today it is used for reception of emergency discharges of slurry from the local milling plant. Residual uranium content in the tailing is approximately 0.007%. Dusting of dry beaches presented considerable radioecological problem before this tailing was partly restored by covering with clay layer of 0.4 m thickness. This measure reduced the dose-rate on the surface of the tailing from 450-600 μR/h to 24-56 μR/h (background level is 24-56 μR/h); Radon exhalation was reduced from 0.05 - 20.0 Bq/sq.m*s to 0.028 - 10 Bq/sq.m*s.

Table II
Characterization of the mill tailings at Zhovti Vody area

Tailings, years of operation	Inventory, million tonne	Tailings area, hectares	Inventory activity, Ci	Dose rate on the surface, mkZv/h	Distance from living zones, km
Tailing "ЩЦ" (1957-68)	34.5	250	47750	4-60	1.4
Tailing "КБЖ" (1966-1990)	19.3	54	14435	4-60	2.0
Tailing "P" *	-	342	-	0.08-0.18	0.5
Total:	53.8	646	62185		

* iron ore milling sludge tailing used as a deposition pond for uranium mining drainage waters.

Tailing "ЩЦ" is now the only one in operation in Zhovti Vody, Ukraine. Residual uranium content in the tailing is 0.007%. Tailing is located in the close vicinity of the residential area, and essentially dusting of dry beaches still presents problem. Different remedial measures were used to cope with this problem which are described and illustrated in [2].

2.2.1. Zhovti Vody Living Zone

Location of the town in the centre of uranium mining area created multiple ecological and radioecological problems. Mining venting discharges and dusting of dry beaches with mill tailings represent the risk with adverse impact of the uranium industry to the living areas. In the 50's and 60's waste rock was extensively used for building purposes, thus creating a complex case of in-built contamination and source of considerable radiological risk.

During 1994-1995 detailed radiological characterization of residential areas was performed which discovered more then 5000 radioecological anomalies with gamma dose rate exceeding 1.2 μSv/h. Thus, level of 10 μSv/h was exceeded in 460 cases and that of 30 μSv/h - in 57 cases. About 20% of the territory has dose rate levels exceeding 0.3 μSv/h.

Methodology of radiological survey is described in more detail [1]. Measurement of the equilibrium equivalent radon concentrations in houses has demonstrated that level of 100Bq/m^3 is exceeded in 36.5% of surveyed sample of 2000 buildings, and in 3.5% of the cases equivalent radon concentration exceeded the level of 1000 Bq/m^3. Current regulations (PCH 356-91) establish a limit of 100 Bq/m^3 for existing buildings, and 50 Bq/m^3 - for newly built ones.

2.3. Kirovograd region

Today Kirovograd region remains the only place of active uranium mining in Ukraine. **Ingul** mining site is located in the Southern outskirts of Kirovograd. Main areas for environmental restoration here is waste rock piles, uranium ore storage place and ore transportation routes. Waste rock piles with a volume of 2.5 million m^3 occupy an area of 44.7 ha. Radionuclide content in waste rock piles lies in the range of 800-10830 Bq/kg of Ra-226. Rn-222 exhalation from the piles surface is 0.85-1.28 Bq/m^{2}sec.

Mining waters at the rate of about 2.6 million m^3/year are discharged into river Ingul after passing through deposition pond.

Smolino site is located in Kirovograd region near the town of Smolino. Underground mining of uranium deposit is carried out in 4 mines at a depth of 500 m. Waste rock piles occupy an area of 5.3 ha with a volume of 1.06 million m^3. Mining water is discharged into river after passing through filtering system.

City of Kirovograd (population - 281 400 inhabitants) was affected by the uranium mining activities: Radiological survey conducted in 1990-1992 identified 800 contaminated spots, 28 of which having gamma dose rate exceeding 10 μSv/h, 106 - within 1 - 10 μSv/h, and the rest within 0.45 - 1 μSv/h. This high radiation background is the result of utilization of uranium mining wastes in the road and building construction industry.

2.4. Dnieprodzerzhinsk Area

Until 1990 uranium milling was carried out at **Prydniprovsky Chemical Plant (PCP)**, in the town of Dnieprodzerzhinsk, population - 287,300 inhabitants.

Processing of uranium ores at PCP was started as early as in late forties, using ores shipped from countries of Central Europe. Since then there is an accumulation of more than 33 million tonnes of uranium mill sludge located in five mill tailings dumps. Total area of the mill tailings at the PCP comes to 580 ha. Nowadays uranium milling at PCP is suspended and there are no plans to resume operations in the future. Table III gives characteristics of the PCP mill tailings.

Uranium milling activities in Dnieprodzerzinsk caused contamination of both the industrial and residential areas. Radiological survey conducted in 1990-1992 identified 381 contaminated spots with areas from 1 to 7000 m^2, and gamma dose-rate in the range of 0.40 - 47 μSv/h. As many as 176 of these spots are situated in the territory of local metallurgical works, and their contamination is caused by scattered uranium ore pieces, metallurgical slag, gravel, brick debris, concrete, asphalt, contaminated soil and trash. In the 50's and 60's one of the blast furnaces of the plant was used for processing of the iron ores from Zhovti Vody deposit, rich with uranium. In the early 70's blast furnace No.6 was demolished and disposed of as radioactive waste. Total amount of disposed debris was about 40,000 m^3, with mean specific activity of 333 kBq/kg.

