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Planning for environmental restoration of radioactively contaminated sites in central and eastern Europe

Volume 2: Planning for environmental restoration of contaminated sites

Proceedings of a workshop held within the Technical Co-operation Project on Environmental Restoration in Central and Eastern Europe in Piestany, Slovakia, 11–15 April 1994

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PLANNING FOR ENVIRONMENTAL RESTORATION OF RADIOACTIVELY
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FOREWORD

The radioactive contaminant materials resulting from diverse activities in relation to the nuclear fuel cycle, defence related operations, and various industries in addition to medical and research facilities represent perhaps the most severe and immense pollution left from a past era. The political changes in central and eastern Europe (CEE) not only brought some disclosure of the radioactively contaminated sites, but also resulted in a political condition in which this region became receptive to co-operation from a range of outside countries.

It is under these circumstances that the IAEA decided to launch a Technical Co-operation (TC) Project on Environmental Restoration in Central and Eastern Europe. The project was initiated in the latter part of 1992 and ended in 1994. The countries that were involved and represented in this forum are: Belarus, Bulgaria, Croatia, Czech Republic, Estonia, Hungary, Kazakhastan, Poland, Romania, Russian Federation, Slovakia, Slovenia and the Ukraine. Several experts from countries outside the region participated and offered their co-operation throughout the project.

The TC regional project consisted of three workshops that addressed different, but sequential, themes. The basic criterion consisted in matching the structure of the IAEA project with a real-scale environmental restoration project. The main focus was to identify radiological conditions in the region and remediation plans, if any.

The subject of the first workshop held in Budapest, 4-8 October 1993, was the identification and characterization of radioactively contaminated sites in the region. The second part of the project and the second workshop (Piestany, Slovak Republic, 12-16 April 1994) involved planning and preparing the identified sites for restoration. This included items such as the restoration objectives, dose and environmental assessment, cost analysis, strategy and prioritization. Eventually, the third part of the project covered technologies for, and the implementation of, environmental restoration. The third and final workshop was held in Rež, Czech Republic, 12-16 December 1994.

A great deal of technical and scientific information which was formerly classified or only available confidentially was disclosed under the auspices of the project. Information available only in national languages (mainly Russian) was made available in English. The three volumes of this TECDOC incorporate reports submitted by national experts and invited speakers at or following the three workshops. Volume 1 includes papers describing the identification and characterization of contaminated sites in the region. It also presents the objectives of the project, illustrates past and current IAEA activities on environmental restoration, provides a scientific framework for the project and the individual workshops and summarizes the results achieved. Volume 2 includes the papers that involve planning and preparing the sites for restoration. Volume 3 presents technologies for, and the implementation of, environmental restoration.

It should be noted that papers submitted by national experts are variable in length and content, as this reflects national conditions and approaches. Countries having one or two contaminated sites concentrate on technical details, countries with dozens of sites offer a general overview. Problems associated with contamination from the uranium mining and milling industry are intrinsically different from those related to accident generated contamination. By means of the papers contained in this TECDOC, the reader may get a general impression of the vastness of the problems in central and eastern Europe. The IAEA officer responsible for the workshops was M. Laraia, of the Division of Nuclear Fuel Cycle and Waste Management. Papers were compiled and edited by J. Wiley, of the same Division.

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 that hosted the project workshops.

EDITORIAL NOTE

CONTENTS

Background Paper

PLANNING FOR ENVIRONMENTAL RESTORATION OF CONTAMINATED SITES: CRITERIA AND METHODS

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Abstract

If decontamination of contaminated areas is required, the organization managing the operation should review and update relevant parts of any preliminary plan, and assemble the human and other sources needed to implement the cleanup and disposal operations. The characterization of the contamination and knowledge of the extent and types of areas affected would permit planners to determine boundaries and define zones needing special attention or special equipment. The final management plan must tie together all elements linked to the cleanup of the area. Therefore, the plan will include subplans on items such as: contamination characterization, details of the cleanup methods and equipment selected for various zones, logistics and supply, health physics support, transportation, packaging and disposal. Although the safety and radiation protection aspects of the plan are paramount in the implementation, the cleanup work must be done in an efficient and cost effective manner because of the potential for extremely high costs of an operation of this magnitude. Most of the information contained in this paper is based - with modifications and adaptation - on IAEA Technical Report Series No. 327, Planning for Cleanup of Large Areas Contaminated as a Result of a Nuclear Accident, 1991.

1. INTRODUCTION

Once the contaminated areas have been adequately characterized, planning for environmental restoration may start. It should be recognized that, as a result of planning activities and also during the implementation of cleanup programmes, a need for additional characterization may arise. However, in principle, pre-restoration radiological characterization should be good enough not to require further significant characterization efforts during later phases.

The types of information that should be developed by the management team during planning are summarized in Table I. In addition, it is very important that the management team identifies how the subelements of the plan interrelate and interact in an overall operational cleanup plan so there will not be misunderstandings and bottlenecks in implementation.

Items spelled out in Table I are individually discussed in the following sections. Items relevant to radiological characterization were already discussed in a previous paper and will not be re-discussed. Technologies, including those for waste treatment, transportation and disposal, will be discussed at length in a subsequent paper.

2. RATIONALE AND GOAL FOR CLEANUP

Actions to remediate very large areas contaminated as a result of a serious accident or past, bad waste management practices could cost hundreds of millions of dollars and cause risks and inconvenience to the public. If it is decided that the resulting detriment to health and social life of this kind of intervention would be less than that resulting from further exposures, all reasonable means should be used to minimize the costs and detriment to humans of such a cleanup. The best way of doing this is by ensuring that proper planning, co-ordination and management of activities are enforced at all stages.

TABLE I

SUMMARY OF ITEMS TO BE INCLUDED IN ENVIRONMENTAL RESTORATION PLANS

Rationale and goal for cleanup (Section 2)

Characterizing the affected area

Radiological characterization

- source term estimate
- environmental monitoring database
- characterizing the contamination
- statistical sampling plan to validate cleanup
- cleanup criteria (Section 3)
- confirmatory monitoring plan

Managing the cleanup

- management structure for cleanup (Section 4)
- analysis of cleanup options (Section 5)
- co-operative agreements (Section 6)
- data management plan (Section 7)
- planning the implementation (Section 8)

Logistic support for cleanup

- provision of required resources (Section 9)
- provision of required personnel (Section 10)
- logistic support office (Section 11)
- quality assurance (Section 12)

Transportation plan (Section 13)

Waste disposal plan (Section 14)

Radiation protection and safety (Section 15)

The potential detriment to the public if the contaminated area is not cleaned up in a reasonable time will depend on many factors such as the radioactive source terms, distance from the source, population distribution and density, weather conditions, downstream use of water and other protective measures that may have been implemented. For example, in case of an accident, if serious contamination of a heavily populated urban area was not cleaned up quickly to acceptable levels, the resulting health, social and financial costs of caring for the displaced persons would be very serious and much greater than if the accident occurred in a remote area. Loss of wages and economic output for the area would also be a major economic problem.

In environmental restoration plans, the rationale behind the planned actions and the goals for cleanup should be clearly defined.

The rationale behind the decision whether to implement decontamination/stabilization or do nothing to large affected areas should be carefully and fully established beforehand, probably in the form of Derived Intervention Levels (DILs) worked out using international principles and site or country specific data. In addition to the DIL, the decision making process should include socioeconomic, political and psychological factors, the type of area, population distribution, environmental impact of cleanup, availability of cleanup equipment/personnel as well as normal cost-benefit analysis, etc. A decision to implement cleanup of an area would be appropriate only if the detriment to health and the social and economic cost of implementing the cleanup will be less than the detriment resulting from further radiation exposure and/or exclusion of the population from the area.

The major goal of cleanup would be to reduce, as soon as is feasible, the contamination levels such that the dose to humans through direct exposure or food pathways would be acceptable by removing or immobilizing the contamination. The goal is generally expressed in terms of cleanup criteria (Section 3). Even if the dose to humans via direct exposure is acceptable, removal of contamination may be required if pathway analyses indicate that the food path, especially where long lived emitters are involved, could become a problem in the future. Terrestrial and aquatic pathways may be important in some scenarios and should be considered in the development of criteria. Societal and political acceptability could influence the objectives of the cleanup. In the past, some cleanup actions have had to be repeated because society no longer accepted past actions.

The rationale, goals and timing of the cleanup could vary from country to country and from site to site and would depend on a great many factors including: societal expectations, wealth of the country, availability of equipment, land usage and population density.

3. CLEANUP CRITERIA

The decision to remediate a contaminated area is made on the basis of the derived intervention level for this protective measure. Once the decision to implement such a cleanup has been made, cleanup criteria must be available to define the specific radionuclide concentration limit/gamma exposure level which must be achieved by the workers doing remedial action. In addition, criteria for the release of the whole or part of the area for unrestricted or restricted use must be available to allow the return of the population and/or reuse of the land for agriculture, etc.

The development of such criteria which relate dose-to-humans to contamination levels using pathway analysis is difficult for small sites and extremely difficult for large diverse regions. In practice, different acceptance criteria may be set of different zones or situations in large contaminated areas. For example, much higher residual activity levels may be acceptable for remote rural, forest or desert areas and for buildings with good shielding properties or low occupancy.

It is beyond the scope of this paper to give detailed guidance on the development of such criteria since it is a specialized task, However, the criteria should be based on internationally accepted risk levels translated into acceptable dose limits. Concentration limits for radionuclides in soil, water, air and food or acceptable radiation levels can be derived using suitable pathway analysis and, where possible, realistic site specific parameters.

In the past, various criteria have been used for the release of sites from decommissioned reactors, mine/mill facilities or contaminated areas such as Enewetak or Palomares. For example, USNRC Regulatory Guide 1.86 has been used in the USA and elsewhere for the cleanup of reactor and other sites.

During the final planning of the cleanup these criteria would have to be reviewed for suitability and applied in a site specific manner in various zones during implementation of the plan.

It should be noted that release criteria developed for planned activities (e.g. the decommissioning of nuclear facilities at the end of their operational lifetime) may not be adequate to intervention situations as defined by the ICRP (1991). In particular, unrestricted release criteria such as those promulgated by USNRC R.G. 1.86 may be unachievable under the circumstances. In general, derivation of cleanup criteria will require some form of cost-benefit analysis to ensure that the limited resources are used to achieve the best overall results. Other factors which should be considered in the decision making process related to the type of remedial actions employed and the timing include: environmental impacts, short and long term interdiction of land or buildings, the dose burden on cleanup personnel, and socioeconomic and psychological impacts.

4. MANAGEMENT STRUCTURE FOR CLEANUP

Fig. 1 is a schematic picture of the management structure for cleanup of contaminated areas after an accident. For cleanup exercises other than post-accident situations, the flow chart cannot generally have management levels above implementation organization. A cleanup control centre would be used by the cleanup management team to prepare and implement the final plan and to exert overall control of the cleanup. The management team could, for example, consist of the cleanup director and his advisers on topics such as: radiation protection and safety, surveying and sampling, urban and rural cleanup, transportation, disposal and data management. The final cleanup plan and the implementation strategy would be developed by the cleanup team.

In certain cases, for example cleanup after a nuclear weapons accident or waste transportation accident, the cleanup control centre may have to be mobile.

The control centre should also include items such as:

- The generic and site specific data gathered as part of planning for cleanup.
- Maps showing the current status of the radioactive contamination levels in the defined zones.
- Maps showing information such as control check points, decontamination centres, status of the cleanup, transportation routes, disposal areas, etc.
- Communications equipment and operators, including direct contact with contamination monitoring and cleanup groups in each zone and teams controlling common facilities/functions.
- Computer centre for data acquisition, analysis, plotting and recording. The system could be used to calculate, record and assess radiological survey data and occupational doses, status and location of major equipment, waste transportation waybill data, location and status of disposal sites, etc.

Responsibilities of the cleanup organization could include: public relations; information flow to local and national authorities, the public and the media; enforcement of zonal control; liaison with other organizations such as the police, public health authorities and the facility owner; and assessment of doses to the public.

In addition to the central management team, the cleanup organization would probably consist of:

(a) Field teams for zonal control and cleanup plan implementation. Each team should consist of a zone manager and enough special personnel and equipment to clean up the zone in a safe and efficient manner. The make-up of a typical team could, for example, be as shown in Fig. 1.

(b) Teams for the control and operation of common facilities such as waste disposal sites, and the co-ordination of other common functions such as transportation systems (Fig. 1).

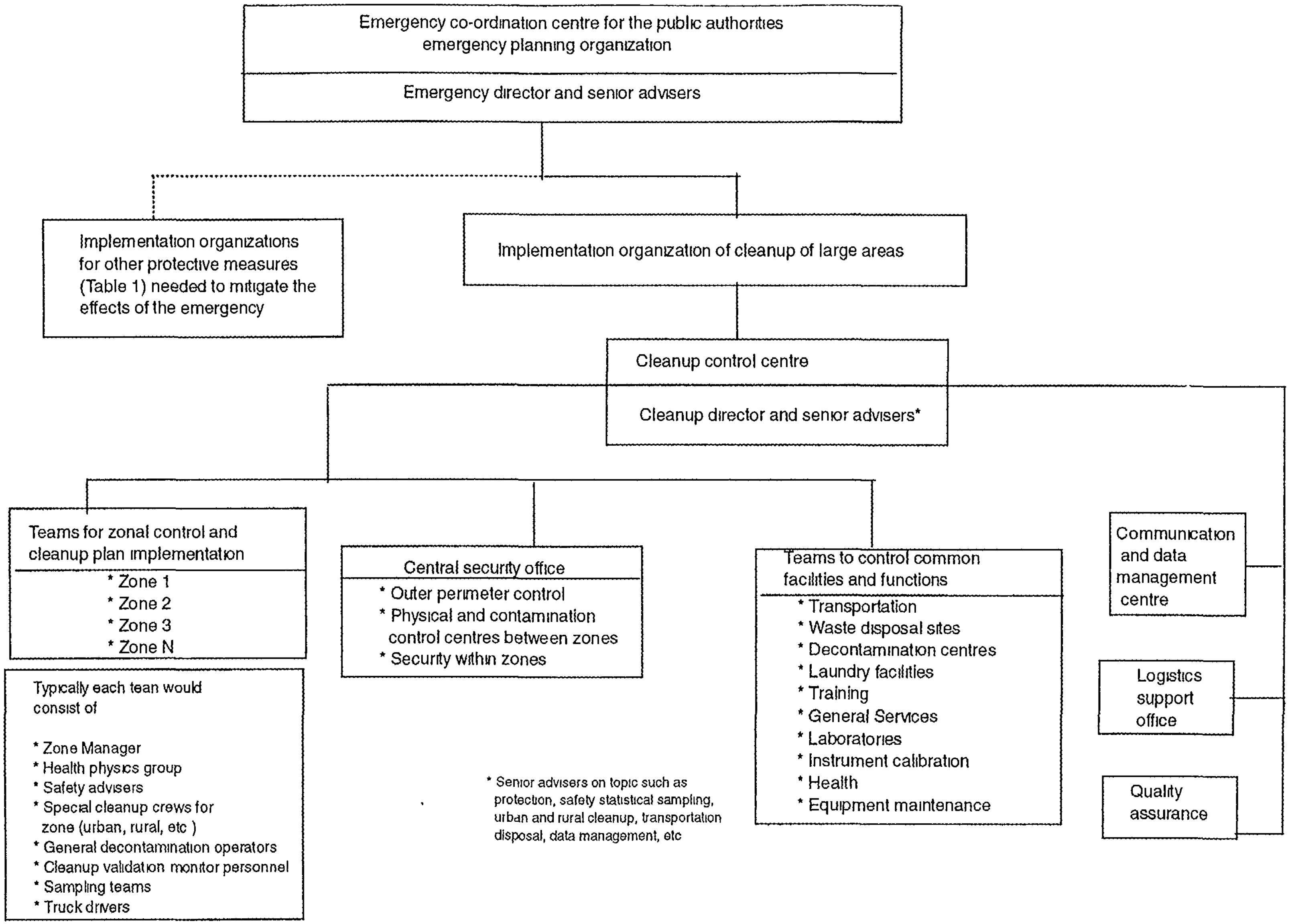


FIG. 1. Management structure for cleanup of contaminated areas.

The number of field teams and their make-up would depend on site specific factors such as the size of the affected area, the type of zones (urban, rural, etc.), the number of people affected, the urgency for cleanup, and the availability of trained teams and suitable equipment. The teams would probably specialize in the cleanup of one type of area, for example urban, farmland forests or groundwater.

The cleanup organization described above is given only for illustrative purposes. The exact organizational structure, the number of field teams and their make-up would vary considerably depending on factors such as: site and contamination specific conditions, availability of equipment and trained staff, local infrastructure, urgency of cleanup, etc.

5. ANALYSIS OF CLEANUP OPTIONS

A preliminary analysis should be made to determine which remedial options would best reduce the detriment in various zones in the affected region. Preliminary decisions can be made on such things as:

- interdiction versus decontamination
- most probable cleanup techniques for certain areas or surfaces
- evaluation of the trade-off between cleanup standards and decontamination costs
- sequence of cleanup steps for selected areas, e.g. vacuuming before hosing, crop removal before ploughing.

Interdiction of an area for short or long periods is the simplest means of mitigating the radiation exposures to the population due to widespread contamination.

The cost of interdiction of economically important areas could be quite high and in general it is less expensive to decontaminate such areas rather than interdicting the land for long periods. On the other hand, the interdiction of limited-use land such as grazing lands, certain forests, mountaineous areas and marshes would involve small economic penalties. However, since this type of area would only receive limited use normally, its interdiction would not greatly reduce overall radiation exposures to the public. Since the subject of this project is environmental restoration, no further mention of the interdiction option will be made.

6. CO-OPERATIVE AGREEMENTS

Information should be available on the co-operative agreements between various levels of government and between the Member States and other Member States and/or international organizations related to sharing of expertise, equipment, facilities and personnel.

7. DATA MANAGEMENT PLAN

Technical means should be developed for identifying, recording, collating, categorizing and assessing information received on items such as: samples taken, volumes of wastes, radionuclide content of wastes and where each truckload of waste is disposed of. It should be made clear that critical data points and the location of disposal sites or trenches should be surveyed and the information recorded.

During preliminary planning, the goals and requirements for the data management plan should be clearly defined. If during the actual cleanup, feedback of monitoring results is required daily to assist in decision making for soil cleanup and removal operations, the data management techniques must be able to process the input data to allow such decisions to be made. For example, during the Enewetak cleanup, monitoring data collected before and after soil removal on the vehicle borne gamma spectrometer tape storage system were shipped back 30 km to the support base at the end of each day. At the base the data were analysed and combined with soil analyses to produce ^{239}Pu and ^{240}Pu isoconcentration areas on grid maps. The information was then sent back to the decision makers for planning follow-up activities. This type of close support is necessary for high working and cleanup efficiency and subsequent radiological verification.

Flow diagrams for the monitoring and chemical analysis data joined to time charts for the operation can reveal potential bottlenecks in the data flow. From this type of analysis, it can readily be determined how much lead time is required for soil sampling to prevent holdups. The flow diagram/time chart analyses also permit survey requirements to be closely defined. Time constraints and data demands can be used to determine the data collection capacity required in the field and laboratory. Because demands on data processing will be heavy, it is important that well developed protocols and quality assurance programmes be set up. To remove soil which was clean or to have to go back later to clean up areas missed in the analysis can be costly errors which significant effort should be made to avoid. Therefore the data must be of high quality and provided on time so that the operation will run smoothly and be cost effective.

Special data management needs arise in the event of a very large accident such as Chernobyl, especially if large urban areas are affected. At Enewetak and at most of the uranium mill tailings cleanup projects in various parts of the world, large urban areas were not involved. For a very large cleanup involving urban areas, the amount of data required to safely and efficiently manage the cleanup/decontamination of buildings, land and water systems and for the transport and disposal of waste could be very large. The data recording and management teams would have to be bigger and well integrated and the planning more detailed. The connection and data feedback between the central data management computer and the small mobile computers with the field units and analytical laboratories would have to be well developed.

Further work is required to assess the data management requirements to ensure that the cleanup of very large areas seriously contaminated with radioactive materials can be done safely and efficiently.

8. PLANNING THE IMPLEMENTATION

The implementation of remedial actions must be based on a well defined final plan if it is to be safe, efficient and cost effective. Although the safety and radiation protection aspects of the plan are paramount in the implementation, the cleanup work must be done in an efficient and cost effective manner because of the extremely high cost of an operation of this magnitude.

To implement the plan effectively and safely requires that the following personnel, equipment and facilities be available:

- a good management team
- well trained and dedicated monitoring, sampling, maintenance and cleanup crews
- mobile monitoring instrumentation and radiochemical laboratories
- a data management programme for storing and analysing information
- equipment and techniques for cleaning up the contamination
- means of loading, transporting and disposing of the wastes
- decontamination facilities for equipment and personnel at the interfaces between the clean and contaminated areas and at the disposal unloading area
- health physics and radiation protection supplies and equipment.

Some management aspects related to implementation of the cleanup plan would be as follows:

(a) Define cleanup priorities

The first task in defining cleanup priorities is to produce a detailed map of the type, mix, concentration and spatial distribution of the radionuclides released and relate these data to the characteristics of the affected area, especially population density, land usage, types of building, etc.

With this information, the management team in conjunction with the emergency director can delineate cleanup zones and determine which area should be cleaned up first. Table II gives examples of cleanup priorities which could be assigned to different categories. The assignment of actual priorities can only be made on a site specific basis.

(b) Implement the cleanup

The cleanup would probably be implemented in stages as the cleanup teams are assembled and trained and equipment and facilities are made available. Each team must have a working knowledge of the means of applying the special cleanup techniques, preferably on a large scale, required for their

TABLE II
EXAMPLES OF GENERAL CATEGORIES FOR PRIORITY DECONTAMINATION AFTER A NUCLEAR ACCIDENT

Categories		Cleanup priority		
		High	Medium	Low
I	Residential areas - large developments - remote single residence	 X 	 X	
II	Other structures - hospitals - businesses	 X 	 X	
III	Water sources - primary municipal source - secondary water source - recreational use	 X 	 X 	 X
IV	Agricultural land - foodstuff products - non-food products - gardens - frazing, etc.	 X X X	 X X 	 X
V	Forests - commercial forest - non-utilized areas		 X 	 X
VI	Roads, rights of way - primary - secondary	 X 	 X	
VII	Remote areas - deserts, forests, etc.			 X
VIII	Plant site and adjacent buildings	X		

Note: From the results of pathway analyses, the above categories could be weighted on the basis of the resultant dose equivalents and the percentages of total area encompassed in the particular land use.

particular zone. The rate of implementation of the cleanup would be determined by factors such as the number of teams available, the equipment available, the efficiency of the cleanup techniques, the effectiveness of the monitoring and sample analysis teams, the urgency to return people to the area, weather conditions, etc.

(c) Co-ordinate the cleanup

The management team must ensure that all components of the cleanup are developed and implemented in an integrated and co-ordinated manner. Some examples are:

(i) The rate of cleanup must be matched to the output of the confirmatory monitoring teams so that contamination is not left behind. The instruments used must be appropriate to the radionuclides present and suitable monitoring protocols must be developed to ensure efficiency of monitoring, especially with newly trained monitoring staff.

(ii) The laboratory support must be able to meet the projected sample load and provide results in a timely manner so evacuation crews are not kept waiting to see if more material must be removed.

(iii) The ability to handle, interpret and use the data provided from a multitude of sources must be well developed, along with the means of communicating the results to the appropriate team.

(iv) The disposal site capacity and transport system must be matched to the cleanup rate.

(v) The lessons learned by teams should be fed back as rapidly as possible to other teams and into the training programme.

9. PROVISION OF REQUIRED RESOURCES

Any environmental restoration plan should include a list of equipment and facilities required for the cleanup. This list should be compared with the availability of similar resources in the region or elsewhere that could be called on, for example resources in nuclear facilities, military bases and industry. Equipment such as radiation instruments, cleanup equipment, large trucks and remotely controlled equipment would be of interest. Data on suitable disposal areas should be collected in this phase.

A detailed description of equipment and facilities required for the cleanup will be given in a subsequent paper.

10. PROVISION OF REQUIRED PERSONNEL

The environmental restoration plan should include details of the management structure required to prepare the final plan and to implement and co-ordinate the cleanup. Key personnel should be listed with their telephone numbers so they can be contacted quickly in the event of a cleanup emergency.

Details of the personnel requirements for cleanup teams for various types of area (urban, rural, forest, etc.) and for special facilities such as disposal sites and decontamination centres should also be available. Although some of this information is generic in nature, it should be applied in a site specific manner during planning.

11. LOGISTIC SUPPORT OFFICE

A great deal of logistic support would be necessary to supply and maintain: the staff and equipment associated with the Cleanup Control Centre and its associated facilities; the field teams doing the cleanup; the personnel controlling and operating the common facilities such as machine shops and decontamination centres; security offices; etc.

A Logistics Support Office (LSO) should be set up to fulfil these functions and the head of this office should be one of the senior advisers to the Cleanup Director (Fig. 1). The LSO could provide some or all of the following functions:

- Order and supply all necessary materials and equipment for the teams and facilities which are under the direct control of the Cleanup Director, including health physics equipment and supplies;
- Provide food and accommodation for all cleanup personnel;
- Provide auxiliary facilities such as health clinics, mobile showers and personnel decontamination centres, and respirator cleanup areas;
- Keep records of all materials, and equipment supplied to the restricted area as well as data on personnel;
- Provide maintenance and construction assistance;
- Provide warehousing for chemicals and materials, and mixing areas and facilities for chemicals such as the spray solutions used for decontamination or fixation.

12. QUALITY ASSURANCE

Any activity which could have an impact on the health and safety of the workers or the public or affect the success of the cleanup should be covered by a suitable quality assurance (QA) programme. For such activities it is necessary to have procedures, documentation, controls, guidance on selective application of QA procedures, and accurate information and techniques to verify compliance with QA procedures. Personnel working in these areas should be well qualified and trained to implement such programmes.

Since QA is an essential element of all cleanup activities, the programme should be applicable to all activities that could compromise the successful cleanup of the area. The development and co-ordination of the QA programme should be assigned to a Quality Assurance Office (Fig. 1) which reports directly to the Cleanup Control Centre. This office defines an overall QA plan which describes how the appropriate criteria are to be applied to all cleanup activities. The QA Office would also have each subcontractor provide a detailed QA plan applicable to each phase of the work, e.g. for sampling, monitoring, procurement and transportation.

In developing the plan, it should be recognized that public health and safety are not always affected to the same degree and a graded approach to QA can be developed to ensure an adequate level of quality for factors such as maintenance and operational reliability. Less stringent but still viable quality levels could be utilized for quality related functions not affecting safety whereas the criteria should be applied to the maximum for safety related functions.

The overall QA plan should show the compatibility of QA programmes applied to the cleanup and outline how each QA subplan fits into the overall picture to give total QA coverage.

13. TRANSPORTATION PLAN

Large volumes of contaminated soil, concrete, asphalt, equipment, vegetation, etc. could arise from the cleanup of a large contaminated area. For example, the removal of a thin (average thickness of about 5 cm) layer of contaminated material from a 7 km radius around a damaged facility could result in 8×10^6 m^3 of waste which has to be transported to a disposal site and buried. The loading and moving of such large volumes of soil is time consuming and expensive but the experience is not unique.

For example, during the construction of large earth dams, millions of cubic metres of inactive soil and concrete have to be loaded and moved. It is also common to load and move large volumes of product and waste rock in mining.

Operational experience on the procedures, techniques and equipment actually used to safely load, transport and dispose of large quantities of soil containing low concentrations of radioactivity can be found in the literature. For example, in Canada 70 000 m^3 of ^{226}Ra contaminated soil were gathered from an urban area and loaded into trucks during the Port Hope cleanup and transported to a disposal site 350 km away in 20 m^3 dump trucks without incident. The wastes were covered with a tarpaulin during transport. In the USA, remedial actions have been completed to clean up a 51 ha uranium mill site in Utah and move 2.16×10^6 m^3 of contaminated soil by train to a disposal site about 140 km away.

Effective management and control systems will be required to move and dispose of large quantities of earth safely. The protection of the operational staff and the environment must be important factors during the planning and cleanup. One of the biggest problems on a job of such magnitude may be to ensure continual maintenance of safety and health physics procedures once the job becomes routine.

In planning for the loading and transport of these wastes there are certain basic requirements:

- a modified waybill control technique in conjunction with a data handling system to control the loading, transport and disposal of wastes;
- well defined transportation routes and truck control points to ensure compliance with the routing plan;
- truck cleanup areas and monitoring points either at the dump site or between the contaminated and clean zones;
- an emergency response plan for implementation in the event of a transportation accident.

14. WASTE DISPOSAL PLAN

The objective of disposing of radioactive wastes is to confine the radionuclides within the respository site until they no longer represent an unacceptable risk to the environment and the public. A repository should fulfil two important and related functions in this regard: firstly to limit dispersion of the radionuclides contained in the wastes by water-borne and airborne pathways and to protect the waste from surface and near surface deteriorating processes such as erosion or intrusion by humans, burrowing animals or deep-rooted vegetation.

The radionuclides of longer term concern in the soil after an accident at a nuclear power plant are ^{90}Sr and ^{137}Cs, both with a half-life of approximately 30 years. After about 300 years, the concentrations of these radionuclides in soil would be about 0.1% of the concentrations after the accident. Therefore, a storage facility capable of containing these wastes for several hundred years should be suitable for most of the soils collected.

The type of facility selected for disposal of the soil will be dictated by many factors, including the availability of equipment to move the wastes, the volumes to be moved, the distances involved, the availability of natural or man-made disposal sites such as quarries, mines or depressions and the hydrogeology and geology of the area. The basic factors which must be considered in order to achieve a suitable disposal repository system are: the quantity and nature of the wastes, the engineering features incorporated into the repository design, the site characteristics and the time period allowed for institutional control. Conditions are combined in the safety assessment (Fig. 2) to achieve a disposal system that will meet the regulatory or desired environmental protection requirements. For example, a special cover to prevent intrusion by humans would not be required if the institutional control period is expected to be longer than the hazardous life of the wastes.

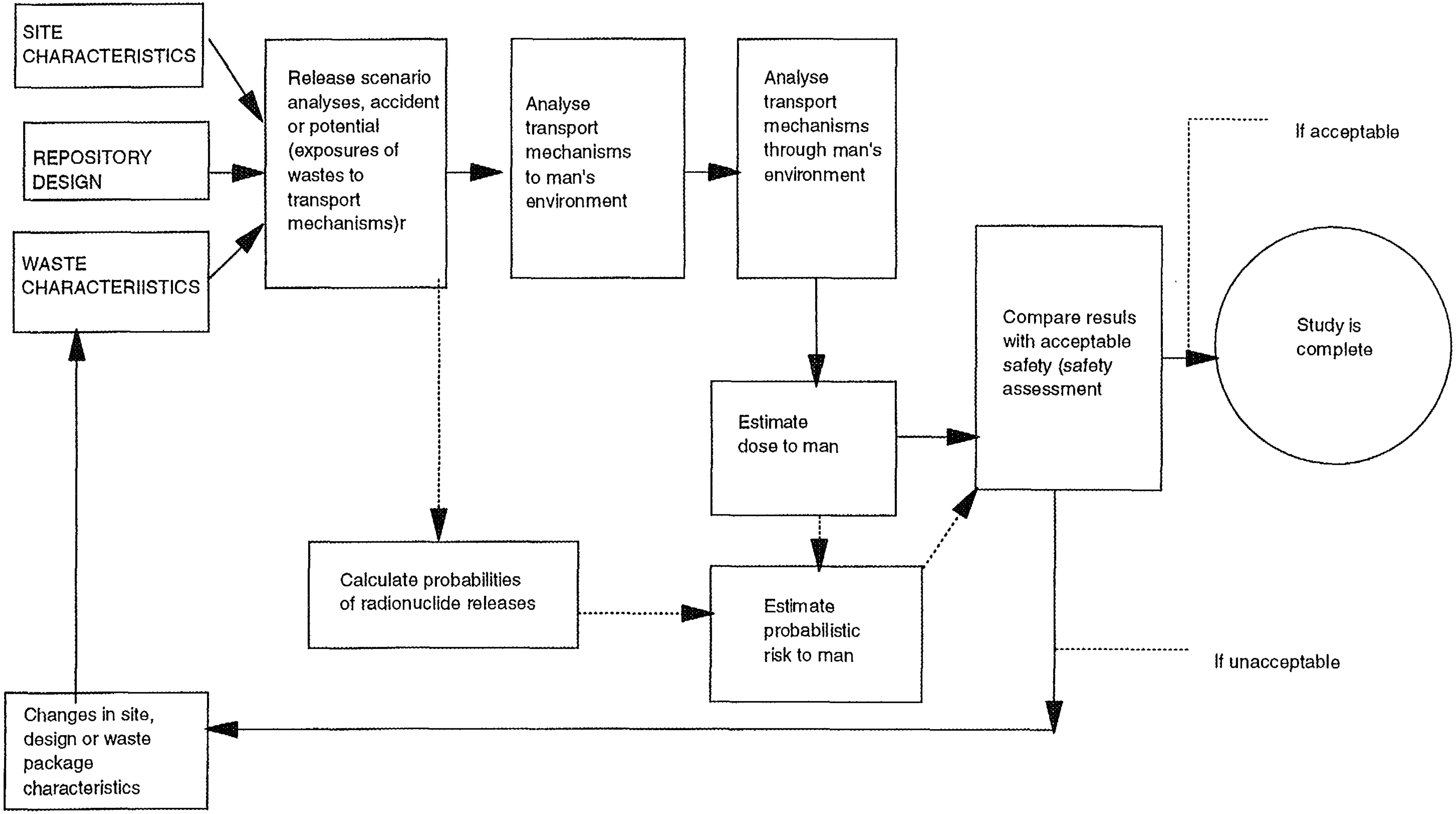


FIG. 2. Relationship between safety analysis activities. Dashed lines indiicate additional activities when analysing probabilistic safety.

While the specifics of any accident will affect the disposal plan, some general guidance can be offered regarding disposal of large volumes of contaminated soils (Fig. 3).

The idealized sequence of investigation for the selection of any waste disposal site has four general phases:

- planning and general studies
- area survey
- preliminary site selection
- site confirmation.

Figure 4 shows details of these four phases for a rock repository for low/intermediate level wastes. The hydrogeological considerations applied in selecting a site for shallow land disposal of radioactive wastes are given in Table III.

15. RADIATION PROTECTION AND SAFETY

15.1. Introduction

Radiation protection and safety planning and implementation are inherent parts of all nuclear activities and are especially important in the cleanup of very large contaminated areas.

During the last 35 years, considerable work has been done on the development of the principles of radiation protection and on the techniques and instrumentation required to implement these principles. A wide variety of instruments are available for personnel monitoring, air monitoring and the detection and measurement of all types of radioactivity. These principles and techniques are demonstrated daily at nuclear facilities around the world and have been applied successfully to small and large cleanup tasks. Such tasks include the rehabilitation of seriously damaged reactors, the cleanup of large contaminated sites and areas, the decommissioning of nuclear facilities for unrestricted use and regular maintenance procedures in operating facilities.

Most countries operating nuclear power plants have statutory emergency planning procedures to cope with accidental releases of radioactivity. Experience gained through emergency exercises together with technological developments in monitoring equipment and data handling and the impetus provided by incidents such as TMI have led to continual improvements in these procedures.

To protect public health in the event of a nuclear accident, methods for determining derived intervention levels have been published. These ensure timely application of protective measures. Decontamination of land and property is one such measure which may be considered during the intermediate and late phases.

During the cleanup of land and property, the radiation protection and safety programme has two basic components:

(a) Ensuring the protection of the workers and the public during the cleanup.

(b) Ensuring that the cleanup meets certain criteria so that the people returning to their homes do not receive uncontrolled exposures. The present section of the paper does not deal with this particular aspect of radiation protection and it is assumed that the confirmatory monitoring plan has verified that the cleanup has met the stipulated criteria.

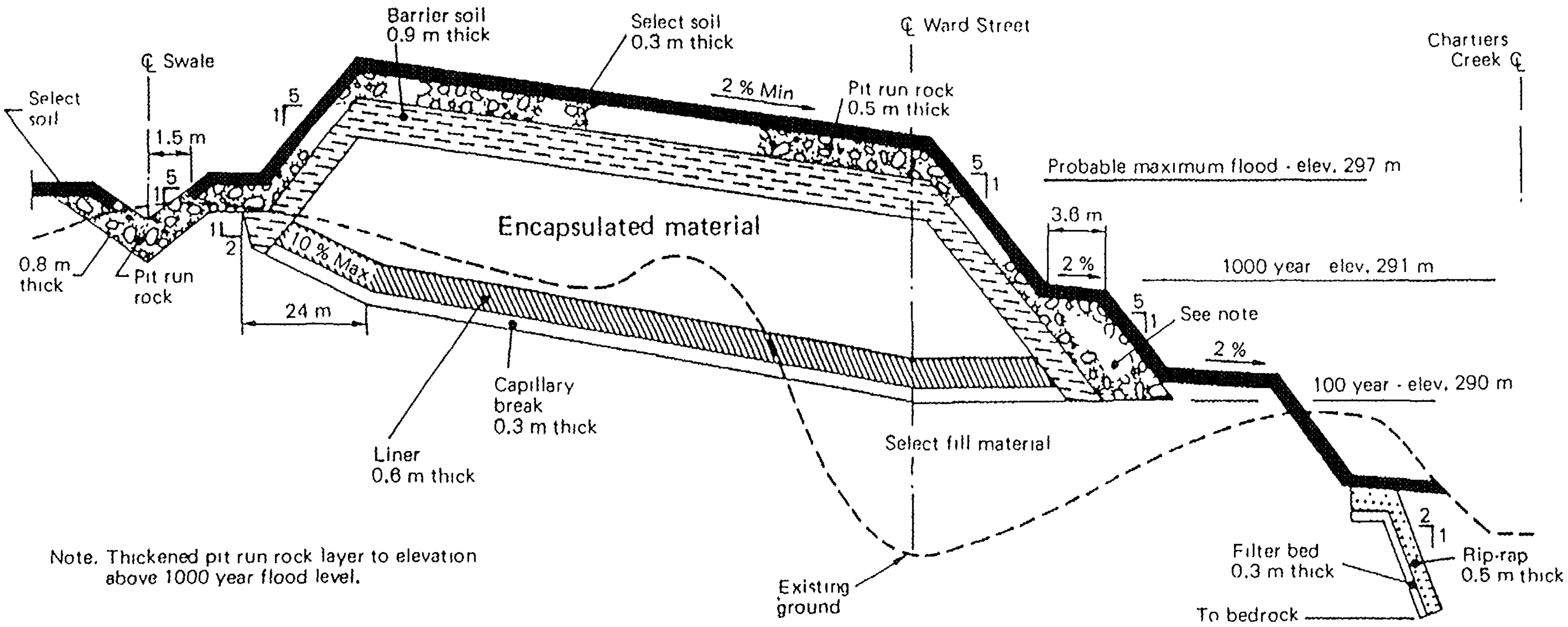
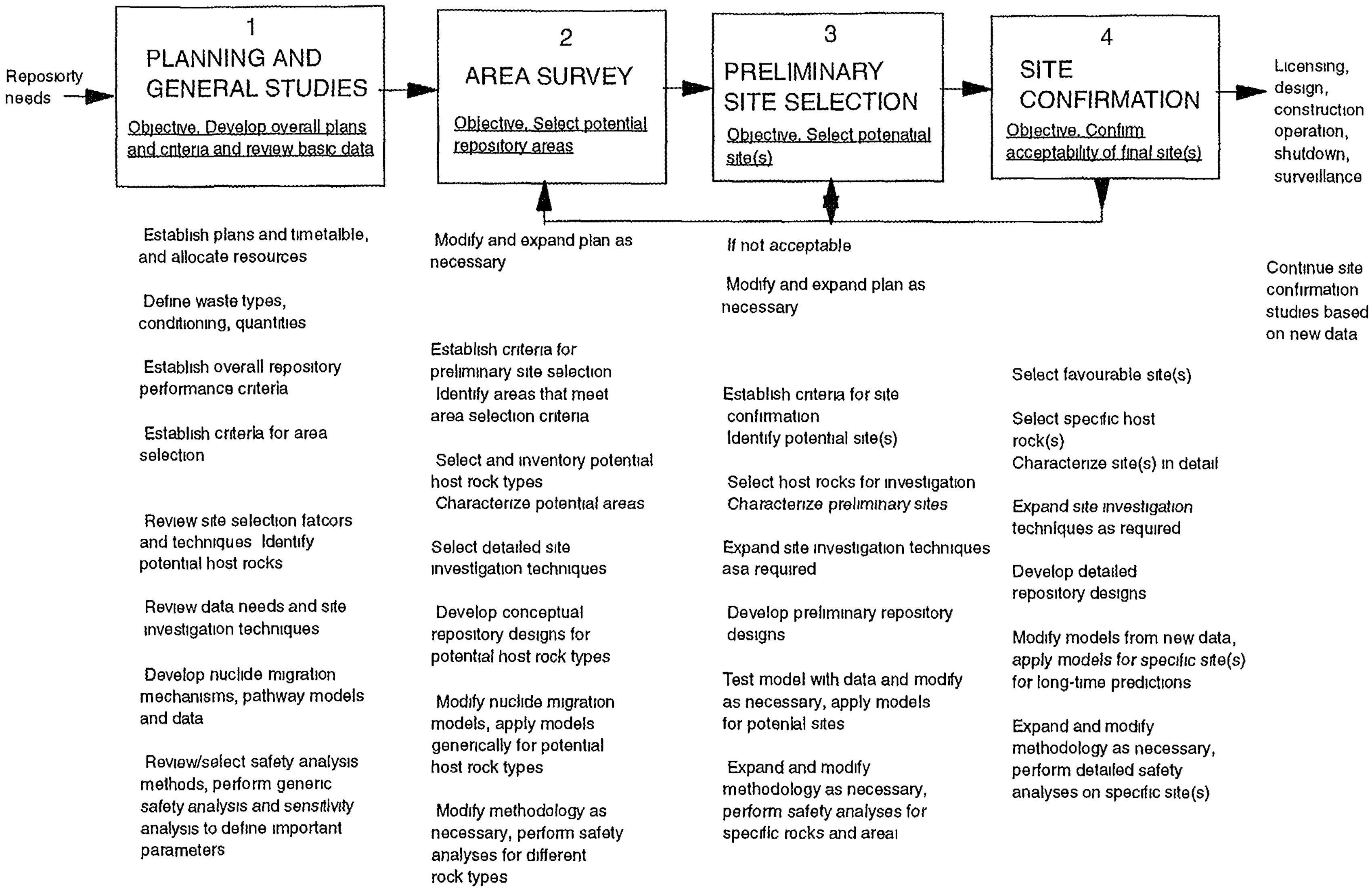


FIG. 3. Typical cross-section (not to scale) through the capsulation area of the uranium mill tailings remedial action project site at Canonsburg, PA



Note At each stage of the site investigations societal ecological and national legislative issues are considered The regulatory body should be involved according to national requirements
The term rock in this table includes all earthen materials including unconsolidateld material such as soil (see Glossary)

FIG. 4. Idealized sequence of investiqations for site selection

TABLE III HYDROGEOLOGICAL CONSIDERATIONS IN SITE SELECTION

Map/Literature

Geology
Topography
Precipitation
Evapotranspiration
Nearest surface water
Nearest water use or discharge point

Field reconnaissance

Preliminary

- Type of disposal media
- Prevailing wind direction
- Relief
- Subsidence
- Slope stability
- Flooding potential
- Erosion potential
- Depth of water table
- Depth to fractured bedrock

Intermediate

- Existing geological faults
- Disposal media
  - Sorption capacity
  - Thickness
  - Engineering properties
  - Permeability
  - Effective porosity
  - Structure
- Hydraulic gradients
- Hydrological budget
- Hydrological complexity
- Adequate water supply
- Monitorability
- Remediability

Detailed site analysis

- Three dimensional head distribution
- Disposal media and underlying site geology (including nearest confined aquifer)
  - Water chemistry
  - Stratigraphy
  - Ion exchange capacity
  - Moisture content of unsaturated zone
  - Soil moisture tension
  - Transmissibility
- Natural fluctuation of water table
- Flow data for nearest streams including underflow
- Water table contour map
- Possible measures for groundwater manipulation

15.2. Radiation protection and safety plan

This plan should include a comprehensive radiation monitoring programme which provides for the measurement, evaluation and recording of exposures incurred by individuals through different pathways. The plan should also deal with practical matters related to the implementation of the programme including such things as the training and classification of personnel, the duties and responsibilities of various groups in all aspects of the cleanup (e.g. handling, transport, disposal) and the use of protective clothing.

The plan should also include a list of required equipment, facilities and personnel needed to implement the radiation protection programme and details of where these resources could be obtained.

The extent to which the monitoring programme for the general public could be achieved if relocation has not been carried out and cleanup is proceeding would depend on the number of people involved and the availability of trained staff and equipment.