In addition, uranium reloading point 10 kilometres to the South-East from PCP has contamination with characteristic dose rates in the range of 0.3 - 48 μSv/h. Residual wastes have volume of 0.316 million tonnes with average activity of 16 kBq/kg.

Table III
Characterization of the mill tailings at Prydniprovsky Chemical Plant

Tailings, years of operation	Inventory, million tonnes	Tailings area, hectares	Inventory activity, Ci	Max. dose rate on the surface, μSv/h	Distance from residential zones, km
Tailing "Д" (1957-68)	11.7	7.3	21024	13	2.0
Tailing "КП" (1949-54)	0.2	2.4	2800	44	1.2
Tailing "5" (1954-57)	0.7	6	4900	25	1.2
Tailing "ЮВ" (1956-80)	0.3	1.8	1800	23	1.2
Tailing "C-1" (1968-83)	15.4	302.7	15386	16	1.7
Tailing "C-2" (1983-90)	7.4	189.7	5600	5	1.5
Total:	35.7	576.9	51510		

Other contaminated spots found in the populated regions of the city, were caused by utilization of contaminated wastes of the local metallurgical industry for building purposes (building foundations, roads, etc.).

2.5. In-Situ Leaching Sites

In-situ leaching of uranium was performed in three locations: Devladovo, Bratske and Saphonovo deposits.

Devladovo site was exploited from 1966 to 1983 by injecting sulphuric and nitric acids into paleogen clay sandstone uranium deposit at a depth of 80 m. Area of the underground deposit was 120 ha, surface site area - 12 ha. As a result of the in-situ leaching, the amount of residual acidic solutions in the buchak aquifer comes to 7.09

million m^3. Nearest village is 4 km in the direction of the ground water flow. According to preliminary assessment, without remedial measures contaminated front would reach the boundaries of the village in 40 years. As a result of the leakage in recovery piping, surface soil of the site was contaminated with technological product solutions to an extent of about 50,000 m^3.

The same scheme was used for Bratske and Saphonovo in-situ leaching sites in the Mykolaiv region, during the periods 1971 - 1989 and 1982-1993, respectively. Volume of residual acidic solutions is 5.2 million m^3. Contaminated soil on the surface was partly restored.

3. ENVIRONMENTAL RESTORATION PROJECTS UNDER WAY

To ensure addressing the radioecological problems of the uranium mining and milling regions in Ukraine adequately, two state programmes were approved for the period 1995-96:

(i) State Programme on Radiation Protection in Nuclear Industry.

(ii) State Programme on Radiation and Social Protection of the Zhovti Vody population.

First one has a special section dealing with environmental restoration of the industrial areas, and the second one deals with restoration issues in residential zones, and remediation measures concerning population of the town of Zhovti Vody.

With respect to environmental restoration, State Programme on Radiation Protection in Nuclear Industry envisages following measures:

- completion of environmental restoration of the "**КБЖ**"tailing on the North-West boundary of the Zhovti Vody town;
- restoration of the waste rock piles at uranium mining areas in Kirovograd region (Ingul, Smolino);
- decontamination and waste disposal at uranium reloading unit "C" of the Prydniprovsky Chemical Plant;
- in-situ restoration of the tailing "C-1" and completion of restoration of tailing "**Д**".

Restoration of the "**КБЖ**"tailing was started in 1991, and now about 85% of the surface is covered with the first clay layer of 0.4 m thickness. It is planned to cover tailing surface with a multilayer consisting of clay, clean waste rock and fertile soil. After finishing restoration it is planned to release the site for agricultural usage. Technical and cost aspects for different options of mill tailing cover layer are given in [2].

For the waste rock piles of the Ingul mining area it was decided to choose the option of waste rock relocation into natural pits in the vicinity. Total volume to be relocated comes to 500,000 m^3.

Restoration of the "Д" tailing of PCP was partly completed in the mid-eighties, covering it with a 10 - 15 m layer of phosphogypsum, which is the waste byproduct of the local fertilizer industry. Phosphogypsum was found to bind radionuclides very efficiently, as such restoration measures planned now envisage only putting fertile soil and planting vegetation on the top of the tailing site. Total planned budget of the environmental restoration activities is equivalent to approximately 120 million USD.

State Programme on Radiation and Social Protection of the Zhovti Vody population in fact represents the pilot programme, which is supposed to be followed with similar actions for Dnieprodzerzhinsk, Kirovograd, Kryvyj Rig and other population centres affected by uranium mining and milling practices.

Zhovti Vody Programme was approved in June 1996, and is to be implemented until the year 2005. The structure of the programme and planned budget is given in Table IV.

Table IV

The structure of activities and budget of the State Programme on Radiation and Social Protection of the Zhovti Vody population

Action	Expenditures, thousand Ukrainian Grivna's		
	1996	1997	Total up to year 2005
Feasibility study for the environmental restoration and radiation protection measures	250	-	250
Planning for environmental restoration and radiation protection measures	450	-	450
Implementation of environmental restoration and radon protection measures		1910	1910
Relocation of inhabitants from contaminated buildings to new ones	-	1750	15750
River Zhovta restoration within the town boundaries	490	1000	6090
Ecological assessment measures	200	200	800
Development of the specific radiation protection regulations	90	80	450
Implementation and operation of the system of complex radioecological monitoring	-	200	18000
Total:	6320	6320	63200

As is clear from Table IV, the share of the planning and implementation of environmental restoration measures in total financing for technical mitigation countermeasures comes to some 21% for the period of 1996-1997, and only 4.1% for the whole period to 2005. Essential drawback of the programme is that restoration implementation is planned to take place only within one year of 1997.

For comparison, Table V shows the list of social mitigation measures and corresponding planned expenditures:

Table V
Social mitigation measures for the population of the Zhovti Vody

Measures	Number of addressed people	Annual expenditures, thousand Ukr.Grivnas
Additional monthly payments 30% of the minimum salary, for all citizens, including children	64140	13900
Additional monthly payments 25% of the minimal pension, for all retired professionals from uranium industry	4500	1600
Partial compensation of the medical treatment	40000	19500
Total :		47000

Comparison of these two sections demonstrates considerable domination of the social compensation aspects over the real environmental restoration and radiation protection measures that permanently eliminate corresponding risks. Annual expenditure for the social compensation measures is 7 times that of the whole radiation protection measures, and 20 times of the real remedial measures for restoration. This is a reflection on the wrong approaches and decision-making practices applied in Ukraine for the Chernobyl accident consequences mitigation and restoration [1, 2].

4. CONCLUSION

First steps in the development and implementation of environmental restoration programmes in the regions of uranium mining and milling industry in Ukraine demonstrated following essential difficulties:

- considerable inertia in development of environmental restoration regulations and practical guidance;
- lack of assured financial mechanism to support the regional environmental restoration programmes on a sustainable basis;
- decision making deficiencies adversely affecting optimal distribution of budget resources for environmental restoration;
- lack of a single implementation organization dealing with environmental restoration for the population centres.

The most critical issue in implementing the programmes is the deep economic crisis that Ukraine is experiencing today. As a result nearly all actions planned for 1996 were frozen.

In the situation of lack of adequate financial resources for full-scale implementation of the restoration activities there is a need to direct available resources towards limited priority tasks of infrastructural nature to prepare for future actions. This includes:

- development of general regulatory provisions and detailed practical guidance on the environmental restoration in the areas affected by uranium mining and milling activities;
- thorough regulatory review and optimization of the regional environmental project elements;
- elaboration of the region-specific mechanism for financing of the environmental restoration measures.

Essential assistance for all these three tasks could be provided through a series of expert reviews and project assistance missions with the involvement of the international experts.

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OVERVIEW OF URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT OF THE UNITED STATES OF AMERICA 1995-1996

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Abstract

From the early 1940's through the 1960's the United States federal government contracted for processed uranium ore for national defense research, weapons development and commercial nuclear energy. When these contracts were terminated, the mills ceased operation leaving large uranium tailings on the former mill sites. The purpose of the Uranium Remedial Action Project (UMTRA) is to minimize or eliminate potential health hazards resulting from exposure of the public to the tailings at these abandons sites. There are 24 inactive uranium mill tailings sites, in 10 states and on Indian reservation lands, included for clean up under the auspices of UMTRA. Presently the last 2 sites are under remediation. This paper addresses the progress of the project over the last two years.

1. INTRODUCTION

Uranium ore has been mined in the United States in significant quantities for more than 40 years. Initially, the ore was mined by private companies for federal government use in national defense programmes. After the 1950s, uranium was also needed as fuel for nuclear power plants.

When the mills shut down, they left behind large piles of uranium mill tailings, the sand-like material that remains after uranium has been extracted from the ore. They contain 85 percent of the radioactivity present in the unprocessed uranium ore and small concentrations of naturally occurring materials that radioactively decay to radium and produce radon, a radioactive gas.

Levels of human exposure to radioactive materials from the piles are low; however, in some cases, tailings were used as construction materials before the potential health hazards of the tailings were recognized. In homes or other structures containing tailings, the radon gas can concentrate in enclosed spaces.

The purpose of remedial action is to minimize or eliminate potential health hazards resulting from exposure of the public to residual radioactive materials at the former processing sites and at contaminated properties.

Legislation

After determining that uranium mill tailings might pose a public health hazard, Congress passed Public Law 95-604, the *Uranium Mill Tailings Radiation Control Act (UMTRCA) of 1978*, to clean up all inactive uranium mill sites that had been abandoned by the late 1960s. Uranium mill sites still in operation in 1978 or later remained the responsibility of their private owners. The U.S. Department of Energy (DOE) was given the responsibility for carrying out the project at the 24 inactive sites, and in 1979, the UMTRA Project Office was formed as part of the DOE Albuquerque Operations Office.

The processing sites are located in 10 states: Arizona, Colorado, Idaho, New Mexico, North Dakota, Oregon, Pennsylvania, Texas, Utah and Wyoming. In addition, a 1983 amendment to the UMTRCA gave the UMTRA Project responsibility for cleaning up vicinity properties (VPs) near Edgemont, SD The former Tennessee Valley Authority uranium mill site in Edgemont was remediated in the late-1980s.

The UMTRCA also called for the U.S. Environmental Protection Agency (EPA) to establish remedial action standards. Congress directed the U.S. Nuclear Regulatory Commission (NRC) to provide consultation and concurrence in the type of remedial action performed. Before remedial action, the DOE must comply with the requirements of the *National Environmental Policy Act (NEPA)* and perform detailed studies of the environmental impacts that remedial action would have at each site.

The states and tribes enter into cooperative agreements with the DOE, concur on the selected remedial action and acquire rights to the final disposal site when necessary. Participating states have responsibility for 10 percent of the cost of remedial action; the federal government pays the remaining 90 percent. When the site is on tribal land, the federal government is responsible for 100 percent of the cost.