16. CONCLUSIONS

Actions to remediate large areas contaminated as a result of a nuclear accident or past, bad practices could cost hundreds of millions of dollars and cause inconvenience to the public. Such a cleanup programme would be undertaken only if the detriment to health and social life resulting from cleanup activities would be less than that resulting from further exposures. All reasonable means should, however, be used to minimize costs and detriment to humans of such a cleanup. For such a cleanup to be carried out safely, efficiently and as quickly as possible under adverse conditions requires:

(a) Good planning,
(b) A cleanup team having a well defined management structure and well trained personnel,
(c) Suitable cleanup methods and equipment and cleanup criteria.

METHODS OF PLANNING AND PREPARATION FOR RESTORATION OF BELARUS TERRITORIES CONTAMINATED WITH RADIONUCLIDES AS A RESULT OF THE CHERNOBYL ACCIDENT

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Abstract

Organization of works on the problems of clean-up is considered. The works are carried out in accordance with the State program on elimination of the consequences of the Chernobyl accident.

The Institute of Radioecological Problems of the Academy of Sciences of Belarus is the leading organization in the Republic on the problems of decontamination.

Up to 1994, the works on restoration of contaminated territories haven't been practically carried out.

The problems of carrying out the restoration, methods of planning and preparation for it based on the "cost-benefit" analysis are considered. Technical and economic aspects of restoration of contaminated territories are analysed.

It is shown, that the combined methods of clean-up are the most promising. Determination of advisability of clean-up is carried out on the basis of economic evaluation of risk when a person is chronically exposed to 1 man-rem, with allowance for risk factors: premature death, shortening of lifetime, loss of ability to work, reduction in life standards.

It should be recognized, that restoration must be done in complex for several regions, as the clean-up of a single region can lead to its secondary contamination.

Determination of the clean-up consequences of the affected regions is an important problem.

Remedial actions should include the complex of measures on clean-up, changing the industrial and agricultural structures, medical services, social and other problems.

In addition, common criteria and methods should be worked out for all countries with contaminated territories.

It would be advisable to create the united financial center and the International group of executors.

The works on elimination of the consequences of the Chernobyl accident in Belarus are carried out in accordance with the approved State program. The main attention of the program is paid to the problem of construction of new settlements at clean territories and relocation of population, payment of allowances and rendering assistance.

Up to 1993, works on environmental restoration haven't been practically provided.

The problems of decontamination have been included in the special section of the State program known as "Development of the Methods of Decontamination, Processing, Utilization and Storage of Radioactive Wastes and Products of Decontamination". The Institute of Radioecological Problems of the Academy of Sciences of Belarus is the leading organization in this field. 10 research institutes and designing organizations are involved in the work. State Committee of Chernobyl finances the work.

Investigations have been devoted to determination of the volume of works on decontamination. The fuel and nuclide balance of the damaged Unit-IV of the Chernobyl NPP has been determined together with detailed measurements of contaminated territories. It helps to specify the radiation situation from the initial stage of the accident to present days. In 1993, $3.7 * 10^{16}$ Bq of activity have been present at the territory of Belarus.The territories contaminated with radionuclides have been defined more accurately. The overall areas with density of contamination more than $3.7 * 10^{10}$ Bq/km^2 come to 46.5 thousands of square kilometers. Large volume of work has been completed on classification and determination of amount of radioactive wastes. It has been found out that the housing and communal services of contaminated territories are the potential places of accumulation of radioactive wastes. 14.8 thousands of tons of ash classified as radioactive wastes are being formed when burning firewood. In this connection, the works on centralized collection of ash, its transportation in special containers, processing and disposal are carried out. It has been determined, that about 70.000 tons of ferrous and non-ferrous metals need decontamination.

The works on development of the complex of compositions for decontamination, processing and utilization of liquid and solid radioactive wastes, system of radiation control over the sites of disposal of radioactive wastes and the products of decontamination, system of structural-geological and hydrogeological control over the selected sites for disposal of radioactive wastes are carried out. There are two sites in the Gomel' and Mogilev Regions selected for construction of the facility for processing and disposal of radioactive wastes.

On the basis of resarch works carried out in 1993, the standard and legal documents have been issued. They regulate the works on decontamination. The documents give provisions for decontamination and waste management, sequence of organization of works on decontamination of settlements, control levels of contamination, methods and regulations. The documents have been approved and coordinated in accordance with the laws in force in the Republic of Belarus.

In accordance with the "Concept of Residence on the Territories Suffering as a Result of the Accident at the Chernobyl NPP" approved by the Decision of the Council of Ministers from April, 8, 1991, N 164, the principles and criteria of substantiation of practical measures on elimination of the negative consequences for health, compensation of the detriment have been formulated. The dose is the main index for decision making on protective measures and compensation of the detriment.

According to the average annual effective dose equivalent, permissible excess of natural and man - made radioactive background totals 1 mSv/year from 1991 and for the following years. It is essential to carry out protective measures when additional dose exceeds 1 mSv/year.Such measures include:

- carrying out the radiation control over the environment and food-stuffs in case of necessity;

- measures directed to the decrease of the content of radionuclides in air, water, soil;

- measures directed to the decrease of radionuclides in agricultural products;

-reduction of dose loads from X-ray examination and entering of radon into buildings from the environment.

The system of protective measures should guarantee average effective dose equivalent less than 5 mSv (0.5 rem) in 1991 and maximum possible annual reduction up to 1 mSv (0.1 rem).

In Belarus, density of soil contamination, but not the dose, is still the main factor determining the activities of population.

Depending on the density of contamination of the territory, Belarus is devided into five zones: the zone of evacuation with controlling and carrying regime; the zone of immediate change of residence with controlling and carrying regime, the zone of subsequent change of residence with activity under control, the zone with the right of changing the residence with activity under control, the residence zone with periodical radiation control.

There are temporary control levels of radioactive contamination for making decisions about carrying out the clean-up of zones with subsequent change of residence and zones with the right of changing residence and activity under control. These zones are evaluated in terms of density of contamination $1.85 * 10^{11}$-$5.55 * 10^{11}$ Bq/km^2 and $3.7 * 10^{10}$ - $18.5 * 10^{10}$ Bq/km^2, correspondingly. The exposure dose rate is the criterion for carrying out the clean-up. For various sites it is as follows:

1. Territories of kindergartens, schools, hospitals 35 μr/h
2. Territories of private yards 40 μr/h

3. Indoors of kindergartens, schools, hospitals, buildings 25 μr/h

4. Working places of offices:
   with permanent residence 50 μr/h
   with temporary residence 200 μr/h

5. Territories of national economic institutions and other open territories of settlements 60 μr/h

Inner surfaces of dwelling-houses, private property, kindergartens, schools, hospitals, offices, external surfaces of buildings, transport are standardized according to beta-contamination.

Presently, there is no general practice of clean-up of sites for zones of subsequent change of residence and zones with right of changing the residence.

Clean-up is not also foreseen for zones of evacuation and changing the residence. In case of necessity, in the zone of changing the residence, the works on demolishing and disposal of buildings and constructions are carried out.It is done in order to prevent forbidden move of contaminated construction materials, reduction of fire hazard, illegal residence and activities. As a rule, wooden buildings are considered in the zone of immediate change of residence. At the territory of the zone of subsequent change of residence ramshackle buildings are demolished, excluding brick, stone, concrete buildings. The decision about a building demolishing is made when the exposure dose from this building is 1.5 times higher than from the surroundings. Besides, the radioeclological danger of migration of radionuclides is taken into account. Works connected with demolishing of buildings are carried out according to special orders.

Such is the state of works on clean-up of contaminated territories nowadays. As can be seen from the above data, the work on clean-up is only of local character and it can be considered as a "fast aid".

Nowadays, in the Institute of Radioecological Problems of the Academy of Sciences of Belarus, the works on creation of the long-term large-scale program for remediation of territories contaminated with radionuclides have begun in co-operation with foreign experts. The aim of this program is to change the contaminated territories into the safe system and to restore the normal activities. The following factors determining the necessity for creation of such program should be noted.

There is the large gradient of contamination density of territories. It is the basis for transport of radionuclides to clean territories. There are local spots with density of contamination more than $3.7 * 10^{13}$ Bq/km^2 at these territories.

The surface layers of soil from large territories belong to low-level and intermediate-level wastes, In addition, both physical and legal problems arise.

Regrettable experience of the secondary transfer of $222*10^{15}$ Bq of activity from contaminated territories in ten years after the accident at the Ural confirms the actual radiation danger of contamination both for Belarus and other countries. Presently, it is impossible to carry out normal control over execution of temporary admissible levels of activities. In addition, enormous expendituries are needed for devices and special control systems which will be abolished afterwards.

Serious problems arise in control of illegal settling of contaminated territories and in carrying out activities there.

It should be taken into account, that a sudden increase of caesium content in agricultural products cultivated nowadays with permissible levels of activity can be the result of rise of its soluble forms in soil.

When the sources of radiation are not removed, the continuous increase of sick rates and the corresponding rise of expenditures on public medical services should be expected.

The above are the logical pre-conditions for carrying out the works on environmental restoration of territories contaminated with radionuclides. Clean-up of soil is one of principal measures of restoration. The main factors determining the advisability of soil clean-up are as follows:

1. Potential danger of radionuclides in soil.

2. Technological effectiveness of clean-up. The decontamination factor is the criterion of decontamination:

$$\lambda_d = \frac{A_{in}}{A_f},$$

where λ_d - decontamination factor;

A_{in} - initial density of contamination;

A_f - final density of contamination.

3. Stability of results of clean-up or the possibility of the secondary contamination.

4. Ecological acceptability of the methods of clean-up. This requirement means:

- restoration of initial productivity of soil;
- minimum level of rem-expenditures in decontamination;
- migration of radionuclides.

5. Economic efficiency.

6. Significance of the subject intended for decontamination in the system of interregional connections.

7. Feasibility of the methods of clean-up.

Cost-benefit analysis is the basis for determination of the efficiency of clean-up. Difference between benefit and cost is the criterion of the efficiency of clean-up.

$$C_e = D_e + P_a - E_c,$$

where C_e - efficiency criterion;

D_e - eliminated detriment;

P_a - additional production at cleaned-up soils;

E_c - expenditures on clean-up.

The schematic diagram of advisability of soil clean-up according to the criterion is given in Fig. 1. Clean-up is advisable in case of its higher efficiency in comparison with alternative methods of restoration.

It is generally acknowledged that owing to high expenditures on clean-up and the need in large investments for equipment, clean-up of all territories contaminated with radionuclides is impracticable with the present-day level of equipment and technology. But inactivity is impermissible too. It leads to continuous accumulation of collective dose by population. In actual situation characterized by

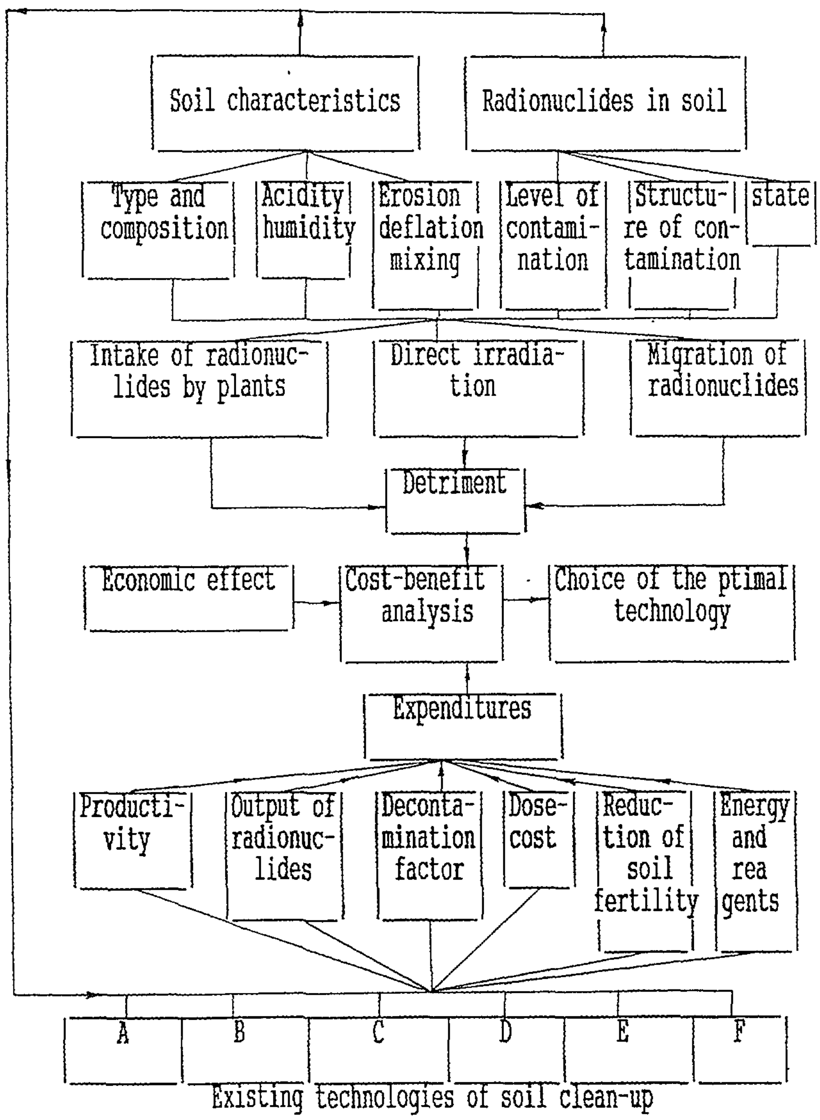

Fig. 1. The choice of optimal technologies for clean-up of various types of soils.

strict economic limitations on the scale of use of soil clean-up methods, it is advisable to start from the specific efficiency of expenditures invested in restoration when comparing the methods of soil restoration:

$$\overline{C_e} = (D_e + P_a)/E_c > 1,$$

where $\overline{C_e}$ is specific efficiency calculated as the ratio between benefit of clean-up (in roubles) and cost of its realization (in roubles).

When using $\overline{C_e}$ criterion, the measures on soil restoration (including clean-up) with minimum investments and operational costs are preferencial. Really, the wide class of measures is involved in the process of restoration. The benefit of their fulfilment will exceed the cost of their realization. In accordance with the developed scheme, the advisability analysis of clean-up of various types of soils include the following steps:

1. Advisability of clean-up depending on the extent of danger of radionuclides in soils of various types.

2. Advisability of clean-up depending on the technological efficiency of the known methods of clean-up for various types of soil in comparison with other methods of restoration.

3. Economic expendiency of clean-up.

Let us consider in detail the components of detriment. The detriment for health of a human is calculated according to the method of ICRP (7).

$$D = \alpha S + \beta \sum_j N_j f_j (H_j), \quad D = a + b,$$

where a - economic equivalent of the stochastic component of detriment;

α - cost of the unit of the collective dose;

S - collective dose;

b - economic evaluation of anxiety of population about possible risk and any unfavourable consequences for their living standards owing to exposure to radiation;

H_j - equivalent dose for individuals from j group;

N_j - function of distribution of individual dose dependent on relation to risk and national or departmental rules;

β - cost in monetary units attributed to the unit of other components of detriment by the decision making person.

Economic detriment includes 3 components:

1. Detriment from partial or complete exclusion of agricultural lands from economic use;

2. Detriment from partial or complete exclusion of the basic reserves (buildings, constructions, infrastructures, etc.).

3. Detriment from partial or complete exclusion of natural resources from usage (forests, deposits of minerals, etc.).

Collective effective dose equivalent is the main factor determining the integral detriment to health of a person. But with equal doses the detriment can vary depending on specific conditions, namely:

1. Forming the dose loads depending on time;

2. Availability of combined effects.

Table 1 gives the evaluation of risk for a person receiving the chronic dose equal to 1 man-rem. This dose is taken as a basis for further calculations of advisability of soil clean-up.

The advisability of soil clean-up is dependent on the type of soil. In addition, agrotechnical (applying fertilizers, lime, ploughing), mechanical and physical, chemical and biological, electrokinetic methods can be used.

Let us consider some results obtained for conditions of Belarus.

Fig. 2 shows the economic efficiency of clean-up when removing upper layer of soil.

TABLE 1. ECONOMIC EVALUATION OF RISK WHEN A PERSON IS IRRADIATED WITH CHRONIC DOSE EQUAL TO 1 MAN REM

FACTORS OF RISK	RISK	VALUES OF FACTORS OF RISK			SPECIFIC DETRIMENT ROUBLES/MAN REM			
		ECONOMIC DETRIMENT	DETRIMENT FOR A PERSON	TOTAL DETRIMENT	ECONOMIC DETRIMENT	DETRIMENT FOR A PERSON	TOTAL DETRIMENT	
							ROUB/MAN REM	% TOTAL
PREMATURE DEATH	$0.07*10^{-2}$ CASE/MAN REM	$100*10^3$ ROUBL/CASE	10^6 ROUBL/CASE	$1.1*10^6$ ROUBL/CASE	70	700	770	15
TOTAL SHORTENING OF LIFE	$0.2*10^{-2}$ MAN YEAR/ MAN REM	$8*10^3$ ROUBL/ MAN YEAR	$14.3*10^3$ ROUBL/ MAN YEAR	$22.3*10^3$ ROUBL/ MAN YEAR	16	29	45	1
TOTAL LOSS OF ABILITY TO WORK	$3.2*10^{-2}$ MAN YEAR/ MAN REM	$11*10^3$ ROUBL/ MAN YEAR	-	$11*10^3$ ROUBL/ MAN YEAR	350	-	6	
DISABILITY TO WORK	$1.1*10^{-2}$ CASE/MAN REM	$40*10^3$ ROUBL/CASE	$100*10^3$ ROUBL/CASE	$140*10^3$ ROUBL/CASE	440	1100	1540	30
LOWERING THE LIVING STANDARDS	$2.8*10^{-2}$ CASE/MAN REM	-	$100*10^3$ ROUBL/CASE	$100*10^3$ ROUBL/CASE	-	2800	2800	54
TOTAL :					876	4629	5161	100

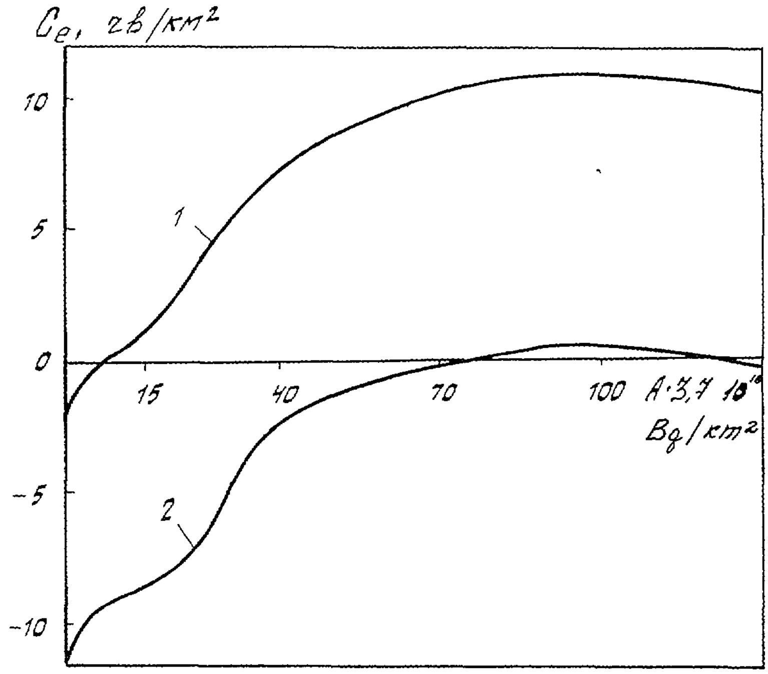

Fig. 2. Economic efficiency of clean-up when removing upper layer of soil:
1 - Ltp = 5 km; 2 - Ltp = 50 km

Fig.3 presents the data on eliminated detriment depending on the depth and quality of deep ploughing.

Fig. 4 shows economic efficiency of phytodecontamination with utilization of energy of phytomasses. The results are given for phytodecontamination with the help of grain-crops. Biological method of decontamination is efficient when density of soil contamination with caesium exceeds $0.37*10^{12}$ Bq/km^2 and with expenditures for cultivation of phytomass equal to $exp._{phyt.}$ = 10 thousands of roubles/ km^2 (in prices of 1989) and the intake factor = 0.005.

Fig. 5 presents the advisability of soil clean-up by chemical methods with various state of contamination. The data are given for turf-podsol sandy soils after washing with iron salts followed by collection of exhaust solution.

The given results on the clean-up efficiency show that the choice of the advisable method is possible only for a specific site on the basis of detailed landscape-geochemical, geological, hydrological, radiochemical and ecologo-economical studies. Large cost

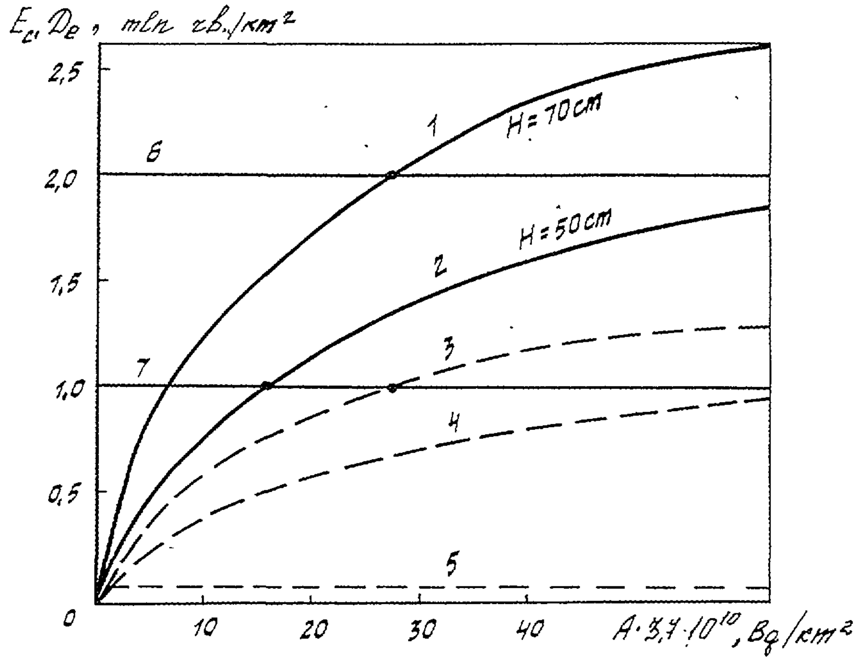

Fig. 3. Effectiveness of soil clean-up by deep ploughing.
1 - eliminating detriment when H = 70 cm, Cq = 1.0;
2 - the same with H = 50 cm, Cq = 1.0; 3 - the same with H = 70 cm, Cq = 0.5; 4 - the same, with H = 50 cm, Cq = 0.5; 5 - expenditures on deep ploughing (H = 70); 6 - expenditures on substitution of the detriment for harvest with cost of land equal to 120 thousands of roubles/ha; 7 - the same with cost of land 40 thousands of roubles/ha.

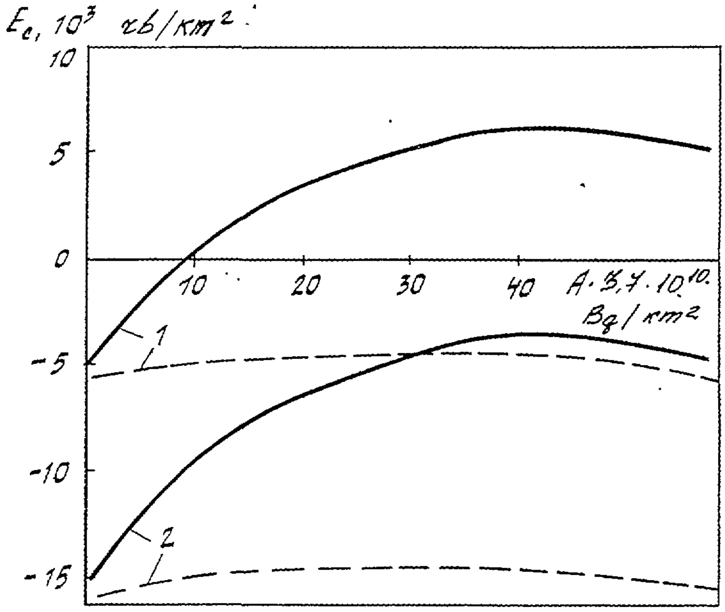

Fig. 4. Annual economic efficiency of phytodecontamination with utilization of energy of phytomasses (for Cr-137)
1 - $exp_{phyt} \cdot m$ = 10 thousands of roubles/km2;
2 - $exp_{phyt} \cdot m$ = 20 thousands of roubles/km2.
——— Cin = 0.005 — — — Cin = 0.001

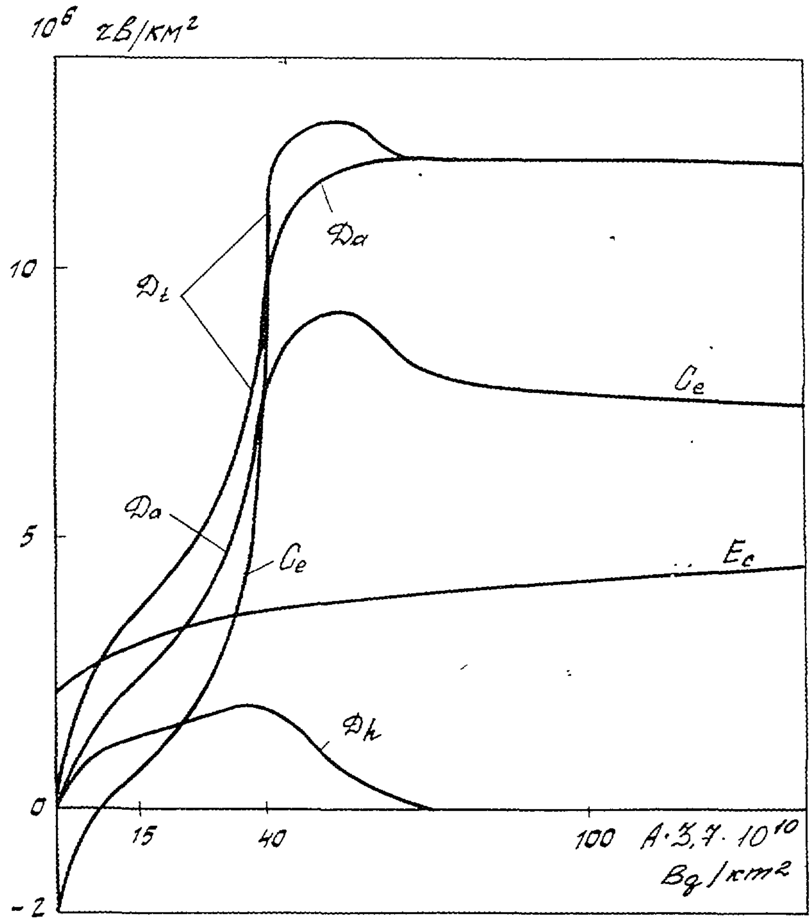

Fig. 5. The advisability of soil clean-up by chemical methods with various levels of contamination with radionuclides.
E_c - expenditures for decontamination;
C_e - effectiveness of clean-up;
D_h - detriment for health of population;
D_a - detriment for agriculture;
D_t - total detriment.

of clean-up demands the development of detailed methods as any mistake would result in large material detriment.

Combined methods of decontamination are the most promising. Organization of works on clean-up of contaminated territories has a number of specific features.

First, the problem is not of local character. It is essential to consider jointly several regions as the clean-up of a single region can lead to its secondary contamination. Planning the sequence of remediation of separate places in a region should be the subject of special research work. In addition, the works on changing the damaged Unit-IV of the Chernobyl NPP into ecologically safe system should be taken into account. Presently, there are $0.85*10^{18}$ Bq of long-lived radionuclides in the Unit-IV. More than 10 tons of fuel is in the form of fine-dispersed dust. According to the results of carried out investigations it has been determined that this object presents nuclear and radiation danger. Thus, any unforeseen situations can lead to secondary contamination of cleaned-up territories of Belarus, the Ukraine, Russia and other countries. Therefore, such project can be considered as International. The Ukraine and Belarus came to the agreement about creation of the united concept of maintaining the evacuation zones with the aim of development of the common method.

It is expedient, that each country concentrates its ability in one of the following branches: methods, instruments, equipment, technologies of clean-up, waste treatment, disposal and other processes of restoration. While developing the clean-up project, it is advantageous to work out in separate document the feasibility study of safety of the processes of restoration with allowance for possible emergencies, natural disasters at all stages of restoration.

The clean-up organization would advisably consists of four structures:

1. The centre of scientific guidance of the project headed by the supervisor.
2. The chief designers of equipment, devices, systems, etc.
3. The designer - general of the project.
4. Teams for clean-up plan implementation.

The supervisor works out the scientific grounds for the project. He makes the methods of investigation, substantiates the possibility of the project and provides all stages of the project with scientific guidance.

The designer - general of the project draws up the general project of clean-up of territories on the basis of suggestions of supervisor and designings of chief designers.

The chief designers design the equipment for clean-up, processing and disposal of radioactive wastes, means of transportation and other systems.

The teams for clean-up plan implementation fulfil the clean-up of the territories contaminated with radionuclides in conformity with the developed and confirmed project.

It would be advisable to create the united financial center and the International group of executors for development of the International project.

REFERENCES

1. Sharovarov G. A. Problems of Restoration of the Territories of Belarus Contaminated as a Result of the Chernobyl Accident, Minsk: AS B, Preprint IREP, 1992.
2. The Chernobyl Accident: Its Causes and Consequences, Minsk: TEST, 1003.
3. G. Sharovarov, J. Milligan, A. Buoni. Contamination of the Territory of Belarus as a Result of the Chernobyl Accident.
4. V.I. Gorbacheva, G.A. Gotovchits, S.S. Ogorodnik, G.A. Sharovarov. Problems and Prospects of Reducing to a Minimum and Elimination of the Consequences of the Chernobyl Accident, Minsk: AS B, 1992.
5. Zh.V. Davydova, S.V. Morozov. G.A. Sharovarov. Methods of Mathematical Modelling of Spreading of Radioactive Discharges of Nuclear Power Plants.
6. The Chernobyl Trace in Belarus, Minsk: Glavgidromet, 1992.
7. Optimization of Radiation Protection on the Basis of Cost-Benefit Analysis. 37 Publication of ICRP, Minsk: Ehnergoatomizdat, 1985.

8. International Chernobyl Project. Technical Report. Evaluation of Radiological Consequences and Protective Measures. Report of ICC. Edited by Shigematsu, IAEA, Vienna, 1992.- 740 p.

9. Standards of Radiation Safety - 76/87 and the Principal Sanitary Norms OOP - 72/87, Ehnergoizdat, 1988. - 160 p.

10.G.A. Sharovarov, A.I. Bykov, V.T. Veretennikov. Decontamination of the Territories of Belarus Contaminated as a Result of the Chernobyl Accident, Minsk: AS B, Preprint IREP, 1994, 19 p.

URANIUM INDUSTRY IN BULGARIA AND ENVIRONMENT: PROBLEMS AND SPECIFIC FEATURES OF THE PERIOD OF THE TECHNICAL CLOSE-OUT AND REMEDIATION OF THE NEGATIVE CONSEQUENCES

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Abstract

The uranium industry in Bulgaria started immediately after the II World War with classical underground mining and hydrometalurgical processing of the ore to uranium concentrate. Up to 1958 no tailings pond existed at the Bukhovo plant and the result is $1.2x10^6$ square meters contaminated with radium land along the rivers Yanishtitsa and Lesnovska. In the process of mining approximately 300 heaps of low grade ore and sterile rock and three tailing ponds were generated mainly in the southern part of the country. Along the valleys of the rivers Maritsa, Tundzha and Struma approximately 15 low grade ore deposits were processed by in-situ leaching with sulphuric acid. The surface communications (tubes) cover approximately $1.6x10^7m^2$ agricultural land and forests. Some of the heaps of the underground mines have been processed by combined in-situ leaching technologies. Almost no preventive or counter measures have been implemented during the whole period of operation for preservation of water, soil and air from mechanical, chemical and radioactive pollution. Therefore in the period of the close-out of the uranium industry a programme has been developed for remediation procedures which includes assessment of the status of the environment, prognoses for the influence of the uranium sites on the region, technical projects for cleaning facilities and remediation procedures. For each case, depending on the type and the level of contamination, the specific optimal ecological solutions have the purpose of reasonable minimization of the risk at minimum cost. In the present work estimations and predictions for the underground and surface waters and surface contamination for several typical uranium sites are discussed.

1. INTRODUCTION

The strategic importance and the secrecy of the uranium industry from the very beginning are the reasons for the main problems for the environment and the population of the villages and towns near uranium sites.

The earliest measurements and laboratory analyses of samples from workplaces and the environment started after the first Standards for radiation protection were approved in July 1958. (Decision of the Council of Ministers No.147). Regular monitoring was performed by the Dosimetry Laboratory of the "Redki metali" corporation ("Redki metali" operated the uranium industry). For 30 years the files total 35 volumes of 400-500 pages each.

2. ENVIRONMENTAL PROBLEMS OF THE REGIONS WITH URANIUM INDUSTRY SITES

2.1. Site differentiation

According to the type of uranium industry unit, the technological processes and the operation time, the sites can be categorized into:

- sites with serious environmental impact;
- sites with negligible consequences for a limited area;
- sites with no consequences for the surrounding area.

The Bukhovo and Eleshnitsa processing plants [1], the nearby mines and other accompanying facilities are sites with serious environmental impact.

The first uranium mines in Bulgaria ("Deveti septemvri", "Seslavtsi") and the first processing plant are near Bukhovo. A large area of the land of the villages Yana and Bogrov is contaminated with radium since no tailing pond existed up to 1958. The ore and the uranium concentrate were exported. Through the Yana railway station. On the Bukhovo site there are also a factory for repair of equipment, a shop for sample preparation, a geology unit and a science unit.

In the Eleshnitsa region there existed for more than 30 years underground mines, several open-pit mines. Two attempts were made for underground leaching, heap-leaching was applied for several years and in 1966 the second processing plant was built.

A general feature of the two regions is that both sites are very near to living areas. Some mines in Eleshnitsa are even within the village limits. Similarly, in Seslavtsi (Bukhovo) there are houses situated in the plume of the exhaust ventilation tube. Some fodder areas and even cultivated land are neighboring waste heaps (Bukhovo), in Eleshnitsa there is cultivated land over waste heaps without any restoration, other than leveling of the heap.

The problems of the discussed regions are complex - there are radioactive and chemical contaminations of underground and surface water, of nearby agricultural land, of roads for ore transportation some of which go through living areas.

The highest risk is due to radon and radon progeny inhalation - the rates of radon exhalation are very high and especially the exhalation from waste heaps. The gamma-background in ore regions is 2-3 times the average for the country.

The radon inhalation hazard in Eleshnitsa was discussed in Budapest [1]. The observed annual cumulative dose of 0,92 WLM has to be confirmed by epidemiological surveys.

Thus all elements of the environment are contaminated which results in considerable total dose from inhalation, water and food for the population and especially for some critical groups.

The small sites far from living areas have much less environmental impact. Most often the radiation and chemical effect are due to hydrotransport and in some cases to the transportation of the ore. The specific feature of such sites is that some population groups are subject to measurable dose levels.

Sites with no consequences for the surrounding area are sites which have been investigated for mining but proved to be unprofitable and also sites which have been operated for short time.

On the previous workshop in Budapest [1] a general picture of the Uranium industry in Bulgaria was presented and specifically the Bukhovo-Yana-Bogrov-Seslavtsi region. In the present paper we report some dose estimations due to consumption of vegetables grown in contaminated areas in Eleshnitsa (Table 1) and Bukhovo (Table 2). The source data were recently obtained in the course of research which was performed prior to the closure of the uranium industry [2].

Table 1

Specific activity of natural radionuclides in vegetation samples from Eleshnitsa region (fresh weight, Bq/kg) [2]

No	species	coeff.	238U, Bq/kg	226Ra, Bq/kg	transfer coeff.	
	location	dry/fresh			^{238}U	^{226}Ra
1.	pine needles benchmark	0.52	< 4	2.2	-	0.048
2.	pine needles waste heap 18	0.52	9.5	24.2	0.014	0.018
3.	lucerne waste heap 18	0.14	10.5	47.7	0.014	0.065
4.	cornstalks waste heap 18	-	84.3	196.0	0.114	0.266
5.	colt's foot waste heap 17	0.196	12.6	30.4	0.059	0.092
6.	chilli waste heap 20	-	136.0	162.0	0.226	0.216
7.	grass weighbridge	0.183	<15	3.0	-	0.045
8.	barley "Poliane" pit"	0.198	-	1.6	-	0.017
9.	fungi "Poliane" pit	0.084	<20	0.9	-	0.010
10.	tobacco	-	<40	12.1	-	0.184
11.	white beans	-	<13	6.4	-	0.091

Table 2

Uranium and radium activity of vegetables and plants from the Bukhovo region

sample	uranium	radium
	Bq/kg	
lucerne	0.68-2.81	25.3-116.9
beet-leaves	0.26-7.73	0.4-10.7
beet root	0.26-0.64	0.4-10.7
corn-root	0.26-1.0	0.4-4.3
corn-leaves	0.21-1.26	3.7-82.5
corn-grain	0.05-0.07	22.0-40.9
corn-stem	0.15-1.52	13.2-140.2
wheat-stem	0.83-12	9.2-34.4
wheat-grain	0.29-4.92	3.8-59.9
barley	0.68-12.2	9.8-37.4
tomato	0.32-2.51	0.1-15.6
cabbage	0.44-2.51	0.4-15.5
cucumber	0.98-16.3	0.1-0.9
clover-leaf	43.6-521	9.7-225

The content of uranium and radium in food is within 13-136 Bq/kg and 6.4-162 Bq/kg correspondingly, and the transfer coefficients from soil to vegetables is 0.010-0.226.

The Bukhovo-Yana-Bogrov region and the Eleshnitsa region cannot be directly compared since the Bukhovo land is contaminated with waste from the chemical concentration plant, while the Eleshnitsa land is contaminated by the waste heaps of the underground mines. Nevertheless, the measured radium and uranium activities are close.

2.2. Chemical contamination

The excess waters from the tailing ponds and the solution of the in-situ leaching contain radioactive isotopes and also heavy metals and salts.

The waters in the tailing ponds contain Fe, Cu, Zn, Mo, As, Cd, Cr, B, Mn, sulfates between 4 and 6 g/l and also other substances - oil and chemicals. Only Mn and occasionally Fe and Cu are above the accepted limit for II category surface water.

For underground in-situ leaching (combined method) with acids and bases the concentrations of elements which accompany uranium rapidly increase - Fe, Cu, Co, Ni, Mo, As , some rare earths. In mine "Deveti septemvri" [3] Mo reaches 13425 μg/l (limit 500 μg/l) and Mn (used as oxidizer in potassium permanganate) reaches 13000 μg/l (limit 300 ug/l) for adit 123, 7600 μg/l for adit 32 and 4200 μg/l in the same dam. Some micro quantities of B and Hg were detected which according to our national rules are not limited.

The content of sulfates in the waste water reach 2500 - 3000 mg/l (limit 300 mg/l), the carbonate and bicarbonate ions vary within 3-50 and 80-512 mg/l.

Very high concentrations of sulfate ions are measured in surface water and even in wells of private owners as a result of accidental spilling of solutions in sites of in-situ leaching [4,5]. At the site "Cheshmata" (Haskovo), in the valley downstream from the sorption station, the measured content of sulfates is 1400 mg/l, free H_2SO_4 is 392 mg/l and pH is 2.2 (5.5 - 8.5 for 3-rd category water). A similar case has been recorded in Navusen where in a valley the sulfate concentration is 13362 mg/l and almost 5 g/l H_2SO_4, which means that actually the water is a leaching solution.

In the underground water of such sites the salt content is >20 g/l, from which the sulfates are 12-15 g/l. In some cases heavy and rare earths were detected (V, W, Mo, La) due to recycling of the solution.

The examples show that the chemical contamination has a competitive negative impact and in some regions prevails over the radioactive contamination.

There exist also bacterial contaminations but we cannot predict due to the limited experience even qualitatively their effects. The contamination from technological point of view improves the leaching process.

It should be remembered that the acid method was preferred to the alkaline methods which is a favorable point as far as contamination of water is concerned. Nitric and phosphoric acid were not used since the consequences are much worse. Similar arguments prevented the use of sodium nitrite for oxidizer, potassium permanganate was used only in the processing plants.

3. SITE REMEDIATION AND ENVIRONMENTAL RESTORATION

The present state of knowledge and technology make possible the minimization of the negative impact to very low values but in most of the cases that is not economically justified especially for countries with limited resources.

The technical solutions should be considered and implemented according to the principle of as low estimated risk as reasonably achievable or optimization of the ratio "environmental risk/expenditures". The most indefinite parameter is the far future of the site or the area.

A problem of great importance is also the lack of generally accepted criteria for contaminated site. Most probably we should follow examples of "good practice" adapted to the national laws.

Each particular case should be considered in order to achieve a justified compromise for acceptable ecological risk for the environment and population at a reasonable price. Following these guidelines a national approach was created for the critical period 1989-1992 during which some industries were closed and the market economy was introduced in uranium production. The economical considerations were prevailing for the decision for closing-down of the uranium industry. It should be noted that the requirements of the Law for Environmental Preservation are so strict that the needed money for compliance with the Law make uranium production unprofitable.

The achievement of acceptable level of environmental protection is possible only if funds are planned at very early (planning) stages of uranium production and also if preventive measures are implemented during the production. Since nothing had been done, now the needed money make the uranium production economically unjustified.

4. SPECIFIC FEATURES OF THE PERIOD OF THE CLOSING-OUT OF THE URANIUM INDUSTRY

4.1. Stages of the process

Of course there are sites and mines which have been closed long before the present period. The only difference is that at the present moment the uranium industry is totally closed and simultaneously many sites are put out of operation and closed. For the observation of the ecological requirements of the law the following stages of the process were planned (the stages are summarized in the Appendix):

- technical closing-out;
- site characterization - radiological and hydrogeological survey and short and long-term prediction;
- preliminary design studies;
- design and construction.

The closing-out of a site according to the "Instruction for termination of the uranium industry" [6] implies closing-out of the site and restoration of the environment. The projects are approved by the Ministry of Industry, Ministry of Environment, Ministry of Health, Ministry of Finances, the Committee of Geology, the Committee of the Uses of Atomic Energy for Peaceful Purposes and other agencies.

The radioecological and hydrogeological estimation and predictions (site characterization) include measurements and investigations for sources and levels of contamination in water, soil, air, migration along the food chain (environment-plant-man, environment-animal-man). The present and past information from routine control measurements is collected, some experiments are also performed.

The measured and calculated values are compared to the background ones for the region and also to the limits (if any) and the dominant and secondary negative agents specified and thus the need for a technical solution is justified - cleaning facilities, mechanical and biological recultivation, protection layers, protection measures.

The next stage is the preliminary design studies during which all previous information is collected and several options are suggested for environmental restoration and preservation of the ore bodies for a possible future extraction.

The design and construction period of cleaning and protection facilities is the last step which also includes measures for employment of the former uranium industry workers according to their old or new qualification.

The priority of the sites is defined by the scale of the contamination and also by the risk estimations and the social impact of the site.

The surveys, predictions and the decision making is a very important stage which often includes considerable expenditures. The process is influenced also by the pressure of local authorities and the population which usually require new water facilities, recultivation of larger areas than the actual contaminated areas, road construction, money compensations for imaginary radiation effects etc.

After the Chernobyl accident there exists a considerable radiophobia in the country and the radiation hazard is overestimated at public hearings of the projects. The requirements are for absolute minimization of the radioactivity and the ALARA principle is no more considered reasonable.

4.2. The problem of "contaminated site"

A very serious problem is the lack of common agreement and regulations about what is a radioactively contaminated site. In a report of the previous workshop [7] the level of 200 Bq/kg of radium and uranium in the 15 cm layer is suggested and 1000 Bq/kg is a level over which the site has a radiological significance (also in [7]). This is a good working guide although there are no solid arguments for such classification. In a similar way conditional levels were suggested in Bulgaria [8] for natural radiation in soil which depend on the region.

The problem of radioactively contaminated water is very similar to the problem of "contaminated site". It is not yet completely clear whether the underground water from the sites of in-situ leaching should be cleared (the present conclusion from the estimations and predictions is that it is not necessary).

4.3. Planned methods for environmental restoration

The major hazard for regions with uranium industry sites is due to radioactive wastes deposited in waste ponds and heaps.

The status and the volume of the tailings ponds and heaps are summarized in Table 3 and 4.

Planned methods:

- tailing ponds - conservation by water resistant layers, covering the water resistant layer with a blanket of soil and biological recultivation with resistive plants and trees. This is the long-term perspective. Meanwhile all removed soil from remediated sites is stored over them. Some of the sites are still operating.
- waste heaps - stabilization against erosion, leveling and covering with small rock fraction, soil if available, surrounding with water drains for prevention of erosion of heavy rains, a ban for the use of the rock for construction of living houses, restriction of the construction of community buildings over the heaps.
- water from underground mines - precipitation and purification if necessary, neutralization of water from sites where chemicals have been used.
- in-situ leaching - disassembling of all facilities, pipes and pumps, cleaning of spots of contaminated soil, neutralization of acidic soil, fertilization and crop rotation. For land which cannot be restored, a regime for the use must be planned.
- water from sites of in-situ leaching - neutralization of deep underground water from ore bodies and limitation of its movement in horizontal and vertical direction.