The EPA established standards requiring DOE to stabilize and isolate the tailings from the environment in order to control radiation emissions for 200 to 1,000 years. After completion of remedial action, the NRC issues a license for future surveillance and monitoring of each disposal site.

To date, surface cleanup is complete at 18 UMTRA sites: Ambrosia Lake, Canonsburg, Durango, Falls City, Grand Junction, Green River, Gunnison, Lakeview, Lowman, Mexican Hat, Monument Valley, Rifle (two sites), Riverton, Salt Lake City, Shiprock, Spook and Tuba City. Remedial action is under way at four sites: Maybell, Naturita and Slick Rock (two sites). DOE has suspended all surface and ground water activities at the remaining two sites, Belfield and Bowman. The state of North Dakota has proposed removing the two sites from the list of sites which the UMTRCA identified for remedial action. In addition, NRC has issued licenses for seven sites: Canonsburg, Durango, Lakeview, Lowman, Shiprock, Spook and Tuba City.

Vicinity Properties

An important component of the UMTRA Project is the cleanup of residences, commercial buildings or open lands - called vicinity properties - where tailings were used as construction materials before the potentially harmful effects of the tailings were recognized, or where tailings were transported away from the site by wind or water erosion. Over the past 14 years, the DOE identified over 5,300 vicinity properties for remedial action. Properties were surveyed, and if uranium mill tailings were found to cause radiation levels in excess of standards set by the EPA, then, at the landowner's request, the DOE officially included the property for remedial action under the UMTRA Project. Currently, remedial action for more than 97 percent of those properties has been completed.

Ground Water Compliance

A second phase of the UMTRA Project initiated over the past three years addresses ground water compliance at the 24 former processing sites. Before becoming inactive, milling operations at many of those sites may have resulted in the contamination of ground water. The ground water project addresses subsurface contamination with the goal of complying with EPA ground water protection standards, which are designed to protect human health and the environment. After assessing the condition of the ground water, the UMTRA Project will develop a strategy to comply with EPA standards based on the specific conditions at each site. Options include: (1) no remediation at sites where milling-related contamination of ground water is not considered a risk to human health; (2) natural cleansing of milling-related ground water contamination (natural flushing); and (3) active programmes to clean ground water using engineered systems. The UMTRA Ground Water Project is the responsibility of DOE's Grand Junction Projects Office, Grand Junction, Colo.

UMTRA Team Office

The UMTRA Team in Albuquerque, NM, is responsible for (1) planning, scheduling and budgeting; (2) federal, state, tribal and local coordination; (3) engineering, design and remedial action; and (4) health, safety, environmental protection, quality assurance and public affairs.

2. ACCOMPLISHMENTS

The UMTRA Project achieved new milestones in FY 1995-96 in both the surface and ground water phases of the Project. The UMTRA Project Team completed surface remedial action at the 13th through 17th of the 24 UMTRA sites -- Mexican Hat, Utah, Monument Valley, Arizona., Ambrosia Lake, New Mexico, Rifle and Gunnison, Colorado. -- and started surface work at Maybell, Naturita, and Slick Rock, Colorado. The team also took a giant step forward with the ground water phase through the release of the draft UMTRA Ground Water Programmatic Environmental Impact Statement (PEIS) for public comment.

Major FY 1995-96 Accomplishments: Surface Project

As of September 30, 1996, surface cleanup is now complete at Monument Valley and Tuba City, Ariz.; Durango and Grand Junction, Colo.; Lowman, Idaho; Ambrosia Lake and Shiprock, N. M.; Lakeview, Ore.; Canonsburg, Pa.; Falls City, Texas; Green River, Mexican Hat and Salt Lake City, Utah; Rifle and Gunnison, Colorado; and Riverton and Spook, Wyoming. Remedial action is in progress at four Colorado sites -- Maybell, Naturita, and Slick Rock (two sites). All activities related to the two North Dakota sites -- Belfield and Bowman -- are on hold pending a request by the state that these two sites not be remediated.

- Held closing ceremonies signifying completion of remedial action at the Mexican Hat and Monument Valley (joint ceremony), Gunnison, Rifle, and Ambrosia Lake sites.

- Completed phase I remedial action at the Naturita, Slick Rock, Maybell.

- Completed the NEPA process with the approval of the environmental assessments (EAs) for Maybell, Naturita and Slick Rock, and issued Findings of No Significant Impact (FONSIs) for each.

- Conducted opening ceremonies and started remedial action at Maybell, Slick Rock and Naturita.

- Submitted to NRC and the state of Colorado for review the final Remedial Action Plans (RAPs) for Maybell, Slick Rock, Naturita.

- Received title to the Canonsburg and Lakeview sites from the states of Pennsylvania and Oregon.

- Obtained NRC certification for Canonsburg and Riverton.

- Obtained NRC licensing for Lakeview, Lowman, Canonsburg, Shiprock, and Tuba City.

- Transferred the long-term surveillance and monitoring responsibility for Canonsburg, Lakeview and Lowman to the DOE Grand Junction Projects Office (GJPO).

- Completed cleanup of the 5,000 VP at Grand Junction.

- Finished remediation of Residual Radioactive Material (RRM) at the former uranium processing site in Gunnison to the disposal cell.

- Finished remediation RRM from the Old Rifle processing site to the Estes Gulch disposal site.

- Decided to relocate the RRM from the former uranium processing site in Naturita to a disposal cell at a currently licensed Title II facility at Uravan, Colo.