Table 3

Status of the tailings ponds and wastes of the uranium milling plants

		Area, ha	Volume	Waste volume	Waste Mass	Total Activity, Bq
site of t. pond	status of the t. pond	project/ real area	project/ real vol.	present m^3	$x10^3t$	$x10^{14}$
Metalurg	con-served	35/35	1300/1300	1300	2080	5.4
Buhovo	operated	56/55	10000/8800	3900	6240	12.0
Zvezda	operated	95/42	34000/10600	4800	7680	14.9
Eleshnitsa						
total "Redki metali"		186/132	45300/20700	10000	16000	31.0

Table 4

Wastes from U-mining sites

Site	Place	number of waste heaps	area xE3 m2	volume xE3 m3	Quantity xE3 m3 t	Activity 10^{13} Bq
"Druzhba"	Eleshnitsa	43	153	1747	2900	26,5
"Vazhod"	Smolyan	12	71	743	1240	11,3
"Izgrev"	Barutin	13	14	118	200	1,8
"Septemvriitsi"	Smolyanovtsi	1	39	270	480	4,7
"9 Septemvri"	Seslavtsi	200	475	4800	7900	72,2
"Minyoz"	Sliven	18	27	82	140	1,3
"Iskra"	Kutina	5	35	330	530	4,8
"Senokos"	Senokos	2	19	70	120	1,1
waste	Selishte	1	0.2	0.5	0.8	-
"Byalata voda"	Dolna banya	3	12	151	220	2,0
TOTAL		298	845	8311	13720	125,7

- auxiliary facilities and sites - disassembling, cleaning and recommendation for use of mining of other ores.

4.4. Manpower resources

The experience showed that it is better to form temporary teams of various specialists for complex estimations of large areas.

The extremely short time-table for some of the projects (1-3 months) made impossible in-depth analysis of the already present information, collection of additional data and observation for at least two seasons. The reports were short, in some cases formal, uninformative, with very few measurements and laboratory analysis.

The number of specialists with adequate knowledge of the problem is also limited. At one and the same time a lot of site surveys and estimations had to be performed and therefore the number of the teams had to be increased.

Very recently the Council of Ministers shifted the closing dates and that will help for better site evaluations and better restoration projects.

5. CLOSING REMARKS

The environmental conditions near the sites of the uranium industry in Bulgaria most probably are similar to those in the other East European countries. Due to the arms race and the ambition of extracting and manufacturing as much as possible fissile isotopes immediately after the war, little attention was paid to soil or water contamination in western countries also. In this context the problems of restoration of environment near uranium sites and limitation of the negative consequences are international.

Therefore the creation of an expert group within or after the conclusion of the project which could advise the national programmes and/or develop recommendation guides based on experience and good practice will be acceptable for most of the member states.

REFERENCES

[1] Vapirev E. I., M. Dimitrov, L.Minev, T.Boshkova, M.Guelev, D.Pressyanov, Radioactively Contaminated Sites in Bulgaria. First Workshop on IAEA Regional Project for Central and Eastern Europe on Environmental Restoration, Budapest, Hungary, 4 - 8 October 1993.

[2] Nikolov P. et al. Preliminary Studies for Biological Recultivation of Technological Contaminated Areas in Eleshnitsa Region. Report of the Institute for Nuclear Research and Nuclear Energy, Sofia, June 1993 (in Bulgarian).

[3] Dimitrov M. Influence of the Combined Systems on Environment in Seslavtsi Region. (Unpublished report, in Bulgarian).

[4] Dimitrov M. Ecological Problems as a Result of the U-Industry and Approach for their Solution. Report for the meeting on the U-mining problems in the Ministry of the Environment, 22 January 1992 (in Bulgarian).

[5] Dimitrov M. Environment Preservation of In-situ Leaching Uranium Mining. Proc. First Applied Science Conference on In-situ methods for mining of rare metals, Sofia, April 1987 (in Bulgarian).

[6] Temporary Instruction for the Closing-Down of Uranium Mining. Ministry of Industry, Sofia, September 1992 (in Bulgarian).

[7] Ettenhuber E., W. Röhnsch. Identification and Radiological Characterization of Sites Contaminated Due to Mining and Milling: Methods and Criteria Applied in Germany. First Workshop on IAEA Regional Project for Central and Eastern Europe on Environmental Restoration, Budapest, Hungary, 4 - 8 October 1993.

[8] Dimitrov M. Radioecological Approach to the Contaminated Land. XIII Colloq. "Physics in the Protection of Man and his Environment", (Topic Antropogenic Pollution of Soils), Giulechitsa, June 1992 (in Bulgarian).

APPENDIX

PLANNING FOR ENVIRONMENTAL RESTORATION IN BULGARIA

A. Technical closure

- collection of data on sites;
- decontamination and demolition of buildings, machines, facilities;
- isolation of underground mine workings, pits, bore holes, open-pit mines, etc.;

B. Characterization of sites

- radioecological assessments and prognosis;
- hydrological and hydrogeological surveys and prognosis of impact of radioactive and chemical contamination of surface and underground water;
- chemical contamination with oils, heavy metals, ions, etc;

C. Design and construction

C1. Preliminary design studies

- additional surveys, tests and experiments (if necessary);
- modeling and verification of data;

- consideration of alternative options, cost-benefit analysis and decision making;
- tendering;

C2. Design and construction

- construction of facilities for neutralization and purification of contaminated water;
- decontamination and recultivation of agricultural lands;
- stabilization of heaps and mill-tailing ponds;
- volume reduction of residues in heaps and planning for partial reuse;

D. Monitoring

- selection of systems and networks of monitoring in areas in the post restoration period;
- dose estimations for the population and critical groups in the region of the site;
- health and epidemiological studies if necessary.

RESTORATION OF RADIOACTIVELY CONTAMINATED SITES IN THE REPUBLIC OF CROATIA

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Abstract

In accordance with the scope of work, which was presented and fundamentally accepted at the First Workshop in Budapest, there has been made some progress in the project implementation. Firstly, the highest priorities have been identified. They are related to two from four listed groups where higher radiation doses could be expected: [1] sites containing coal/ash piles (INA-VINIL plant in Kaštel Sućurac, coal-fired power plant PLOMIN); and [2] sites containing phosphates and phospho-gypsum remaining from fertilizer industry (INA-PETROKEMIJA in Kutina). The most sensitive site is INA-VINIL plant in Kaštel Sućurac, since there is (1) considerable population (some 250,000 residents) living within radius of 10 km around the site; (2) besides radiation there is additional, non-radioactive contamination generated by the plant (mercury, vinyl-chloride-monomer etc.); and (3) the site is situated at the seaside in close, densely populated Bay of Kaštela. Sampling and detailed measurements at all three sites are under way. At *INA-VINIL plant in Kaštel Sućurac*, where exist two coal slag- and ash dumps of some 10,000 m^2 in total, we are going to carry out sampling at grid 20 x 20 meters, i.e. to analyze about 30 samples (gamma-spectrometry above all). TLDs and GM probes will be set up on the site, and contamination will be measured during a period of some 6 months. In addition, the concrete as the final product of nearby cement factories in Kaštel Sućurac and Solin (where mixing of cement and coal-ash as a matrix is suspected) will be also inspected. Similar measurements are under way in *the coal-fired power plant PLOMIN*. The site is situated close to the TUPJAK black coal mine wherein radon contamination is also foreseen to be measured (since both Plomin and Kaštela sites were using mainly this coals). In *INA-PETROKEMIJA Kutina* the samples of phosphates (raw-material), phosphoric acid, fertilizers (final products) and phospho-gypsum (waste material) have been already taken. They will be subjected to gamma-spectrometry, along with the air samples from the phosphoric acid plant. Radiochemical analysis (^{226}Ra) will be done at water samples (from piezometers) and wells in surrounding populated area. Working level (for ^{222}Rn daughters) is also foreseen to be done. TLDs and "diffusion chambers" were set up at desired places. Besides previously involved Institute "Ruđer Bošković", another institution, i.e. the Institute for Medical Research and Occupational Health from Zagreb has been included into the project. Unfortunately, due to lack of needed funds we are meeting some obstacles in the project evolution in terms of the proposed (time) schedule. Nevertheless, it is realistic to expect final decisions on necessity and - if needed - modes of additional protection measures at the sites, or even removal of contaminated material to more convenient areas by the end of 1994. It is worth mentioning that we are simultaneously running the project of site selection of radioactive waste repository in Croatia, and few preferred (candidate) sites are supposed to be identified and verified up to the end of the year. Namely, it is supposed that some of contaminated materials involved in the project, will be eventually disposed at our radioactive waste repository.

1. INTRODUCTION

Radioactively contaminated sites in Croatia are not related to any accident-generated contamination or uranium mining and milling industry, but - in most cases - to waste dumping practice. Waste dumps of concern represent mostly a back-end of regular industrial production and can not be easily shut down. Major waste dumps which were expected to be radioactively contaminated have been controlled by authorized bodies and institutions, but some uncertainties referring to complete cleanup actions have remained up to now. The initiative of the IAEA in starting Regional project on environmental restoration in the countries of Central and Eastern Europe gave an impetus to our current efforts in Croatia to run cleanup of most contaminated sites. Unfortunately, there are some aggravating factors which do not allow the implementation of entire programme as it is suggested by the IAEA. Firstly, it is unstable political situation in almost a third of Croatian territory, and - above all - the war which has not yet been stopped in some parts of the country. Close to this are some traffic difficulties causing considerable troubles in access to some sites of interest. In addition, there is a lack of financial means in the country which would be necessary for regular project implementation. Nevertheless, there have been reached some progress in the project performance in the period after the First Workshop, although the started actions do not strictly follow the proposed performance plan. For this reason the report structure is slightly different from the IAEA proposal for the Second Workshop, but contains most of topics such as definition of restoration objectives, restoration strategy, identification of priorities, project status at high-priority sites, valid regulatory framework in the field and responsible bodies, as well as some financial aspects of the project performance. In the post-Budapest period the Institute of Medical Research and Occupational Health has been involved in the Project. Consequently, the experts from this Institute -together with experts coming from the Institute "Ruđer Bošković" - participated in creation of this report. It is also worth mentioning that measuring of in-door working level in industrial facilities situated at high-priority sites has been also included into the project. However, the assessment of radon in human environment in Croatia, including radon exposure of people living for a long time in cellar shelters in the areas of Croatia affected by the war, is conceived as a separate project being also controlled by the IAEA. Finally, the process of radioactive waste repository site selection in Croatia is entering the last phase, so that such a repository - which could be eventually very important for some of radioactively contaminated dumps - is foreseen to be operating until 2002. Last, but not least is to mention that a detailed and well-organized management structure for cleanup of contaminated sites cannot be elaborated at the moment since institutional and capacity building, as well as infrastructure set up in Croatia as a newly independent country, have not yet been completed.

This report is related mainly to prioritization of contaminated sites, presentation of collected data on that sites, description of present status in contamination and current cleanup measures, as well as forthcoming remediation actions at high-priority sites.

2. RESTORATION OBJECTIVES

In the First progress report were identified a lot of potentially contaminated sites which could be possibly involved in the project. Due to significant differences in their known of expected dose and environmental impact, as well as the different nature of radiation emitting materials, a fairly wide span of possible cleanup actions has been foreseen in the project continuation. In order to act as efficiently as possible, some interim goals have been determined. Nevertheless, no palliative approach has been accepted as a method of acting. In short, our immediate objectives are:

- select sites of highest priorities;
- collect all relevant documentation referring to high-priority sites;
- involve competent regulatory bodies in the clean-up process;
- identify high-quality expert teams for all needed stages of cleanup action;

- ensure sufficient interim storage capacities for removal of identified radioactive materials, if needed;
- carry out sampling and measurements of radiation at selected contaminated sites;
- resulting from the above item, perform cost-benefit analysis which is needed for decision making on the most convenient cleanup method (e.g. dump control improvement, improvement of the on-site engineered barrier system, suspension of any further accumulation at dump sites, removal of dumped material etc.)

The ultimate goal of the action is a reasonable reduction of present radiation contamination in the country and consequent reduction of possible harmful effects to the environment and human health. Aimed cleanup level is referring to creation of prerequisites at contaminated sites which would enable realization of the mentioned goal.

Due to very limited financial resources available in Croatia, running institutional and capacity reconstruction as well as unstable political and military situation in the country, we have to act as reasonable as possible to achieve positive long-term effects in shortest time and at extremely reduced number of sites.

However, it should be added that identification, separation, measurement of radiation and removal (if needed) of building materials remained after war destructions at sites where installed radiation sources were damaged, could be included into the project as an emergency action.

The clean-up actions at sites characterized by increased radon emission (e.g. spas of Istarske toplice and Bizovačke toplice) - which were proposed to be included in this project - will be performed within the IAEA co-ordinated project "Radon in the Human Environment".

Performance of sampling and measurements of gas- and oil-wells is postponed due to some administrative reasons.

An expert support for creation of new legislation and regulations in the field, which is under way for almost last two years, seems also very important for further progress in cleanup process.

3. PERFORMANCE SCHEDULE FOR THE STAGE II

Due to the above mentioned difficulties in the project implementation, revised and more realistic performance schedule should be defined. There have been partially or entirely completed tasks 1, 3, 4 and 5 which were listed in the First Progress Report, but other four activities have not been started so far. Hence, they have to be included in this stage. For this reason, our proposed schedule (Fig. 1) has been revised in some extent, so that the following tasks are foreseen to be done in forthcoming period (deadline for task completion is given in brackets):

TASK 1 Completion of sampling and measurement at the high-priority sites together with other radiometric surveying in order to carry out their radiologic characterization (March 1995);

TASK 2 Calculation of risks to the environment and human health generating from the "status quo" at selected sites (May 1995);

TASK 3 Performance of cost-benefit analysis and decision making on the most convenient cleanup method at each of concerned sites (July 1995);

TASK 4 Identification and categorization of areas at selected sites into following three groups: (1) areas prohibited to human access; (2) areas allowed to restricted release; and (3) areas allowed to unrestricted release (September 1995);

TASK 5 Performance of needed preparatory actions for realization of "physical" cleanup at the sites of concern, according to selected restoration method for each site, as derives from Task 3 (November 1995);

TASK 6 Evaluation and interpretation of results relevant for the final, third project stage and issuing the referent report which will be submitted to the IAEA (December 1995).