- Prepared completion reports for Ambrosia Lake, Falls City, Grand Junction, Lowman, Mexican Hat, Monument Valley and Salt Lake City.

- Completed final LTSPs for Durango, Falls City, Lowman, Tuba City, Shiprock, and Lakeview.

- Submitted ground water compliance changes for Green River to the NRC in a proposed modification to the RAP.

- Completed negotiations with the Navajo Nation for custodial access agreements (CAA) for Shiprock and Mexican Hat and with the Navajo Nation and the Hopi Tribe for Tuba City. CAAs are documents that must be included in the final LTSPs before NRC can license these sites. This documentation of perpetual access to tribal sites is necessary for NRC licensing in place of documentation of site transfer to the DOE.

- Instituted the "permit by rule" provision of the *Resource Conservation and Recovery Act (RCRA)* for the state of Colorado to allow treatment of commingled waste properties in Grand Junction.

- Saved $10.3 million through the Cost Reduction/Productivity Improvement Programme (CR/PIP). The UMTRA Project has saved $70 million since the beginning of the programme.

Major FY 1995-96 Accomplishments: Ground Water Project

The ground water project, although in its early stages, achieved the following milestones in FY 1995-96:

- Completed ground water PEIS and published a Notice of Availability in the *Federal Register* inviting public review of the document.

- Held public hearings on the PEIS in nine UMTRA communities to receive public feedback on the document.

- Gathered 500 verbal and written public comments on the draft PEIS.

- Completed draft Baseline Risk Assessments (BLRAs) for Durango, Lakeview, Maybell, Naturita, Rifle (2 sites), Slick Rock (2 sites), Belfield, Durango, Grand Junction, Green River and Riverton.

- Completed the Site Observational Work Plans (SOWPs) for Ambrosia Lake, Falls City, Mexican Hat, Monument Valley, Riverton, Shiprock, Spook and Tuba City.

- Completed the Water Sampling and Analysis Plans (WSAPs) for Falls City, Grand Junction, Green River, Gunnison, Lakeview, Rifle (2 sites), Riverton and Slick Rock (2 sites).

- In conjunction with Sandia National Laboratories (SNL), completed a major field characterization effort at Riverton. This work included the installation of monitor wells, core collection, tracer and aquifer tests and numerous sample collection efforts.

3. STATUS OF DESIGNATED SITES

Ambrosia Lake, New Mexico

The UMTRA Project Team completed remedial action at Ambrosia Lake ahead of schedule in FY 1995-96. DOE conducted a closing ceremony at the Ambrosia Lake disposal site on June 22, 1995. DOE also transmitted a draft completion report and final audit report to the NRC and the state of New Mexico for review. In addition, DOE conducted the final round of water sampling proposed under the surface phase of the UMTRA Project.

For the ground water phase of the UMTRA Project, a draft SOWP was prepared and transmitted to the NRC for review.

Belfield and Bowman, North Dakota

At Belfield and Bowman, DOE suspended all surface and ground water activities. The state of North Dakota has proposed removing the sites from the list of sites that the UMTRCA identified for remedial action.

Canonsburg, Pennsylvania

Licensing activities continued at Canonsburg, with NRC granting its concurrence on site certification, which certifies that the completed remedial action is in compliance with the EPA standards. The USACE has completed its deed acquisitions' review and the state of Pennsylvania transferred the deed to the site to DOE. The only remaining licensing action is NRC acceptance of the LTSP.

The UMTRA Project Team prepared the revised citizen summary for the BLRA.

Durango, Colorado

Durango is in the licensing phase, and the DOE prepared a draft LTSP for the site in FY 1995. DOE transmitted the final LTSP to the NRC in November 1995. The UMTRA Project Team completed a study of the toe drain system for the disposal cell at Bodo Canyon. DOE also developed plans to install a pilot water treatment system. The purpose of the system is to determine the effectiveness of different materials in reducing certain radioactive and heavy metal's constituents from the toe drain water. Sampling for this research should be completed in FY 1996.

In support of the ground water phase, the UMTRA Project Team prepared the final BLRA for the site in FY 1995.

Edgemont, South Dakota

DOE was not required to conduct remedial action in Edgemont. All the RRM from the former processing site was stabilized on the site by the owners prior to enactment of the UMTRCA; however, the UMTRCA was amended in 1978 to include cleanup of all VPs contaminated with tailings from the Edgemont site. DOE remediated all VPs in Edgemont subsequent to FY 1992. To date, the NRC has certified 129 VPs of the 135 requiring certification. Two properties will not be cleaned because their owners refuse to participate in the programme.

Falls City, Texas

With the completion of all Falls City site remedial activities, DOE efforts in FY 1995 focused on documenting the completion of site activities with the submittal of the disposal site completion report to the state of Texas and the NRC. This report documents the surface remedial activities conducted at the site and its current condition. Following NRC and state of Texas review and comment resolution, the DOE will finalize the completion report. NRC licensing of the site is expected in 1996. In addition, DOE completed radon sampling at the site and removed the alpha track radon detectors and their holders. DOE also completed the draft LTSP and delivered it to the state of Texas and NRC for review.

Under the ground water phase, DOE collected domestic water samples from private properties in the vicinity of the disposal site. The samples were part of the data collection objectives identified in the SOWP, which is undergoing stakeholder review. DOE also planned for the associated SOWP field effort, which will include the installation of 12 monitoring wells to determine the extent of downgrading contamination. As part of the data collection effort at the site, a DOE contractor installed ground water elevation data loggers and collected the data, in addition to conducting slug tests at selected wells.

Grand Junction, Colorado

Following the planting of vegetation at the former Climax Mill processing site, DOE completed all surface-related activities in Grand Junction in FY 1995. Future plans for the site include a project by the state of Colorado, Mesa County and the city of Grand Junction to construct a state park facility and possibly a foot bridge across the Colorado River.

To document the completion of the site, DOE transmitted the completion report to the NRC and state of Colorado for approval. The report documents the surface remediation activities conducted at the processing site and its current condition. Once NRC and the state of Colorado review and comment on the report, DOE will finalize it and ask NRC to certify that the site meets EPA standards. Certification of the processing site is expected in mid-FY 1996.

In the past year, VP assessment and remedial activities continued in Grand Junction. Construction activities are complete at 4,186 of the 4,266 VPs included in the cleanup (98 percent), and DOE has certified that 3,764 (88 percent) are complete. The remaining properties are in various stages of investigation, remediation or certification. DOE's major VP remedial action activities in FY 1995 were conducted at the Hansen Container, Colorado National Monument, Industrial Construction Corporation and Doug Jones Sawmill VPs.

At the Cheney disposal site, the RAC has continued operations and monitoring activities to insure safe placement of contaminated materials from VPs in a reserved area of the cell. The RAC also installed two monitoring wells for long-term monitoring of the site. The wells collect daily water level measurements and semiannual analytical samples. In addition, DOE conducted a vegetation study at the site to look at plant species, their densities and their impact on the cell.

Under the ground water phase, DOE modified the final BLRA to incorporate the final EPA ground water standards and a revised risk assessment methodology. In addition, DOE initiated the processing site SOWP to build on the data gathered for the BLRA and provide a comprehensive picture of the ground water regime beneath the processing site. This document will identify possible alternatives for ground water remediation at the site and identify potential data gaps.

Green River, Utah

In FY 1995-96, DOE submitted the new Green River ground water protection strategy to the NRC and the state of Utah for concurrence. The related revisions of the LTSP and RAP was completed in FY 1996. The USACE site acquisition efforts were completed in 1995.

The UMTRA Project Team completed the revised final BLRA in FY 1995, while routine ground water sampling continued at the site.

Gunnison, Colorado

Construction crews in Gunnison completed hauling RRM from the former mill processing site to the disposal site in October 1994. Backfilling and restoration of the processing site was nearly completed by the end of FY 1995. Seeding and planting of cottonwood trees at the site were completed in early FY 1996. Similarly, work to reclaim the Tenderfoot Mountain haul road, the route that was used to transport the contaminated materials to the disposal site, was also nearly complete by the end of FY 1995.

Construction of the disposal cell was completed in FY 1996.

The UMTRA Project performed monitoring activities at nine sites which were constructed on BLM lands to mitigate the impact to wetlands and wildlife during remedial action construction.

Lakeview, Oregon

DOE resolved the remaining title transfer issues and the state of Oregon transferred the Collins Ranch disposal site title to the federal government. The NRC accepted the Lakeview site under its general license in September 1995. The UMTRA Project transferred the site to the DOE GJPO in September 1995 for LTSM.

For the ground water phase, the UMTRA Project prepared a draft BLRA and updated the WSAP. The ground water at the former processing site was sampled in FY 1995.

Lowman, Idaho

The UMTRA Project Team transferred the Lowman site file to the DOE GJPO in March 1995 while continuing "point of compliance" ground water monitoring, as dictated by the LTSP. The results are being evaluated in support of termination of ground water activities at the Lowman site as recommended in the NRC's Technical Evaluation Report.

Maybell, Colorado

DOE Headquarters approved the Maybell final EA in January 1995, and remedial action construction started in May 1995. The remedial action will stabilize the RRM on the existing tailings pile, i.e., consolidate windblown and mill demolition debris and reshape the tailings. Primary construction activities consisted of:

- Site preparation and mobilization
- Demolition of mill-related structures and placement of the debris in the disposal cell
- Cleanup of windblown contamination
- Reshaping the tailings pile
- Site grading.

As part of the ground water phase, the UMTRA Project Team completed BLRA in 1996.

Mexican Hat, Utah

DOE completed all remedial action construction activities at Mexican Hat in FY 1995, including LTSM features, e.g., site fencing and survey monuments. DOE conducted a closing ceremony for the combined Mexican Hat and Monument Valley surface remedial action on October 5, 1994.

DOE finalized the draft completion report and initiated preparation of the draft LTSP for the disposal cell in FY 1995. GJPO and UMTRA Project Team personnel conducted a prelicensing inspection of the site.

Monument Valley, Arizona

Remedial action at the Monument Valley UMTRA Project site was completed in March 1994 following removal of the on-site RRM to the Mexican Hat disposal cell.

For the ground water phase, the DOE completed the first draft of the SOWP. The SOWP process allows for flexibility in investigating and assessing the ground water at the site, and selecting a remedial action. The process involved seeking Navajo Nation review, comments and approval.

Naturita, Colorado

Phase I of the remedial action in Naturita, which consisted of demolishing the structures at the former processing site, was completed in November 1994. DOE Headquarters approved the EA and published the FONSI in FY 1995.

Disposal of the contaminated material from the former mill site will be at an existing Title II facility located at Uravan, Colo. The RAP and cell design, developed by Umetco Minerals Corporation, have been submitted to the NRC and the state of Colorado for review and approval. The actual disposal site, the Upper Burbank Repository, will be acquired by DOE prior to the placement of any contaminated materials.