It is expected that both creation of Regulatory body and preparation of needed legislation and regulations in the field will be simultaneously completed.

```
TASK 1   *********************
TASK 2                                  ****
TASK 3                                       *****
TASK 4                                              ******
TASK 5                                                     *****
TASK 6                                                           ***
         V VI VII VIII IX X XI XII I II III IV V VI VII VIII IX X XI XII
               1994                            1995
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Fig. 1. Schedule of task performance

Clean-up actions will be performed publicly, i.e. the public will be informed completely, simultaneously and honestly on all actions to be done. Moreover, due to special public attention to some of contaminated sites, representatives of local communities are expected to participate in discussions and decisions on final clean-up measures, i.e. further status of concerned dumps.

4. PRIORITIZATION

Although prioritization of contaminated sites is important for continuation of the project activities, it represents not more than an interim goal of the entire clean-up action, as it is shown in the following scheme:

1° Sites suspected to be contaminated (approx. 50)

2° Collection of available data on suspected sites

- quantity of contaminated material (dump surface and depth)
- composition of radionuclides contained in the material
- history of contamination
- type and status of facility generating contaminated material
- lithology, hydrogeology, and seismo-tectonics of sites
- vicinity to major urban or other densely populated areas
- identification of transportation routes of the material

3° Identification and ranking of priorities

4° High-priority sites (3)

5° On-site inspection, detailed sampling and measurements

6° Risk assessment

7° Cost-benefit analysis for possible clean-up options

8° Decision making on physical clean-up option

From the scheme it is obvious that collected data on all suspected sites and measurements which have been carried out so far, are accepted as a reliable basis for prioritization of radioactively contaminated sites in Croatia. Amongst a series of sites involved (referring to fields of oil- and gas-exploitation, petrochemistry, energy production, cement industry, quarries, metallurgy, fertilizers industry, transportation etc.), three sites have been selected as high-priorities (Fig. 2):

1. INA-VINIL in Kaštel Sućurac
2. Coal-fired power-plant PLOMIN
3. INA-PETROKEMIJA phosphate fertilizers factory Kutina

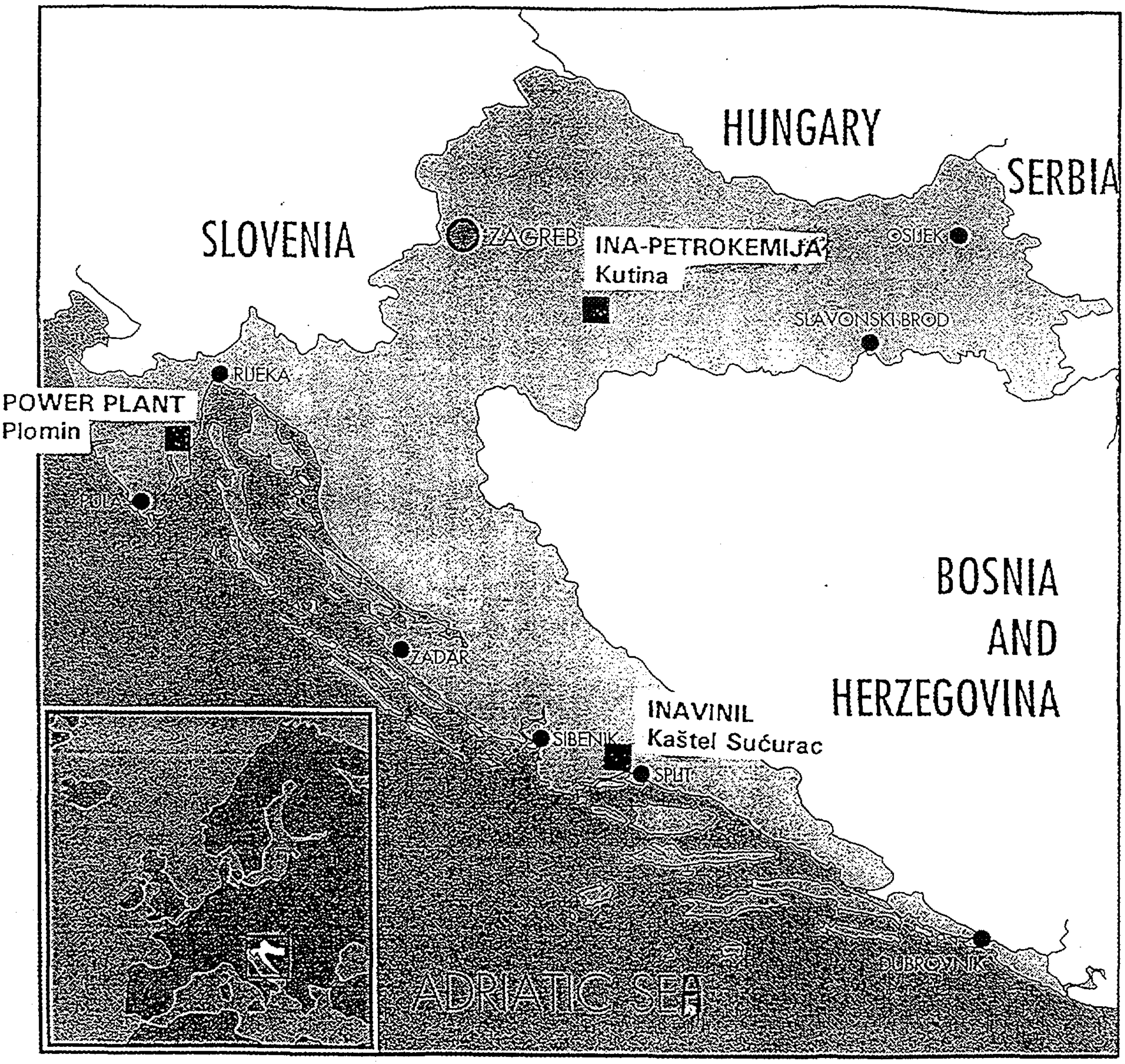

Fig. 2. Geographical position of high-priority sites

Coal slag and ash are identified as radioactively contaminated materials at sites (1) and (2), whilst phosphates, fertilizers and phospho-gypsum are related to the site (3). Basic criteria for prioritization were quantities of contaminated material, supposed or measured on-site radiation dose, vicinity to major urban or densely populated areas, type of waste generating facility, etc.

At some of sites exists even an increased opposition of local population (realized mainly through mass-media and greens) to waste dumps, demanding their removal as soon as possible. It is true that some of waste dumps are in collision to planned development of tourist valorization along the seaside in particular. Anyway, environmental preservation and human health protection should be realized in a reasonable extent in shortest possible time, but any exaggeration of real hazards coming from contaminated sites cannot be accepted as a standpoint for possible cleanup actions.

Current status at every of the high-priority sites in the frames of the project is described later on.

5. REGULATORY FRAMEWORK

Law and regulations concerning radioactive waste management, as well as other issues related to handling with radioactive materials in complete, which are temporary implemented in the Republic of Croatia, are former Yugoslav regulations. In general, these regulations are based upon worldwide practice and support other regulations such as regulations on environmental protection or the management of other wastes. The basic regulation is "Law on Ionizing Radiation Protection and Special Safety Actions in Nuclear Energy Implementation" issued in 1984. From this law, 17 regulations and codes of practice have been derived. Among them it should be mentioned "Code of Practice on Conditions for Locating, Construction, Start-up and Operation of Nuclear Facilities", the "Code of Practice on Standard Format of Safety Report and Other Documentation Needed for Safety of Nuclear Facilities", and "Code of Practice on Methods of Collecting, Account, Processing, Storing, Final Disposal and Release of Radioactive Waste Substances in the Environment" (issued in 1986-88). All these regulations went into effect according to " Law on Taking Over the Federal Laws in the Field of Health Protection, Applied in the Republic of Croatia as Republic Laws" [1].

Besides the mentioned law and regulations, the Law on transportation of dangerous materials (issued in 1984) is also applying in Croatia under the same temporary conditions (i.e. until the preparation of new Croatian law). Transportation of radioactive materials (including radioactive waste), as well as possible removal of some contaminated piles considered in this report, should be done in accordance with this law.

In spite of the above mentioned facts, the original Croatian law on radiation protection has been already drafted. Some incomplete or incorrect statements existing in the mentioned temporary regulations were replaced by the statements representing the most recent achievements in the field that have been incorporated in most of modern regulations. At the same time, the need to develop legislation in the field of radioactive waste management and related safety actions should also be met.

6. LIMIT VALUES OF RADIONUCLIDE CONCENTRATIONS AND DOSE LIMITS IN THE ENVIRONMENT

In order to compare measured concentrations of radionuclides and elaborate identified radiation doses with corresponding referred values, it follows some of respective limit values taken from valid regulations of Croatia and the USA.

Tab. 1

Derived radionuclide concentrations in the air and drinking water in Croatia and USA, and average monthly emissions allowed in sewage system /AMESW/ in the USA (in Bq/m^3) [2,3]

Radio-nuclide	CROATIA Air	CROATIA Water	USA Air	USA Water	USA AMESW
^{3}H	5,000	$6x10^{7}$	3,700	$3.70x10^{7}$	$3.70x10^{8}$
^{14}C	300	$2x10^{6}$	11	$1.11x10^{6}$	$1.11x10^{7}$
^{40}K	40	$2x10^{5}$	22	1.48x105	$1.48x10^{6}$
^{58}Co	70	$1x10^{6}$	37	$7.40x10^{5}$	$7.40x10^{6}$
^{60}Co	3	$1x10^{5}$	2	$1.11x10^{5}$	$1.11x10^{6}$
^{89}Sr	10	$4x10^{5}$	7	$2.96x10^{5}$	$2.96x10^{6}$
^{90}Sr	0.4	$2x10^{4}$	0.2	$1.85x10^{4}$	$1.85x10^{5}$
^{90}Y	60	$4x10^{5}$	33	$2.59x10^{5}$	$2.59x10^{6}$
^{131}I	5	$2x10^{4}$	7	$3.70x10^{4}$	$3.70x10^{5}$
^{134}Cs	10	$6x10^{4}$	7	$3.30x10^{4}$	$3.33x10^{5}$
^{137}Cs	10	$8x10^{4}$	7	$3.70x10^{4}$	$3.70x10^{5}$
^{210}Pb	0.03	$4x10^{2}$	0.02	$3.70x10^{2}$	$3.70x10^{3}$
^{211}Pb	0.7	$8x10^{6}$	33	$7.40x10^{6}$	$7.40x10^{7}$
^{214}Pb	0.7	$6x10^{6}$	37	$3.70x10^{6}$	$3.70x10^{7}$
^{210}Bi	3	$6x10^{5}$	1.5	$3.70x10^{5}$	$3.70x10^{6}$
^{214}Bi	0.7	$1x10^{7}$	37	$1.11x10^{7}$	$1.11x10^{8}$
^{210}Po	0.07	$2x10^{3}$	0.03	$1.48x10^{3}$	$1.48x10^{4}$
^{226}Ra	0.07	$1x10^{3}$	0.03	$2.22x10^{3}$	$2.22x10^{4}$
^{228}Ra	0.1	$2x10^{3}$	0.07	$2.22x10^{3}$	$2.22x10^{4}$
^{228}Ac	0.1	$2x10^{3}$	0.7	$1.11x10^{6}$	$1.11x10^{7}$
^{230}Th	$7x10^{-4}$	$2x10^{3}$	0.007	$3.70x10^{3}$	$3.70x10^{4}$
^{232}Th	$1x10^{-4}$	6x102	$15x10^{-4}$	$1.11x10^{3}$	$1.10x10^{4}$
^{235}U	$4x10^{-4}$	$1x10^{4}$	0.02	$1.10x10^{4}$	$1.11x10^{5}$
^{238}U	$5x10^{-3}$	$1x10^{4}$	0.02	$1.10x10^{4}$	$1.11x10^{5}$
^{239}Pu	$5x10^{-4}$	9	0.007	$7.40x10^{2}$	$7.40x10^{3}$

Tab. 2

Limits of allowed radionuclide concentrations in building materials (in Bq/kg) in Croatia and some other countries [3,4]

COUNTRY	^{226}Ra	^{232}Th	^{40}K	ARTIFICIAL RADIONUCLIDES
Croatia	400	300	5,000	4,000
Germany	185	259	4,810	-
Sweden (old buildings)	1,000	700	10,000	-
Sweden (new buildings)	300	200	3,000	-
OECD countries	150	259	4,810	-

From these values the following relations have been derived (C = concentration):

CROATIA
C(Ra)/400 + C(Th)/300 + C(K)/5,000 + C(art.)/4,000 < 1

GERMANY
C(Ra)/185 + C(Th)/259 + C(K)/4,810 < 1

SWEDEN
- old buildings: C(Ra)/1,000 + C(Th)/700 + C(K)/10,000 < 1
- new buildings: C(Ra)/300 + C(Th)/200 + C(K)/3,000 < 1

OECD COUNTRIES
C(Ra)/150 + C(Th)/259 + C(K)/4,810 < 1

7. RESPONSIBLE BODIES

Since institutional and capacity building is in process, the structure of responsible, i.e. regulatory bodies, as well as legislation itself, are in transitional phase in Croatia. Therefore, we are still operating in accordance with the old regulatory body structure, but considerable changes are expected to be done until the end of 1994. For this reason, main characteristics of both, past and future regulatory body in the field are given below.

7.1. Present status of the Regulatory Body structure

The Regulatory Body for the Radiation Protection and Radioactive Waste Management in Croatia has not been organized as one institution covering all related issues. It has been organized as sections of three ministries: the Ministry of Health, the Ministry of Economy, and the Ministry of Civil Engineering and Environmental Protection. Unfortunately, there is no established permanent body co-ordinating activities of the ministries in the field. It should be added that few other ministries are responsible for licensing of some radioactive waste management activities, such as transportation, import-export, release of effluents etc. [5].

Sanitary Inspectorate, as a part of *the Ministry of Health*, is the competent national authority for radiation protection, including big part of radioactive waste management. The Ministry of Health has authorized three additional institutions to perform some parts of specific regulatory tasks. There is more expertise in the authorized institutions than in the Sanitary Inspectorate itself. The Ministry of Health suffers also from limited budgeting for regulatory tasks.
Restoration of radioactively contaminated sites is performing under control of the *Ministry of Health*, which is authorized to inspect all actions having any possible impact to human health. Hence, all on-site actions which the Project team is expected to carry out (like inspection, sampling, measurement etc.) may be performed in co-operation with the Ministry of Health. This ministry will also participate in decision making on further actions at the high-priority sites (e.g. whether dumps will be removed or not, which additional safety measures should be done on the sites, etc.).

The current basic organizational chart of the Ministry of Health and subordinate institutions is presented in Figure 3.

The Ministry of Economy (Department of Nuclear Safety) is the competent national authority in the field of nuclear facility siting, construction, start-up, operation and closure, which also includes affairs related to the planned LLW/ILW repository in Croatia. Department of Industry as another section of the Ministry of Economy will have significant role in decision making of final clean-up actions of all dumps related to industrial facilities. Similar role is given to Department of Energy in the same Ministry for all contaminated sites connected with operation of various energy generating plants.

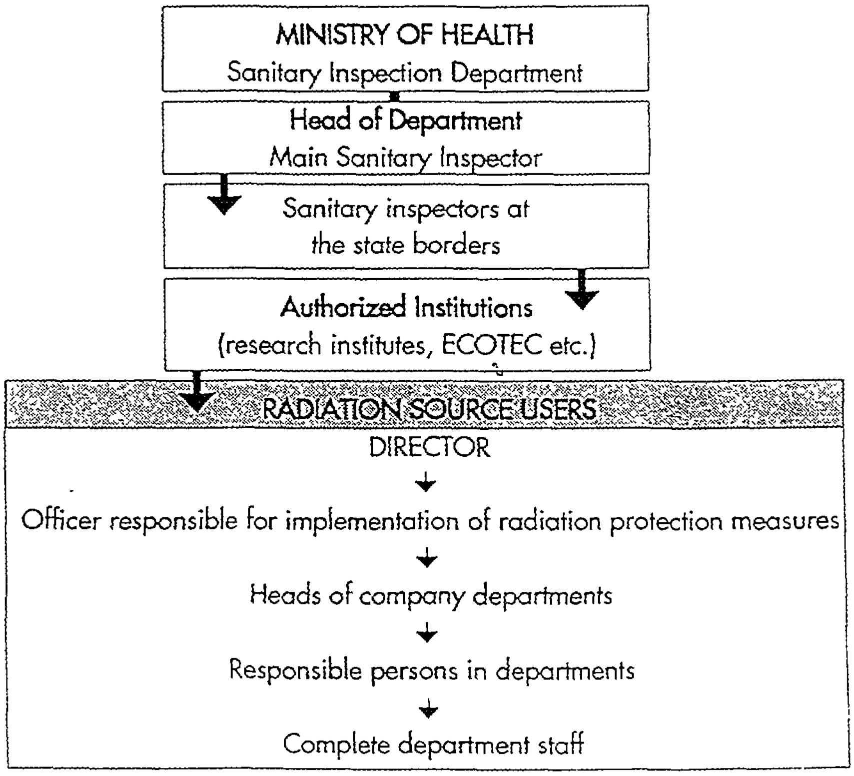

Fig. 3. Basic organizational chart of the Ministry of Health and subordinate organizations

The competence of *the Ministry of Civil Engineering and Environmental Protection (Department of Environmental Protection)* is directed to issues related to environmental restoration actions of contaminated sites, hazardous waste management, siting of radioactive waste repository, etc. The Ministry is also charged to adjust all activities which could have any harmful effect to the environment with the Regional Plan of Croatia.

It should be also mentioned that some other ministries like the Ministry of Navigation, Transportation and Communications and the Ministry of Interior are expected to participate in final stages of clean-up action, especially in cases of possible removal of contaminated dumps.

In addition, there are four groups of institutions dealing with radioactive waste in Croatia:

(1) *The APO*, which is close to the Government (Ministry of Economy, M. of Civil Engineering and Environmental Protection, M. of Health), and responsible to establish and maintain an efficient hazardous, including radioactive waste management system. It is supposed to be the national operating radioactive waste management organization. It is also authorized by the Government to organize and perform some specific actions like environmental restoration and human health protection, which include the handling, storage and disposal of radioactive waste.

(2) *National research institutes "Ruđer Bošković" and "Institute for Medical Research and Occupational Health"* are both equipped with experts needed for environmental clean-up actions from various pollutants including radioactive waste. They are authorized to perform personnel dosimetry and radiological monitoring programmes, such as the monitoring of releases of the Krško NPP into the environment. In addition, there are storage capacities for radioactive waste and radiation sources organized at both institutes to meet total needs of the country.

(3) *The ECOTEC* - a private company, as the institution authorized for the import and transport of radiation sources and some other tasks, has an important role in all *in situ* actions where the handling with radioactive materials (and waste) is needed.

(4) *Users of radiation sources* are obliged to manage their own waste using, in general, following three methods: (a) waste is stored until its activity falls below the prescribed level, and then is managed as a common (municipal) waste; (b) waste containing long-lived radionuclides is stored at one of two storage facilities (until the final radioactive waste repository starts operating); and (c) some spent radioactive materials are foreseen to be re-used in the same or other purpose, or - if it is not possible - they are returned back to the producer (mostly out of Croatia).

The basic organizational chart of current regulatory body structure in Croatia -referring to the clean-up actions of radioactively contaminated sites - is as follows:

MINISTRY OF HEALTH	M. OF ECONOMY	M. OF CIVIL ENGINEERING & ENVIRONMENT. PROTECTION
Sanitary Inspectorate	**Department of Nuclear Safety**	**Department of Environmental Protection**

A P O - HAZARDOUS WASTE MANAGEMENT AGENCY

Institute "Ruđer Bošković"	Institute for Medical Research and Occupational Health	ECOTEC

Contaminated sites
* inspection, sampling, measurements
* on-site radiation safety measures
* decision on status of dumps (clean-up, conservation, removal)

7.2. Expected reorganization of the Regulatory Body

Although there is not any definite solution on how the Regulatory Body will be organized, the following option (Fig. 4) is based on possibilities and real organizational needs in Croatia in the forthcoming period. It also respects recommendations given by the RAPAT/IAEA Mission [6], the experiences of some European countries comparable with Croatia in size, population, energy generating policy and ambitions, such as Finland, Denmark, Netherlands, Hungary, Bulgaria etc.

The affairs related to radiation protection and nuclear safety are supposed to be regulated by an independent authority - the State Administration for Radiological and Nuclear Safety (SARNS). The SARNS could be supported by the National Nuclear Commission (NNC), which is expected to be established by the Government. Activities committed to the SARNS may be divided into three groups: (a) radiation safety, (b) nuclear safety, and (c) common services distributed to particular sections.

On the other hand, the recently issued Law on Health Protection foresee the creation of the National Institute for Radiation Protection (NIRP) which is supposed to perform similar activities committed to the Section of Radiation Protection as a part of SARNS (including licensing, issuing of codes of practice, and control of radiation sources). It is suggested that the NIRP could act within the Ministry of Health until the SARNS will be established.

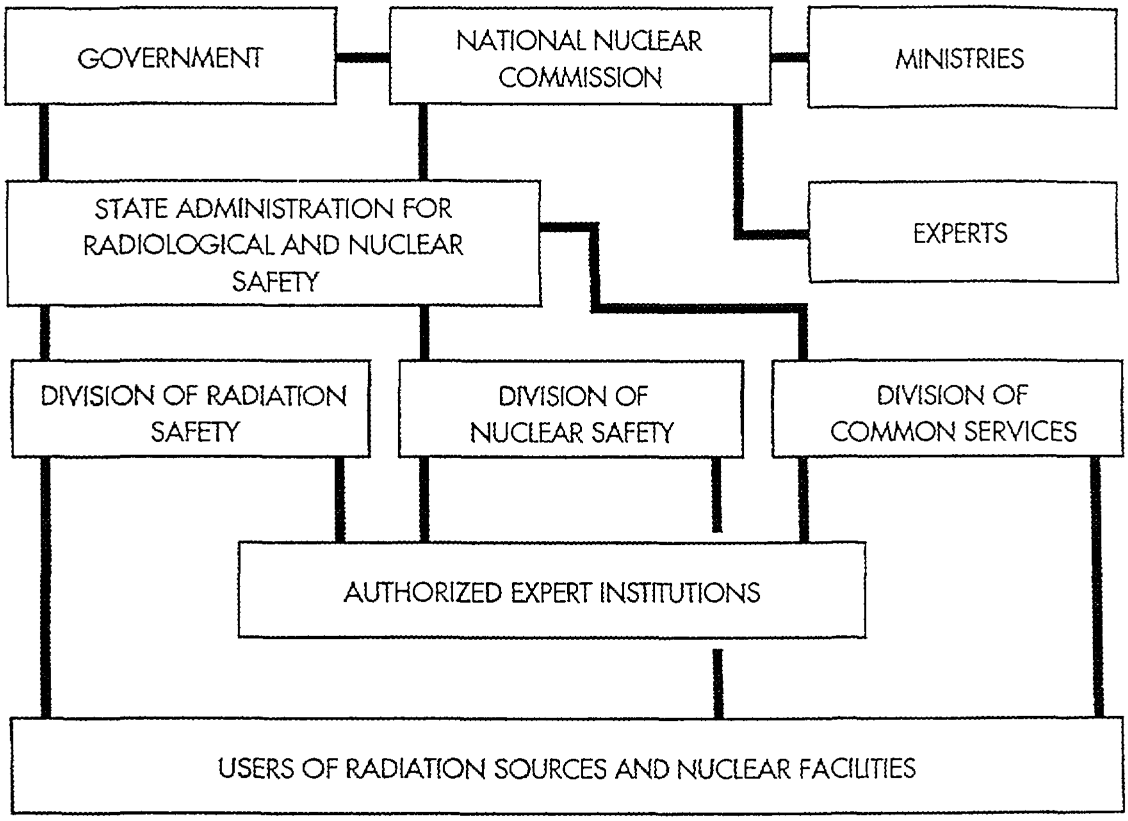

Fig. 4. Expected organizational chart of the re-organized regulatory body

All tasks from the field of nuclear safety are foreseen to be relocated from the Ministry of Economy to the SARNS sectors of nuclear safety and common services. As a consequence, the Ministry of Economy is expected to abandon its responsibilities upon the safety of nuclear facilities.

8. FINANCIAL ASPECTS

Performance of the project activities - stage II, as they are scheduled in the chapter 3 of this Report (i.e. for the period May 1994 - December 1995), depends upon provision of the basic finances, which cheapest option is roughly estimated in the below presented cost-breakdown list - given in US dollars (needed equipment is calculated separately):

	TASK1	TASK2	TASK3	TASK4	TASK5	TASK6
A. FEES[1]	8,000	5,000	6,000	4,000	4,000	10,000
B. SUBSISTENCE[2]	2,400	-	-	1,200	2,400	-
C. TRAVEL EXPENSES[3]	1,200	-	-	800	1,200	-
D. SAMPLING[4]	6,400	-	-	-	-	-
Total	**18,000**	**5,000**	**6,000**	**6,000**	**7,600**	**10,000**

II STAGE ACTIVITIES - TOTAL 52,600 USD

This cost-breakdown structure is based on the following unit prices:

1 1 expert-man/month = 2,000 USD
2 1 subsistence rate per day = 20 USD
3 1 l petrol = 0.8 USD (based on average consumption 10 l per 100 km)
4 1 sample analysis = 100 USD (average)

The above given expenses are referring to performance of II stage activities only, i.e. to the project implementation up to the stage of physical clean-up activities. It is not realistic to give any estimation for the cost of the third project stage itself now, since no decision for remediation actions at any of high-priority sites has been made so far.

The indispensable equipment for the project continuation, i.e. those items which are not available at the project operating institutions, includes the following instruments:

1. **Multi-purpose gamma-monitor (MFM-202)**, measuring radiation doses in the range 50 nSv/h - 100 mSv/h: measures continuously, identifies and print out the measured radiation doses.
   4 pieces a ca. 6,000 USD = <u>24,000 USD</u>

2. **Portable radon monitor GENTRON (Alpha Guard P 2000)**
   2 pieces a ca. 10,000 USD = <u>20,000 USD</u>

3. **Gamma Guard portable VICTOREEN**
   2 pieces a ca. 2,000 USD = <u>4,000 USD</u>

4. **Survey meters VICTOREEN**
   5 pieces a ca. 1,000 USD = <u>5,000 USD</u>

In addition to these items, following instruments - which were specified in the Progress report I - are also necessary for planned project activities:

1. Satisfactory calibrated **portable instrument** (provided also with battery unit) **for measuring low radiation doses** within the secondary standard range (eg device H7907-1, produced in Halle, Germany) - 1 unit.

2. Satisfactory calibrated **portable instrument** (provided also with battery unit) **for measuring low radiation doses** within the secondary standard range (eg. NaI(Tl) scintillation detector) - 2 units.

3. **TLD-700** - 1,000 units
   CaF_2Mn TLD - 1,000 units

9. CURRENT PROJECT STATUS AT HIGH-PRIORITY SITES

The fact that facilities generating contaminated waste dumps at all high-priority sites are still in operation, presents considerable limitation for planning of clean-up actions at these sites. Namely, it is not probable that shut-down of further accumulation on the piles or simply their removal can be realized until some additional way of waste release will be operating.

9.1. INA-VINIL Kaštel Sućurac

Site:

- coal slag/ash piles

Quantity of contaminated material:

- approx. 10,000 cubic meters

Geology:

- flysch (Eocene), limestones and dolomites (Cretaceous, Jurassic)

Facility:

- PVC factory (in operation)

Population in 10 km radius:

- approx. 250,000

Possible contaminated area:

- piles and surrounding soils and littoral sea of the Kaštela bay

Transportation route of contaminated material:

- coal was transported by ship from Rijeka and Bay of Kotor (Boka Kotorska) and by railway from adjacent coal-mine basin in hinterland of Šibenik (Dubravice, Širitovci).

There are two coal slag- and ash dumps with increased radioactivity, operating at the INA-VINIL plant in Kaštel Sućurac, some 5 km northward of Split (population 200,000). One of them, with dimensions 100 x 100 m, i.e. 10,000 m^2, is fairly organized and periodically controlled: as the average depth of accumulated material is about 1 m, total present quantity is some 10,000 m^3. However, the other, smaller dump, has not been satisfactory monitored. Additional problem is the position of dumps close to the seaside, and filling the material directly in the sea (having, as a consequence possible pollution of submarine area in the Bay of Kaštela). The slag/ash has remained after the burning of coal used as energy source for the PVC synthesis and treatment plant INA-VINIL in Kaštel Sućurac. Slag and ashes have remained here after the coal has been used as fuel since 1950s onward. The material partly originates from fire-room of the facility energy-plant itself, but a part of it has been shipped by the sea from Rijeka and Boka Kotorska. After available data it is realistic to suppose that coal from which the slag deposits have been derived, was mined mostly at minor brown coal mines in the karst area (carbonates!) of the Šibenik hinterland (Dubravice, Širitovci). Deposits shipped from Rijeka probably represent residue remained from combustion of black coal mined at Labin and Raša. There is no reliable information on origin of deposits delivered from Boka Kotorska.

According to past measurements of radioactivity there are 18,640 Bq/kg ^{238}U and 6,200 Bq/kg ^{226}Ra identified in the coal-slag and ash.

After some calculations of uranium content in the slag and ash, some 7.5 t ^{238}U and about 55 kg ^{235}U are contained in the dumps. Additional problem represents a continuous practice of mixing cement with ashes as a matrix in nearby cement industries in Kaštel Sućurac and Solin). Hence, the concrete as the final product in the mentioned plants is also foreseen to be inspected in the frames of clean-up action in the area. Some attention should be payed to surveying of adjacent family houses, which foundations were in some cases filled by contaminated material (referring to this, some health problems at locally living population have been reported). However, the opposition of local population and, especially, greens against further operation of dumps has been derived not only for possible radiation contamination at the dump sites, but also for other harmful effects of local industries, as it is pollution by mercury, vinyl-chloride monomer, "PVC-sludge" etc. Anyway, the idea of removal of the dumps to some more convenient place is very popular in local population.

In order to get most recent, accurate and reliable data on real radioactive contamination at the site, we have planned to carry out sampling on both dump sites at grid 20 x 20 meters, i.e. to analyze about 30 samples (gamma-spectrometry above all), as it is shown in the Figure 5. TLDs and GM probes are foreseen to be set up on the site, and contamination should be measured during a period of some 6 months. Due to some technical difficulties the start of sampling and measurements at this site are postponed for some six month.

Sampling requires piercing of surface plastic sheet and digging of holes in overlying protection earth-cover for each sample. During on-site sampling and set up of measuring devices operating members of project team will be accompanied by the state inspector for radiation protection. All measurements are foreseen to be performed at coal piles itself, as well as at concerned slag- and ash piles. Field trips including performance of the mentioned on-site activities are about starting, so that first laboratory analyses are expected to be done in May-June 1994. After preliminary elaboration the site INA-VINIL is thought to be most delicate of all high-priority sites.

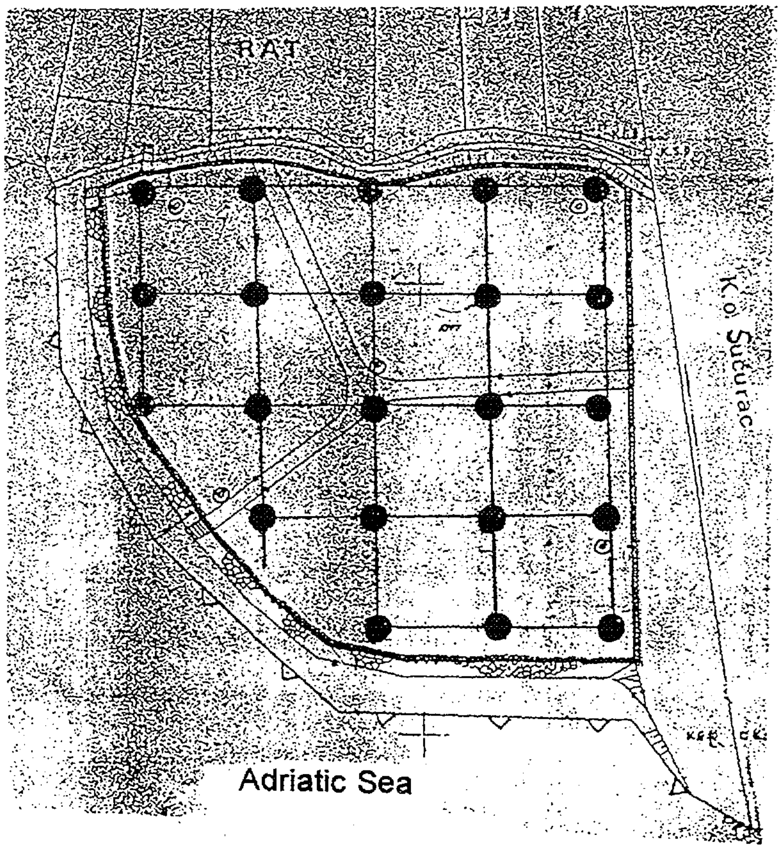

Fig. 5. Planned sampling-grid at the INA-VINIL site

9.2. Coal-Fired Power Plant PLOMIN

Site:
- coal- and coal slag/ash piles

Quantity of contaminated material:
- approx. 800,000 tons

Geology:
- flysch (Eocene), limestones and dolomites (Cretaceous)

Facility:

- coal-fired power plant (in operation)

Population in 10 km radius:

- approx. 20,000

Possible contaminated area:

- neighboring settlements, local streams, Plomin bay

Transportation route of contaminated material:

- coal is mined at adjacent Raša coal mine area (some 10 km from the plant site)

The coal slag/ash pile is situated close to the power plant site. Slag and ash is accumulating continuously, consequently to regular operation of the power plant. The pile is not covered or protected in any other way excluding the facility fence. Past investigations point at some 1,000 Bq/kg ^{226}Ra in ash pile. Furthermore, ash removed from electro-filters in the power plant contains 2,562 Bq/kg ^{238}U and 2,540 Bq/kg ^{226}Ra. In slag has been determined some 1,550 Bq/kg ^{238}U and 800 Bq/kg ^{226}Ra.

Additional burdening factor is the fact that coal slag and ash, stored at the plant enter freely by wind and streams into environment. Radioactivity of locally mined coals varies considerably, and mean content of uranium in ashes and slag might be somewhere around 2,000 Bq/kg. There have been performed some measurements of natural radiation (in marine and fluvial sediments) in vicinity of Raša coal mine and Plomin power-plant, as well as in ashes generating in the power-plant, which were presented in the I Progress Report. It should be added that besides the stored slag and ash, there is another source of pollution acting at the power plant: release of gas and contaminated smoke into the atmosphere.

In order to identify real recent pollution the following sampling and measurements have been started:

- gamma-spectrometry and radiochemical analysis of coal-, slag- and ash-samples from the piles at the power plant;
- measurements of natural radionuclide concentrations (6 air-samples) taken inside the 20 km radius around the power plant;
- measurements of natural radionuclide concentration in soil (4 samples) taken within the 2 km radius around the power plant;
- measurements of radionuclide concentrations in pedological horizons at few vertical profiles (3-5 samples per profile) in order to determine vertical migration of radionuclides (especially uranium) which could be caused by acid rains.

Finally, there is taken into consideration possibility of measurement of possible radiation contamination in the Plomin bay. This idea is initiated by the fact that long-term pollution of the bay seabed is very probable due to continuous accumulation of polluted terrestrial material which has been entering the bay by activity of local streams. Some five seabed boreholes are suggested as it is schematically presented in the Figure 6.

Stream sediments in the plant vicinity are also supposed to be sampled until the end of 1994 in order to prove radioactive contamination caused by inadequate disposal of slag and ash from the plant.

9.3. INA-PETROKEMIJA Kutina

Site:

- waste/phospho - gypsum landfills

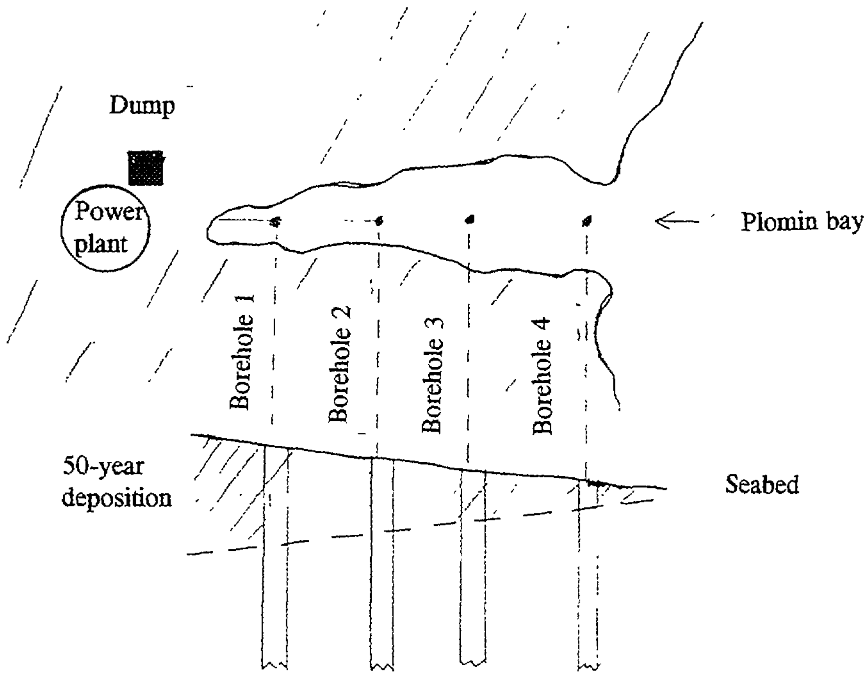

Fig. 6. Scheme of proposed sampling in the Plomin bay submarine area

Quantity of contaminated material:
- 3.5 million cubic meters

Geology:
- Quaternary fluvial sediments (mud, sand, gravel)

Facility:
- phosphate fertilizers factory (in operation)

Population in 10 km radius:
- approx. 30,000

Possible contaminated area:
- phospo-gypsum landfills, arable land where fertilizers are applied, streams running through fertilized croplands, groundwater at phospho-gypsum landfills and fertilized agriculture land.

Transportation route of contaminated material:
- PHOSPHATE ORE - railway Rijeka-Karlovac-Zagreb-Kutina (former railway route Šibenik-Knin-Sisak-Kutina); FERTILIZERS are in use throughout Croatia, but mainly in interior part of country (e.g. Slavonia), and are transported by railway or lorries.

The fertilizers factory INA-PETROKEMIJA in Kutina consists of two sites where increased radiation is expected: (1) the factory in-door area (phosphates as raw material, phosphate acid, fertilizers as final products), and (2) phospho-gypsum landfills, lying ca. 5 km southward from the factory (see the map) . As sites of fairly increased radiation contamination are identified agricultural lands where fertilizers are used. Basic difference between a nature of contamination of these sites is derived from the fact that ^{238}U is identified as a basic radio-pollutant in fertilizers, whilst ^{226}Ra prevails in phospho-gypsum. Although routes of phosphates (raw materials) have been precisely defined, it is not realistic to expect any considerable contamination along transportation routes from the entering Croatian ports (Šibenik, Rijeka) and factory in Kutina.

Basic input data on radioactive contamination were given mostly in the I Progress report. They pointed at increased radioactivity in all components of production cycle, as follows:

- phosphates (raw material)	15,000 - 17,000 Bq/kg ^{40}K 2,000 - 3,000 Bq/kg ^{238}U 1,000 - 1,500 Bq/kg ^{226}Ra
- phosphoric acid and mono-ammonium phosphate	3,000 - 3,500 Bq/kg ^{238}U
- phosphate fertizers (final product)	6,000 - 7,500 Bq/kg ^{40}K 1,000 - 1,700 Bq/kg ^{238}U
- phospho-gypsum	700 - 1,200 Bq/kg ^{226}Ra

The most recent results of phosphates and potassium-chloride analyses, which were performed in March 1994, are as follows (in Bq/kg):

SAMPLE	^{40}K	^{228}Ac	^{226}Ra	^{235}U	^{238}U
KCl (white)	15,939	0	0	0	0
KCl (red)	16,132	0	0	0	0
Potassium sulphate	13,824	0	0	0	0
BOUCRA PHOSPHATE					
Sample 1	11	7	848	26	565
Sample 2	27	12	1,229	43	938
Sample 3	15	8	830	27	577
MOROCCO PHOSPHATES					
Sample 1	16	11	1,140	44	951
Sample 2	28	8	1,120	42	917
Sample 3	9	9	1,423	51	1,103

Due to significant variations in contents of ^{226}Ra and ^{238}U, it seems reasonable to introduce a permanent control of radioactivity in imported phosphates.

In addition, through analyses have been identified: (a) up to 80 Bq/m^3 ^{226}Ra in groundwater (radiochemistry measured in piezometers); (b) 1,000 Bq/m^3 ^{40}K and 40 Bq/m^3 226Ra in well-water; and (c) 3,500-4,000 Bq/m^3 ^{40}K and up to 50 Bq/m^3 ^{226}Ra in waste water (gamma-spectrometry).

Investigations of phosphate fertilizers used in eastern Slavonia [7] pointed at following radioactivity: 75 Bq/kg ^{226}Ra, 9 Bq/kg ^{228}Ra, 52 Bq/kg ^{235}U and even 1,120 Bq/kg ^{238}U. The estimated annual deposition of uranium and radium in soils of agricultural fields in the area of Vinkovci is 4.5 Bq/m^2 ^{226}Ra, 0.5 Bq/m^2 ^{228}Ra, 3.1 Bq/m^2 ^{235}U and 67 Bq/m^2 ^{238}U. The highest concentrations of both uranium isotopes were measured in drainage channels water having mean values of 120 Bq/m^3 ^{238}U and 5.5 Bq/m^3 ^{235}U.

Anyway, the most sensitive point in the fertilizer production from the standpoint of clean-up measures are landfills of phospho-gypsum. There are four pools organized in the floodplain of Sava river, some 5 km southward from Kutina (i.e. fertilizer factory). Their respective size is 43 hectares (ha), 33 ha, 28 ha and 32 ha, i.e. their total surface is 136 ha. Pools are arranged along an area 1 km long and 700 m wide. Total capacity of pools are 20 million cubic meters, but only 3.5 million cubic meters of phospho-gypsum have been accumulated so far. Waste gypsum, mixed with water, is transported from the factory to pools by special pipeline. Radionuclide contents of phospho-gypsum itself, groundwater and waste-water is controlled continuously (their highest concentration values are given above). Nevertheless, it is out of any doubt that clean-up of these pools, which are indispensable for regular operation of INA-PETROKEMIJA factory, represents highly recommendable action necessary for improvement of environmental quality and, consequently, human health protection. Some improvement in fertilizers production should be also discussed since generation of 4-5 tons of phospho-gypsum (as waste material) from production of 1 ton of phosphoric acid is not rational and represents considerable ecological burden.

10. MAIN RESULTS

Most of necessary data on radiation contamination at the INA-PETROKEMIJA factory in Kutina which had been foreseen to be obtained in the project, have been collected so far (sampling and measurements were performed in the period March-July 1994):

(1) sampling and measurement of radon concentrations;

(2) radiochemical analysis ^{226}Ra in groundwater (piezometers) and well-water;

(3) measurements by thermo-luminescent detectors (TLD) of in-door phosphoric acid- and fertilizers processing area, phosphate and potassium-chloride storage areas, phospho-gypsum pools and some places in vicinity of the plant;

(4) gamma-spectrometry of phosphates (raw material), fertilizers (final products), phospho-gypsum (waste material) and air samples;

(5) measurement of Working Level (^{222}Rn daughters)

(Ad 1) Sampling and Measurement of Radon Concentrations

	Location	Concentration (Bq m^{-3})
01	Phosphate warehouse	123
03	MAP/NPK: New facility - phosphate warehouse	20
04	MAP/NPK: Granulator	53
05	MAP/NPK: Command room	25
06	MAP/NPK: North warehouse	122
07	Phosphoric acid facility: Office	16
08	Phosphoric acid facility: Phosphate milling - command room	13
09	Phosphoric acid facility: Filtration	12
10	Phosphoric acid facility: Command room	12
14	NPK-1 (old facility) - at spherodizer	80

(Ad 2) Radiochemical analysis of ^{226}Ra

SiF landfill

- vertical piezometer D1 112.2 +/- 12.2 mBq/l

Phospho-gypsum landfill

- horizontal piezometer D2	112.7 +/- 12.2 mBq/l
- vertical piezometer D3	165.9 +/- 31.5 mBq/l
- vertical piezometer	87.5 +/- 12.9 mBq/l
- horizontal piezometer	101.4 +/- 13.4 mBq/l

Well-water samples

- family-house in Radićeva street 388	36.5 +/- 11.4 mBq/l

(Ad 3) Radiation doses in air samples (measured by thermoluminescent dosimeters /TLDs/)

TLD No.	LOCATION	MEASURED DOSE* (in 29 days)	ANNUAL DOSE* (365/29 x D_{29})
44/1	Town Sport Hall (2,5 km from INA-P)	101	1,271
24/1	Public Restaurant (Kutina)	74	931
34/1	INA-PETROKEMIJA Laboratory (room 19/1)	76	957
46/1	The nearest house to the phospho-gypsum landfill (Radićeva street 388)	100	1,259
13/1	Phosphoric acid warehouse	**208**	**2,618**
21/1	MAP/NPK - new facility (warehouse of white KCl)	**130**	**1,636**
16/1	MAP/NPK - new facility (warehouse of red KCl)	**125**	**1,573**
41/1	MAP/NPK - new facility (warehouse of BOUCRA phosphate and quartz sand)	**217**	**2,731**
19/1	MAP/NPK - new facility (granulator)	103	1,294
35/1	MAP/NPK - new facility (command room)	87	1,095
33/1	MAP/NPK - new facility (northern warehouse of final products)	68	856

TLD No.	L O C A T I O N	MEASURED DOSE* (in 29 days)	ANNUAL DOSE* (365/29 x D_{29})
06/1	Phosphoric acid facility (vice-director room)	81	1,019
43/1	Phosphoric acid facility - phosphate milling plant (command room)	91	1,145
20/1	Phosphoric acid facility - filtration (filters)	**132**	**1,661**
31/1	Phosphoric acid facility (command room)	83	1,045
38/1	Packing area III - NPK lines 8 & 9	74	931
32/1	Packing area I (old) - lines 5 & 6	77	969
45/1	NPK-1 (old) - command room	87	1,095
09/1	NPK-1 (old): at spherodizer	102	1,284
25/1	NPK-1 (old): warehouse of final products	**120**	**1,510**
18/1	Phospho-gypsum landfill: pumping station	68	856

* given in micro-Grays (1 micro-Gray = 1 micro-Sievert)

N o t e : For comparison pay attention to the following annual doses at meteorological observing points: Bjelovar - 1,023 micro-Sv, Daruvar - 1,062 micro-Sv, Sisak - 981 micro-Sv (measured values which are considerably higher than background values are printed in bold mode).

(Ad 4) Gamma-spectrometry of phosphates, phosphate fertilizers (final products) and phospho-gypsum (waste material)

SAMPLE	^{40}K	^{228}Ac	^{226}Ra	^{235}U	^{238}U
KCl (white)	15,939	N D	N D	N D	N D
KCl (red)	16,132	N D	N D	N D	N D
K-sulphate	13,824	N D	N D	N D	N D
BOUCRA phosphates					
Sample 1	11	7	848	26	565
Sample 2	27	12	1,229	43	938
Sample 3	15	8	830	27	577
MOROCCO phosphates					
Sample 1	16	11	1,140	44	951
Sample 2	28	8	1,120	42	917
Sample 3	9	9	1,423	51	1,103
Phosphoric acid					
High concentrated - sample 1	32	4	12	77	1,680
High concentrated - sample 2	28	3	10	77	1,681
Low concentrated - sample 1	3	2	43	39	853
Low concentrated - sample 2	6	1	7	41	897
Phospho-gypsum					
Landfill (1/94)	17	5	377	1	4
Filter (3/94)	25	6	702	2	47
MAP	32	2	31	83	1,797
NPK-fertilizers					
20-10-10	2,438	2	95	20	440
13-10-12	3,153	3	192	10	210
13-13-21	5,296	2	46	9	202
15-15-15 (1)	3,795	3	94	18	392
15-15-15 (2)	3,885	3	114	18	392
08-16-24	6,358	2	130	18	384
18-18-18	4,924	3	10	28	611
08-26-26	7,016	3	7	36	780
Soot	4	N D	N D	1	22

N D = not detectable

In accordance with these gamma-spectrometry results, the following statements and recommendations related to improvement of the plant processing technology (in both economic and ecologic senses) have been given to the INA-PETROKEMIJA Plant Management Team:

11. RAW MATERIALS

11.1. Potassium chloride (KCl)

Both KCl samples show a high purity levels (white KCl about 98.3 %, red KCl about 99.5 %; possible deviation is not higher than 1 %). Namely, the measured specific activities of ^{40}K are roughly identical to specific activity of chemically pure KCl (i.e. 16,220 Bq/kg). Due to insignificant content of admixtures, all other observed radionuclides (^{238}Ac, ^{226}Ra, ^{235}U, ^{238}U) have not been detected in any of samples.

11.2. Potassium sulphate (K_2SO_4)

The measured specific activity of ^{40}K in the potassium sulphate sample shows at very high level of raw material purity (99.6 %, i.e. 13,824 Bq/kg in the sample, related to 13,880 Bq/kg in chemically pure potassium sulphate). Specific activity of other observed radionuclides is equal to zero, as it was expected due to almost quite chemically pure sample.

Conclusion and recommendations

On the basis of the performed sampling and measurements (but referring also to the measurements done in the late 1980s), it is obvious that potassium concentrations in raw materials are in harmony with their chemical composition. Further determination of potassium specific activity in potassium salts is considered to be not necessary, with exception of control measurements if source of raw materials is changed. Potassium load degree of agricultural lands can be simply identified and calculate according to the annual plant consumption of potassium salts alone.

11.3. Phosphates

The term "phosphates" or "phosphorites" is used for rocks abundant in phosphorus containing minerals (e.g. monazite, triphyline, copite, colinsite, lithophylite, vivianite, guanite, monetite, phylovite, pyro-phosphorite, natriphylite etc.). Main natural phosphor bearing minerals are apatite, collophane and dalite.

Apatite, $Ca_5(F,Cl)(PO_4)_3$, has either igneous or sedimentary origin. Apatite consisting igneous rocks originates through crystallization of magma as an accessory mineral, and is often admixture in biotite and quartz. Apatite found in sedimentary rocks is known as basic mineral of phosphorite and - in opposite to igneous apatite - does not include higher radionuclide concentrations of thorium series.

Collophane, $3Ca_3(PO_4)_2$ x n $Ca(CO_3, F_2O)$ x H_2O, is calcium-carbonate-phosphate, mostly known by amorphous structure, although there are also samples of crypto-crystalline collophane. It is mainly solid, and in some cases oolitic. Mineral fragments of glauconite, carbonate and biogenous opal, as well as remnants of organisms are often found incorporated into the mineral. It is sedimentary (marine) mineral, found in phosphorites as white, yellowish-white to brown matrix.

Dalite, $3Ca_3(PO_4)_2$ x $CaCO_3$, generates by recrystallization of collophane and is known as a crust on phosphate rocks.

From the above mentioned it gets obvious that phosphates can be described by the general formula $(Ca_3(PO_4)_2)_3CaF_2$, but content of admixtures (mainly carbonate component - $CaCO_3$ can be fairly high and is usually indirectly proportional to the content of pure phosphor.

11.3.1. "Boucra" phosphates

Measured specific activities of ^{228}Ac show at marine sedimentary origin or raw material wherein the phosphoric component is probably completely related to collophane matrix and - in less extent - maybe to dalite. Radiochemical balance of ^{226}Ra and ^{238}U is disturbed "in favor of" ^{226}Ra (which prevails in shallow or even surface layers) in all samples. This situation is realistic to be explained by migration of ^{238}U in deeper formations. Concentrations of ^{226}Ra and ^{238}U are very similar in the samples 1 and 3 (both samples originate probably from the same, surface or very shallow layer). Concentrations of ^{226}Ra at the sample 2 are elevated (46 % higher than at other samples), while concentrations of ^{238}U are higher some 64 % than a normal value (the layer is slightly deeper but also fairly shallow). The same conclusion can be derived from relation $^{226}Ra/^{238}U$ in the sample 2 (1.31) referring to the samples 1 and 3 (where the same relation is 1.47).

11.3.2. "Morocco" phosphates

Similar to the "Boucra" phosphates, "Morocco" phosphates are undoubtedly of marine sedimentary origin. Their radiochemical balance is disturbed "in favor of" ^{226}Ra, but not so apparently (about 1.25) as in the case of the "Boucra" phosphates. Concentration rates of ^{226}Ra and ^{238}U are somewhat higher than at "Boucra", but they are considerably lower in relation to concentrations measured in late 1980s at "Morocco" phosphates. In distinction from the sample 3, the samples 1 and 2 originate probably from the same layer.

12. PHOSPHORIC ACID

Specific activity of all analyzed radionuclides, excluding uranium isotopes, at all samples is expectedly low. High specific activity of uranium in all samples of phosphoric acid are caused by the fact that uranium is "bounded" with phosphor. Thus, uranium concentrations in phosphoric acid are proportional with uranium concentrations in raw phosphates and phosphor content in the acid, i.e. phosphates. According to the content of phosphor in pure phosphates (containing no carbonatic admixtures) and phosphoric acid, it is possible to conclude that 1.72 tons of phosphates are required for production of 1 ton of phosphoric acid.

Conclusion and recommendations

Control of specific activity of uranium in phosphoric acid is not necessary if ^{238}U concentration in raw phosphate is not higher than some 1,000 Bq/kg. Namely, the uranium content in phosphoric acid in pure phosphate (content of P^2O^5 is about 42.2 %) is simply detectable by multiplication of uranium content in phosphate by factor 1.72 if no uranium is transferred into waste gypsum. In addition, if phosphates are not pure and uranium concentrations are lower than 1,000 Bq/kg, it is also possible to calculate uranium content in amount unit of phosphor, and resulting value multiply with 31.6 (expected error is negligible). Measurements of ^{238}U specific activity in phosphoric acid and phospho-gypsum, performed at the site in late 1980s, showed the uranium transfer from phosphates with fairly high content of ^{238}U (2,000-2,500 Bq/kg) into phospho-gypsum to be remarkable. Hence, it is obvious that the uranium transfer from phosphates into phosphoric acid was lower that the factor value (1.72).

13. WASTE GYPSUM

Waste gypsum (or "phospho-gypsum") generates in production of phosphoric acid as it is described by the following reaction:

$$(Ca_3(PO_4)_2)_3CaF_2 + 10H_2SO_4 + 2H_2O \text{ ----- } 6H_3PO_4 + 10CaSO_4 \times 2H_2O + 2HF$$

In the case of pure phosphates some 3 tons of waste gypsum remain after production of 1 ton of phosphoric acid. As most of admixtures in phosphates are carbonatic compounds, the resulting amounts of waste gypsum exceed about 4 tons per 1 ton of produced phosphoric acid (if P_2O_5 content in phosphates is about 33 %). ^{226}Ra, contained in phospho-gypsum, is fully incorporated into qypsum, replacing the homologous calcium in chemical structure of gypsum. Some previous measurements of waste gypsum radioactivity showed that ^{238}U comes in minor amounts also to gypsum if uranium concentrations in raw phosphate are higher than 1,000 Bq/kg. Anyway, this interesting problem is not yet known in details, and for more accurate conclusions additional investigations are necessary. Hereby, some possible disturbances of processing of phosphoric acid could be additional causes of ^{238}U removal into waste gypsum. In that case, a considerably elevated content of uranium into gypsum could point at phosphor losses in processing of phosphoric acid. Therefore, we suggest the radium and uranium concentrations to be continuously monitored, in particular in case of increased uranium concentrations in raw phosphates (i.e. if the values are remarkably higher than 1,000 Bq/kg).

Conclusion and recommendations

Annual rate of ^{226}Ra generation at waste gypsum landfill can be assessed on the basis of radium concentration in raw phosphate. Since no systematic measurement of uranium and radium concentrations in imported phosphates has been performed so far, the estimate of presently accumulated amounts of radium and uranium can be done only through detailed sampling at the landfill. Due to accumulated quantities of waste materials and high variability of ^{226}Ra and ^{238}U in raw phosphates, the emplaced radionuclides could be estimated more accurately by radioactivity measurements of at least some fifty gypsum samples, taken from the entire landfill area in accordance with convenient sample-network.

14. NITROGEN-PHOSPHOR-POTASSIUM (N-P-K) FERTILIZERS AND MONO-AMMONIUM-PHOSPHATE (MAP)

Uranium and radium concentrations in fertilizers and mono-ammonium-phosphate (MAP) are in keeping with their concentrations in treated phosphate ore. It is worth mentioning that uranium and radium concentrations in series of measured fertilizer samples are considerably lower than in fertilizers measured in late 1980s. According to measurements of uranium and radium concentrations in phosphates and nitrogen-phosphor-potassium (N-P-K) fertilizers it gets clear that fertilizers have been produced from phosphates containing uranium and radium concentrations even lower than those, identified in phosphates. The only exceptions are probably two samples of N-P-K 15-15-15, a sample N-P-K 8-26-26 and a sample N-P-K 8-16-24 (Table - Ad 4), where declared content of phosphor convenes entirely to ^{226}Ra and ^{238}U shares in Boucra-phosphates /samples 1 and 3/ (Table - Ad 4), assuming the phosphate purity is 80-85 % . All measured samples were produced directly adding different portions of raw phosphates; exceptions are two samples - N-P-K 18-18-18 and N-P-K 8-26-26 (Table - Ad 4) - which were produced exclusively from phosphoric acid.

Conclusion and recommendations

Measurements of radionuclide concentrations in fertilizers are not necessary if radionuclide content in treated phosphate ore and processing method are known. In accordance to the mentioned findings, our strong recommendation to the plant management staff was to use onward the phosphate ore containing the higher possible share of phosphorus and the lower possible portion of uranium and radium. Thus, the maximum possible economic benefit with minimum environmental burden would be achieved.

15. SOOT

Concentrations of all measured radionuclides in soot sample are expectedly low or even equal to zero value (the only exception is ^{238}U). Since the carbon content in soot is high due to incomplete combustion, the measured content of ^{238}U can be accepted as normal and additional control is not necessary. Namely, increased concentrations of ^{238}U can be expected only in solid residuum after complete combustion.

16. MAIN RECOMMENDATIONS TO THE INA-PETROKEMIJA PLANT

In order to improve processing methods and decrease environmental risks at the INA-PETROKEMIJA Plant, the plant management staff is recommended to introduce following actions:

[1] to measure continually all imported phosphate shipments (3-5 samples per ship);
[2] to measure periodically radiation contamination of waste (phospho) gypsum (1 sample from filters monthly);
[3] to carry out detailed sampling of waste gypsum landfill (some 50 samples per pool); and
[4] to measure (a) uranium and radium concentrations in one sample of phosphates before reaction, (b) waste gypsum on filters and (c) phosphorus content in the same waste gypsum sample. These measurements should be performed during 10-15 days period aiming to eliminate doubts in possible deviations in processing of phosphoric acid (the measurements are recommended if uranium concentrations in phosphates containing remarkable share of impurities, are higher than 2,000 Bq/kg).

17. FINAL STATEMENT

All presented results, as well as findings of investigations which have not yet been done, are expected to give a reliable input for performance of risk assessment study, cost-benefit analysis for possible remediation options and background for final decision on most convenient clean-up action(s). Most of these planned activities depend on circumstances at the sites of concern, and are supposed to be at least partly presented in the Final Project Report (Stage III).

REFERENCES

[1] THE LEGISLATION OF THE REPUBLIC OF CROATIA, "Law on Taking Over the Federal Laws in the Field of Health Protection, Applying in the Republic of Croatia as Republic Laws", National Gazette (Narodne novine), **53**, Zagreb (1991) /in Croatian/.

[2] THE LEGISLATION OF THE USA, Office of the Federal Register, "**10** Code of Federal Regulations (10 CFR)", Parts 0 to 50, US Government Printing Office, Washington, D.C. (1993).

[3] THE LEGISLATION OF THE REPUBLIC OF CROATIA, "Code of Practice on Maximum Limits of Radioactive Contamination of the Environment and Performance of Decontamination", Official Gazette of Yugoslavia, **8** /accepted as temporary applied regulation in the Republic of Croatia until the new Croatian regulation will be issued/ (1987), 226-245.

[4] THE OECD RECOMMENDATIONS, "Exposure to Radiation from the Natural Radioactivity in Building Materials", Report by the Group of Experts of the OECD, OECD, Paris (1979).

[5] SUBAŠIĆ D., ŠALER A., "The Challenges and Issues Facing the Radioactive Waste Management in Croatia", Waste Management Symposia '94, Proceedings, Vol. 1, Tucson (1994), 181-185.

[6] "RAPAT MISSION TO CROATIA", Travel Report, 28 June - 2 July 1993 (TA #931010243), IAEA, Vienna (1993), 1-17.

[7] BARIŠIĆ D., LULIĆ S., MILETIĆ P., "Radium and Uranium in Phosphate Fertilizers and Their Impact on the Radioactivity of Waters", Water Resources, Vol. 26, **5**, United Kingdom (1992), 697-706.

PLANNING FOR ENVIRONMENTAL RESTORATION OF CONTAMINATED SITES OF THE URANIUM INDUSTRY IN THE CZECH REPUBLIC

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Abstract

This article follows the previous report presented at the last workshop in Budapest in October 1993. Radioactive contamination as a result of the uranium industry activities does not have a breakdown character so the cleanup can be made gradually with respect to all ecological, economic and social relations. 1. Rationale and Goal for Cleanup The Czech Republic is a country with dense population and that is why there is a direct contact of community with uranium industry regions - Therefore the basic goals of cleanup are: 1) health protection of inhabitants 2) ecological incorporation of particular sites into the countryside. Cleanup criteria can are divided into three main groups: a) Results of studies of radiation impact on critical groups based on common methods ICRP used particularly for the most important sites. As an example of this procedure the assessment of inundated soil contamination near the Ploučnice river has been presented. Currently the criteria for cleanup of ground water generated by in-situ leaching (ISL) have been made through this procedure; b) legal provisions for radioactive nuclide concentrations in environmental components. The review of valid Czech Republic regulations is listed. 3) Nature's ecosystems impact data. These data are determined with the help of toxicity tests, mutagenity tests, ecological studies. The examples of impact acceptability assessments (of the Ploučnice river) are listed. The cleanup programmes are being made for the four basic types of objects: 1) heaps; 2) tailings pile; 3) buildings and equipment; 4) in-situ leaching. There are planning and managing diagrams listed in this report.The inseparable part of the cleanup plan is its incorporation into a region environment protection programme. At the same time we have to respect the cost effectiveness and risk reduction relation.This can be done e.g. through combining of cleanup and waste management. We have to realize that it is the costs that can become the decisive fact whether the cleanup will be carried out in the near future.

1. REASONS AND GOALS FOR CLEANUP

At the present time, the production of uranium in the Czech Republic is being reduced. Problems are being brought into prominence how to liquidate uranium industry buildings.

Explanation and conception of cleanup start at basic data as follows:

a) There are no breakdown characteristics as regards radioactive contamination as a result of uranium industry activities. Therefore, it is possible to realize the cleanup step by step respecting entire ecological, economical and social relations;

b) The Czech Republic is a territory with dense settlement and in the course of more than 40 years, several tens of projects have been realized in the uranium industry. That is why also direct contact exists between settlement and uranium industry localities. For example, about 40,000 inhabitants live within 10 km from the most important deposit Stráž pod Ralskem.

Main goals of cleanup are:

(a) Health protection of inhabitants;

(b) Ecological incorporation of localities in question into landscape.

2. CLEANUP CRITERIA

Existing cleanup criteria can be divided into three main groups:

1. - studies of radiation impact on critical groups of population;
2. - legal provisions for radionuclide concentrations in environmental components;
3. - data concerning impact on natural ecosystems.

2.1. Studies

As an example, the assessment of inundated soil radioactive contamination near the Ploučnice river from the point of view of population health protection can be shown.

There are three possible critical ways for radiation exposure:

- through a food chain, e.g. from products which were grown in the contaminated soil;
- consequently to water penetration from the Ploučnice river into drinking potable water resources, resp. to utilization the river Ploučnice to watering;
- external radiation while working in the inundation area.

Our attention has been concentrated to the radiation exposure through a food chain, which is the most important critical way.

Two possible approaches to assessment can be taken into consideration:

1. If the problem is assessed as a consequence of planned exposure from natural resources which are significantly influenced by uranium mines, then an effective dose equivalent criterion for individuals of population is $H_E = 1.0$ m Sv.year^{-1}, and it is possible to derive from that an upper limit of ^{226}Ra activity in the inundation area soil in relation with an assumed way of contaminated area utilization.

   In the case of growing leaf vegetables consumed by local inhabitants in full, values as follows are valid:

   Using recognized concentration factors and transition coefficients [1] for ^{226}Ra, at average vegetable consumption per person 90 kg.year^{-1} (max. data for Central Europe) and not to exceed the fixed dose criterion, contents of ^{226}Ra would not be allowed to exceed the value 600 Bq.kg^{-1} of dry soil [2].

   In the case that the inundation area would be utilized for growing of feeding grass only (on assumption that a feeding dose is 50 kg of fresh grass a day and a milk consumption is 0.5 l per person a day), contents of ^{226}Ra would not be allowed to exceed the value approximately 6 000 Bq.kg^{-1} of dry soil.

2. Other alternative: Contamination area is assessed as a pre-existing situation (pre existing exposure) [3]. The first step is to compare a contribution of utilizing the soil and gross social expenses for cleanup. On the basis of this comparison to give reasons for the advisable utilization of the inundation area, taking the soil area and contamination level into consideration.

   In this case of leaf vegetables production throughout a part of the inundation area with an average specific activity 210 Bq.kg^{-1} of soil and considering assumptions mentioned above, the average intake would be 756 Bq and the load per year would be $H_E = 0.54$ mSv. If about 5000 consumers were supplied with these vegetables, then the collective effective dose 2.7 Sv per year and the money equivalent about 70,000 Kč per 1 Sv (data 1990) would cause social expenses consequent to the radiation risk of approximately 190,000 Kč.

2.2. Basic legal provisions

The basic legal provisions for radionuclide concentrations in environmental components which are valid in the Czech Republic are:

a) The CR Ministry of Health Decree No. 59/1972 Sb. Decree on health protection against ionizing radiation [4]. The decree mentioned has been valid from 1972 and has taken account of a limit of effective dose equivalent for individuals of population $H_E = 5$ mSv.year^{-1}. At the present time, a new wording of the decree is being prepared which gives the value $H_E = 1.0$ mSv.year^{-1}. Besides common provisions, the decree declares an ingestion intake limit per year, an inhalation intake limit per year and an average volume activity in breathed air for individuals of the population. These values for radionuclides which are typical for the uranium industry are shown in Tab. 1.

Table 1

Ingestion intake limits, inhalation receiving limits and average volume activity in inhaled air values

		Individuals of population		
Radionuclide and compound type	Critical organ	Ingestion intake limit [Bq.year^{-1}] 1)	Inhalation intake limit [Bq.year^{-1}]1)	Average volume activity in inhaled air [Bq.l^{-1}] 1)
	Kidneys	1.4 .10^{6}μg	5.5 .10^{4} μg	8.10^{-3} μg.l^{-1}
$U_{nat.}$soluble	Lungs	-	4.8 .10^{4} μg	7.10^{-3} μg.l^{-1}
insoluble	Organs of digestion	3.9 .10^{7}μg	-	
^{234}Th soluble	Organs of digestion	5.18 .10^{5}	-	-
	Bone	-	5.55 .10^{5}	7.4 .10^{-2}
insoluble	Lungs	-	2.96 .10^{3}	3.7 .10^{-2}
	Organs of digestion	1.4 .10^{7}	-	-
^{230}Th soluble	Bone	5.18 .10^{4}	21	2.96 .10^{-6}
insoluble	Lungs	-	96	1.11 .10^{-4}
	Organs of digestion	9.62. 10^{5}	-	-
^{226}Ra soluble	Bone	1 322	2 516	3.33 .10^{-4}
insoluble	Lungs	-	481	7.40 .10^{-5}
	Organs of digestion	9.62 .10^{5}	-	-
^{210}Po soluble	Spleen,kidneys	2.15 .10^{4}	4 440	7.40 .10^{-4}
insoluble	Lungs	-	1 850	2.59 .10^{-4}
	Organs of digestion	8.51 .10^{5}	-	-
^{210}Pb soluble	Kidneys	-	1 147	1.48 .10^{-4}
	Whole body	3 552	-	-
insoluble	Lungs	-	2 220	2.96 .10^{-4}
	Organs of digestion	52	-	-

1) converted from pCi

b) The CR Government released Provision No. 171/1992 Sb. from February 26th, 1992 [5], where indicators for allowable water pollution are declared. The allowable water pollution values have been declared in this provision for both waterworks and non-waterworks courses in the CR. These values state surface water pollution at Q_{335} and after mixing with waste effluent. Composition and volume of waste effluent being discharged have to be found not to exceed the values declared in the Government Provision No. 171/1992 Sb. after mixing with surface water. The values stated in the Government Provision No. 171/1992 Sb. for radioactive materials are shown in Tab. 2.

Table 2

Government Provision No. 171/1992 Sb. - Values for radionuclides

	Unit	Waterworks courses	Non-waterworks courses
Gross alpha-activity	$Bq.l^{-1}$	0,3	0,5
Gross beta-activity	$Bq.l^{-1}$	1,0	2,0
U_{nat}	$mg.l^{-1}$	0,05	0,1
^{226}Ra	$Bq.l^{-1}$	0,1	0,3
^{3}H	$Bq.l^{-1}$	700	5 000
$^{90}Sr + ^{90}Y$	$Bq.l^{-1}$	0,3	0,5
^{137}Cs	$Bq.l^{-1}$	0,5	1,0

c) Methodical Instruction of the Law No. 92/1991 Sb. on conditions for a transfer of state-owned property to other persons [6]. Indicators and remediation directions for soil pollution, soil air pollution and ground water pollution have been declared in this Methodical Instruction.

The indicators are declared in three levels:

A background values;

B limiting concentration; when reached, it is necessary to initiate research or investigation to explain origin or source of the pollution

C limiting concentration; when reached, a cleanup action is taken, if a risk of pollution migration throughout surroundings and danger of other environmental component damage is evidenced.

The values A, B, C for radionuclides are shown in Tab. 3.

Table 3

Values A, B, C for radionuclides

		Unit	A	B	C
SOIL	U_{nat}	$mg.kg^{-1}$ 1)	10	30	50
	^{226}Ra	$Bq.kg^{-1}$ 1)	100	600	1000
	$^{137}Cs + ^{134}Cs$	$Bq.kg^{-1}$ 1)	10	100	500
GROUND	$U_{nat.}$	$\mu g.l^{-1}$	5	20	100
WATER	^{226}Ra	$Bq.l^{-1}$	0.05	0.1	0.5
	$^{90}Sr + ^{90}Y$	$Bq.l^{-1}$	0.02	0.1	1.0
	$^{137}Cs + ^{34}Cs$	$Bq.l^{-1}$	0.02	0.1	2.0
	^{3}H	$Bq.l^{-1}$	3.0	100	5000
Gross alpha-activity		$Bq.l^{-1}$	0.1	0.3	1.0
Gross beta-activity		$Bq.l^{-1}$	0.2	1.0	3.0

1) dry matter

d) The CR Government Standard No. CSN 75 711 for drinking water [7] gives the value of alpha-activity, beta-activity and radon concentration. The values are shown in Tab. 4.

Table. 4

Drinking water standards CSN 75 7111

Gross alfa-activity	$Bq.l^{-1}$	0,1
Gross beta-activity	$Bq.l^{-1}$	1,0
^{222}Rn	$Bq.l^{-1}$	20

If these values are exceeded, individual radionuclides (^{226}Ra, $U_{nat.}$, ^{210}Pb, ^{210}Po) are determined. Based on this analyses the district health officer permitted this water for drinking use.

In addition to the national provisions mentioned above, provisions for the uranium industry have been issued.

e) Complementary provisions for mines and finishing mills in the uranium industry, were issued by the Central mining office in wording of the Czech mining office decree from November 5th, 1975 (file number: 6971-Z/1975) [8]. Apart from other facts, the value of surface alpha-activity 0.37 $Bq.cm^{-2}$ is declared there. Any instruments, devices, things, etc. which leave a plant have to be decontaminated to this value.

f) Conditions fixed for utilization of waste rock material from waste heaps at uranium mines in Main hygienist's office decision, file number: HE-342.3 from May 15th, 1968 [9], were as follows: Waste rock materials have been classified into three groups with different radionuclide concentrations as shown in Tab. 5.

Table 5

Values 1, 2, 3 groups for waste rock

	Unit	1	2	3
^{226}Ra	$Bq.kg^{-1}$	2 220	740	111
U nat.	%	0.02	0.006	0.001
absorbed dose rate	$\mu Gy.h^{-1}$	2	0.7	0.1

Materials from group 1 can be used:

- for various road buildings, provided that the material is fixed thoroughly and prevented from crumbling. It can be used outside municipalities;
- as ballast chipping for railway buildings outside municipalities;
- to manufacture some concrete panels which are to be placed in the open air, for example railway sleepers, road guardstones, posts, etc.

Materials from group 2 can be used:

- for road buildings inside municipalities, on the same conditions as group 1;
- for railway buildings inside municipalities;
- to manufacture concrete panels for buildings both in depth and on surface, but these products are not allowed to be used in walls for closed space.

Materials from group 3 can be used:

- to manufacture concrete panels for industry buildings, both in depth and on surface, and these panel are allowed to be used in closed space, however, not for flats.

As an example, Fig. 1 presents results of air gamma-ray spectrometry for the motorway type road from Dobřiš to Praha. Waste rock material from Příbram uranium mining area has been used to build a part of the road.

This decision was amended in April 22nd, 1991. The only absorbed dose rate value - 0.7 $\mu Gy.h^{-1}$ - was given.

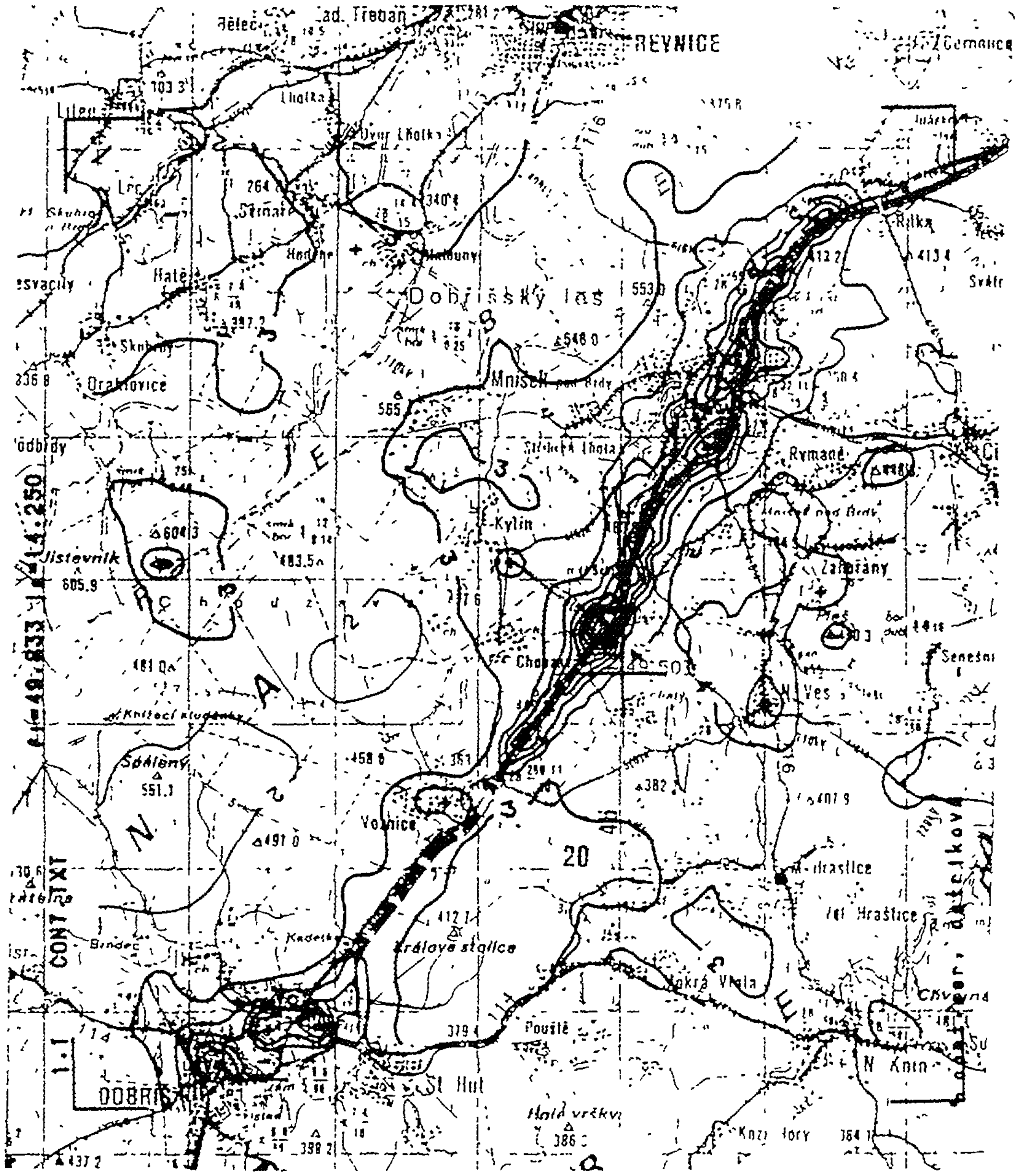


FIG 1. *Geofyzika s.p. Brno*
AIRBORNE GEOPHYSICAL SURVEY 1991
MAP OF RADIOACTIVE CONTAMINATION
OF THE TOWNS AND THE CONNECTING ROAD
(the source is building material from uranium dump)
THE URANIUM CONCENTRATION (ppm U)
SCALE 1 : 100 000

In case of materials with value higher than 0.7 $\mu Gy.h^{-1}$, there is the strong obligation to have every use approved by a sanitary service individually.

Materials with value lower than 0.7 $\mu Gy.h^{-1}$ can be used to some purpose as group 2 and 3 (see above).

Utilization of aggregates with value lower than 0.7 $\mu Gy.h^{-1}$ from uranium heaps in Western Bohemia has been planned for building of the motorway from Plzeň via Rozvadov to Weidhaus (Germany).

2.3. Impact on natural ecosystems

Generally stated, any negative changes in plant associations and animal communities should not occur. It is very difficult to predict anything exactly and that is why simple toxicity tests are used at least. These tests use sensitivity of choice model organisms (for example, plant Sinapis alba, alga Scenedesmus quadricauda, fish Poecilia reticulata). First of all, they are used in two cases:

a) To fix a level which must be reached while cleaning mine water before discharging.

b) To rate dangerous character of waste when dumped. The toxicity tests are made with leaches being prepared under standard conditions:

- ratio solid phase:liquid phase is 1 : 10
- solution: distilled water
- contact time: 24 hours

For example the toxicity tests used for technological and dispersion solutions in ISL - technology:

- tests of semichronical toxicity on seeds of Sinapis alba plant. The germinating power of these seeds has been inhibited by technological solutions even in dilution of 1 : 1000, dispersion solutions inhibit the germinating power up to dilution 1 : 200
- biological test for acute toxicity on Daphnia magna (Straus). The culture tested perishes in technological solutions as well in dispersion solutions even in dilution of 1 : 1000
- biological test for acute toxicity on Poecilia reticulata (Peters). In technological solutions diluted 1 : 1000, 100 per cent of fish died off. Dispersion solutions diluted 1 : 50 caused 100 per cent to die, but none died in dilution of 1 : 100

- acute toxicity test on Scenedesmus quadricauda alba. The growth of inhibition is 100 per cent even for dilution 1 : 1000 of technological solution. Dispersion solution diluted to 1 : 200 still inhibits growth.

To assess impact of radioactive contamination, it is suitable to use mutagenity tests as well. As regards methodics, these tests are more exacting. To get assessment of water impact in case of water which is discharged out of the mine Hamr, alga Chlamydomonas geitleri and bacteria Escherichia coli have been used as model organisms [10].

According to the Government Provision No. 171/1992 Sb., as regards waste effluent being discharged:

- water ecosystem productivity cannot be reduced;
- number of species, as regards water organisms, cannot be reduced;
- neither maximum allowable dose nor volume radionuclide activity can be exceeded.

3. PLANNING AND MANAGING THE CLEANUP

From the point of view of liquidation, four basic types of objects have been assessed:

- uranium mines and uranium mine waste heaps;
- uranium mills;
- tailings in uranium mills;
- in-situ leaching.

3.1. Liquidation of uranium mines and heaps

In the course of uranium mining, the first period of liquidation passed in the late fifties and early sixties. At that time, mines were liquidated at the region of Jáchymov and Horní Slavkov (north-west Bohemia, near Karlovy Vary). Since sixties, individual smaller mines and prospecting pits have been liquidated and recultivated.

At the present time, the second period of liquidation has been running. Mines at the regions of Western Bohemia and Příbram have gone into liquidation. Mining at the area of Hamr - Stráž pod Ralskem has been held up.

Mining runs at the region of Dolní Rožínka (about 50 km north of Brno). - Liquidation diagram - see Fig. 2.

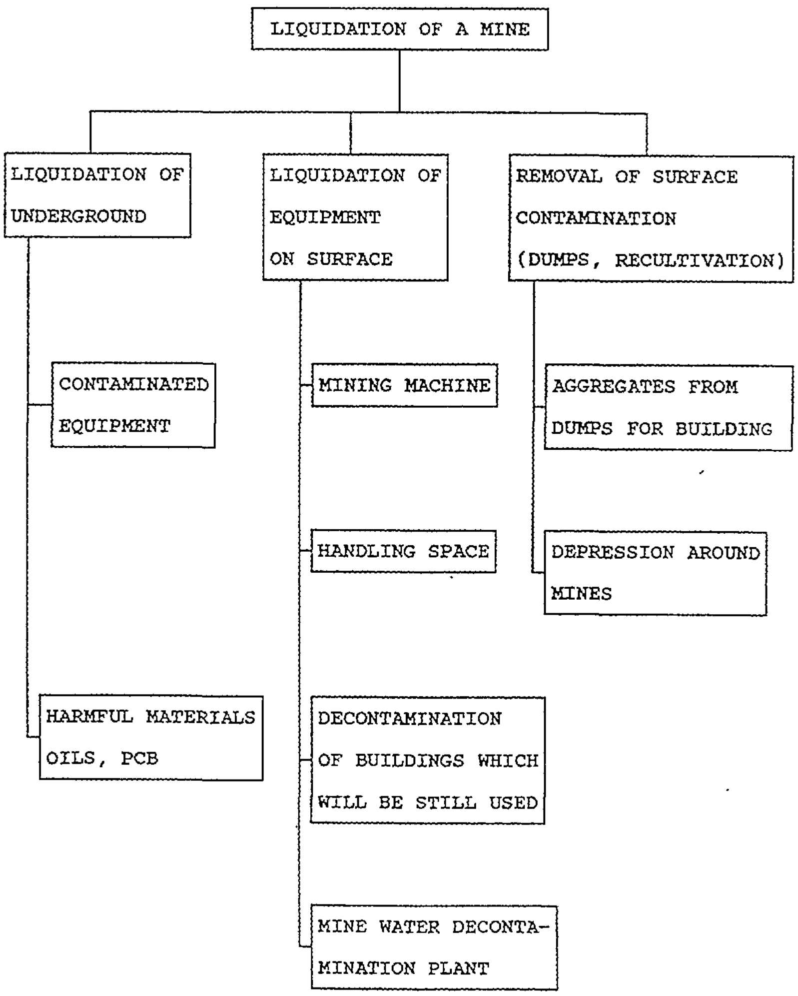


FIG. 2. LIQUIDATION OF A MINE

3.1.1. Liquidation of the underground

Means to remove machines, equipment, distributions, etc. The reason is to utilize materials again and remove materials which could contaminate ground water. It is necessary to pay attention to oil materials and equipment with PCBs.

Development in mine water composition after the mining has been brought to an end is very important. If mine water rises on surface and is still contaminated, it is necessary to keep a mine water decontamination plant station. Time of flood for uranium mines in the Czech Republic is from 6 months to 7 years; it depends on mining space volume and water inflow into the mine.

3.1.2. Liquidation of equipment on surface

When liquidating equipment on surface, the essential thing is whether the area around the mine is to be liquidated in full or buildings and equipment will be used for other activities.

Buildings in uranium mines - after bringing the mining to an end - are used for other activities in the Czech Republic. Working plan is worked up for these another activities which states what buildings and equipment will be maintained and what will be liquidated. There are two important parts of the working plan:

- results of gamma-radiation level measurement and alpha-activity surface contamination measurement;
- methods of decontamination.

Contaminated equipment from underground and surface is decontaminated. The equipment is taken for cleared when the value of alpha-activity lower than 0.37 $Bq.cm^{-2}$ has been reached. If the value is higher than 0.37 $Bq.cm^{-2}$, the equipment is liquidated as an active waste.

3.1.3. Liquidation of waste heaps

As mentioned above, a part of waste rock in the heaps, after control measurement is done, is used to various building purposes out of the uranium industry.

A part of waste rock is used to building purposes in the uranium industry, for example, to build dams for uranium mill tailings. This method is used in places where mining and milling are next to each other. Waste rock is used for filling of surface depression which arise due to uranium ore mining. It is used to fill existing depression and, in places where depression are expected, a heap is piled up in a mirror-like shape of the depression expected.

As regards a remaining part of waste heaps, fail-safe works to prevent from negative impact on environment have been and still are done. Seepage water is caught from waste heaps and is made harmless. In case of removal these heaps, they are moved to such places which are isolated from bedrock so that see page could not contaminate ground water.

3.2. Liquidation of uranium mills

At the beginning of sixties, the uranium mill in Nejdek (near Karlovy Vary) was liquidated.

At the present time, the uranium mill MAPE in Mydlovary (near České Budějovice) is being liquidated and production in the uranium mill in Stráž pod Ralskem has been held up.

Liquidation diagram for an uranium mill see Fig. 3.

Liquidation of a tailing is shown in an individual diagram.

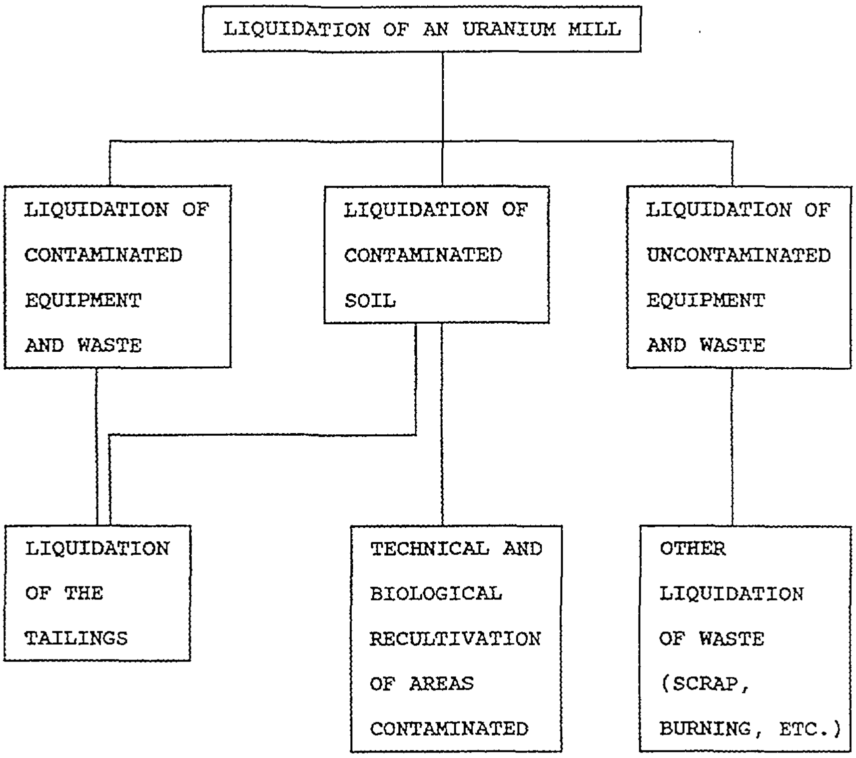


FIG. 3: LIQUIDATION OF URANIUM MILLS

Liquidation of equipment in uranium ore mills corresponds to liquidation of surface parts in mines. In this case, existing buildings and equipment are considered to be used for other activities as well.

There are some differences between liquidation of uranium mines and uranium mills:

- technological solutions (leach liquors, eluates) from the mill contain higher concentrations of uranium and radionuclides from uranium series than mine water;
- consequently, contamination of equipment and materials in buildings is higher and it is more difficult to liquidate that;
- there is a possibility of higher soil contamination which was caused by technological solutions; even under buildings as well.

Contaminated equipment and waste, in case that the decontamination is ineffective, are dumped to the tailings mill. Contaminated soil from area of the mill is dumped there as well.

3.3 Liquidation of the tailings

Liquidation diagram for the tailings see Fig. 4. When the mill is in operation, there is free over-balanced water in the tailings. As the first phase of liquidation, it is necessary to remove free water.

In case of the mill in Mydlovary which has got several tailings, the liquidation of free water has been solved as follows:

- free water from tailings which are to be liquidated and recultivated is drawn to another tailings with sufficient space for free water;
- draining water from tailings is cleared and then discharged into a river;
- there is higher evaporation than rainfall in tailings places. In an adequate time (about 6 - 8 years), free water will evaporate.

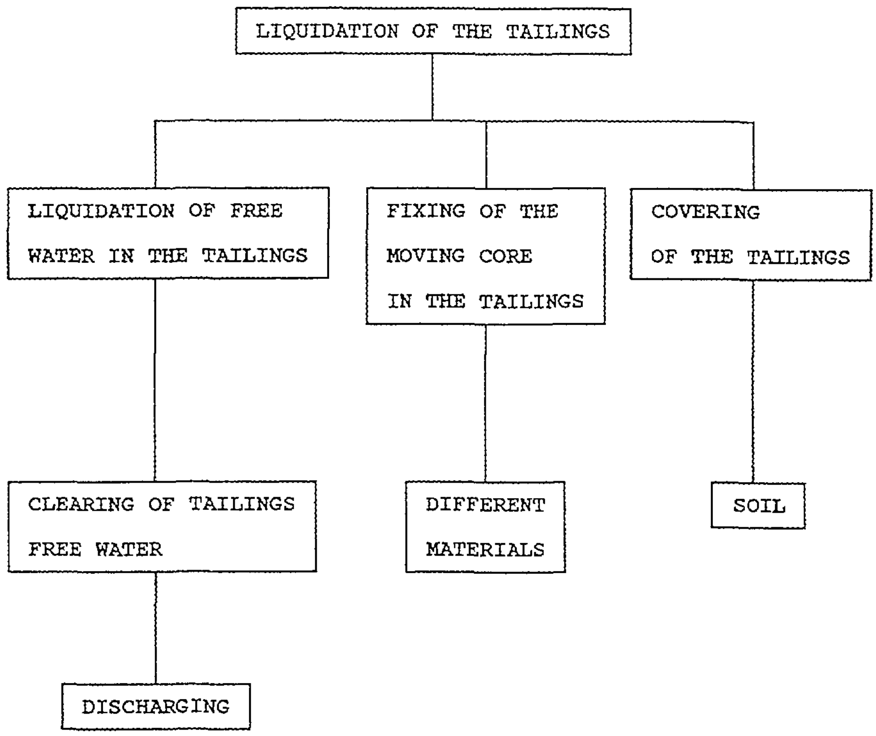


FIG. 4. LIQUIDATION OF THE TAILINGS

After removal of free water from the tailings, a liquid core in the tailings is fixed;, it is filled step by step with rough pieces of material. It is necessary to fix the tailings core so that heavy building machines could be used to recultivate the tailings.

After fixing the core in the tailings, the tailings surface is covered. The reason is to prevent from a negative impact of the tailings on environment. Negative factors are as follows:

- external gamma-radiation on the tailings surface;
- radon air pollution;
- dust nuisance from the tailings surface (radioactive dust);

- impact on ground water quality. To prevent from a negative impact of three factors, the 30-50 cm-thick layer of material is sufficient.

Prevention from rainfall water getting into the tailings body requires isolation and change in shape of the tailings. To this purpose, much more volume of material is necessary.There is a problem how to ensure necessary material, transport and dump it. To secure tailings means considerable expenses. In many cases, liquidation and recultivation expenses can be the decisive criterion whether the recultivation will be realized in near future or not. Consequently to the political and economical changes, production of uranium has been reduced quickly in the Czech Republic. Therefore considerable free volume is available in built-up tailings.

It seems to be suitable for us to use liquidation and recultivation of tailings to solve environmental problems in respective region, that means to dump choice waste and utilize waste sludges from town water treatment plants for recultivation of tailings surface.

3.4. Liquidation of in-situ leaching

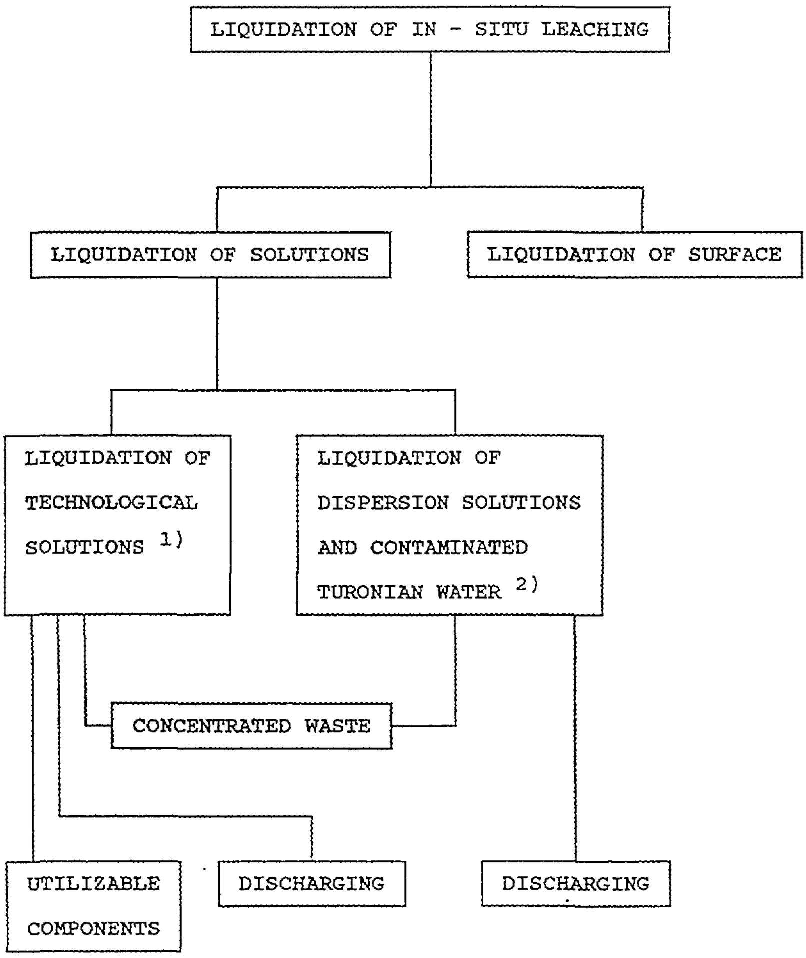
In view of the fact that conditions at in-situ leaching are too specific in the deposit of Stráž (see the previous study), it is not possible to use any experience from other places.

Approved conception for liquidation of in-situ leaching see Fig. 5.

The liquidation of the surface of ISL is analogous to liquidation of equipment on surface and contaminated areas of mines and mills. The main problem is how to liquidate in-situ leaching solutions.

The liquidation of in-situ leaching solutions is divided according to the composition of solutions. Technological solutions with contents of dissolved materials about 70 $g.l^{-1}$ will be liquidated at an evaporating plant. Cleared water will be utilized to technological purposes or discharged into a watercourse.

Utilizable components will be gained from a concentrated part. Dispersion solutions and contaminated water with contents of dissolved materials 0.5 - 7 $g.l^{-1}$ will be cleared using a reverse



1) DISSOLVED MATERIALS - 70 $g.l^{-1}$

2) DISSOLVED MATERIALS - 5 $g.l^{-1}$

FIG. 5. LIQUIDATION OF THE TAILINGS

osmosis method. Cleared water will be utilized to technological purposes or discharged into a watercourse. Concentrated solution from the reverse osmosis will be worked up at the evaporating station.

At the present time, problems of residual concentrations in ground water and on rocks after finishing the in-situ leaching have been solved.

The detailed description of this technology will be presented on the following workshop.

4. MANAGING THE CLEANUP OF URANIUM INDUSTRY IN THE CZECH REPUBLIC

Managing the cleanup of uranium industry in the Czech Republic see Fig. 6.

The cleanup of uranium industry in the Czech Republic is managed by the government through Ministry of Industries, Ministry of Environment, Ministry of Health and Ministry of Finance. The state-owned firm DIAMO is subordinated to the Ministry of Industries. The DIAMO is a main organization which manages directly the cleanup works starting from an order in project organizations to works control and fulfillment of cleanup works. Region bodies, that means the district office and the sanitary service, assess the worked-up projects, and the district office issues a building permission to begin working. Control on cleanup works which have been finished is made by the DIAMO and by the sanitary service. The cleanup of uranium industry is financed by the Ministry of Finance from the state budget.

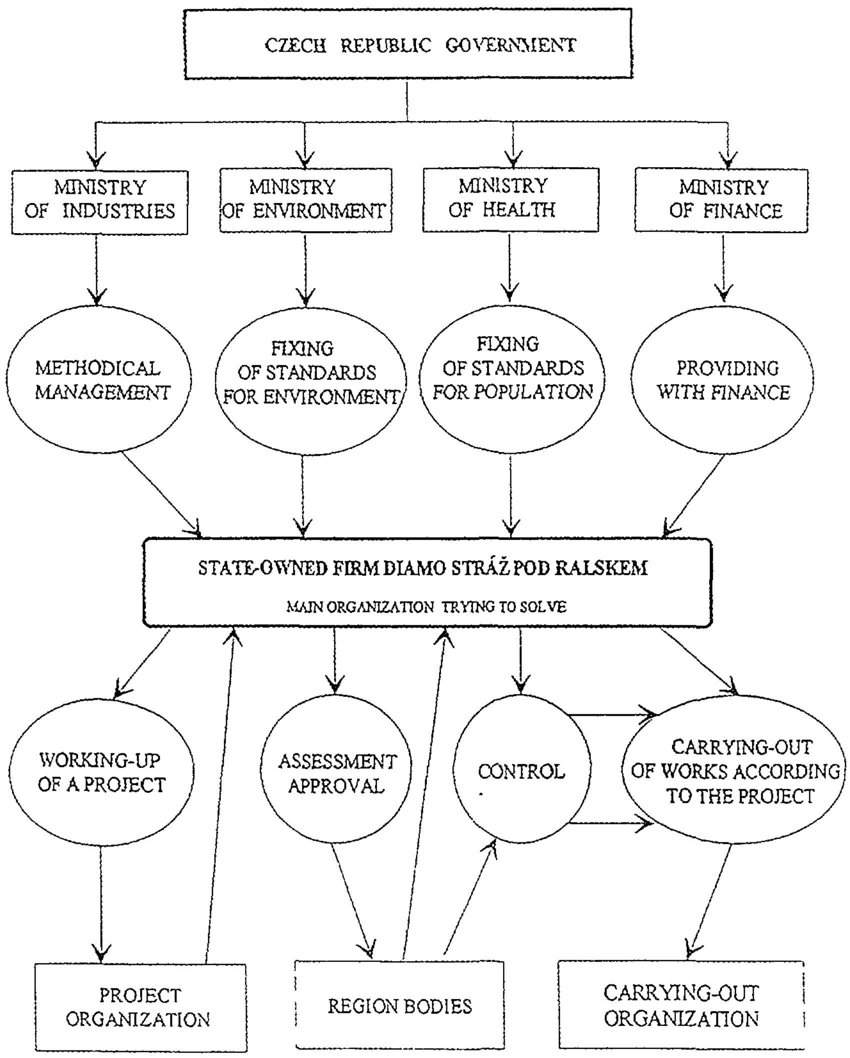


FIG 6 MANAGING THE URANIUM INDUSTRY CLEANUP IN THE CZECH REPUBLIC

REFERENCES

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Generic Model and Parameters for Assessing Transfer of Radionuclides from Rutin Releases, Safety Series 57, Vienna (1982)

[2] KUNZ, E., Kontaminace litorálního pásma Ploučnice radioaktivními látkami, ÚHE, Praha, 1990 (Contamination of the banks river Ploučnice with radioactive isotopes, ÚHE, Praha, 1990)

[3] ICRP PUBLICATION 60, Radiation Protection, 1990 Recommendations of the international commission on radiological protection, November, 1990

[4] Vyhláška Ministerstva zdravotnictví č. 59 (r. 1972): O ochraně zdraví před ionizujícím zářením (Ministry of health Decree No. 59/1972 Sb: Decree on health protection

[5] Nařízení vlády ČR č.171 (r. 1992), který se stanoví ukazatele přípustného stupně znečištění vod (Government released Provision No. 171/1992 Sb. where indicators for allowable water pollution are declared)

[6] Zákon č. 92 (r. 1991) o podmínkách převodu majetku státu na jiné osoby (závazky podniku z hlediska ochrany životního prostředí), (Law No. 92/1991 Sb., Methodical instruction on conditions for transfer of state-owned property to other persons)

[7] ČSN 75 711 - Pitná voda (The Czech Republic Government Standard No. ČSN 75711 - for drinking water

[8] Doplňkové předpisy Českého báňského úřadu, č.j. 6971-Z/1975 z 5.11.1975 (Complementary provisions issued by the Central mining office - file number: 6971-Z/1975)

[9] Vyhláška Ministerstva zdravotnictví HEM-342.4 (7.2.1991), (Ministry of Health Decree No. HEM-342.4)

[10] ANDĚL,P. et al., Vliv uranového průmyslu na životní prostředí v oblasti Stráž pod Ralskem, MEGA, Stráž pod Ralskem, 1991 (Environmental impact of the uranium industry in the region Stráž pod Ralskem)

MILLING SITES REMEDIATION - ELEMENTS FOR A METHODOLOGY AS DEVELOPED IN FRANCE BY COGEMA

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Abstract

Compared to other metals, mining and milling of uranium generate specific potential hazards due to radioactivity. Remediation of the sites concerned and specially impoundments of mill tailings is a very important step of mining. We first remind the principles and objectives governing site remediation in France. Important steps of the methodology are reviewed : inventory (characterization of the wastes products, location and tonnages), some studies which support the choice made for remediation techniques (mineralogical studies, leaching tests, hydrogeologic, compaction, stability studies ...) and communication. Some of the costs estimates are mentioned : impact on the environment but also occupational exposure and of course financial costs of the operations.

Introduction

Since 1946 COGEMA has been prospecting, extracting and treating uranium ore first in France then all over the world. Usually sites have been regularly remediated following closure. Due to general reduction of the uranium mining in France, remediation of the main impoundments has become a major concern in terms of long term efficiency and financial costs. Consequently it is necessary to be aware of the different factors and to evaluate or measure the long term impact of each choice.

1. PRINCIPLES AND OBJECTIVES OF REMEDIATION

The main concern is long term public security and health.

In France the philosophy of environmental restoration fulfills the following general principles:

- highest efficiency of the remediation action,
- final impact of the site must comply with all french regulatory constraints especially rules concerning radiological impact,
- all types of residual impacts are made as low as reasonably achievable (ALARA).

Concerning radiological impact, the basic principles of ICRP are applied:

- justification, optimization and limitation,
- large information and participation of the public.

In this frame, the main objectives of site remediation are :

- long term stability of the remediated area in order to assure the confinement of the radioactive materials,
- prevention against human intrusion (for instance, the residues should never be used for construction),
- choice of natural barriers in order to rely on passive controls and reduce or suppress future technical supervision requirements,
- reduction of the total land consumption and the following need for institutional control,

- integration into the surrounding landscape. If possible operator will try to match the wishes of the local or regional groups concerning future use of land (local needs for irrigation including water storage and supply, revegetation, hunting etc... are possible if the remediation is not affected),
- of course the resulting project must be technically and economically workable.

1.1. Frame of the French Regulation

General laws concerning Protection of Nature were published in 1976 among them the rules concerning Impact Studies which have to be carried on for every new project.

Laws concerning Environment include special regulations concerning air, water as well as public inquiries.

The laws concerning ICPE (Classified Installations for Protection of Environment) set a frame for all industrial activities including wastes but radioactive wastes are considered apart.

In France exploration, mining and remediation are controlled by the regional authority (Direction Regionale de l'Industrie, de la Recherche et de l'Environnement - DRIRE) within the framework of the French Mining Code. The impact study is compulsory for the rehabilitation of the site when it closes down. A specific impact study will be conducted for the remediation of on an old mining or milling site which started before this type of study was compulsory.

The environmental impact study includes the initial radiological state and the technical aspects of the remediation. Technical reports of impact studies are prepared and submitted to DRIRE and open to public inquiry. Final decision is signed by the prefect.

Radiation protection of the environment during and after mining is the purpose of Decree No. 90-222 dated 9th March 1990.

This decree was drawn up on the basis of the French mining code, Euratom directives, the French decree concerning the general principles of protection against ionizing radiations, itself based on the recommendations of the ICRP (International Commission on Radiological Protection) and the directives of the European Community. It was submitted for approval to the Central Service for Protection against Ionizing Radiations (Ministry of Health) and the General Council of Mines.

It forms the "ionizing radiation" section of the RGIE (General Instructions for the Mining Industry). The main quantified objective is ***the Added Total Annual Exposure Rate*** (ATAER or TAETA).

The ATAER is determined from the measurements at the site (with subtraction of the natural background exposure) and from an exposure scenario which is established for the population. This means that :

ATAER = $TAER_{(A)}$ Total annual exposure rate at the site (minus)

$TAER_{(B)}$ Total (natural) annual exposure rate measured in the general region or established from analogous sites

$$ATAER = (TAER_{(A)} - TAER_{(B)})$$

must be less than 1 (the value of 1 corresponds to an exposure of 5 mSv/year).

TAER is calculated using the following formula :

$$TAER = \frac{gamma}{5\ mSv} + \frac{PAE\ Rn\ 222}{2\ mJ} + \frac{PAE\ Rn\ 220}{6\ mJ} + \frac{IE\ dust}{170\ Bq\ alpha} + \frac{IE\ Ra\ 226}{7000\ Bq} + \frac{IE\ U238}{2\ g}$$

gamma: external exposure through gamma irradiation in mSv

PAE Rn 222:
PAE Rn 220: potential annual inhaled alpha energy from short lived decay products of Rn 220 and Rn 222 in mJ

IE dust: total activity of long lived alpha-emitters of the U-chain, present in the air in the form of dust or in suspension, inhaled annually, in Bq

IE Ra 226: internal annual exposure by ingestion of Ra 226 (through water and the food chain) in Bq

IE U 238: internal annual exposure by ingestion of U 238 (through water and the food chain) in grams

2. METHODOLOGY

First of all an inventory is necessary : assessment of the wastes which have to be handled, their location and quantities.

Studies allow a better understanding of the wastes, their possible evolution and the relationship between the impoundment and the environment.

Applied studies lead to the definition of procedures for the remediation actions.

2.1 Different types of wastes products

The main types of products are :

- pit run rocks and stockpile of poor ore.

According to the type of ore treatment, two main categories of wastes are produced :

- heap leaching wastes resulting from low grade ores which were usually sprayed with acid without any crushing,
- mill tailings disposed of in settling ponds after neutralization : they are fine grained (<500µ) but have low permeability,
- other wastes are the materials resulting from the dismantling of the facilities ; their activity is low and they represent less than a percent of the initial activity of the ore treated,
- waste waters coming from the different type of wastes,
- other wastes are the materials resulting from the dismantling of the facilities ; their activity is low and they represent less than a percent of the initial activity of the ore treated,
- waste waters coming from the different type of wastes,
- sludges resulting from the treatment of waste waters which might last after the end of activity.

2.2. Different types of sites - Tonnages

Years of uranium mining by COGEMA and subsidiaries have lead in France to:

- more than 200 mining sites, three fourth of them being more than an hectare. Either open pit or underground, we have to deal with the associated waste dump,

- 11 industrial sites where operations were mill or heap leaching,
- 22 storage sites for the residues of ore treatment residues.

Total area for the industrial sites and the associated impoundments range from 3 hectares to more than a hundred.

Due to the very low grade of uranium which were treated in France (average 0.15%U or 0.23%U if heap leaching is excluded) more than 99% by weight goes to waste and very important tonnages have to be dealt with. By the end of 1993, a total of nearly 50 million tons has been accumulated.

Dismantling of a mill leads to several thousand tons of slightly contaminated concrete debris and scraps. The most contaminated equipments being those for attack and resin extraction. The estimated activity is less than one percent of the activity treated during the life time of the mill and already included in the calculated activity of the impoundment.

Types of storage are well known. Either piles of heap leached ores or impoundments of mill tailings. Impoundments are limited by dikes or fill an open pit.

2.3. Residues mineralogical and geochemical characterization and studies

The main concern in this presentation are the residues coming from treatment of uranium ore.

However characterization of the materials used for a solid cover of the residues is also necessary although french ores are usually low in pyrite content and stripping materials do not lead to acid mine drainage problems.

The mineralogical content of the residues is the original association of quartz, feldspar and aluminosilicates (for granites) as well as carbonates, metal oxides and hydroxides and secondary sulfates resulting mainly from neutralization.

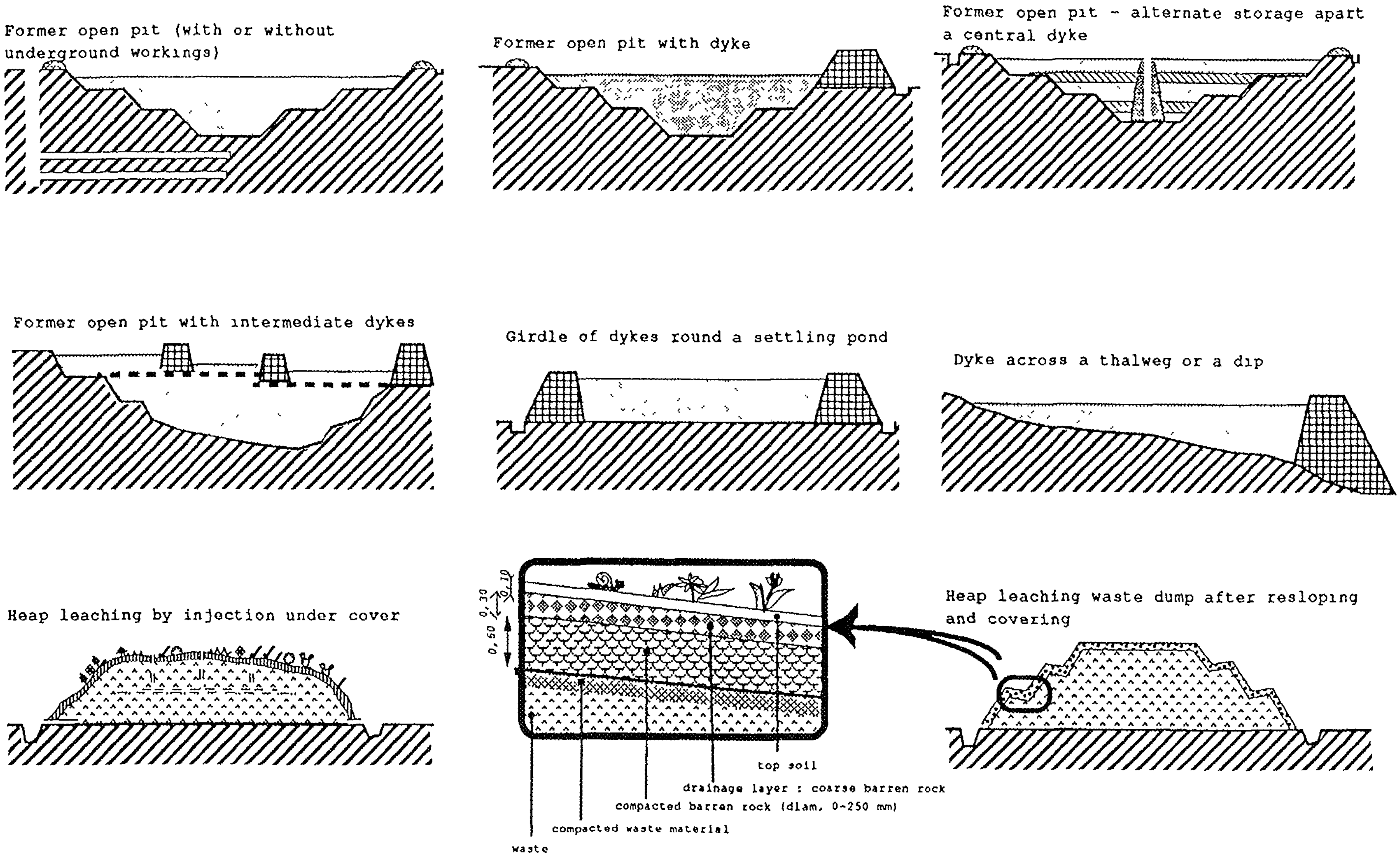
Radionuclides are all natural and correspond to the decay products of U238, U235 and a little Th232. Due to uranium extraction with a mill recovery ranging from 92 to 97%, total radioactivity of the waste is about 70% of the original ore. Average total specific activity of the mill tailings is 300 $Bq.g^{-1}$ and around 20 $Bq.g^{-1}$ for Ra226 alone. pH is a matter of concern mainly for heap leaching residues which usually have been only flushed with weak acids and water at the end of the U extraction.