Phase II of the cleanup, the relocation of the RRM from the former mill site and associated VPs to the repository, began in the Spring of 1996.

The final document was completed in early FY 1996.

Rifle, Colorado

DOE is remediating two former uranium processing sites along the Colorado River in Rifle: the Old Rifle site on the east side of the city and the New Rifle site to the west.

Construction crews completed surface remedial action at the Old Rifle site and from the New Rifle site. Approximately 3.5 million cubic yards of tailings and RRM were placed in the Estes Gulch disposal site. Construction of the disposal cell cover began in FY 1995. The cover is expected was completed in mid-FY 1996.

The UMTRA Project prepared a white paper on private wells and springs in the Rifle area, and prepared responses to comments on this position paper from the state of Colorado and the city of Rifle. The white paper described the hydrochemical relationship between the New Rifle and Old Rifle processing sites and the domestic wells in the vicinity of the former processing sites.

The final BLRA for both sites was also completed in FY 1995.

Riverton, Wyoming

NRC signed the site certification for the Riverton site in January 1995, signifying that remedial action was complete and that the site meets applicable EPA standards.

FY 1995 was a busy year for the Riverton site under the ground water phase. DOE transmitted the draft SOWP to the NRC, the state of Wyoming and the Northern Arapaho and Shoshone Tribes for review. The UMTRA Project Team also sent the revised final BLRA to the tribes for review, and prepared a supplemental WSAP to define the additional characterization proposed in the draft SOWP.

The Riverton draft SOWP field characterization programme was conducted during the summer of 1995 with the assistance of the Tribes and SNL. A DOE contractor installed nine new monitor wells and 10 tracer study wells to further characterize the hydrologic regime at the site. Another well was installed in response to the request of local residents northwest of the site who were concerned about the effect of the site on their ground water.

The UMTRA Project Team also collected core samples during the well installation programme for SNL to use in aquifer matrix studies, and jointly conducted aquifer and tracer tests with SNL in the latter part of the summer programme. They collected sediment, surface water and biota samples throughout the site area, and sampled all of the new wells. Finally, they surveyed all new well locations, sample locations and several water level points along the river and at wetlands adjacent to the site.

Salt Lake City, Utah

Surface remedial action and prelicensing activities in Salt Lake City focused primarily on developing the completion reports for the Clive disposal site, Vitro processing site and Central Valley Water Treatment Facility, a nearby VP. These reports are in various stages of review by the NRC.

The UMTRA Project developed a plan to address the outstanding issues related to the licensing of the Clive site. This included an inspection of site conditions by a team consisting of people from the DOE, TAC, RAC and NRC. The GJPO also conducted a prelicensing inspection of the Clive site.

Routine ground water sampling continued at the Vitro site. Quarterly monitoring of water levels at a local golf course continued and a contractor installed three additional data loggers. DOE also evaluated the potential effects and risks of proposed expansion of the golf course. The UMTRA Project prepared the final BLRA in September 1995.

Shiprock, New Mexico

The Shiprock UMTRA Site was licensed in 1996.

DOE completed the draft SOWP in FY 1995. The document discusses the two distinct ground water regimes and proposals for investigating and mitigating the ground water.

Slick Rock, Colorado

DOE approved the Slick Rock final EA in January 1995 and published a FONSI in the *Federal Registrar* on February 23, 1995. Resolution of NRC and CDPHE comments on the final RAP was completed in 1996. DOE sent the final RAP to NRC and CDPHE for concurrence.

Slick Rock is another UMTRA Project location with two former processing sites that DOE is remediating. The North Continent site and the Union Carbide site are both adjacent to the Dolores River about one mile apart. Remedial action and relocation of the RRM to the Burro Canyon disposal site, about six miles from the processing sites, started in March 1995.

Excavation of the cell and relocation of the RRM from the North Continent site were the primary activities initiated in FY 1995; however, the subcontractor did not make appropriate progress and the contract was terminated in September 1995. The RAC is taking steps to complete cell excavation, North Continent site material placement and Union Carbide site temporary construction facilities early in FY 1996. The RAC will also seek new bids from experienced contractors for the remaining work, and proposes to complete the remedial action on schedule in the first quarter of FY 1997.

DOE completed the ground water BLRA for both sites in FY 1995, preparing it for transmittal to stakeholders.

Spook, Wyoming

The UMTRA Project prepared the ground water draft SOWP and sent it to the NRC and state of Wyoming for review. No water sampling is proposed under the ground water phase.

Tuba City, Arizona

The Tuba City UMTRA site was licensed in FY1996.

The UMTRA Project Team finalized the completion report for the disposal site in FY 1995. The Project Team also completed the draft SOWP and sent it to stakeholders for review.