Study of the physical characteristics (§ 2.6.1 and 2.7.2) of the residues is the first stage for the different geotechnical studies (settlement, compaction, stability).

Main facts from detailed mineralogical and geochemical studies are :

- important enrichment in Ra226 in the fraction less than 28 microns,
- differences between mill tailings issued from sedimentary carbonatic ores (ex. Lodève) and granitic ores. In Lodève Ra226 seems to be fixed but residues issued from acid mill leaching show a significative redistribution of trace elements (As - Cu - Fe - Pb) and radionuclides (Ra226, Pb210),
- secondary formation of minerals (gypsum and argilous minerals) which tend to be more important from the top to the base of the pile of residues (Somot S, and all 1994),
- very limited migration of radium in the granitic or sedimentary basement of our impoundments.

These observations allow us to conclude that residues are not fixed entities but are submitted to diagenetic phenomenon which may contribute to fixation and retention of heavy metals and radionuclides.



Different types of impoundments

TABLE: CHARACTERISTICS OF WASTE PRODUCTS FROM TREATMENT OF URANIUM ORES

	HEAPLEACHING WASTES	MILL TAILINGS
U ore grade	0.15 - 0.6 ‰	1 to 10 ‰
Particle size	Crushed or not : < 500 - 1000 mm	D80 < 450 μm
Weight	100 % of original ore	≈ 110 % of original ore
Residual U	20 to 40 % of original ore	3 to 10 % of original ore
<u>SITUATION IN 1992</u> Number of sites Tonnage (10^6t)	18 17	 32
RADIONUCLIDES	U235: Th231, Ra231 .... U238: Th230, Ra226, Ra222	Th232, Ra228 .... Rn220 ....
Activity Ra226	≈ x ‰U grade x 12.4 $Bq.g^{-1}$ 2 to 7 $Bq.g^{-1}$	Average 20 $Bq.g^{1}$
Total Massic Activity	Average 40 $Bq.g^{-1}$	Average 300 $Bq.g^{-1}$
Radiological concern	Gamma exposure Rn222 exposure Transfert of radionuclides (U - Ra) in water	
Other chemicals	pH - Dissolved salts (SO_4 , HCO_3) - (heavy metals)	

2.4. Leaching tests

Components of the residues have gone through the strong chemical attack of the ore. Nevertheless, further leaching tests can quantify the residual ability of the materials to release potential pollutants (radium, uranium; metals or acid in case of potential AMD for any pit run rock).

We have used dynamic leaching tests according to the french norms (AFNOR X 31.210 - L/S = 10) extended up to ten successive extractions (L/S up to 300).

Main conclusions for granitic ores residues after acid treatment are :

- leached radium is linked first to solubilization of gypsum then to barium minerals,
- total leached radium is limited to a small fraction of the initial quantity in the residue,

- leaching of radium is less efficient with stocked residues than with fresh,
- quality of leachate is never higher than a few Bq Ra226/l,
- metals and uranium do not move during these tests.

The same experiments conducted with sludges produced by the treatment of Le Cellier waste waters ($BaCl_2$ for radium, lime for U and pH control, floculants) give the following results :

- small quantities of uranium (less than 2%) and radium (less than 0.1%) removable with fresh water. Metals non detectable,
- leaching with on site radioactive water show absorption of the incoming radium.

Leaching test and petrographic studies support the idea of a weak impact of the milling activity through the impoundments.

2.5. Hydrogeology

Alteration of granitic basement lead to superficial disconnected aquifers. Permeability of argilous altered granite are usually low (10^{-8} $m.s^{-1}$) and are a good natural water tight layer for impoundments.

Deeper, permeability is linked to the fracturation of granite and the "connection index" of the fractures. Permeability can be as low as 10^{-10} $m.s^{-1}$ 300 meters deep with poor drainage capacity.

Correlation between flow of mine dewatering and rain, water quality around the sites and detailed hydrogeologic studies usually conclude to :

- direct feeding of the mine by superficial water,
- no direct link between mine waters, the near impoundment site or superficial neighboring springs.

The impoundment is a pile of argilous material with poor permeability ($<10^{-7}$ $m.s^{-1}$) which allows a theoretical very low rate of water renewal in the residues (up to one every ten years).

Accordingly risks of groundwater pollution through seepage of the impoundment are limited.

Hydrogeological studies will predict the location of future springs of seepage water and the best locations for water monitoring stations.

2.6. Settlement of the residues

2.6.1. Geotechnical characteristics of the residues

Main characteristics necessary to assess the possible evolution of the materials are :

	RESIDUES	
	ECARPIERE	Possible range
Grain size % < 500 microns	100	100
% < 80 microns	80	40 - 100
Water content w%	35 - 130	25 - 130
Dry specific weight $T.m^{-3}$	0.6 - 1.2	0.6 - 1.3
Consolidation Cv $cm^2.s^{-1}$	$6.5 . 10^{-3}$	10^{-5} - 10^{-2}
Cohesion Cu $T.m^{-2}$	0.5 - 8	
Permeability K $m.s^{-1}$		$< 10^{-7}$

2.6.2. Settlement

Observation of the surface of dewatered impoundments show vertical cracks with stairs : this is the result of settlement (self compaction) by natural dewatering.

Results from Ecarpière with low density of the residues, getting higher with depth, degree of consolidation lowers down to 30 %, confirm that natural compaction of the impoundment is not finished.

In this case, settlement compaction was predicted to reach up to 5 meters, which should need 25 to 30 more years, for the thickest part of the impoundment (40m).

Of course the final compaction shall be reached earlier by technical dewatering. In order to link the sand lenses and enhance drainage, vertical drilling (and pumping ?), can be used. In the case of Ecarpière 90% of final compaction could be reached in a six months time.

2.7. Cover for the residues

2.7.1 Objectives

A cover should first enhance protection of the impoundment : that is radiological and mechanical protection (erosion).

The cover must also limit infiltration of rain water and allow their selective drainage.

The topographic modelling of the final cover will allow landscape integration of the remediated site.

2.7.2. Characterization of materials for covers

Apart from petrographic, chemical and radiological characteristics which have to be in accordance with the general objectives of the remediation, geotechnical characteristics shall be assessed.

Here are some measures gained during the study for Ecarpière project.

	Altered Gneiss	Heap leached ore
Grain size max mm		60 - 150
< 80 microns %		6 - 12
Water content w %	5 - 16	5 - 8
Dry specific weight kN m^{-3}	19 5	20
Permeability K m s^{1}		
non compacted	1 2 10^{-4}	8 4 10^{5}
after compaction	3 0 10^{7}	2 5 10^{-8}

2.7.3 Compaction and test plots for cover

Objectives listed earlier can be enhanced through compaction. According to different tests plots implemented :

- permeability can be reduced two to three order of magnitude by compacting,
- one meter of non compacted material (barren gneiss) is equivalent to 0.5m of the same compacted material,

- radon flux were reduced by 82% while gamma radioactivity is 70% lower.

Tests show that heap leached materials (compacted or not) have lower permeability than the original ore : thus it is a good source of materials to cap mill tailings impoundments.

2.8. Stability

Stability problems are linked to the followings aspects :

- lateral containment of the residues (as written earlier impoundments are often limited by dikes),
- disposal of the cover for mill tailings,
- stability of piles of heap leached residues and their cover.

In all cases general procedure is :

- geotechnical characterization of the different materials (see 2.6.1 and 2.7.2),
- water pressure inside the materials,
- calculation of the stability coefficient according to FELLENIUS or BISHOP who give a good evaluation of the constraints along the breaking-down circle,
- these methods can take into account the horizontal static added effort linked to the most likely earthquake.

The long term stability is assured if the coefficient reaches 1.3 to 1.5 and in any case remains higher than 1, specially in the case of an earthquake.

2.9. Surface hydrology - erosion and seeding

Three main origins of flows must be estimated and separated :

- external non contaminated water which will have to be diverted around the site,
- surface running water which requires only a settling pond and control before being released,
- seepage water coming out of storage sites which must be treated for pH and/or for U and Ra content.

In order to control surface erosion it is suggested to :

- avoid steep slopes, unless specially designed, and organize a network of small water basins able to cope with possible floods,
- allow surface infiltration by engineering a multilayer cover with a compacted layer burried under a loose upper coat,
- have a quick vegetal coverage of the surface which will prevent direct impact of rain drops, slow down the rainwater flow and trap small particles.

2.10. Water treatment

After remediation, settlement of the materials, soaking of the different impoundments produce a continuous flow of water which cannot be released to the environment. If collected separately the flow of water needing treatment can always be adjusted to the evolution of its quality.

The former water treatment plant must go on operating, often it will be rebuilt near the lowest water collecting point of the site.

2.11. Monitoring

The monitoring network which has been going on all through the operation and site remediation must be adapted to the situation after remediation.

2.11.1. Geotechnical monitoring.

If containment is linked to the stability of a dike, controls will include :

- topography measurements,
- measurements of water levels in piezometer holes,
- measurements of water flows in drains and leaking points,
- visual inspection of the site.

2.11.2 Radiological monitoring.

According to the specific risks of the site, waste water and stream water are sampled for chemical analysis and suspended solids, also water from piezometer holes.

For radiological monitoring, the network must take into account the critical groups, that is the population living near to the site. Monitoring stations must include devices for water sampling or air sampling.

Air monitoring stations are equipped with :

- small sedimentation plates for airborne dust measurement,
- thermoluminescent dosimeter for external irradiation measurements (gamma radiation),
- CRPM (Center de Radioprotection dans les Mines) integrated site dosimeter measuring :

  * potential alpha energy (PAE) from radon short live daughter products,
  * alpha activity of airborne dust particles.

On top of those continuous samplings and measurements, periodic analysis are made in the food chain.

2.12. Communication

As provisionned by law, the projects have to be submitted to the authorities and to the public. The authorities give the final authorization after the public inquiry. However this is not enough and the legal frame should be completed by regular information of the public and this may contribute to anticipate objections.

Results of the environmental monitoring are regularly sent and explained to mayors and town councillors or can be explained to local commissions. Direct information of the public is part of a long term project :

- sites open to visits (schools, relatives of the workers, ...)
- regular publication of information sheets sharing news of the site activity, explaining radioactivity and the environmental monitoring, and giving the last measurements. Distributed in public halls and in shops, they can be mailed free of charge to those asking for it,
- brochures explaining technical matters are planned.

Of course QUALITY of remediation work goes through information of the team in charge of the job. This is easier and better when it is done by the former miners who were already concerned by quality during extraction.

2. 13. Main options for remediation - implementation

According to the results of the different studies described earlier, details of the remediation project will change from site to site but two main options can be distinguished according to the cover chosen :

- wet option with a water cover,
- semi dry option if a solid material cover is implemented.

Although one site (Le Forez) is for the moment under water, the second option is favored in France.

For good results implementation needs :

- a special team with appropriate equipment,
- a strict topographical and radiological follow up .

The principal stages involved in implementing the remediation are as follows :

- Drawing of the project : topographic modeling will link landscape integration of the remediated site, technical constraints for slopes, water and road networks, calculation of the different volumes to push, load and carry, ...
- Dismantling of the mill. Contaminated equipment are placed with the residues.
- Cleaning up of the site for gathering of the products in the main impoundment.
- Backfilling, earthmoving, capping, compacting and resloping is the biggest part of the job in terms of spending.
- Finishing works include water treatment plant, ditches, roads, all installation of monitoring equipment, revegetation and signalization.
- Controls to check effectiveness and quality as regards stability, drainage, radioactivity, ...
- Gather experience for new projects.

3. FIGURES ABOUT SOME COSTS

Remediation of mining and milling sites induces certain costs. Apart the direct expenses linked to the studies and field work, occupational exposure and the impact on the environment should be considered.

3.1. Occupational exposure

As part of the total "cost" of the remediation, personal dosimetry of the members of the team in charge of the operation should be as efficient as before.

In Ecarpière remediation of the open pits followed by that of the impoundment was operated by part of the personal formerly in charge of the open pit extraction. Average exposure is slightly lower during remediation (about 20% for a total exposure less than 1 mSv/year) than during the phase of extraction.

3.2. Impact on the environment

The following table gives the order of magnitude of the different exposure factors comparing the levels for natural background and the nearby areas surrounding the sites.

Considering the minimum and maximum values of the different factors, the added exposure is a maximum of 4 mSv, which is within the regulatory limit (5mSv for the public).

TABLE: ORDER OF MAGNITUDE OF DIFFERENT FACTORS OF EXPOSURE (in equivalent mSv*)

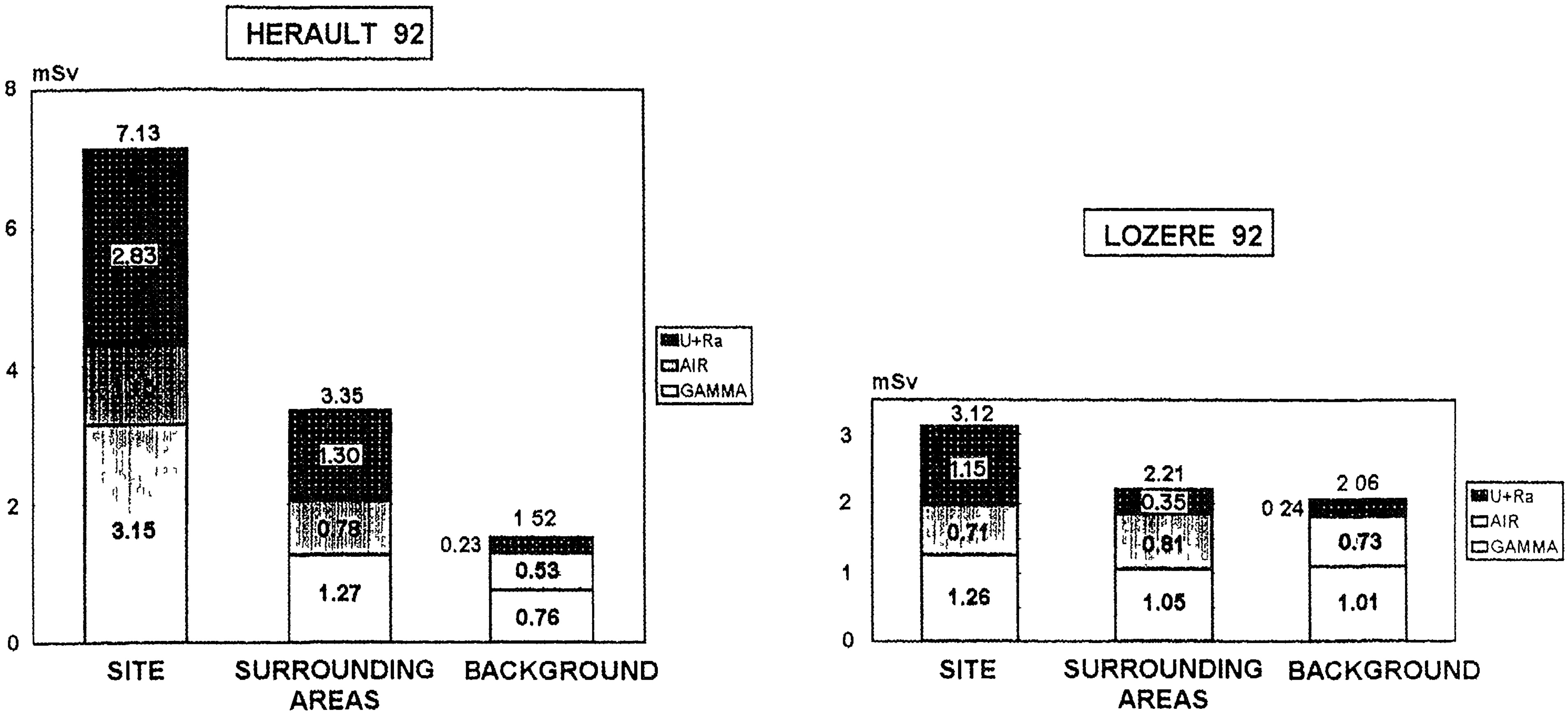
	NATURAL BACKGROUND LEVEL FRANCE		NEARBY AREAS SURROUNDING MINING AND INDUSTRIAL SITES (1991)	
	%	Min Max	%	Min Max
Gamma	57	0.75 to 1.96	47	0.84 to 2.73
Rn222	25	0.32 to 1.81	24	0.29 to 2.38
Rn220	4	0.06 to 0.11	4	0.06 to 0.11
Dust	5	ns to 0.16	4	0.16 to 0.31
Soluble U	9	ns to 0.20	21	0.20 to 1.89
Soluble Ra		0.01 to 0.07		0.06 to 0.20
Fluctuations for total exposure (considering individual stations)		1.92 to 4.26		2.26 to 6.07
Average for background stations of CRPM		2.24		

* According to ICRP 26

The main problem is the evaluation of the natural background levels before activity started on the site. Considering that natural variation ranges from 2 to 4 mSv (even 6 if radon indoor is considered), one can imagine that it will be difficult to certify an added exposure limited to 1mSv as recommended by ICRP 60.

However a comparison between total exposure on an operating site (Herault) and a remediated site (Le Cellier in Lozère) shows a significant decrease as the added exposure is also decreasing. After remediation the added exposure is negligible.

In the environment of our sites, the air and water pathways represent nearly 100% of the radiological impact. Analysis in the food chain (vegetables, grass and milk and the associated soil) show very little difference between samples collected up and down stream of impoundments.



OPERATING INDUSTRIAL SITE

WITH IMPOUNDMENT

ATAER → Site = 1.22

ATAER → S. Areas = 0.37

REMEDIATED INDUSTRIAL SITE

WITH IMPOUNDMENT

ATAER → Site = 0.21

ATAER → S. Areas = 0.03

Results of remedatıon

In France, analysis and results of radiological monitoring are certified by ALGADE/CRPM (Center de Radioprotection dans les Mines) and sent to regulatory authorities (DRIRE and SCPRI = Ministry of Health).

3.3. Elements for financial costs

3.3.1. Team and equipment

The mill of Ecarpière which produced (mill and heap leaching) 14000 t of uranium from 1957 to 1991 is now under remediation with very long haulage distances (average 2 kms).

It is planned to move about 3 millions cubic meter of material in three years time.

The team is altogether 40 people among them 20 engine drivers divided in two shifts.

3.3.2. Costs

Expenses for site remediation of mill installations/mill tailings storage range from 600 to 1100 kF an hectare. Dismantling of the mill itself cost around 15 to 20000 kF.

Total cost for an average lot producing more than 1000 tU/year (mining sites and a mill) ranges from 8 to 13 F a kgU (depending on the size of the site).

These costs split into :

- Studies : 5%
- Earth moving : 70 %
- Finishing works : 10%
- Revegetation : 5%
- Controls : 10%

4. CONCLUSION

Site remediation has always been part of COGEMA and subsidiaries' activity : as for industrial sites, six out the eleven sites mentioned earlier have been completely remediated between 1980 and 1991. Only two mills will remain operating at the end of 1995.

Site remediation is very expensive and has to be carefully studied and planned in order to apply the general principles on a site specific basis.
Usually :

- the wastes which have to be managed after uranium extraction represent very large volumes but they have low initial specific activity and low reactivity,
- impact on the environment due to good confinement and stability of the impoundment is limited,
- on site remediation work can efficiently reinforce the system for the long term.

Stability calculation take into account a seismic event. Moreover the provisional radioactive impact is conforted (or improved) by the natural evolution of the residues.

At the end of remediation :

- operators shall remain owner and responsible of the site,
- operator goes on measuring its radiological impact on the environment.
- if necessary, the operator treats the remaining flow of water,

In order to keep a long term memory of the sites, a double institutional control is set in France:

- restricted use of the sites is attached to the land, recorded by the "Conservatoire des Hypothèques" and shall be transmitted to the new owner in case of sale,
- a national agency is in charge of a record of all low radioactive storage sites including mill tailings.

REFERENCES

[1] Baschwitz, R., Kuhlmann, J., 1992 : "The Rehabilitation of Mining Sites - The Remediation of Nuclear and Industrial Sites", St. Petersburg/Russia, Conference of Nuclear Society, 13 - 19 September 1992.

[2] Bernhard, S., 1992, "Health physics in uranium, mines", Nuclear Europe Worldscan, 5 - 6.

[3] Bernhard, S, Vauzelle, Y, Fourcade, N; Zettwoog, P, 1993, Measurement network for impact assessment of industrial radon sources, Prague Czech Republic, International Conference on Nuclear Waste Management and Environmental Remediation, 5 - 11 September 1993.

[4] Bernhard S., Miller W., Zettwoog P., 1994, : "Recent development of instrumentation and methods for the assessment of the radon 222 route in the vicinity of uranium ore mining," WM'94, Tucson, Arizona, February 27 - March 3, 1994

[5] C.E.A., 1993, "Résidus miniers" Rapport pour la Commission pour les questions scientifiques relatives à la gestion des déchets radioactifs auprès du Conseil Scientifique du C.E.A. March 1993 (internal report)

[6] Daroussin, JL., Fourcade, N., Zettwoog, P., 1992 : " Le Réaménagement des Sites Miniers et Industriels de COGEMA-SIMO", internal company report.

[7] Daroussin, JL., Pfiffelmann JP. , 1993 : " Uranium Mining and Milling Sites Remediation - Its Impact on the Environment", 18th Uranium Institute Annual Symposium, London September 1993.

[8] Fourcade, N., Zettwoog, P., 1991, "Expertise en Réhabilitation des Sites d'Extraction et de Traitement de Minerais d'Uranium", Séminaire sur la gestion des déchets radioactifs organisé par l'Université de Regensburg au Château de Theuern, Bavière, 26 Avril 1991.

[9] Fourcade N., Mery G., Zettwoog P., 1994, : "Radium 226 and lead 210 water extraction from laboratory samples", WM'94, Tucson, Arizona February 27 - March 3, 1994

[10] Hähne, R., 1991, "Environmental issues related to the decommissioning of mine sites and to the rehabilitation of sites of WISMUT Corporation", International Atomic Energy Agency, Technical Committee Meeting on New Developments in Uranium Exploration, Resources, Production and Demand, Vienna, Austria, 26 - 29 August 1991.

[11] International Atomic Energy Agency, 1987, "Safe Management of Wastes from the Mining and Milling of Uranium and Thorium Ores, Code of Practice and Guide to the Code", Safety Series No. 85, IAEA, Vienna.

[12] International Atomic Energy Agency, 1992, "Current Practices for the Management and Confinement of Uranium Mill Tailings", Technical Report Series No. 335, IAEA, Vienna.

[13] Michel, P, 1986, "The uranium industry : from geology to chemistry. COGEMA Group experience in exploration, mining, milling and uranium recovery from phosphoric acid" Nuclear Power Workshop - Kuwait November 3-6, 1986.

[14] Pradel J. and Zettwoog, P., 1986, "The French research program on the management of uranium mine wastes", International Symposium on Radiation Protection in mines, Beijing, China 9 - 15 november 1986, sponsored by Chinese Nuclear Society, responded by Society of Uranium Mining and Metallurgy CNS.

[15] Quarch, H., Daroussin, JL., Kuhlmann J., Poyser, RW, 1993, "International Developments in Uranium Mining and Milling Site Remediation" Prague Czech Republic, International Conference on Nuclear Waste Management and Environmental Remediation, 5 - 11 September 1993, proceedings published by The American Society of Mechanical Engineers.

[16] Uranium Institute, 1991, The management of radioactive waste, A report by an international group of experts, August 1991.

[17] Somot S., Pagel M., Pacquet A., Reyx J., 1994, "Diagénèse des résidus de traitement du minerai d'uranium sur le site de l'Ecarpière (Vendée)", 15ème réunion des Sciences de la Terre, Institut Lorrain des Géosciences, Nancy 26-28 avril 1994

[18] Zettwoog, P., 1991, "Gestion des déchets radioactifs issus des opérations d'extraction et de traitement des minerais d'uranium. Conception des sites de stockage - Réaménagement", CRPM Séminaire Vassivère I/91, du 23 au 24 janvier 1991, - environnement-, Document de référence no. 10/16.

[19] Zettwoog, P, Miller, W, Bernhard, S, 1993, "The contribution of environmental dosimetry to designing the most appropriate site remediation concept", Prague Czech Republic, International Conference on Nuclear Waste Management and Environmental Remediation, 5 - 11 September 1993.

RADIATION EXPOSURE OWING TO SITES CONTAMINATED BY MINING AND MILLING - METHODS OF DOSE ESTIMATION

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Abstract

A proper dose estimation is the indespensable pre-requisite for classification of sites as "radioactive contaminated" and for decisions on remidial measures. The parameters applied for dose estimations should be established "as realistic as possible" and site specific investigations would be required. In the most cases generic approaches are possible if "realistic but sufficiently conservative" parameters are applied for doese estimation.

The major pathways considered and parameters applied in Germany for estimation of radiation dose to man owing to sites contaminated by wastes from uranium mining and milling are described.

1. Introduction

- Summarizing the discussions during the first workshop the participants of this meeting arrived at the conclusion that a primary reference level (level of effective dose) should be established as deciding criterion for radioactive-contaminated sites. If no person will be exposed to more then the established level, the site can classified as "non-radioactive-contaminated", in the other case it is "radioactive-contaminated".

- International organisations should provide the general guidance and the national authorities have the task of setting a figure. In setting up the figure all aspects of relevance and the whole situation in the country have to be taken into account.

- The national authorities have also the task to regulate the matter of dose estimation required for decision making (e. g. definition of exposure pathways, parameters for dose calculation).

2. Radiological assessement of sites contaminated by uranium mining and milling - the practice in Germany

2.1 General remarks

- It is the normal practice in radiological protection to account for the variability of the actual radiation dose received by members of the public by identifying an appropriate critical group. When undertaking pre-operational dose assessements to prevent environmental contamination, critical groups have to be regarded as "hypothetical" groups whose members are living at the point which lead to the highest dose from effluents of an installation. In a pre-existing situation (the dose assessement is undertaken a posteriori) the critical group should be regarded as "realistic" group and dose assessements required for the classification of a site as "radioactive-contaminated" and for decisions on remedial measures should be implemented "as realistic as possible". It fallows from this requirement that site-specific investigations have to be carried out. In the most cases more generic approaches can give reasonable results if the parameter applied are choosen "realistic but sufficiently conservative".

- Fallowing the mentioned princip the dose estimations are carried out for the major exposure pathways that may be reasonably expected. Hypothetical pathways are not considered in dose estimation.

- The following exposure pathways are usually considered for a person staying on a contaminated site:

  * external exposure to gamma radiation from contaminated grounds

  * internal exposure owing to inhalation of short-lived radon daughter products and radioactive contaminated dust

  * internal exposure owing to direct ingestion of contaminated soil and dust, in particular, this pathway has to be considered for children playing on contaminated grounds.

- Additionally radiation exposure can result from the consumption of food produced on contaminated grounds and from the consumption of contaminated drinking water. Are these exposure pathways actual they must be taken into account.

- With the exception of the external exposure to gamma radiation from contaminated grounds and the internal exposure resulting from ingestion of soil and dust the mentioned exposure pathway can be real generally for a person staying off a contaminated site. The gamma dose rate is decreased to the natural level already in a distance up to some ten meters from the object of interest.

- The competent authority decides which of the pathways have to be considered following the principle "as realistic as possible" and whether other pathways have to be included possibly in the assessement procedure.

- The radionuclides considered in the estimations of internal dose are choosen taking into account the relevant dose coefficients. Only the most relevant radionuclides of the U-238 and U-235 decay chain are considered, additionally the short-lived radon daughter products. (Radionuclides and dose coefficients see Table 1)

TABLE I. DOSE COEFFICIENTS [mSv/Bq]

Radionuclide	Infants (1 year)		Children (5 years)		Adults	
	Inhalation	Ingestion	Inhalation	Ingestion	Inhalation	Ingestion
U-238	1.5E-01	2.8E-04	8.7E-02	1.6E-04	3.2E-02	6.9E-05
U-234	1.7E-01	3.1E-04	9.6E-02	1.8E-04	3.6E-02	7.7E-05
Th-230	2.5E-01	4.3E-04	1.6E-01	2.8E-04	8.6E-02	1.4E-04
Ra-226	1.6E-02	2.6E-03	7.9E-03	1.3E-03	2.3E-03	3.6E-04
Pb-210	1.2E-02	4.9E-03	7.5E-03	3.0E-03	3.7E-03	1.5E-03
Po-210	1.6E-02	3.3E-03	7.9E-03	1.6E-03	2.5E-03	5.1E-04
U-235	1.6E-01	3.0E-04	9.0E-02	1.7E-04	3.3E-02	7.2E-05
Pa-231	7.1E-01	5.8E-03	5.5E-01	4.5E-03	3.5E-01	2.9E-03
Ac-227	6.3E-00	1.3E-02	4.0E-00	8.5E-03	1.8E-00	3.8E-03
Mixture*)	9.5E-01	1.3E-02	5.8E-01	7.1E-03	2.6E-01	3.0E-03

*) U-238 decay chain: 1 Bq of each radionuclide
U-235 decay chain: 0.047 Bq of each radionuclide

2.2 External exposure

- The following dose conversion factors [1] are applied for calculation of the radiation dose to man owing to external exposure from contaminated grounds:

  * adults: 0.32 μSv h^{-1}/Bq Ra-226 g^{-1}

  * children: 0.37 μSv h^{-1}/Bq Ra-226 g^{-1}

- A time spent outdoor of 2000 $h \cdot a^{-1}$ (work and spare time) is applied generally in dose calculation. For special cases (e. g. staying on or close to waste rock piles) smaller values are applied.

2.3 Internal exposure owing to inhalation of short-lived radon daughter products

- The proper estimation of the radon flux is difficult, but approximation assessement is possible (1 Bq Rn/m^2·sec per Bq Ra-226/g [2]).

- Establishing of acceptable models for calculation of the distribution is with difficulties, simple models are not suitable.

- The measurement of radon concentration is more simple in the most cases. The measurements should be executed in such a way that information on the regional (better: site-specific) natural level of radon concentration are available.

- If the radiation exposure owing to radon in surface air is included in the primary reference level. The dose estimation should be performed on the basis of the ICRP-Recommendation No. 65. [3]. (50 Bq·m^{-3} Radon corresponds to an effective dose of 1 mSv taking into account the equilibrium factor of 0.4 and outdoor and indoor staying).

2.4 Internal exposure owing to inhalation of contaminated dust

- The assessement of this pathway should be done without calculations on the basis of models since the estimation of the source term is associated with many problems (resuspension) and the calculation of dispersion of the released dust is difficult as well. Measurements should be preferred to the calculation.

- If information about the specific activity of the dust is available (for many cases the specific activity of dust can be assumed equal to the specific activity of contaminated material) the measurement of dust concentration is sufficient for the assessement.

- Breathing rates are applied for two age groups:

  * adults: 7 300 $m^3 \cdot a^{-1}$ (0.83 $m^3 \cdot h^{-1}$)

    workers (work time): 2 400 $m^3 \cdot a^{-1}$ (1.2 $m^3 \cdot h^{-1}$)

  * children: 1 900 $m^3 \cdot a^{-1}$ (0.22 $m^3 \cdot h^{-1}$)

- If the specific activity of the dust is smaller then 1 Bq/g the pathway can be neglected (pre-requisite: the immission limits for dust are not exceeded!)

2.5 Internal exposure owing to consumption of contaminated food and direct ingestion of soil

- One of the important parameter for the estimation of radiation dose to man owing to the terrestrial pathways is the soil-plant transfer factor. The transfer factors (mean value) for U, Ra, Pb and Po (including the direct deposition of dust on leafs) have been estimated based on experimental investigation in mining district of Saxony and Thuringia:

  * Soil-plant (except grass): $5 \cdot 10^{-3}$
  * Soil-grass: $1 \cdot 10^{-2}$

- All other transfer factors and parameters were taken from [4].

  The consumption rate is estimated taking into account a "dilution factor" for the consumption of all agricultural products (0.25).

- The rate of direct ingestion of soil was established on the basis of investigations for children playing on the ground:

  * time spent: $250\ h \cdot a^{-1}$

  * ingestion rate: $0.3\ g \cdot h^{-1}$

2.6 Exposure owing to waters contaminated by mining relics

- Radioactivity released from mining relics (waste waters from old pits, seepage waters) can contaminate waters (surface waters, ground waters).

- The following pathways can be of relevance for radiation exposure and should be considered, if real.

  * consumption of drinking water

  * consumption of fish

  * using contaminated water as livestock water

  * using contaminated water for irrigation

- Comparison of the exposure pathways illustrates that the consumption of drinking water is the most relevant pathway.

- Additionally staying on overflow areas contaminated by waters can result in external exposure owing to gamma radiation from contaminated banks.

- If contaminated waters are discharged into creeks or rivers the dilution has to be considered as follows:

  * dilution factor: MQ-value (long-term average flow of the river in $m^3\ s^{-1}$).

- If contamineted waters can reach a groundwater horizon by seeping away from contaminated sites, application of site specific models is absolutly necessary.

- Consumption rate for drinking water: $800\ l \cdot a^{-1}$

3. Conclusions

- By applying the mentioned parameters calculations of the radiation dose to man can be untertaken for decisions on radioactive-contaminated site.

- On the basis of a primary reference level (level of effective dose) established by the competent authority derived reference levels can be set up. These levels can be useful for practical purposes (evaluation of results from measuring programmes).

- Normalized to an effective dose of 1 mSv the following derived reference levels can be calculated

* external exposure from contaminated grounds:	$0.5\ \mu Sv \cdot h^{-1}$
* internal exposure from inhalation of short-lived radon daughter products:	$50\ Bq\ Rn\ m^{-3}$
* internal exposure from inhalation of contaminated dust (radioactive equilibrium, natural isotope ratio):	$0.6\ mBq/m^3$
* internal exposure from direct ingestion of soil (radioactive equilibrium, natural isotope ratio):	1.9 Bq/g

* *radiation exposure from ingestion of vegetal products (calculated for soil, radioactive equilibrium):* 1.5 Bq · g^{-1}
* radiation exposure from ingestion of drinking water (calculated for children):

U_{nat}:	13.8	Bq · l^{-1}
Ra-226:	1.4	Bq · l^{-1}
Pb-210:	0.8	Bq · l^{-1}

- The following condition has to be met:

$$\sum_{i=1}^{n} \frac{C_{M,i}}{C_{R,i}} < 1$$

$C_{M,i}$: measured concentration or local gamma dose rate (exposure pathway i)

$C_{R,i}$: reference level for the exposure pathway i

REFERENCES

[1] Sources an Effects of Ionizing Radiation United Nations Scientific Committee on the Effects of Atomic Radiation - UNSCEAR 1993

[2] Measurement and Calculation of Radon Releases from Uranium Mill Tailings
Technical Report Series No. 333
IAEA, Vienna, 1992

[3] Protection against Radon-222 at Home and at Work
ICRP Publication No. 65
Annals of the ICRP
Volume 23 No. 2 1993
ISSN 0146-6453

[4] Modelle, Annahmen und Daten mit Erläuterungen zur Berechnung der Strahlenexposition bei der Ableitung radioaktiver Stoffe mit Luft oder Wasser zum Nachweis der Einhaltung der Dosisgrenzwerte nach § 45 StrlSchV
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RADIOHYGIENIC ANALYSIS OF THE RADIOACTIVE CONTAMINATION IN THE REGION OF THE URANIUM MINING AND MILLING

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Abstract

The radiological impact analysis of the environment has been carried out according to both the mining and milling activities for the planning of the restoration work.At the first step, the source term is to be defined as input to the analysis. A selection was made from the geographical and meteorological characteristics of the territory including the distribution of precipitation and temperature, moisture of soil and wind directions. In the case of the surface waters the activity concentrations, the yields of these and consumption of water (irrigation, drinking) has mainly been studied. The amount of population around the site in the radius of 20 km was summarized, and a sector arrangement was set up in two different distance ranges (0-10,10-20) with sectors. In these sectors the age groups and customs of food consumption were firstly considered.For the earlier and present mining and milling activities the radiological assessment was performed in two ways. On the one hand the radiation burden was calculated by using measurement results, and on the other hand, in lack of exact data the radiological impact was estimated by model calculations. The dispersion of airborne radioactivity and foodchain modelling have been applied for the following radiation pathways:
- external gamma dose in air,
- external gamma dose from contaminated surface,
- inhalation,
- food consumption.

Uranium in the form of dust and radon as a gas are the main sources of air pollution. In conclusion, the 90% of radiation burden is owing to the inhalation of airborne radioactivity and the contaminated food. It's stated that the critical nuclide is Ra-226, the critical pathway is leafy vegetables (contaminated with U-dust) and the critical group is 1 year old child. At the second step, a model investigation for the prediction of radiological consequences of different restoration solutions was carried out to promote the good decision making and the cost-benefit analysis. The radon emanation rate and the radionuclide profile in the near surface of soil have firstly been determined in a function of time after the remedial works. In this modelling the different thickness of cover layer, soil moisture, initial activity concentrations and height of waste rocks, tailings have also been taken into account. The internal and external dose contribution were calculated above the restored site. It's concluded that after the restoration work the critical nuclide is also Ra-226, the critical pathway is the contaminated tuberous vegetable, and the critical group is 1 year old child.

1. INTRODUCTION

For a restoration of uranium mining and milling residues, a lot of variations of solutions exist, depending on the different aspects of the sites and the possibilities of the country. In Hungary the restoration works are mainly approached from the point of view of radiation protection and economical factors. To fulfil the remedial action, at first adequate radiohygienic analysis is to be carried out for both mining and milling activities. The individual and collective doses are taken into account to determine the environmental impact of mining and milling area. To find the best solution, the following three main principles are adopted to the remedial goals:

- increasing the isolation from biosphere,
- tracing the radiological quantities (i.e. activity concentration, dose rate, radon flux)
- ensuring acceptable dose for long term [1, 2].

2. ANALYSIS OF MINING AND MILLING ACTIVITIES

The radiohygienic analysis of the earlier and present radioactive contamination are important to compare the radiation levels before restoration work with the levels after restoration work around the site. The prediction can be performed in two ways. On the one hand the radiation burden was calculated by using measurement results, and on the other hand, in lack of exact data, the radiological impact was estimated by model calculations. To this analysis the source term is to be defined and then the wide collection was made for the characteristics of territory (geographical, meteorological, population, food consumption data).

2.1 Data collection

For the present and earlier impacts on environment the source term is precisely examined and summarized (radiation level of waste rocks, tailings, heap leaching residues, mining and milling discharging). Since the dispersion of radioactive contamination in aquatic and atmospheric environment depends on the circumstances of meteorological, geographical and hydrological parameters, it is very important to make a survey of them. The scope of the survey is mainly justified to the dose calculation.

2.2 Meteorology of Pécs district

The most important meteorological data are the followings: wind direction, stability and velocity, intensity precipitation, soil moisture. They have firstly been collected for the prediction. Table 1 shows the average meteorology values between 1950-1990.

2.3 Features of geography and hydrology

The uranium mining site is located on a hilly countryside and the milling site is placed on a flat area. The geological formation of area is limestone, dolomite, sand and marl. The karstic water table is found between the depth of 200 to 700m. More than 20 water springs and 9 streams exist in the radius of 10km around site. In this territory fishing lakes cover an area of 1200000m^2 and the drinking water supply (capacity of 15000m^3 in a day , wells depth of 30-100m) can be found close to the tailings ponds. The 50-60 dug wells with depth 8-10m serve only water for animals and irrigation near the waste rock piles.

A lot of monitoring wells have been drilled for studying both the water movement and its quality (i.e. activity concentration, chemical compounds), so 120 wells trace the connection between the karstic water table and mining operation, 42 wells (depth of 10-25m) are applied for the monitoring of heap leaching process, and 84 monitoring wells can be found around the tailings ponds. The water arising from mining operation (4000-5000m^3 in a day) is used for different technological process (80%) and released to the streams (20%). Table 2 gives the daily average values of yields for three of the greatest streams in successive two years (in the case of dry and wet weather).

It's stated that the water supply for human is independent of the contaminated water found in this site. It's concluded that there is no evidence that the radionuclides directly transport to the man through aquatic pathways, but more investigations are to be carried out the next future.

2.4 Demography and food consumption

The population living in the radius of 20km around the site has been surveyed in such a way that the territory is divided into two regions, The first region covers the band of 0-10km and the second one ranges from 10 to 20km. The first and the second region is divided into 8 sectors, respectively. In these regions and sectors, the data collection of population are focused on the age distribution and food consumption (Tables 3 and 4).

Table 1

Average Meteorology Data

Month	Mean temperature in C°	Monthly precipitation in mm	Soil moisture in depth of 20 cm (in mm)	50 cm	100 cm
1	-1.2	37	38	9	198
2	1.3	37	36	99	201
3	5.4	34	30	93	197
4	10.6	59	26	76	180
5	15.4	62	24	58	143
6	19.1	83	23	55	116
7	20.6	72	19	47	93
8	19.9	61	20	40	78
9	16.4	47	21	44	81
10	11.0	41	23	52	105
11	5.4	60	32	74	147
12	1.0	46	37	91	181

Table 2

Yields of streams (m^3/day)

Name	Yields in 1992	1993
Zsid stream	535	1471
Bicsérdi stream	504	1972
Kajdács stream	353	1149

Table 3

Age group distribution in thousand inhabitants

Age	Region 0-10km	10-20km
1 year old child	6.2	2.6
10 years old child	38.6	16.3
Adult	134.5	56.8

Table 4

Average food consumption

Food	Unit	Around site	National
Meat	kg	61.5	64.8
Eggs	pc	235	234.9
Milk	l	86.2	91
Vegetable	kg	63.3	55.8
Fruit	kg	52.6	53.3

3. PREDICTION OF RADIATION BURDEN

3.1 On the basis of measurements

Since the contributions are very low the elevated values above the background (i.e. dose rate, radon concentration) couldn't been detected directly by measurement technique. Therefore, for the environmental impact are calculated by using model calculation. However, from the prediction applying for the contaminated industrial area is only concluded what radiation burden would be, if this area isn't restored, and some persons would stay on or close to this area in the near future (Table 5).

The greatest part of radiation burden should mean, if someone stays inside or near the tailings ponds and it's stated that the radon emanation from the tailings pond gives the greatest contribution dose according to the whole mining and milling residues [3].

The water discharging from mines contains uranium level of 10-1000 μg/l and the Ra-226 activity concentration of 0.2-0.4 Bq/l. The water arising from the dug wells around the waste rock piles has uranium of 1-10 μg/l and Ra-226 of 30-50 mBq/l. The radiation level of the groundwater from the monitoring wells close to tailings ponds gives Table 6 [4].

If the groundwater originated from near the tailings pond is used for drinking, then the few percent of ALI has been reached according to adults. But, drinking of the mine water without dilution would mean about one third of ALI. It's noted that this mine water discharging into streams is only used for irrigation (approximately 10-15% of yields).

3.2 Dose assessment on the basis of model calculation

According to the airborne dispersion of the source term from the mining and milling activities the uranium in a dust form and radon as gaseous are the dominant pollution sources. The radon in air results both external radiation burden from the air through its daughter radionuclide of Bi-214 and internal radiation dose by inhalation. The latter case gives a dominant additional dose. The uranium dust also causes an internal dose through inhalation and external radiation burden after fallout on the soil surface. In the case of fallout the transport of radionuclides in soil, plant, groundwater is to be taken into account to assess the total internal dose [5, 6, 7, 8].

3.2.1 Airborne dispersion modelling

The steady-state Gaussian-type dispersion model with sector averaged method is used to describe the atmospheric movements of radionuclides. The calculations by the model gives the activity

Table 5

Measurements and dose assessment on the basis of measured values

Place	Radiation level *		
	Dose rate (μGy/h)	Rn-concentration (Bq/m^3)	Assessed dose (mSv/a)
Inside tailings ponds	2-3	40-1100	2.1-11.3
On dyke of pond	0.9	11.7	1.8
50m of dyke	0.2	8.6	0.5
On heap for alkaline leaching	1.1-1.5	5-50	0.6-2.3
Near waste rock piles	0.2-1.0	5-10	0.1-1.1
At the fence of milling site	0.1-0.2	5-8	0.05-0.1

* occupational factor: 0.2, background: 0.12μGy/h and $10Bq/m^3$

Table 6

Radiation level of monitoring wells at tailings ponds

Statistic of wells	U-content (mBq/l)	Ra-226 (mBq/l)
minimum	61	27
maximum	725	89
mean	150	40

concentration in air and the surface contamination at different distance from site. Table 7 shows the source term that is the summarized radon and uranium activity released during the 30 years.

The model takes into consideration the wind direction and velocity, size of aerosol, total fallout. Table 8 gives a result of the uranium activity concentration in a function of distance and particle size and Table 9 shows the radon activity concentration and at the end the values of the atmospheric deposition is shown in Table 10.

Table 7

Radon and uranium sources in 30 years

Source place	Radon (Bq)	Uranium (Bq)	Effective releasing height (m)
Ventilation of mines	$1.\ 10^{15}$	$1.5\ 10^{10}$	0
Milling site through stack	$2.\ 10^{10}$	$8.\ 10^{10}$	50
Local ventilation	$5.\ 10^{13}$	$3.5\ 10^{8}$	5
Escaping from milling process	$2.2\ 10^{13}$	$2.\ 10^{11}$	10
Tailings ponds	$3.9\ 10^{15}$	-	0
Rock piles	$5.3\ 10^{13}$	-	10

Table 8

The steady-state U-activity concentration in air (Bq/m^3)

Diameter of aerosol (μm)	Distance (km)				
	2.5	5	10	15	20
1-4	9.74E-7	3.27E-7	9.36E-8	4.34E-8	2.49E-8
5-9	3.23E-6	6.78E-7	1.12E-7	3.67E-8	1.66E-8
10-19	4.26E-6	5.81E-7	6.17E-8	1.56E-8	5.79E-9
20-49	5.73E-6	5.52E-7	4.01E-8	7.95E-9	2.43E-9
>50	6.46E-6	2.54E-7	6.36E-9	6.44E-10	1.2E-10

Table 9

Radon activity concentration in air (Bq/m^3)

Distance (km)				
2.5	5	10	15	20
1.65	5.9E-1	1.82E-1	8.91E-2	5.34E-2

In the result of Table 8-10, it's supposed that the releasing height is higher than in reality, and so the effects of the dispersion in a function of distance is also farther than 500m in the case of particles of 1-4μm. Nevertheless, the surface deposition close to the site is not higher than about 1 $kBq/m^2/a$.

The external radiation burden arising from the airborne radioactivity and contaminated soil is demonstrated in Table 11. The total fallout is considered that the wet and dry deposition have been taken place for more than 30 years (from the beginning of mining and milling activities). The convection of the deposited uranium dust from 15 cm surface layer into soil downward has a half-life of 50 years.

Table 10

Annual deposition of uranium dust ($Bq/m^2/a$)

Diameter (μm)	Distance (km)				
	2.5	5	10	15	20
1-4	0.154	0.0157	0.0148	0.0068	0.0039
5-9	5.12	1.071	0.176	0.058	0.026
10-19	13.44	1.84	0.195	0.049	0.018
20-49	27.09	2.6	0.19	0.037	0.012
›50	61.1	2.39	0.06	0.006	0.001
Sum	107	7.95	0.636	0.158	0.058

Table 11

Calculated external individual dose to adult (nSv/a)

Pathways	Distance (km)				
	2.5	5	10	15	20
Airborne U-dust	0.012	0.0043	0.0012	‹0.001	‹0.001
Radon in air	250	86	27	13	7.8
Ground contaminated by dust	400	130	42	18	10

The internal dose to adult through the inhalation of radon at the distance of 2.5 km from site is only 0.02mSv/a. The additional internal dose is due to the uranium dust deposited on soil and then the radionuclides are transferred to the foodchain. The activity concentrations of the important vegetables are defined by using a steady-state foodchain model. There are considered both the direct deposition from the air and the root uptake. The results are presented in Table 12.

Table 12

Vegetable contamination (Bq/kg)

Vegetable	Distance				
	2.5	5	10	15	20
Leafy vegetables leaf	9.4	0.76	0.05	001	0.005
root	2.2	1.7	1.7	1.7	1.7
Feedstuff leaf	0.94	0.07	0.005	0.001	0.0004
root	0.93	0.75	0.74	0.74	0.74
Cereals leaf	1.25	0.1	0.007	0.001	0.0003
root	0.24	0.19	0.19	0.19	0.19
Tuberous vegetables leaf	0.	0.	0.	0.	0.
root	10.	8.1	8.0	7.9	7.9

The deposition on plant, transfer factors (from soil to root), consumption of feedstuff for animal have been taken into account by the foodchain model. Then the internal dose is calculated for the different age groups considering their appropriate consumption factor of each food (meat, milk, vegetable..). It's stated that food contamination beyond 5 km from site is negligible according to the results of dispersion modelling and measurements. After all, the internal radiation burden owing to the inhalation of uranium dust and consumption of the contaminated food is defined by way of individual and collective dose (Table 13).

The radiation dose connected to aquatic pathways is approximately analyzed in the case of irrigation and water for animals, and in the result of this analysis, the value of the additional dose is very low.

In conclusion, the 90% of radiation burden is owing to the inhalation of airborne radioactivity and the ingestion of contaminated food around the mining and milling site. It's stated that the critical nuclide is Ra-226, the critical pathway is leafy vegetables (contaminated with U-dust) and the critical group is 1 year old child.

Table 13

Dose due to uranium pollution in air for different age groups

Age groups	Individual dose(μSv/a)					
	Distance (km)					
	2.5		5.		15.	
	bone	effective	bone	effective	bone	effective
1 year old children	700	42.	260.	15.	26.	1.5
10 years old children	470	25	170	9.	17.	0.9
Adults	280	13	100.	5.2	10.	0.5

Age groups	Collective dose (manSv/a)			
	Sector region			
	0-10 km		10-20 km	
	bone	effective	bone	effective
1 year old children	1.6	0.09	0.06	0.005
10 years old children	6.6	0.35	0.28	0.014
Adults	14.	0.69	0.6	0.028

4. RADIOHYGIENIC ANALYSIS RELATED TO RESTORATION WORK

At the restoration of tailings pond and waste rock pile, one of the most important standpoint is that the radioactive materials of mining and milling residues won't be able to transport to the biosphere with unacceptable level through different diffusion processes. So the model investigation is focused on defining the activity concentration of the covering layer in the future. The long term analysis can cover only periods in 1000 to 10000 years, because of the uncertainty of parameters. The simplified model arrangement can be seen on Fig. 1.

Soil density, layer thickness, moisture, diffusion and decay constants are taken into consideration in the diffusion process of radionuclides expressed by the different equations. The radon emanation is described by the other different equation, It is supposed that uranium content of soil of the basement and the covering layers is a level of 30 Bq/kg. In the solution of equations the time steps (year) are the next:

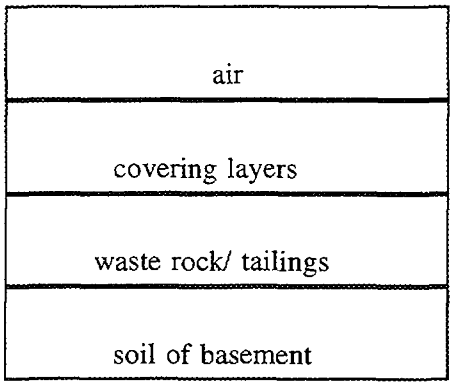

Fig. 1. Layout for diffusion modelling

Period	0-2	2-10	10-50	50-100	100-200	200-1000
Step	0.01	0.1	0.2	0.5	1.	2.

and the height step is: 0.01m. The predicted thicknesses of residues are the followings: 1, 5, 10 and 50 m. The moisture of soil ranges from 1 to 20% in the modelling.

Owing to the migration upward of radionuclides the plant grown in the covering layer can be contaminated. Otherwise, the radioactive contents of meat and milk of cow feed by contaminated feedstuff are determined. At the end, the external and internal doses are predicted in a function of time after restoration.

In the prediction of external dose owing to the nuclides originated from Rn-222, found in the layer thick of 10 cm are considered. In the assessment of internal dose the radon inhalation and the consumption of contaminated food give the dominant part of radiation burden.

4.1 Results of prediction

Fig. 2 shows the changes of U-238 concentration in depth of 1 cm above 5 m thick of waste rock covered with 0.5 m and 1 m thick of layer. It can be seen that without cover layer the beginning activity concentration (1kBq/kg) will be decreased after 1000 years. In the case of 0.5 m thick of layer the increasing of U-238 activity concentration will appear during the period of 500 to 1000 years, while with the 1 m thick cover layer the enhancement of nuclide concentration will begin after 1000 years. Here, it's supposed that the cover layer won't be disturbed during the examination period. The nuclide concentration of the deeper layer (>1 cm) is only exceeded by maximum 30% as compared to the concentration of 1 cm depth after 1000 years. According to the greater content of moisture in covering soil the difference among the activity concentration at the similar case (i.e. thickness of waste rock and layer) is growing and the maximum of activity concentration is moving to the lower value of the time scale.

The change of radon emanation in the case of different covering layer and content of moisture is demonstrated in Table 14, considering a 5 m thickness of waste rock and the beginning value of U-238 activity concentration is 1 kBq/kg.

Table 14

Radon emanation ($Bq/m^2/s$)

Year	Thickness of cover layer (m)								
	0.			0.5			1.		
	Moisture (%)								
	4.8	10.	12.6	4.8	10.	12.6	4.8	10.	12.6
1	0.36	0.16	0.13	0.19	0.043	0.012	0.059	0.014	0.004
10	0.36	0.16	0.13	0.19	0.044	0.013	0.06	0.014	0.004
100	0.36	0.16	0.13	0.19	0.045	0.014	0.061	0.015	0.005
1000	0.36	0.16	0.13	0.21	0.061	0.031	0.07	0.018	0.006
10000	0.35	0.15	0.12	0.26	0.109	0.083	0.15	0.063	0.046

If the thickness of waste rock is greater than 3 m that the radon emanation are equivalent in each case.

The activity concentration of food originated from the restoration site is given in Table 15.

Since the elevated activity concentration of upper layer of covering soil will be increasing in 200 years after restoration, so food contamination will be only expected after this time.

Table 15

Food contamination after restoration
(5 m of waste rock, 0.5 m of cover layer)

Food	Mean activity concentration (Bq/kg)	
	Year	
	10	1000
Leafy vegetables	1.7	12.
Tuberous vegetables	7.9	57.
Cereals	0.19	1.4
Feedstuff	0.73	5.3
Milk	0.0023	0.017
Meat	0.0017	0.012

The external dose is mainly due to the radionuclides (Bi-214,Pb-214) found in 10-20 cm depth of the upper layer (Table 16).

Table 16

External dose to adult above restoration site
(5 m of waste rock, U-238 = 1 kBq/kg)

Year	Individual dose (μSv/a)	
	Thickness of covering layer (m)	
	0.5	1.
100	<1	<1
200	<1	<1
500	9.7	<1
1000	39.	1.1
2000	97	8.
5000	140.	48.

The internal dose is not expected in 200 years in the case of 0.5 m layer and in 1000 years in the case of 1 m layer after the restoration, In the period of 200 to 1000 years the greatest part of internal dose (0.5 m layer) will be determined by the consumption of contaminated food (Table 17). It's supposed that food for consumption is only originated from the restoration site.

It's concluded that the critical nuclide is also Ra-226, the critical pathway is the contaminated tuberous vegetable and the critical group is 1 year old child.

Since the Mecsek Ore Mining Company has begun the restoration work with waste rock piles, so the detailed analysis has been performed firstly for this area. The problem of restoration of tailings ponds and heaps for alkaline leaching is that the survey of the connection of water tables is going on. However, it's very important to assess the dose owing to aquatic pathway for long term, too.

Table 17

Internal dose arising from contaminated food in 500 years after restoration

Age groups	Dose (mSv/a)	
	bone	effective
1 year old children	39.	2.4
10 years old children	25.	1.4
Adults	17.	0.8

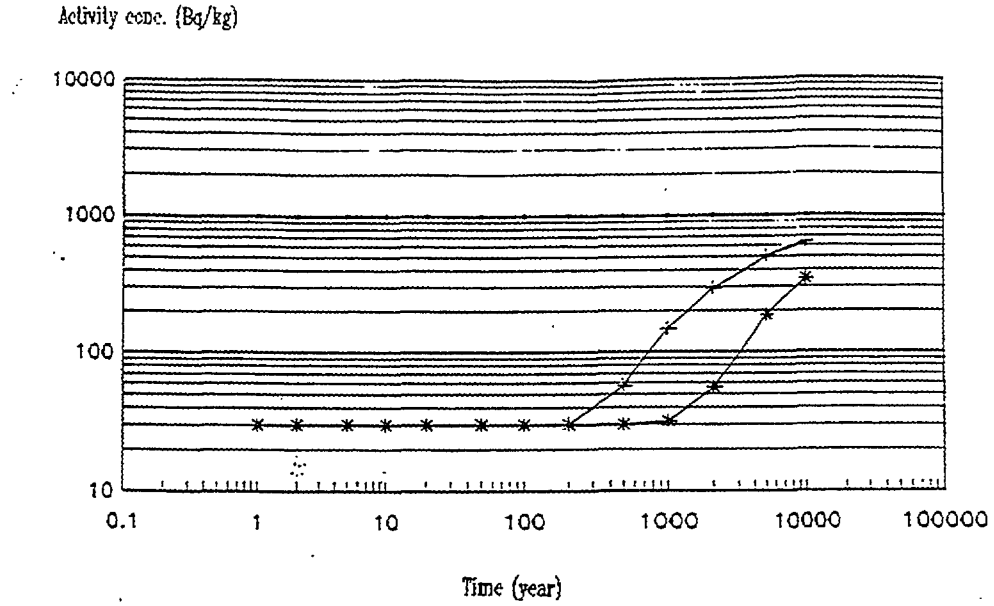

Fig. 2. The change of U-238 activity concentration in 1 cm depth of the covering layer (-- without cover; + 0.5 m; * 1m layer; 5 m waste rock)

5. RESTORATION PLANNING AND ACTIVITIES

The Mecsek Ore Mining Company (MOMC), who is responsible for the restoration work, has made a schedule for different task. This schedule contains the series of restoration tasks are to be performed in one year. Every task can adopt by way of many possibilities to get the goal, but the fund for a task is limited. So each task strives for the preparing of a decision as far as possible with low expenses [9].

The planning of a task is to be include the next important items:

- performing systematically radiation measurements before restoration
- working out many variations for site arrangement
- analysis of cover layer
- planning of revegetation and precipitation removal
- implementation necessity
- post restoration control

The main requirements are to be complied during restoration planning are the followings:

- radiological levels:
  dose rate: 400 nGy/h above 1m on restored site

- radon concentration in air: 20 Bq/m^3
  radon flux: 0.7 Bq/m^2/s

- retaining the topographical features on the landscape

- authorized surface water quality (both radiological and chemical aspect).

It's noted that the planning work is firstly focused on the radiological requirements. The two of the smallest waste rock piles have been restored, one of piles has 0.6 million tons of rock and covers an area of 100000 m^2 and the other pile has 2.5 million tons of residues and area of 140000 m^2.

The main experience related to the restoration has been got that the angle of slope of restored piles after arrangement has to be taken between 2-5°, because the erosion is very early beginning when the angle of the slope is above 6-7°.

Now, these two restored piles are considered to be a "pilot restoration site", where the goodness of the planning can be supervised.

REFERENCES

[1] Long-term radiological aspects of management of waste from uranium mining and milling, OECD/NEA, Paris, 1984

[2] Current practices and options for confinement of uranium mill tailings, IAEA Technical Reports Series No. 209, Vienna, 1981

[3] I. Barany, I. Vados, A. Varhegyi: The radiological impact of Mecsek Ore Mines to the natural environment, 17th Workshop on Radiation Protection, 6-8, May 1992, Balatonkenese (in Hungarian)

[4] J. Csicsak et al.: Annual report on the aspects of hydrology and water supplying in the MOMC, official report, Pecs, 1993, (in Hungarian)

[5] The report on the environmental impact of the Mecsek Ore Mines, made by National Research Institute of Radiobiology and Radiohygiene, 1991 (in Hungarian)

[6] L. Juhasz, B. Kanyar, N. Fulop, A. Kerekes, I. Vados: Radiohygienic study of the uranium mining and milling for the promotion of the environmental remedial action, 18th Workshop on Radiation Protection, 12-14 May, 1993, Balatonkenese (in Hungarian)

[7] N. Fulop, B. Kanyar: SIRATEC a computer program to predict concentrations of radioactive isotopes in the terrestrial foodchains (Conf. on Hygiene Past, Today and Future, Sep. 28-29,1990, Warsaw, Poland

[8] B. Kanyar, N. Fulop: Fitting models and estimation parameters of the radionuclide transport in the environmental components (EEC Workshop, Oct. 5-9, 1987, Athens Greece

[9] Zs. Lendvai et al.: The restoration plan for the mining pile III., official study, Pecs,1993 (in Hungarian)

A PROJECT CARRIED OUT IN ITALY TO SECURE A SITE CONTAMINATED BY CS-137 OF UNKNOWN ORIGIN

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Abstract

The present paper examines the intermediate phases of the work described in the workshop held in Budapest, that is to say of the work carried out to secure a site, precisely an industrial waste disposal radioactively contaminated by Cs137 of unknown origin. In particular, the lecture focuses on the planning and preparation of the works undertaken for the environmental restoration, the constitution of a Technical Committee, the share of tasks and costs, the rationale for remedy, the restoration objectives and, eventually, the project for the intervention.

1. INTRODUCTION

The remediation of a site contaminated by a radionuclide represents, by all means, a major environmental challenge, and in the workshop held in Budapest it was pointed out a few of the problems found to carry out a project to secure an industrial waste disposal contaminated by Cs137 of unknown origin. In that workshop, the subject of the lecture concerned the identification and characterization of the radioactively contaminated site, and in particular concerned the campaign survey carried out to evaluate the amount of the radioactivity on the surface of the waste storage plant and inside the body of the waste itself.

The site involved in the radiocontamination is a waste disposal, situated near Brescia, about 90 Km east of Milan (fig. 1), and consists of seven basins, about 50.000 m^3 each and a total area of about 30.000 m^2, with an average depth of the waste itself of about 14 m, and where a total volume of about 280.000 m^3 of industrial waste had already been discharged at that time.

It is sufficient remind here that from the radiological survey on the surface of the waste plant, and from the samples picked up from the deep waste by a drilling campaign, it was pointed out that the most of the radiocontamination was inside basin n. 3, some meters under the surface, with a total amount of about 29 Ci of Cs137 radioactivity.

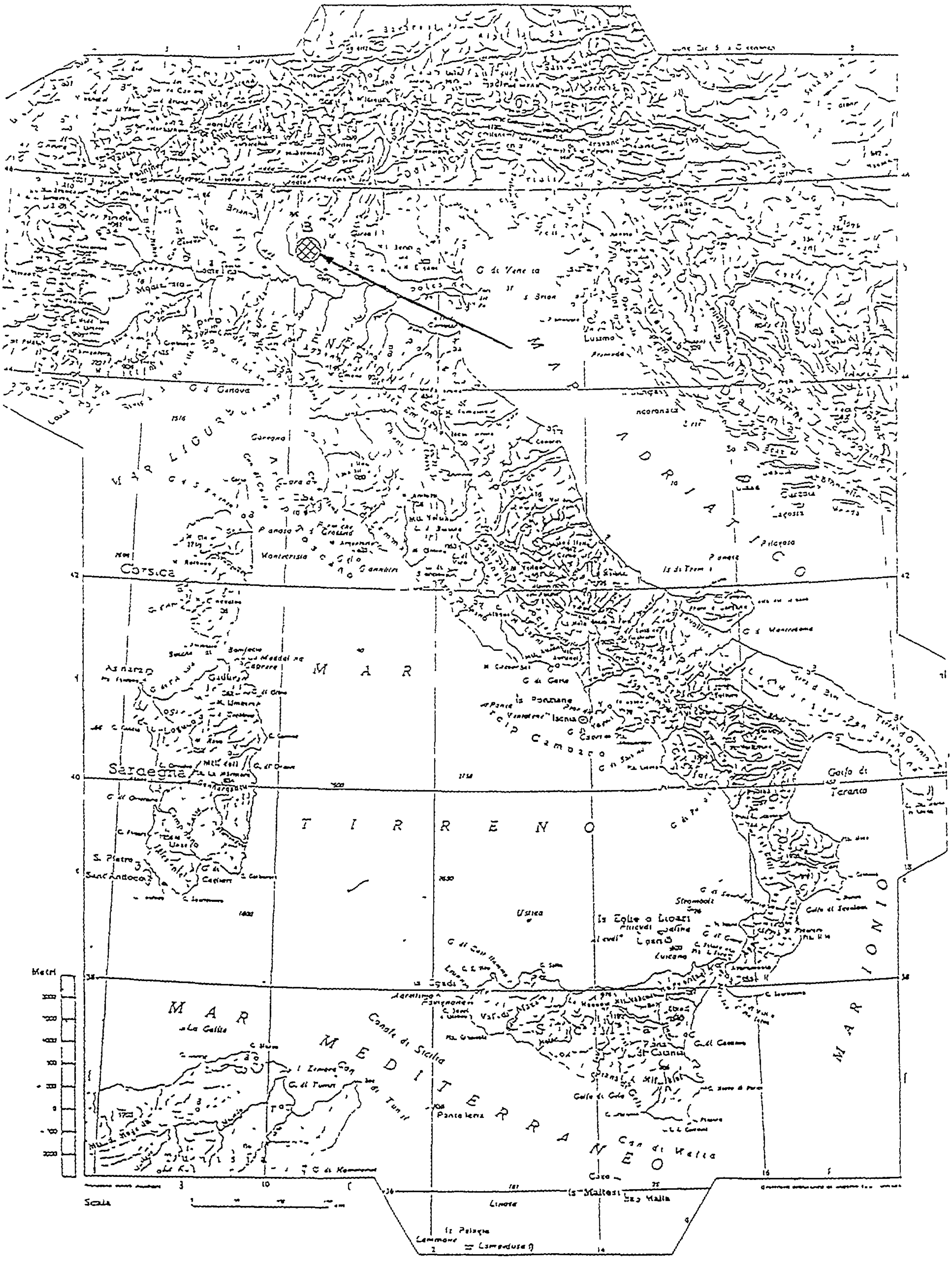
The present lecture focuses on the planning of the works undertaken for environmental restoration, and in particular concerns the constitution of a Technical Committee, the tasks and costs share, the rationale for remedy and the restoration objectives, the project for the intervention.

2. THE REGIONAL TECHNICAL COMMITTEE

Under the responsibility of the Lombardy Region Administration, a specific Technical Committee was established, to which submit all the decisions related to the problem. The Committee was formed by people responsible for the sanitary aspects of Lombardy Region and Brescia Province, as well as by people from ENEA.

One of the most important problems the Committee had to face was how to share responsibilities and tasks, as well as where to find the financial resources necessary to carry on the intervention.

What must be pointed out here is that only recently in Italy a law was passed that has instituted the Agency for the Environmental Protection (ANPA: National Environmental Protection Agency): so, in 1991 there was neither something like the American "RCRA" (Resource Conservation and Recovery



MAR ADRIATICO
MAR TIRRENO
MAR MEDITERRANEO
MAR IONIO
MAR LIGURE
Corsica
Sardegna
Canale di Sicilia
G. di Genova
G. di Venezia
Golfo di Taranto
Is. Eolie o Lipari
Ustica
Pantelleria
Metri
Scala

Fig. 1

Act), nor something like "CERCLA" (Comprehensive Environmental Response Compensation), and hence something like the relating "Superfund". Hence, there was not any effective instrument able to assign responsibilities about environmental contaminations and to attribute tasks and funds for any environmental restorations.

Therefore, to solve this specific problem, it was searched and reached an agreement among Lombardy Region Administration, ENEA, the Commune (Municipality) of Capriano del Colle (where the waste facility is placed), the Local Sanitary Organization (USSL 41 of Brescia, PMIPM) and the Owner of the waste facility itself.

By that agreement:

- ENEA would have set up the solutions to the problem of the restoration, chosen the technologies and prepared the project of the intervention with the corresponding procedures;
- the mentioned Committee would have approved, step by step, every single intervention;
- the Owner of the waste plant would have provided for the necessary funds and means necessary to carry on the restoration works;
- the local Sanitary structure (USSL) would have controlled the good execution of every step of the work;
- ENEA would have carried on the supervision of the whole work;
- the Mayor of the Commune of Capriano del Colle would have delivered the "ordinance" to carry on the works.

Therefore, in conformity with the above agreement, before the beginning of every step of the intervention, the plan of every single step and the related procedures would have been submitted to the approval of the local Town Council, which would have delivered an authoritative ordinance for the works carried on under the supervision of ENEA.

Hence, through a winding path, every single step of the intervention could be "imposed" by an ordinance of the above Municipality, which in such a way became, through the projects provided by ENEA, as a matter of fact, the actual "authority" for the intervention.

3. RATIONALE FOR REMEDY

Another very important problem the Committee had to solve, was whether it was necessary to send the contaminated waste elsewhere, or leave it in the place where it was already situated, and provide a suitable in situ intervention.

First of all, it is necessary to say that the reference regulation in Italy (DPR 185/64 and DPR 1303/69), does not suit well situations of spreading contamination caused by accidents in the environment: much more suitable were then considered, in that situation, the concentration limits recommended by the Group of Experts ex art 31 of Euratom Treaty (Nov. 1988). As it is well known, the Group has recommended an exemption value of 1 Bq/g as concentration limit for a free reutilization of materials coming from the decommissioning of nuclear plants.

In our case, the value of the average concentration of Cs137 was everywhere much lower than that limit, except in the basin No. 3, where an average concentration of about 10 Bq/g was found: a bit higher than the suggested limit.

But, as shown by the Cs137 vertical profiles, the most of the radioactively contaminated material was buried at some meters (5-8 m) under the surface of the basin 3, already naturally surrounded by the huge mass of the basins 2 and 4.

3.1. CS137 behavior in that material

In the rationale, it was very important to realize Cs137 behavior in the specific material in which it had been scattered, in order to understand its mobility and the amount of its fixation on that material itself.

The absorption of caesium by soil minerals has been studied by many authors, and the conclusions, from the present work's point of view, are that almost all of the caesium applied on a soil is rapidly adsorbed, particularly by clay minerals.

Studies on the distribution of solution-applied Cs137 showed that most of the nuclide remained in the upper one-inch of untilled soils, and was concentrated at 5-6 inches (the tillage depth) in the tilled soils; and that the mobility of the nuclide was least in soils having a high clay content. They reported that progressive fixation of Cs137 occurred on clay minerals, and was completed after three years from addition of the solution, and that there was a significant relationship between Cs 137 content and soil clay content.

Hence, after a solution containing Cs137 is added to a soil, it can be expected that the nuclide is strongly bound to clay minerals after a path of few cms in a soil, and that its subsequent movement and distribution chiefly depend on erosion, mostly caused by rainfall. It goes without saying that the nuclide diffusion may be affected markedly by agricultural and cultivation practices.

It was also reminded that a lot of soil, rich in clay, had been continuously added and mixed to the waste materials discharged (melting salts, the most of them consisting of fine powder), in order to prevent powder spreading in case of heavy wind. In other words, the waste could be considered like salts in a matrix of soil rich in clay.

3.2. The groundwater

Particular attention was set toward groundwater because of its great mobility in soil, in which it can quickly migrate and possibly transport contaminants, with the risk of reaching the aquifers underneath,

It is well known that caesium compounds have high solubility: hence the question was whether, by means groundwater, the nuclide could migrate outside the facility.

A deep study of the facilities of the waste plant had shown that it was a very tight system, with a good impermeable lining on the bottom and on the walls of every basin: every single basin can be considered a well controlled system, with a good lining (40 cm clay layer and a polyethylene sheet on the bottom; a whole protection with a polyethylene sheet on the walls of every basin), and with a suitable drainage, canalization and collecting network. A big tank is connected with the over-polyethylene-sheet drainage network; another little tank is connected with the under-polyethylene-sheet drainage network. The big one had been collecting all the groundwater caused by rainfalls during the discharging period: the little one had been ready to receive groundwater owing to incidental leakages on the mentioned polyethylene sheet.

Both the tanks had been found free of any caesium contamination.

3.3. What to do with the contaminated waste

The result of the above considerations, it was pointed out that the radioactively contaminated waste could be therefore seen as a confined "body" situated deep inside the mass of the waste, with the most of the radioactivity already shielded by the waste itself: something like a so called "shallow land buried waste disposal".

In that situation, it was realized that Cs137 could not be but still inside the waste itself, fixed to the clay fraction of the soil matrix, after a first mobilization owing to rainwater percolation: and that was why it had not been found neither in the drainage network, nor elsewhere but inside some of the deep waste layers, where it had been directly discharged.

It became hence evident that it was necessary to direct all our attention towards avoiding any spreading of the contaminated material in the environment, as it could happen for heavy weather conditions: therefore, it seemed to all of us that the most suitable intervention was to "seal" as soon as possible the part of the waste still exposed to atmospheric agents with an effective cover, able to guarantee a good impermeabilization and resistance to erosion.

On the other side, it was unthinkable to remove and put elsewhere such a big quantity the radioactively contaminated material: first of all, because of the prohibitive cost of such an operation; then, because it would have otherwise put the radioactively contaminated material again in contact with the environment, with an high probability of causing spreading of it all around. In other words, this kind of intervention would have caused risks and inconvenience to the public, resulting furthermore in a very expensive action, with a cost of many millions of dollars.

In conclusion, it was considered that the radioactively contaminated material was already placed inside a waste disposal (that is a final waste storage plant - II category, type B, DPR 915/82 - for some specific industrial waste), in an actual situation that could be very well controlled and where a suitable "in situ" securing intervention could be carried out, minimizing the costs through proper planning, co-ordination and management of the activities.

3.4. The public opinion impact

The public opinion impact was not a minor aspect of the problem.

As a matter of fact, the local newspapers had been emphasizing the incident as "a nuclear disaster", and was therefore necessary to give space to the right information and search the public approval for the solutions proposed, before any important action could be carried out.

With that purpose in mind, some lectures and meetings with local population and local administrations were delivered, in order to make them be aware of the actual risks connected with that radiological contamination in that peculiar situation and, on the other hand, in order to make the main characteristics of the proposed intervention known to them.

The purpose of those meetings was also to receive as many suggestions and indications as possible by local people, which of course had a good knowledge of the facts; but the very aim of the meetings was to involve as much as possible the population in the problem, in order to prepare a project with the population's agreement.

As matter of fact, the agreement came, and the local Town Council was able to start approving the project presented by us.

4. THE PROJECT

In order to answer the above considerations, a project was developed together with a proper planning, co-ordination and management of activities, as well as the corresponding costs.

The project was based upon a good protection of basin n 3, and in particular of its slope, against erosion, and in fig. 2 and 3 are indicated the proposed standard cross section and the depths of the covering layers for each basin. Great significance was given to the surficial rain-water collecting network, able to convey all the surficial rain water outside the waste facility, in order to preventing any consistent erosion of the protective layers.

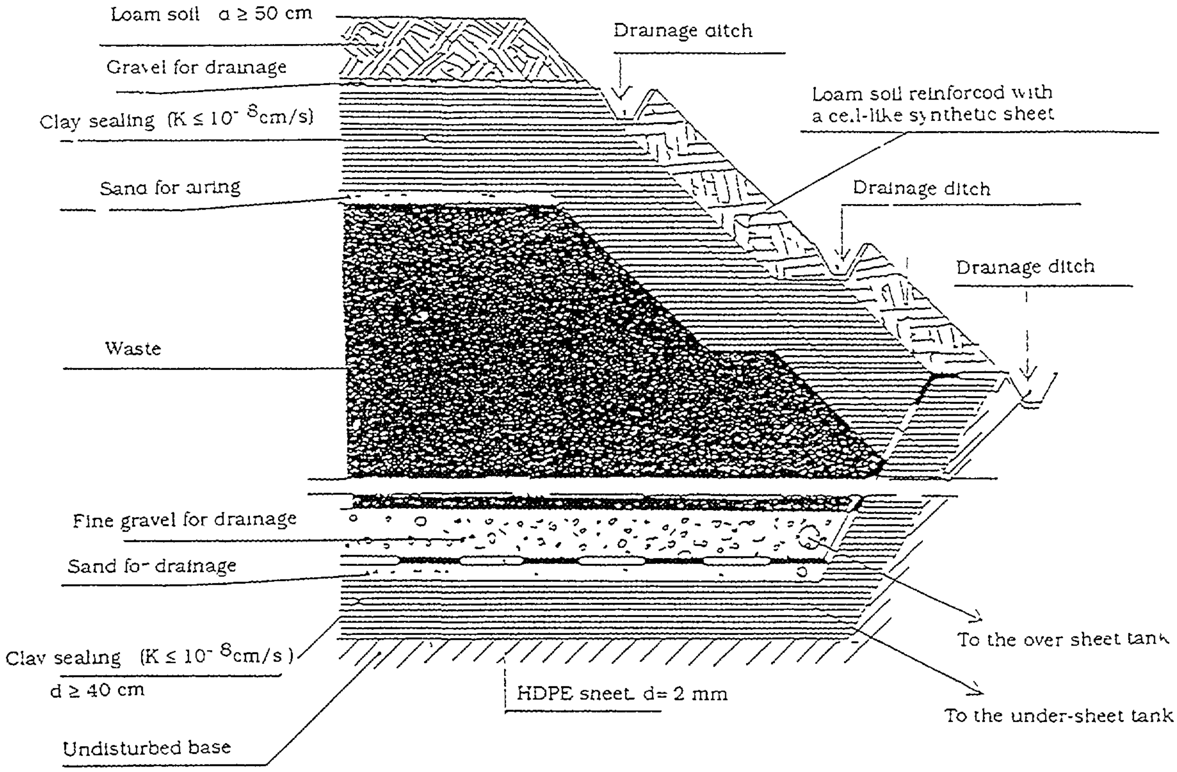


Fig. 2. Standard cross section of basin 3

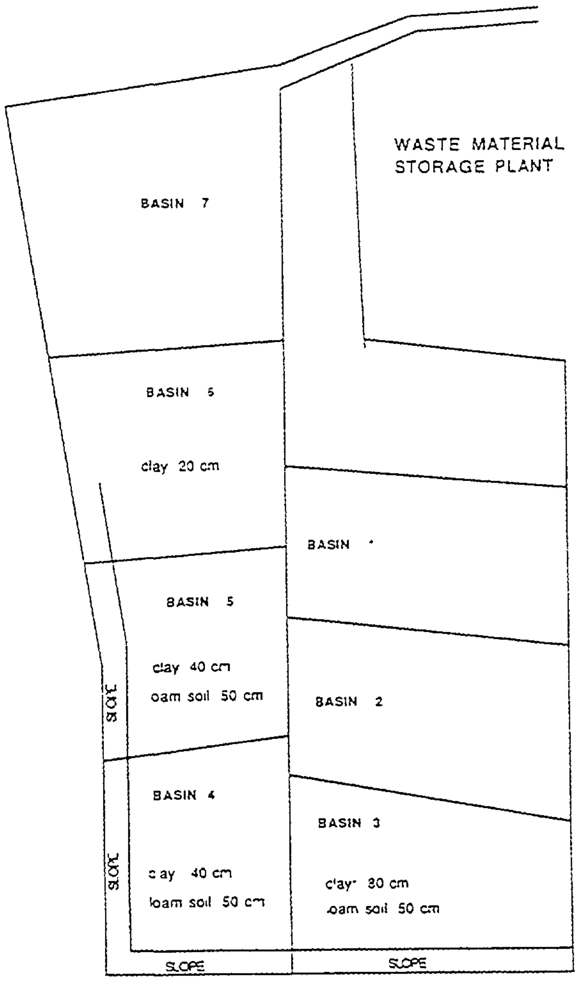


Fig. 3. Depth of the covering layers in each basin.

The very heart of the intervention was of course the clay layer-seal, owing to its absorption characteristics related to caesium: great care was hence devoted in choosing the proper clay, which had to be characterized very well, before and after its deposition and compactization.

As it is shown in fig. 4 and in Table 1, the whole area involved was divided in twenty-four portions, and for each of them the duration, the beginning and the type of works were planned.

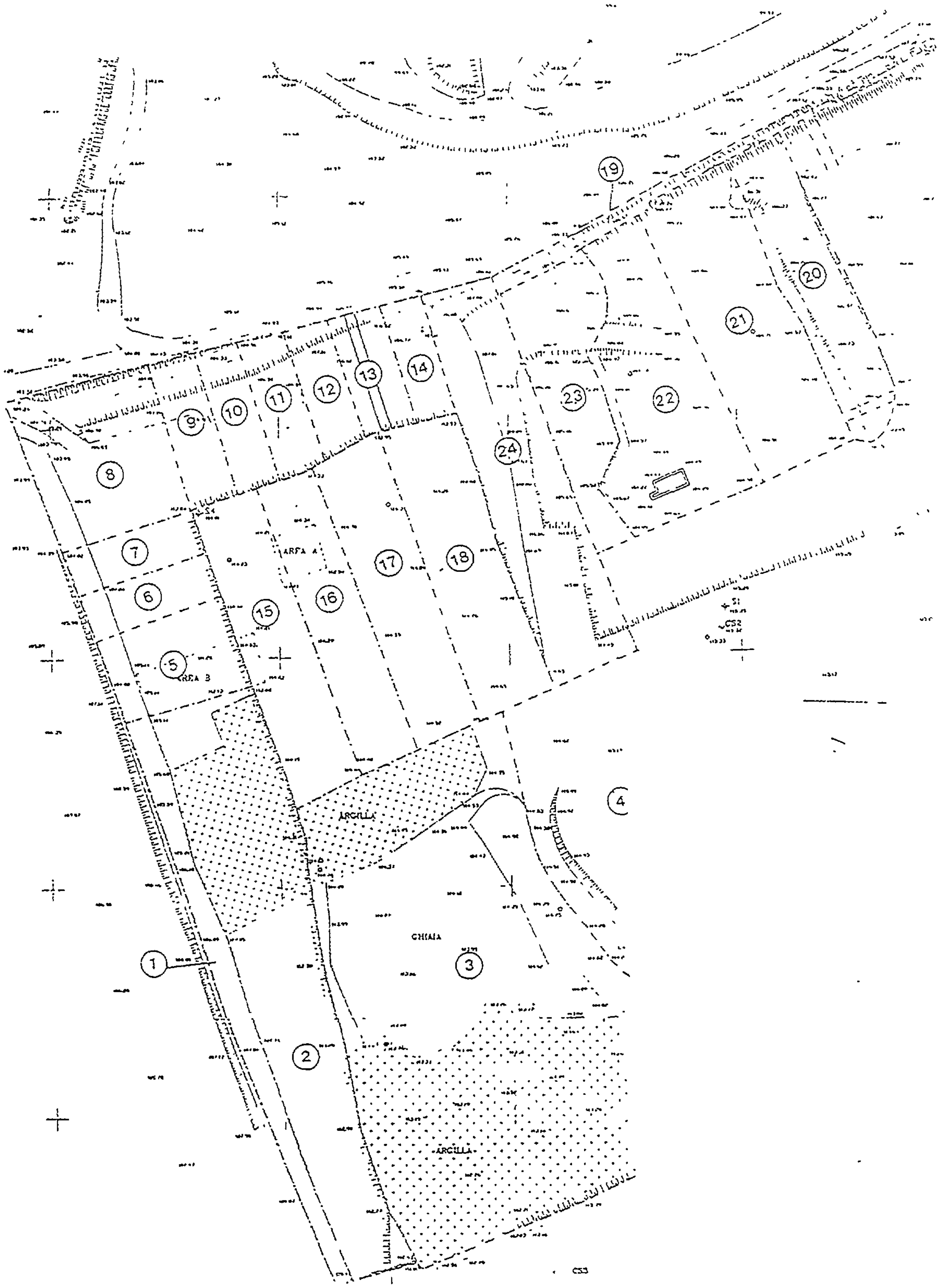


Fig. 4. Delineation of the areas for each single action.

Table 1

Schedule of the actions

Zone	Time required	Beginning of the works	Type of action
1	2 gg	04.02.91	Bottom drainage ditch construction
2	2 gg	06.02.91	Preparation of the slopes
3	2 gg	08.02.91	Preparation of the plain surface
4	4 gg	12.02.91	1Plain surface sealing
5	1 gg	18.02.91	Bottom drainage ditch constr./layers depos.
6	1 gg	19.02.91	Bottom drainage ditch constr./layers depos.
7	1 gg	20.02.91	Bottom drainage ditch constr./layers depos.
8	2 gg	21.02.91	Bottom drainage ditch constr./layers depos.
9	1 gg	25.02.91	Bottom drainage ditch constr./layers depos.
10	1 gg	26.02.91	Bottom drainage ditch constr./layers depos.
11	1 gg	27.02.91	Bottom drainage ditch constr./layers depos.
12	1 gg	28.02.91	Bottom drainage ditch constr./layers depos.
13	1 gg	01.03.91	Bottom drainage ditch constr./layers depos.
14	1 gg	04.03.91	Bottom drainage ditch constr./layers depos.
15	1 gg	05.03.91	Middle drainage ditch constr./layers depos.
16	1 gg	06.03.91	Middle drainage ditch constr./layers depos.
17	1 gg	07.03.91	Middle drainage ditch constr./layers depos.
18	1 gg	08.03.91	Middle drainage ditch constr./layers depos.
19	2 gg	11.03.91	Bottom drainage ditch -tank connections
20	2 gg	13.03.91	Layers depositions on basin 6
21	2 gg	15.03.91	Layers depositions on basin 6
22	2 gg	19.03.91	Layers depositions on basin 6
23	2 gg	21.03.91	Layers depositions on basin 6
24	2 gg	25.03.91	Final restoration touch

Some precautions against risks of swelling, that could rise for gas production in the mass of waste, were taken: therefore, a deposition of a thin sand-gravel layer between the clay and loam layers on the top, and between the waste and the clay layer in the middle, both connected with some proper ventilation openings, was decided.

The cost of any single action and of the whole intervention was then calculated, and resulted about US $ 700.000 (1991).

The final restoration action consists in a continuous deposition of 50-80 cm loam soil layer, on which to plant a field with grass.

5. CONCLUSIONS

Before the final restoration action, a proper planning, co-ordination and management of activities was developed.

The choice of the type of intervention arose from the great amount of waste involved in the radio-contamination, and from caesium behavior in that very material.

Hence, an intervention based on a complete sealing of the waste with a proper clay layer was decided, with many precautions against heavy weather erosion.

A final restoration action made of a continuous loam soil layer, on which to plant a field with grass, was then planned and proposed to the Technical Committee approval.

REFERENCES

[1] Antonioli F., Bocola W. (1983): *Esperienze sulla migrazione di Cs, Sr e I in argille prelevate in alcuni bacini italiani* - ENEA/RT/PROT(83)4.

[2] Antonioli F. et al. (1985): *Element diffusion and oxidation phenomena along permeable fractures in clay formations at Monterotondo, Italy* - Proceedings of the International Clay Conference, Denver, 1985 - The Clay Minerals Society, Bloomington, Indiana, 415-421(1987).

[3] Beone G., Carbone A. I., Zagaroli M.: *La bonifica di aree contaminate* - ENEA/RT/PAS/88/31.

[4] Carlsson S. (1978): *A model for the movement and loss of Cs137 in a small watershed* - Health Phys. Vol 34, pp 33-37.

[5] Coleman N.T. et al. (1965): *Ion exchange displacement of caesium from soil vermiculite* - Soil Sci. - Vol. 99, pp. 243-250.

[6] Cochi C. et al. (1989): *Programma di intervento per la messa in sicurezza della discarica di Capriano del Colle (BS) - Messa in sicurezza meteorica - Specifica tecnica* - ENEA- AMB-RIF-CRIA

[7] Cochi C. et al. (1990): *Programma di intervento per la messa in sicurezza della discarica di Capriano del Colle (BS) - Piano di prelevamento di campioni nel corpo della discarica - Prescrizioni tecniche* - ENEA- AMB-RIF-CRIA.

[8] Cochi C. et al. (1990): *Programma di intervento per la messa in sicurezza della discarica di Capriano del Colle (BS) - FaseIII - Copertura finale - Prescrizioni Tecniche* - ENEA- AMB-RIF-CRIA.

[9] Daniel D. et al. (1986): *Field permeability test for earthen liners* - Proceedings of a Specialty Conference on Use of in Situ Tests in Geotechnical Enginneering - Geotechnical Special Publication - Samuel P. Clemence Editor - pp. 146-160.

[10] Jones et al. (1986): *Development of waste containment structure for Niagara Falls storage site* - Canadian Nuclear Society: Conference Proceedings of 2nd International Conference on Radioactive Waste Management - Sept. 7,11,1986.

[11] Paris P. (1989): *Una valutazione di limiti di concentrazione non pericolose per lo smaltimento dei rifiuti radioattivi in una discarica superficiale* - ENEA DISP/SER/NOR-RT(89)6.

[12] Pegoyev A. and Fridman D. (1978).: *Vertical profiles of caesium 137 in soils* - Soviet Soil Sci., Vol. 10, pp. 468-472

[13] Polyakov Y.A., Kader G.M. and Krintskii V.V. (1973): *Behavior of Sr 90 and Cs137 in soils* - Radioecology, pp. 78-102. Wiley, New York.

[14] Rogowski A.S., Tamura T. (1970): *Environmental mobility of Cs137* - Radiat. Bot., Vol 10, pp. 35-45.

[15] Saltelli A., Antonioli F. (1985): *Radioactive waste disposal in clay formations: a systematic approach to the problem of fractures and faults permeability* - Radioactive Waste Management and Nuclear Fuel Cycle - Volume 6(2), June 1985, pp. 101-120.

[16] Sawhney B.L. (1966): *Kinetics of caesium sorption by clay minerals* - Soil Sci Soc. Am. Proc., Vol 30, pp. 565-569.

[17] Tamura T. (1964): *Selective sorption reactions of caesium with soil minerals* -Nucl. Saf., Vol 5, pp. 262-268.

[18] Amm.ne Prov.le di Brescia (1989): *Indagine idrogeologica dell'area interessata da inquinamento di cloruri e di potassio nei comuni di Capriano del Colle e Poncarale - rapporto conclusivo.*

[19] Ditta Metalli Capra (1990): *Comunicazione personale e foto di stati di avanzamento dei lavori.*

[20] U.O. Fisica e Tutela Ambiente - P.M.I.P. di Milano - U.S.S.L. 75/III - Sezione di Radioprotezione - *Relazione Tecnica: Risultati delle analisi di radiocontamina-zione sui campioni di residuo prelevati presso la discarica Montenetto di Capriano del Colle (BS)* - Milano, 8 November 1991

PLANNING FOR ENVIRONMENTAL RESTORATION OF CONTAMINATED AREAS IN ROMANIA

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Abstract

Presently, in Romania several human activities can imply the enhancement of the concentrations of the natural radionuclides which could lead to potential detriment to the public.
Here, we are referring to the great producers of radioactive wastes: uranium ore mining and milling fertilizer industry and coal-fired power plants.
The most significant contribution to the radioactive contamination is produced by mining and milling of uranium ore; the percent of uranium and the necessaries founds are presented for the five areas of interest. In addition a case study on the implementation of remedial actions is offered.
The contributions of the fertilizer industry through its most radioactive by-product, phosphogypsum, and coal-fired power plants are under evaluations, a number of studies being in work. in this connection some preliminary results on the rationale and goal for cleanup are presented, no remedial actions being implemented so far.

1. IMPLEMENTING OF REMEDIAL ACTIONS IN THE URANIUM ORE MINING AND MILLING

The most significant contribution to radioactive contamination in Romania is produced by mining and milling of the ore containing uranium and its decay products. The first radioactive ore mine have started to work during 1952- 1953.So far the waste rock dumps and uranium ore heaps are located in five areas,[1],[2].

	waste rock dumps (m^2)	uranium ore heaps (m^2)
Bihor	529 300	16 600
Banat	209 500	1 000
Crucea	364 000	-
Tulges	156 847	1 400
Alba Iulia	122 300	500

In addition the milling plant from Feldioara storage the mill tailings in two large ponds. Its storage capacity is of 350 000 m3, roughly half has been used so far.

1.1 Rationale and Goal for Cleanup

In Romania Rare Metals Autonomous Administration have been developed a number of studies on the opportunities and the possibilities offered by the environmental restoration actions [3] .All the methodologies developed so far forecast that the heaps will be covered by a vegetal soil strata. According to Rare Metals Autonomous Administration the percents of the uranium in low grade ore and the necessaries founds in US $ for remedial actions are as below:

Bihor	0.03- 0.04% U	-	500 000
Banat	0.02 % U	-	150 000
Crucea	0.02- 0.04% U	-	250 000
Tulges	0.01- 0.02% U	-	100 000
Alba-Iulia	0.02% U	-	-

1.2 CLEANUP CRITERIA FOR A CASE STUDY

Here are some elements on an environmental restoration measures as were applied for the uranium ore heap from Barzava [4].
The uranium ore was extracted at Barzava during 1965- 1968 when low uranium ore heap and waste rock dumps were stored in the neighborhood of village Barzava. The low grade uranium ore heap, 7 000 m.c. is located roughly half a kilometer away from the railway station between Barzava river and Mures river. In order to be stabilized against unfavorable weather conditions the heap was covered with 5 cm. thickness concrete layer. After a number of years were performed analysis on radioactive contamination and cancer morbidity in Barzava village as preliminary criteria for cleanup. It was found a gamma dose rate of 1- 2 μSv/h in the top of the heap and in some places nearly 9 μSv/h. This studies have not revealing any exceeding of underground water concentration limits and at same time soil, vegetation and river's sediment samples had activity mass concentrations below the prescribed limits; in addition no cancer case was recorded.

The implementation of cleanup had consisted in two stages:
(i) the transport of the low uranium ore heap from Barzava to the milling plant and
(ii) returning the area to public use by a carefully decontamination actions of the ground.
These phases were satisfying carried out, so the Derived Intervention Levels after restoration were found as been in accordance to national, [5], and international, [6], regulations.

Generally, supplementary elements will be taken into account in the near future in order to establish a comprehensive cost-benefit analysis for the uranium ore heaps and waste rock dumps.

2. CONTAMINATED AREAS RESULTED FROM THE CHEMICAL PHOSPHATIC FERTILIZER INDUSTRY

The phosphate fertilizer industry produce several by- products which could provide an additional exposure to the population.
The main contribution to this supplementary exposure is owing to the phosphogypsum. From one ton of raw material are produced roughly 600 Kg of wastes mainly phosphogypsum.
The storage of phosphogypsum in dumps rises major ecological problems. In Romania are large quantities of phosphogypsum,over 500 000 tons are yearly produced, stored in dumps near the four plants each of them being located near human agglomerations. The four dumps mentioned are: Valea Calugaresca - 5 million tons on an area of 29 hectares-, Navodari- 4-5 million tons on an area of 40 hectares-, Bacau- 5 million tons on an area of 17 hectares- and Turnu Magurele - 5 million tons on 20 hectares).

2.1 RATIONALE AND GOAL FOR CLEANUP; CLEANUP CRITERIA

Several research programs are initiated in Romania for the assessment of radionuclide concentrations in phosphogypsum wastes and its ecological impact.

As a primary evaluation of the source term, were found the following concentrations of the natural radionuclides in the samples taken from the four areas mentioned:

Places of the collected samples	Activity mass concentrations (Bq/g)		
	U-238	Th-232	Ra-226
Valea Calugaresca	0.14	0.009	0.319
Bacau	0.12	0.002	0.530
Navodari	0.32	0.007	0.340
Turnu Magurele	0.20	0.010	0.481

The main radionuclides suspected for the public exposure is Ra-226 and its decay products. Thus, the above values for Ra-226 should be multiplied by an factor which take into account the decay products of Ra-226. So, the total activity mass concentrations of radium in phosphogypsum become 3.83 Bq/g for Valea Calugareasca and 4.08 for Navodari. This concentrations range between 6 and 10 % for the maximum activity mass concentration limits (64 Bq/g) stipulated in national regulations. So far, with one exception - an unfinished attempt to stabilize the dump from Bacau)- no remedial action was performed.
However, a number of studies are oriented toward the use of phosphogypsum as a building material instead of natural gypsum, from an economical point of view phosphogypsum is cheaper than natural gypsum [7].

Despite of these efforts, the high content of phosphogypsum induces great concentrations of radon decay products inside the houses. In this connection the Ministry of Health have decided to interdict the use of phosphogypsum as a building material. Anyway the environmental impact of phosphogypsum remain an important field of research in this respect, future tendencies could provide additionally elements on this matter.

3. CONTAMINATED AREAS DUE TO THE COAL-FIRED POWER PLANTS

Generally, the coal used in thermo-electric power plants contains small traces of radionuclides, K- 40, U-238, Ra-226, Pb- 210, Po-210, Th- 232, Th- 228. Owing to the elimination of the organic components from coal the activity of the natural radionuclides in the escaping flying ash is an order of magnitude enhancement. Nearly 35% of energy production in Romania are based on coal use.so a supplementary exposure is expected around the coal-fired power plants.

3.1 RATIONALE AND GOAL FOR CLEANUP

A research program, [8], for radioactivity monitoring have been implemented since 1983 around the following coal-fired power plants:

(i) modern power plants; Holboca- Iasi, Doicesti II, Mintia, Onesti II, Suceava, Timisoara, and Vaslui.

(ii) old power plants; Comanesti, Doicesti, Ovidiu II.

In this frame the potential detriment to the public depend on a number of factors only some of them have been considered so far.

In order to assess the source term were performed measurements of activity concentrations of the natural radionuclides in coal (182) samples, bottom and flying ash (720) samples. Vegetation and snow samples (800) have been collected at 20 locations from the environment of each coal-fired power plant within 5 Km. radius from the station.