At the end of FY 1995, DOE made final preparations for the initiation of field activities at the disposal site in early FY 1996. The field activities include installation of:

- A clean water well to support a University of Arizona project to reestablish native vegetation in the area

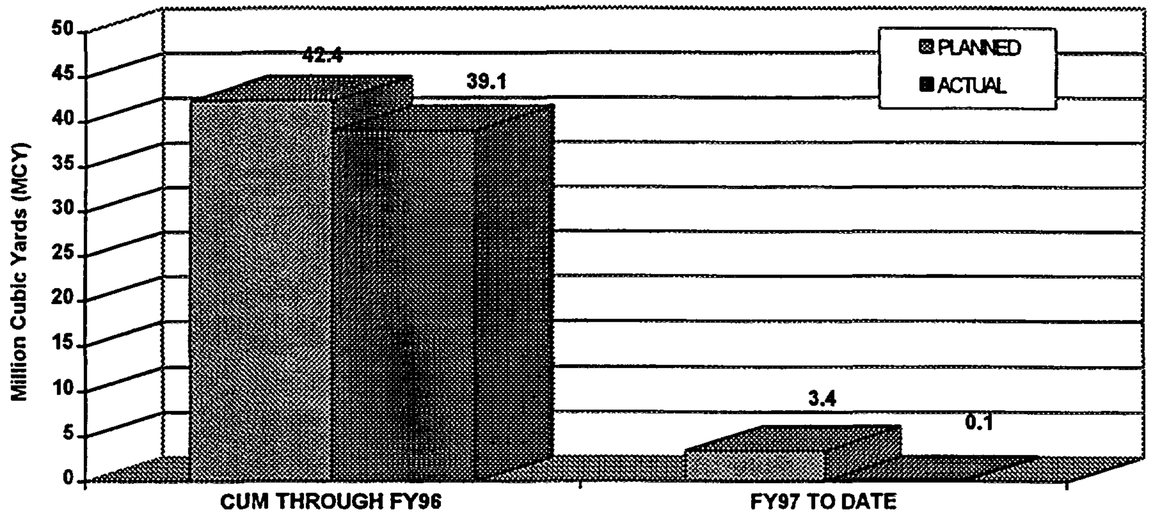
- Seventeen ground water monitoring wells for use in the ground water phase of the UMTRA Project

- Four extraction wells for removing contaminated transitory drainage moving downgrading from the cell. Transient drainage is a predicted phenomenon caused when the weight of the constructed cell "squeezes" water and contaminants into the ground below it.

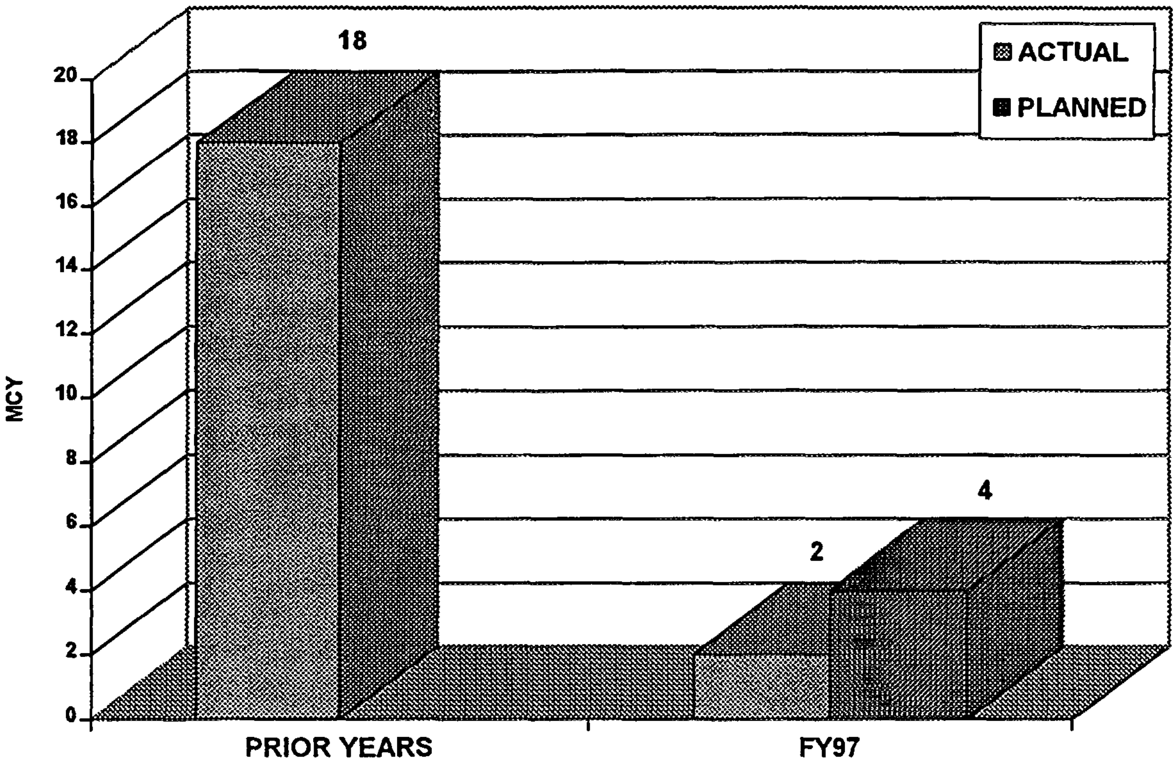
In addition, DOE contractors have constructed three holding ponds for containing the water pumped by the extraction wells. These ponds will be used to test various treatment methodologies for possible groundwater remediation.

4. CONCLUSION

The UMTRA project continues to move ahead towards its goal of having all UMTRA sites brought under the general NRC license by 1998 (i.e. completion of surface remediation). Significant progress has been made in the area of contaminated groundwater characterization at many of the UMTRA sites and will continue well into the future.



U. S. DEPARTMENT OF ENERGY'S
URANIUM MILL TAILINGS REMEDIAL ACTION PROJECT
VOLUME REMEDIATED



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