A total ash production of 0.72E+009 Kg annually for the old power plants (with 0.18 GW cumulative installed power) and 12.2E+009 Kg annually for the modern plants (with a installed power of 2.18 GW). From these values certain fractions are released into the atmosphere as flying ash. By comparison to the concentrations of U-238, Ra-226, Th- 232, K- 40, in the coal samples the activity concentrations in escaping fly ash are given as below:

Activity mass concentrations of natural radionuclides in the fly ash (*) and enrichment factors (EF) **

	K-40	U-238	Ra-226	Pb-210	Po-210	Th-232	Th-228
average	547	80	126	210	262	62	79
maximum	1300	415	557	510	580	170	175
(EF)max	-	3.3	2.6	-	-	1.8	-

(*) Bq /Kg

(**) $EF = \frac{(x)sample \ / \ (K\text{-}40)sample}{(x)coal \ / \ (K\text{-}40)coal}$

where (x)sample is the concentration of the radionuclide in escaping flying ash, and (K-40)sample is the concentration of K- 40 as a reference value - remains more or less constant in all types of ash; (x)coal and (K-40)coal are the correspondents concentrations for the coal.

The emissions of Rn-222 and Rn-220 in the environment must be separately estimated, because the radon can not be retained by the filters. Thus, the activity range of Rn-222 and Rn- 220 released per GW annually have been assessed at 25 to 770 GBq. This research program have emphasized the increased radioactivity in the proximity of the coal- fired power plants, and on the same time the related public exposure [8],[9].
Faced with this situation, supplementary analysis were performed in order to lay down the environmental levels for which cleanup measures are required.

The main pathways for public exposure are inhalation during the cloud passage and external irradiation and ingestion resulting from deposited activity on the ground. The average activity concentrations of the natural radionuclides in soil, vegetation and snow samples were found higher than the local background:

radionuclide	Average activity in soil, vegetation and snow samples.			
	Soil (Bq/Kg) (layer)		Vegetation (mBq/kg)	Snow (mBq/Kg)
	5cm.	5-15cm.		
U-238	30±30	26±25	51±46	4.2±3.1
Ra-226	38±30	30±27	308±75	26±20
Th-232	36±17	29±16	83±61	2.5±1.5
K-40	538±180	420±170	450000	448±400

The individual and collective doses received by the population in these areas were assessed by considering:

(i) the activity released per unit of produced electric energy
(ii) the population density
(iii) the wind rose and the seed of the fall-out
(iv) the effective height of the plant evacuation funnel

The highest value was found for Comanesti 76 man*Sv per GW annually and the lowest value for Suceava power plant, 0.24 man*Sv per GW annually. According to the UNSCEAR 1988 Report /21/ [10] the collective effective dose equivalent commitments (CEDEC) values for Romania are 5-10 times higher.

At this stage, global environmental restoration plans are not available, further cost-benefit analysis should be performed. In this connection loss of wages and economical output for the areas considered might be a major problem.

The present remedial actions in this field consist mainly in the industrial coal ash applications, the most important being this utilization in the cement and concrete fabrication. It is quite difficult to have a comprehensive image on the magnitude of these implications. For example the usage of flying ash in concrete fabrication can produce an additional exposure of roughly 30 uSv per year for the people living in the houses built of concrete and a enhancement of radon exposure from the walls,[11].

4. CONCLUSIONS

1. In Romania, several technological human activities can increase the natural exposure of the population, among these the great producers of radioactive wastes are the uranium ore mining and milling, chemical phosphatic fertilizer industry and the coal-fired power plants.

2. The highest contribution to the radioactive contamination are waste rock dumps and low grade uranium ore heaps, a clean up action was performed at Barzava village.

3. A number of programs are under development both in the field of by-products from phosphatic fertilizers ,i.e phosphogypsum , and on the coal- fired power plants ecological impact.

4. Further tendencies might provide more detailed cost-benefit analysis, in this respect several research projects are under development.

REFERENCES

[1] Sandru, P., " Considerations on some radioactive areas in Romania, potential subjects for environmental restoration "; The IAEA Technical Co-operation Regional Project for Environmental Restoration, First Workshop Budapest,4-8 October 1993.

[2] Bejenaru,C., Caplan, M., Hostuc, P., " The situation of the wastes resulted by uranium ore dressing, mining exploitation and exploration", Report, Bucharest, (in Romanian),1993.

[3] Dinca, G., Peic, T., Sandor, G., " Radioactive contamination

and cancer morbidity in Barzava village ", (in Romanian), 1992.

[4] Ghilea,S., Coroianu,A.,Fekete,I.," Environmental radioactive contamination caused by uranium ore mining in Romania", paper presented at CEC International Symposium on Remediation and Restoration of radioactive-contaminated sites in Europe; Antwerp,1993.

[5] Republican Nuclear Safety Norms for Geological Exploration, Mining and Milling of uranium ore, (in Romanian),1975.

[6] Republican Nuclear Safety Norms- Norms for Radioprotection, State Committee for Nuclear Energy, (in Romanian), 1976.

[7] Bunus,F., Dumitrescu, R., " Radioactive areas due to fertilizer industry ", Bucharest,1993.

[8] Botezatu, E., Toro, L., Botezatu, G., Capitanu, O., Rascanu, V., Aghiorghiesei, D., Balaban,D., Peic,T., Dinca,G., Stoicescu,G., " Coal-fired power plants as a source of population exposure", Radiation Protection national Conference, Oradea 1993.

[9] Botezatu, E., et.al. " Validation of population doses depending on filtering efficiency in coal-fired power plants", Bucharest 1991.

[10] UNSCEAR Report 1988 Annex A.

[11] Oncescu, M., Dinca, G., Milu, C., Sonoc, S., Sandru,P., Chiosila, I., " Natural radioactivity in Romania ", Bucharest,1994.

PLANNING AND PREPARATION FOR ENVIRONMENTAL RESTORATION OF RADIOACTIVELY CONTAMINATED SITES IN RUSSIA: STATUS, PROBLEMS AND OUTLOOK

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Abstract

As shown in previous analitical review [1], in a number of other recent publications (eg. see [2-5]) and some official declarations [6,7], the radiological situation in Russian Federation is sufficiently tense and versatile. As things now stand, heightened attention (both on official and everyday levels) to the problems of radiation protection and rehabilitation of contaminated sites is fully explainable. Because of a number of objective reasons, only of late Russian government, Navy and industry have become active and open in initiatives to identify, remediate and prevent radioactive contaminations. With all this it would be incorrect to assert that nothing was undertaken to improve the situation. However, there still exists vast scope for further urgent and goal-oriented actions in this vital field.

This paper describes key principles of regulatory framework, hierarhy of organizational structure and the present status of Federal and regional restoration programmes with emphasis on actual problems of planning system.

1. BACKGROUND

The question of preparedness for productive remediation activity is, first of all, a question of (1) thought-out and ballanced regulatory basis; (2) well-grounded methodology of planning and decisions making;(3) ablebodied, co-ordinated and effective management system; (4) reliable mechanisms and tools (including proper financial support) for practical realization of selected projects and (5) effective scheme of supervision and control.

Examining specific problems of national strategy in the field of environmental restoration it is necessary to take into consideration general political and socio-econmic situation within the country. Today Russia is in "transfer" stage, and peculiarities of this period of time, undoubtedly, influence all aspects of economic activities including planning and implementation of restoration programmes.

Habitual and, at the first glance, very reliable organizational system existed in the former USSR turned out to be unfit for the new conditions. It is enough to mention, for instance, that from 328 regulatory documents on atmosphere protection, only 8 were accepted without changes, 26 were canceled, and 291 were recomended for revision [8]. The list of the main standards, norms, guides, etc. on radioactively and/or chemically contaminated sites consists of around 150 items [9], and these documents frequently are not coordinated with each other. Every year NPPs are obliged to present six different reports on the same subject - environmental safety - to four different departments [6] which do not co-ordinate their plans and requirements. It is also significant that no one from 34 respondents (including representatives of some key Ministries), already answered a questionaire*, is satisfied with the levels of co-ordination and information on radioecological activity in the country. The main aim of the above examples is just to illustrate correctness of the following conclusion:

for the time being progress in the field of environmental restoration of radioactively contaminated sites in Russia is hindered by the

- *lack of financial resources*
- *imperfection of legistative basis*
- *lack of co-ordination*
- *temporary uncertanties in organizational structure and in distribution of responsibilities between governmental bodies involved.*

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* In the beginning of 1994 specialized "radioecological" questionaire has been prepared and distributed by the specialists of St. Petersburg Institute of Technology (SPbIT) as a part of initiative Departmental project and in support of the IAEA TC Project RER/9/022. The results of inquest in analytical form are expected to be available in November-December 1994.

With all this, it is very important to stress that the target of the present efforts is not an absolute new infrastructure, but rather modification of and improvements in existed system. Russia has an unique experience in restoration activities and practically all necessary components to solve this complex task successfully. To confirm this, it would be useful to compare internationally agreed recommendations on preliminary planning for a potentially affected area [10] with the corresponding practice in Russian Federation (see Tables I, II and Annex I). The more detailed analisis of the various sections of planning system is presented below.

2. DOCUMENTARY FRAMEWORK

In general, all activities on environmental restoration and waste management are regulated by the three-level documentary scheme (Fig.1) which is, when all is said and done, a basis for planning and final decisions making.

2.1. NATIONAL CONCEPTION

The upper level of the scheme - National Conception - defines the general strategic approach to the problem of radiological protection and organization of safe economic activities (if possible) at radioactively contaminated territories. The key principles of this approach are reflected in the document entitled "Conception of Radiation Protection of Population and of Economic Activities at Radioactively Contaminated Territories" [13], which has been elaborated by the experts of the State Committee on Sanitary-Epidemiological Supervision (SCSES), reviewed and approved by the Russian National Commission on Radiological Protection (RNCRP), and issued by the Ministry of Health (MH) in May 1993. Conception [13] is based on national experience, and on fundamental rules and methodology of radiation protection described in the publications of ICRP, WHO, INSCEAR and IAEA. It consists of the following chapters:

(a) Scope (introductory explanations).
(b) Medico-biological consequences of radiation exposure.

TABLE I. PRELIMENARY PLANNING FOR A POTENTIALLY AFFECTED AREA. COMPARAISON OF INTERNATIONAL AND DOMESTIC SCHEMES

Information which should be gathered in accordance with recommendations [10]	Availability of corresponding information/means in Russia. Responsible authorities/organizations
1	2
Demographic data	Available. State Committee on Statistics/Regional Divisions.
Layout of sites/towns, including areas/facilities requiring special attention	Available. Ministry of Environment and Natural Resources (MENR)/Regional Divisions of the State Committee on Geology and Depths Exploitation (SCGDE)/Regional Executive Bodies.
Land classes and usage	Available in principle. State Committee on Land Resources and Land Usage (SCLRLU)/Regional Executive Bodies
Geology and hydrogeology of the area	Available. SCGDE/Regional authorities
Background environmental monitoring data base for the area	Available for majority of populated areas. The new Unified State System of Ecological Monitoring is in progress (Chief-coodinator - MENR; participants - 19 Ministries and Committees [11]).
Type of geographical co-ordinate grid system for the area	Available. Russian Committee on Cartography (RCC)/Regional Divisions
Appropriate sampling and monitoring plans for different zones in the area	Available. State Committee on Sanitary-Epidemiological Supervision (SCSES)/Regional Divisions of SCSES
Locations of critical areas of rever/lake systems and critical downstream drinking water supplies	Available in principal. Committee on Water Branch (CWB)/Regional Divisions/Regional Executive Bodies

1	2
Actions which may have to be taken shortly after the accident	Available. State Committee on Civilian Defence, Emergency Situation, and Liquidation of the Consequences of Natural Disasters (SCCDESLCND)/Ministry of Atomic Power (MAP)/Facilities/Regional Authorities.
Cleanup criteria and other regulatory and radiation protection information	Available but required improvements. SCSES/State Committee on Nuclear Regulations (SCNR)/Ministry of Health (MH)
Organizational aspects of managing the cleanup plan	Available in some regions. More attention should be paid.
Analysis of preferable cleanup options for each area	Responsibility of regional authorities/facilities owners and control bodies
List of equipment and facilities required for cleanup and locations of available items. Assessment of personnel requirements	Responsibility of regional authorities
Cost-risk analysis data	Good basis was elaborated by the Nuclear Safety Institute of Russian Academy of Science (NSI RAS) [12]. Further efforts are necessary
Overal quality control programme requirements	Available in principle. Regional Divisions of SCNR/SCSES/MH

(c) Principles of radiation protection of population.

(d) Categorization of radioactively contaminated territories.

(e) Principles of safe economic activities.

(f) Recommendations to the inhabitants living in contaminated areas.

In accordance with Conception [13] radioactively contaminated territories are devided in four categories/zones (Table III). The main criterion is annual dose limit, i.e. average effective dose for critical group of inhabitants or additional potential exposure due to man-made radionuclides.

TABLE II.PRESENT STATUS OF THE CENTRAL DATA BASE ON TERRITORIES CONTAMINATED IN CONSEQUENSE OF RADIATION DISASTERS [12]

	Localities	Agricultural land	Forests	Atmosphere	Water	Soil	Raions	Regions	Zones
Administration	■	■					■	■	■
Geographical coordinates	■			■	■	■			
Socio-economic data			■				■	■	■
Radioactive contaminations	■	■	■			■	■	■	■
Radioactive contamination of food	■	■					■	■	
Chemical contaminations		■		■	■	■	■		
Chemical contamination of food		■					■	■	
Doses	■						■		■
Demography							■	■	
Medical statistics								■	

■ - implemented

- in progress

Economic activity in zones of radiation control ($1 \text{ mSv/a} < D \leq 5 \text{ mSv/a}$) and zones of voluntary evacuation ($5 \text{ mSv/a} < D \leq 50 \text{ mSv/a}$) is admissible, but only at the following conditions:

- it should be highly profitable and environmentally clean technology
- radiation safety of personel should be guaranteed.

Construction of dwelling houses, public and industrial buildings in zones of radiation control is not restricted, except

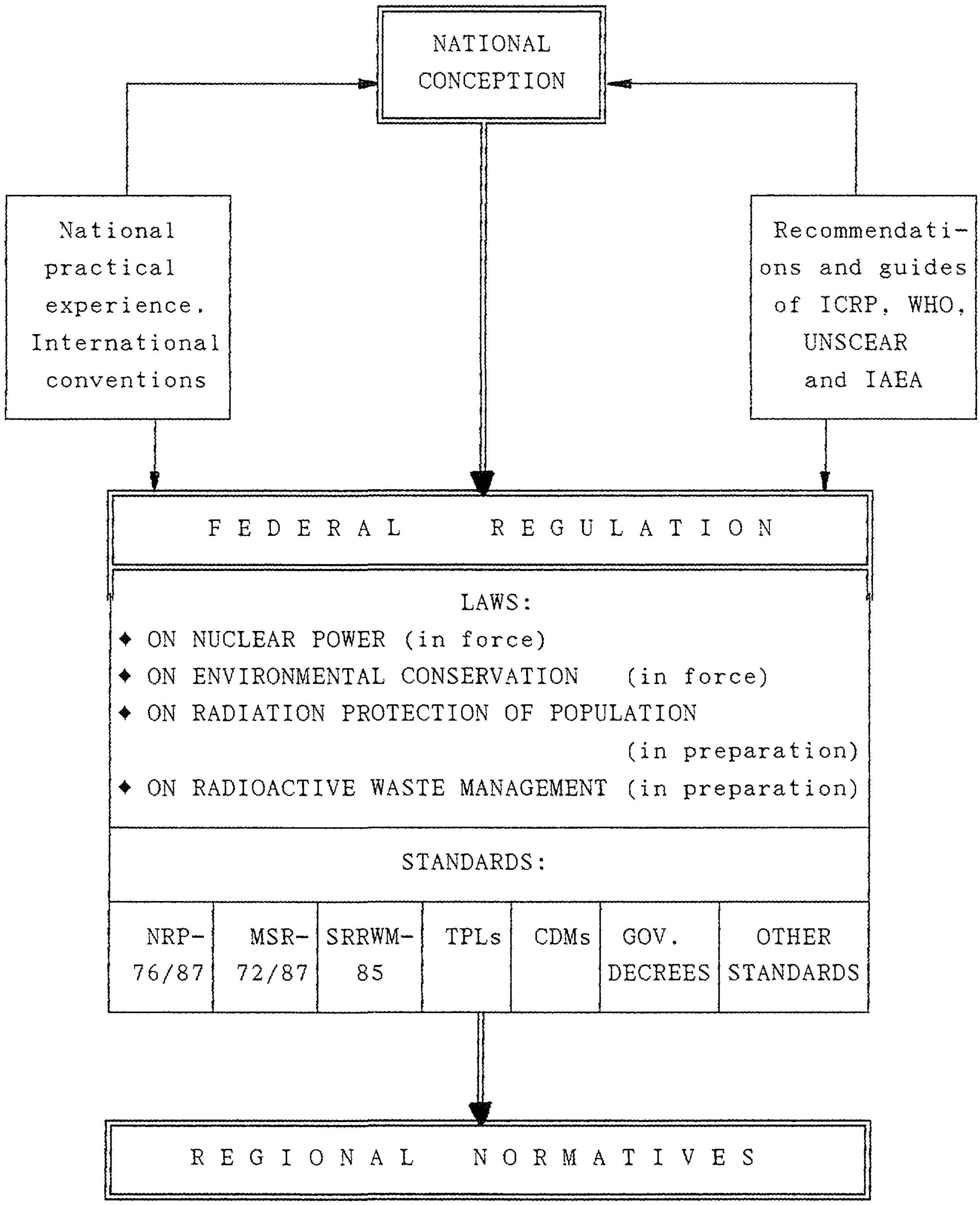

FIG. 1. General scheme of documentary framework.

TABLE III. CATEGORIZATION OF RADIOACTIVELY CONTAMINATED TERRITORIES IN ACCORDANCE WITH NATIONAL CONCEPTION [13]

Dose limit (EDE)	Category	Measures required
$D < 1$ mSv/a	Zone of unristricted use	Routine monitoring of environment and food
1 mSv/a $< D \leq 5$ mSv/a	Zone of radiation control	Radiation monitoring and protective measures
5 mSv/a $< D \leq 50$ mSv/a	Zone of voluntary evacuation	Radiation monitoring, protective measures, explanation of potential health risk to the public and rendering of assistance in voluntary evacuation
$D > 50$ mSv/a	Zone of estrangement	Residence is forbidden, economic activity is regulated by special documents

those which can influence environment negatively. In zones of voluntary evacuation it is not recommended to build a new settlements and recreation centers.

The main measures, providing lowering of radiation exposure to inhabitants of contaminated territories, involve:

- evacuation of inhabitants
- estrangement of contaminated territory (part of territory) or limitation of residence and activities of inhabitants in this area

- decontamination of territory, buildings and other installations
- special agricultural measures to diminish concentration of radionuclides in local food-stuffs
- processing of local food-stuffs to obtain radiologically pure food, and providing of local inhabitants with radiologically pure food from noncontaminated regions
  - introduction of special rules into the practice of daily life and economic activities of inhabitants.

At the stage of decisions making all the above measures have to be optimized taking into account possible negative consequences of protective action, e.g. psychological impact, economic loss, indirect health damage, etc.

In conclusion, Conception [13] is an official document elaborated and approved in full agreement with requirements of the State Law of Russian Federation on "Sanitary-Epidemiological Prosperity of Population" [14]. For all this, one should understand that the scope of Conception [13] is limited by the radiological problems existing at the territories contaminated in consequence of nuclear accidents or nuclear testing only. Thus, related issues of uranium mining industry or other potentially dangerous areas of economic activities are not covered by the above discussed document. This objective fact on no account means that some important fields of radiological safety are out of regulation. It is mentioned here, first of all, to explain why at present time various conceptual radioecological approaches are the subjects of intensive discussions (e.g. see [15-17]) while the official version of National Conception is in force. One can expect that in the near future more comprehensive and advanced conception will be adopted by the responsible authorities.

2.2. CRITERIA AND LIMITATIONS

Among the broad spectrum of regulatory documents, to a certain extent influencing planning for environmental restoration activity, it is reasonable to emphasize the so called

"Criteria for Decisions Making" (CDM) and "Limitations of Radiation Exposure" (LRE) as the most concrete, the most detailed and the most adopted to the changing conditions guides to action. Observance of normative indexes, fixed in these documents, is binding upon all organizations and individuals at the territory of Russian Federation. At the same time the values of these basic figures are the subjects for reviewing and revision every 1-3 years. Such practice, undoubtedly, complicates the processes of planning and implementation of working projects. However, keeping in mind specific problems connected with nuclear disasters in Kyshtym and Chernobyl, accident in Tomsk, consequences of past bad practice at radiochemical combinat "Mayak", etc. [1], one should acknowledge that regular revision of criteria and temporary permissible levels is, maybe, the only way of socio-economic optimization of ongoing and planned programmes on environmental rehabilitation.

To illustrate the last conclusion, let us examine the data compiled in Table IV. Temporary permissible levels (TPL) of radionuclide activities in food products and drinking water were instituted to ensure that the effective dose equivalent (EDE) limitations were met and to limit internal doses to critical organs of inhabitants living in contaminated areas. The first set of standards (May 6, 1986) concerned the content of ^{131}I to limit doses to thyroids of children to 300 mGy. The next set of standards, adopted on May 30 1986, concerned the content of all beta emitters in food. The later sets of TPLs, implemented in 1988 (TPL-88) and 1991 (TPL-91), concerned the total activities of $^{134/137}Cs$ and ^{90}Sr. These standards were developed with consideration of the completing objectives to reduce doses to the population and continue essential agricultural production in the regions affected by Chernobyl accident. The TPLs ensured that if rural inhabitants maintained their usual diet, and all components of the diet contained Cs radionuclides at the maximum permissible level, the annual effective dose equivalent would not exceed 50 mSv (TPL-86), 8 mSv (TPL-88) and 5 mSv (TPL-91).

In August 1993 TPL-91 has been replaced by TPL/GN2.6.005-93 (Table V) which will be in force up to

TABLE IV. TEMPORARY PERMISSIBLE LEVELS (TPLs) OF RADIONUCLIDES CONTENT (Bq/g) IN PRIMARY FOOD PRODUCTS AND DRINKING WATER [25]

Index	4104-88	129-252	TPL-88	TPL-91	
Date of Adoption	05/6/86	05/30/86	12/15/87	01/22/91	
Nuclides	^{131}I	beta-emitters	$^{134/137}Cs$	$^{134/137}Cs$	^{90}Sr
Drinking Water	4	0.4	0.02	0,02	0.004
Milk[a]	0.4 - 4	0.4[b] - 4	0.4	0.4	0.04
Diary Products[a]	19 - 74	4 - 19	0.4 - 2	0.4 - 2	0.04 - 0.2
Meat and Meat Products[a]	-	4	2 - 3	0.7	-
Fish	40	4	2	0.7	-
Eggs	-	40	2	0.7	-
Vegetables, Fruits, Potatoes, Root-Crops	-	4	0.7	0.6	0.04
Bread, Flour Cereals	-	0.4	0.4	0.4	0.04

[a] When a range is presented, the smaller number denotes the TPL adopted for schoolchildren.

[b] Beginning August 1, 1986.

TABLE V. 1993 TEMPORARY PERMISSIBLE LEVELS OF $^{134/137}Cs$ AND ^{90}Sr CONTENT IN PRIMARY FOOD PRODUCTS [20]

No	Food products	Temporary permissible levels of radionuclide content, Bq/l,kg (Ci/l,kg)	
		$^{134/137}Cs$	^{90}Sr
1.	Milk, sour-milk products, sour cream, curds, chees, butter, bread, groats, meal, sugar, margarine, vegetable and animal oil	370 ($1x10^{-8}$)	37 ($1x10^{-9}$)
2.	Child's diet	185 ($5x10^{-9}$)	37 ($1x10^{-9}$)
3.	Tea, spices, honey, herbs (annual consumption < 10 kg/a)	6000 ($1,6x10^{-9}$)	1000 ($3x10^{-9}$)
4.	Concentrated, dry and condensed milk	1200 ($3,2x10^{-8}$)	200 ($6x10^{-9}$)
5.	Other food products	600 ($1,6x10^{-8}$)	100 ($3x10^{-9}$)

01.08.1995. Application of this new stantard of the Russian Federation is spreaded to imported food as well.

Analizing above described materials, it is reasonable to highlight the following circumstances, important from the viewpoint of the main subject discussed (planning of the restoration projects):

- although TPLs were constituted for the regions affected by Chernobyl radioactive release, they are applicable, in principle, for any sites contaminated by man-made radionuclides. This is absolutely correct at least in respect of the latest version (TPL-93) [18]

- in real situation (keeping in mind that the content of radionuclides does not reach 0.1 of maximum permissible level in the majority of local food) TPLs-93 guarantee that annual dose limit can not exceed 0.5 mSv even in Bryansk (the most affected) region. The results of radiation monitoring in 1992 fully confirmed this conclusion

- the norms, introduced by the new standard (TPL-93), are even more conservative than known limits used in European Community and proposed by international organizations (Table VI). Thus, one can conclude that domestic stantdards meet internationally agreed norms and provide a proper regulatory basis for achieving the goals formulated in National Conception [13].

As to external gamma-exposure, these aspects are regulated (in addition to basic documents [19-20]) by the "Temporary Criteria for Decisions Making on Management of Soils, Solid Building, Industrial and Other Wastes, Contaminated by Gamma-Emitted Radionuclides" [21]. This document, in contradiction to TPLs, contains not only fixed dose rate limits but also description of protective measures and waste management modes (Table VII). All the figures presented are the excess of the dose rate over natural radiation background in a given locality. Document [21] dose not cover materials contaminated by radionuclides of Uranium and Thorium series.

TABLE VI. MODERN TEMPORARY PERMISSIBLE LEVELS OF $^{134/137}Cs$ AND ^{90}Sr CONTENT IN PRIMARY FOOD PRODUCTS (Bq/kg). COMPARISON OF VARIOUS NORMS

Document	Child's diet		Milk production		Other products	
	$^{134/137}Cs$	^{90}Sr	$^{134/137}Cs$	^{90}Sr	$^{134/137}Cs$	^{90}Sr
EC N2218/89 of 1989-07-18	400	75	1000	125	1250	750
EC N737/90 of 1990-03-22	370	-	370	-	600	-
FAO/WHO (Codex Alimentaris) of 1989	1000	100	1000	100	1000	100
TPL-93 (GN2.6.005-93) of 1993-07-21	185	37	370	37	600	100

TABLE VII. TEMPORARY "CDM" ON GAMMA-CONTAMINATED SOILS AND SOLID WASTES MANAGEMENT [21]

Objects	Actions required	Waste management
The dose rate (EDR) (1) from 10 μR/h to 30 μR/h	Careful dosimetric evaluation of territory is required. No intervention is necessary if EDR is less than the maximum value fixed in item (1).	
(2) from 30 μR/h to 100 μR/h	Territory should be decontaminated. After that EDR should not exeed norms fixed in item (1).	Contaminated materials are used for filling up the hollows, ravines, etc.; for construction of the roads outside of settlments with subsequent recultivation of these sites. After recultivation EDR should not exceed norms fixed in item (1).
(3) from 100 μR/h to 300 μR/h	Decontamination is necessary. After decontamination EDR should not exceed norms fixed in item (1).	Contaminated materials are moved away and placed on the special plots at the sites for industrial and municipal waste. These plots are the subjects for recultivation. After recultivation EDR should not exceed norms fixed in item (1).
(4) from 300 μR/h	Decontamination is necessary. After decontamination EDR should not exceed norms fixed in item (1).	Radioactive wastes are moved out to special facilities/repositories in accordance with corresponding standards on radwaste management.

Criteria for decision making on natural sources of radiation are described in the standard [22], which is based on the data derived from UNSCEAR publication (1988), documents of ICRP (NN 26, 32, 39, 50), national norms of Canada, states of Northern Europe, UK and USA, domestic basic standards (NRP-76/87 and MSR-72/87), as well as on the results of direct measuring of Rn and his doughter products activities and of dose rates of external gamma-radiation in various regions of the country.

According to CDM [22] for the building/construction materials the following norms are established:

(1) Materials for the new dwelling houses and public buildings (I Class)

$$A_{eff.} = A_{Ra} + 1,31\ A_{Th} + 0,085\ A_K \leqslant 370\ Bq/kg$$

A_{Ra} and A_{Th} specific activities of ^{226}Ra and ^{232}Th in equlibrium with other products of uranium and thorium families,

A_K specific activity of ^{40}K.

(2) Materials for industrial buildings and for the construction of the roads within the boundaries of populated areas (II Class)

$$A_{eff.} \leqslant 740\ Bq/kg.$$

(3) Materials used for the construction of the roads outside the populated areas (III Class)

$$A_{eff.} \leqslant 1350\ Bq/kg.$$

(4) When $A_{eff.} > 1350$ Bq/kg, utilization of materials is a subject of special decision requiring of approval and authorithation by the Ministry of Health.

The norms and corresponding CDMs for Radon content and external gamma-exposure due to natural sources of radiation are presented in Table VIII and IX.

It is evident that the above norms, criteria and recommendations are fully applicable to the sites contaminated in consequence of uranium/thorium production or some nonnuclear economic activities accompanied by the release of natural radioactive nuclides (oil and gas extraction, geothermal power, iodine production, etc.).

TABLE VIII. CRITERIA FOR DECISION MAKING DEPENDING ON AVERAGE EQUIVALENT VOLUMETRIC ACTIVITY (AEVA) OF RADON IN AIR [24]

AEVA, Bq/m^3	Actions required	
	Projected dwelling-houses and public buildings	Existing buildings
100	No actions (permissible level)	No actions
$\leqslant 200$	Not allowed	No actions
$\geqslant 200$	Not allowed	Protective measures required: hermetization of the ground floor; ventilation of basement and premises; imprevious coating on the walls, etc.
>400	Not allowed	Voluntary evacuation of residents; changing of the building's assignement/type; persons, spent more than 5 years in such environment, are subjected to regular medical survaillance

TABLE IX. CRITERIA FOR DECISION MAKING DEPENDING ON THE LEVEL OF EXTERNAL GAMMA-EXPOSURE [24]

Excess of the dose rate in houses above background, μR/h	Action required
$P_d \leqslant 33$	No actions
$33 \leqslant P_d < 65$	Special mesures to reduce the dose rate are recomended
$65 \leqslant P_d$	Voluntary evacuation of residents; changing of the building's assignements/type

Thus, practically the whole spectrum of possible radioactive contaminations (both man-made and natural) is covered by the Federal Regulatory Documents, although their perfection and comprehensitivity are still dibatable. Particular place in this scheme is occupied by the "Criteria" [24]. This Act includes all kinds of harmful substances, and the problems of radiation protection are reflected only in one small chapter 2.5. - "Radiation contamination". However, in the absence of the Federal Laws on Radiation Safety and on Radioactive Waste Management, this is the only document clearly defining what is a zone of extraordinary radioecological state ($D_{eff.}$= 5 - 10 mSv/a), and what is a zone of radioecological calamity ($D_{eff.}$> 10 mSv/a).

Such official definitions are very important because the fixed figures give to the local authorities the formal grounds to demand additional material and financial resources from the Federal budget and, in turn, Federal Government, on the basis of these normative values obtains the formal reasons to decline groundless claims. It is also important that "Criteria" [24] strictly defines all the procedures and a list of the documents needed (see Annexes 2-5). To a large extent and in essence, issues described in the Annexes [24] can be considered as official requirements for planning and preparation processes in terms of environmental restoration programmes.

2.3.REGIONAL NORMATIVES

Regional normatives, by definition, should represent selected compilations from the Federal standards, guides, etc. As a rule, these documents contain all spectrum of harmful contaminations, including radioactive substances (e.g. in [25] twenty three indexes are under control, and only one from them is relevant to radiation safety). Today such normatives not necessarily exist in every region of Russia. More than that, in this sphere there is no any definite regularity: for instance, the normative [25] is in force in relatively clean St.Petersburg, but it is absent in Bryansk region seriously contaminated in April 1986 [1].

In other words, situation with the regional normatives (RNs) is rather uncertain. It could be acceptable under consideration that the main aims of RNs are just a duplication and, to some extent - interpretation of the Federal standards. However, recently another facets of the problem began attracting attention of specialists (at least, we hope so). The essence of the matter is following:

due to anormous variability of climatic, geochemical, hydrological, biological, irradiation conditions, etc. in different parts of the Russian Federation, it is practically impossible (or better to say - irrational) to apply the same norms and priorities for the all regions of the country.

This obvious idea was layed in the foundation of TPLs, indirectly reflected in some publications of conceptual character (eg.[16.17]), and straightly fixed in the working proposals of SPbIT on "Control and Ensuring of Radiation Safety on Industrial Installations, Places of Residence and Economic Activities of the Employees of Mintopenergo. Region of Yamal Peninsula", which were directed to the Ministry of Fuel and Power (MFP) and to corresponding Commissions of Russian Parlament in January 1994. Expediency of the approach discussed naturally rises from the following simple collations:

- it is known that St.Petersburg and Leningrad oblast are the most dangerous regions of the European part of Russia in respect of Radon content [26]. Concentration of Radon can reach 230 kBq/m^3 in underground air, and up to 7000 Bq/m^3 in dwelling houses (Table X). Similar (but due to another reasons) situation is observed at uranium [2] and gas/oil production centres [27]. At the same time, in Kaluga-Tula-Orel spot with relatively high levels of "post-Chernobyl" radioactive depositions, content of Radon is negligible. In the light of the facts mentioned the logical question arises: should we take these objective circumstances into account on the planning stage of restoration programmes, and how to do that?

- according to the information available. around 80% of the natural power resources of Russia are concentrated in the polar regions. Population of these regions. in addition to extreme hostile natural conditions, are under potential influence of the radwaste dumped in the polar seas and nuclear explosions at Novaya Zemlya [1,5,7]. If the main goal of environmental restoration is insuring of high health stantards (as it is declared in [13]), is it justified to apply the same norms for the non-native population of the Far North and for the population of the Middle Russia?

TABLE X. VOLUMETRIC ACTIVITIES OF RADON IN SOME DWELLING HOUSES OF St.PETERSBURG (KRASNOSELSKY RAION) [28]

Volumetric activities of Rn, Bq/m^3	Number of houses investigated	Normative
< 100	25	200 Bq/m^3 for existing buildings (see [24])
100 - 200	11	
200 - 400	4	
400 - 1000	6	
> 1000 (max 7000)	4	

A list of such clear collations can be extended (e.g. difference in living conditions for the rural residents and inhabitants of industrial megapolices, etc.). However, the key idea of the above exercisings is, apparently, enough transparent:

regional normative (perhaps, in the form of Manual or Code of Practice) is the best and, maybe, the only way to formalize (1) intermediate and long-term priorities of restoration activities, and (2) limitations of radiation exposure, applicable precisely for the given region. In some cases these norms may differ from the Federal and/or international standards.*

* In reality the problem of regional regulation is even more complecated, because today there is widespread opinion that human safety at contaminated territories strongly depends on combined influence of a number of anthropogenic factors (in addition to radiation) [15,16], and these factors are changing from region to region.

This approach is dictated by objective specific conditions of Russia, although in principle it correlates with important recommendation of the IAEA : "One cannot give precise instructions on these points,

because in each individual case, the best solution depends on the specific conditions prevaling at the site"

It is also understandable that realization of the proposed approach in terms of generally accepted regulatory practice is difficult task (both in organizational and concrete sense). Nevertheless, there are some grounds to expect that this idea will find comprehension and support among the specialists and decision makers.

3. METHODOLOGICAL AND MANAGERIAL IMPLICATIONS

Methodology (streamlined sequence of ideas) of planning and decisions making is mainly based on the following corner-stones:

- **ICRP Principle of Justification**, coordinated with the key target of National Conception [13,16]
- **ICRP Principle of Optimization**, supported by the concept of risk, cost-benefit analyses and national Criteria for Decisions Making (e.g. [23,24])
- **ICRP Principle of Limitation of Personal Doses**, supported by national TPLs, CDMs, LREs and basic standards (e.g. [20-27])*

More concrete methodological scheme is presented in Fig.2**. According to the "Principles" and the details shown in Fig.2, in addition to radiological protection consideration must be given (for any remedial project) to environmental pro-

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* In ideal case all the principles mentioned and corresponding directives, in one or another form, should be fixed in the National Laws. Such laws - on Radiation Protection of Population and on Radioactive Waste Management - are in the final stage of preparation.

** Fig.2 is borrowed from the document [30] with genial permission of Mr. E. Ettenhuber.

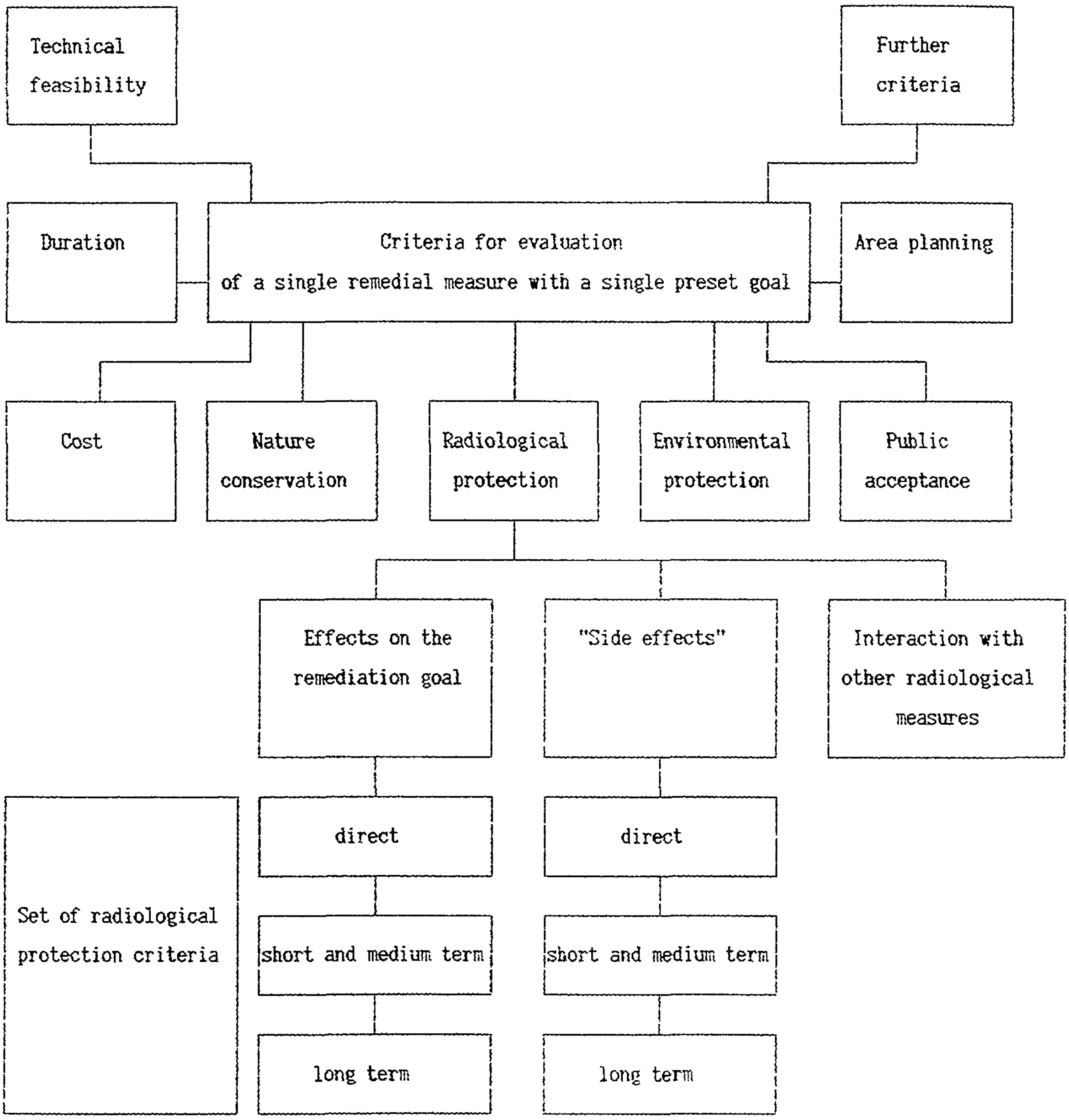


FIG. 2. Aspects to be evaluated for every single remedial measure with a present goal.

tection and nature conservation, public acceptance and area planning; limiting factors include especially the technical feasibility, the duration and the cost of measures. The consequences of the planned measures with regard to the remediation goal and the consequences induced by remediation itself must be accounted for. Special consideration must be given to radiation exposures which might occur immediatly, delayed or in the long run via the different exposure pathways. In many cases this is associated with interactions with other remedial actions which have to be accounted for [30].

In general, one could consider recommendations of ICRP and scheme 2 as a list of the constitutents needed and optimal interconnections between them. At present, practically all necessary components for proper planning are available in Russia, at least formally. However, it does not mean, unfortunatly, that objective and comprehensive procedures of decisions making can be realized on the working level.

The first and the most serious obstacle on this way is chronic lack of financial resources both on Federal and regional/municipal levels. As an example, it is enough to mention that in 1993 only 15% of the sums required were allocated for the most ambitious "State Program of the Russian Federation for Management of Radioactive Waste and Spent Nuclear Materials, their Utilization and Disposal for the Period of 1992-1995 and in Perspective till 2005" (SPUD), primarily oriented on environmental remediation of the nuclear contaminated sites. Almost the same situation is observed for "The State Program of the Russian Federation on Rehabilitation of the Ural's Region and Measures on Rendering Help to the Population Affected by Radiation for 1992-1995" (SPUR); and the state of municipal programmes is totally sad (see [28]).

In the light of the subject discussed such collisions lead to the collaps of methodologically adjusted plans, because in this case priorities of the tasks formulated are defined by their price and ease but not by the objective urgency, necessity and importance. In other words careful and comprehensive planning to a large extent become meaningless.

The second obstacle has more delicate and, apparently, more common character for the most countries . Essential point of the ICRP principle of optimization - " ... bearing in mind the relevant economic and social factors" - could be interpretated as follows:

at the planning stage it is necessary to select and to substantiate such version, which will provide maximum health effect with minimum expenditures and minimum (that can reasonably be achieved) socio-psychological impact.

As a rule, it is very difficult to realize these good intentions in practice, first of all because the public attitude is frequently hard to predict. There are many cases when the people prefer to leave the settlements with permissible level of the dose rate or, on the contrary, to remain in seriously contaminated area, while the new houses are already built for them in radiologically clean regions. Vast medical statistics reliably proves that the short (one or two month) "rehabilitation" of children in unaccustomed climatic conditions is less effective, or even unhealthy, than special recovery treatment at place of residence. However, parents are trying to send their children abroad by one way or another.

Thus, essential material and intellectual resources, spent at the first stage of restoration project, can turn out to be useless at the later stage simply because of unforeseen irrational zigzags in the behaviour of the people.

From methodological point of view, an important component of the planning stage has to be an objective evaluation of the so called "averted detriment". Today such computations are very much embarrasing, because up to now debates are still going on the concrete economic indicies for the land, air, water and other natural resources as well as on the price of 1 man-Sv (human health and life).

The next important obstacle is a lack of experienced managers, professionaly trained workers and an adequate system for further training of staff. It is appropriate to remaind here the results of the SPbIT inquest mentioned in chapter 1: no one from 34 respondents is satisfied with the level of education and the quality of further training. Undoubtedly, this factor influences both methodological perfection of decisions elaborated and their practical execusion.

In the same context one could consider

- necessity to`improve mechanisms of overall co-ordination of restoration projects and co-operation between the

specialists working in various spheres of radioecology (medicine, biology, geochemistry, etc.)
- obvious necessity of systematic work to raise general "radiation" culture of population
- necessity to apply the same safety and control requirements for sivilian and military organizaitions (recent conflict between Navy Headquarters and State Committee of Nuclear Safety made this problem actual)
- urgent introduction of the modern methods of cost-benefit analyses into the routine practice
- extensive dissemination of corresponding positive experience accumulated in selected regions and areas of economic activities, and a number of other important issues.

Materials of present chapter are called upon to highlight actual tasks of common interest but not to dramatize present situation. All the above enumerated problems are at the moment in the focus of experts and responsible bodies. The Government and the local authorities make serious (although some time sporadic) efforts to optimize mechanisms and the structure of organization, supervision and management (e.g.[8,11,26,27,31]). These efforts are well supported by the results of scientific studies and, to a certain extent, by the increased activity of the "Green Peace" groups. Under favorable conditions one can expect considerable progress in the field of environmental restoration, at least in respect of planning and proper organization of the projects.

4. CONCLUSIVE GENERALIZATION

Theoretically, the basic approach to the planning of restoration activities as well as decisive norms and standards are the same (or almost the same) in all countries of the world nuclear community. The factual differencies consist in the scope and prehistory of contamination, nature and concentration of contaminants; climatic, geochemical, hydrological and demographic conditions and, what is even more important - in real capabilities of the concrete country to solve these problems in an optimal way. Thus, attempts to discuss at international level the ideal model of planning and preparation, ignoring the combined influence of various subjective factors, are of little practical value today. On the other hand, these "subjective factors" are common or similar for the most of the countries of the former socialist camp. These special features of the IAEA regional project (RER/9/022) were taken into account in the above chapters: the most attention was given to the special problems and uncertainties existed, but not to a "good intentions".

Cooperation on the topics highlighted in previous chapters seems to be very promissing. It could be bilateral projects or the IAEA co-ordinated research programmes, data bases, consultanties to elaborate internationally agreed manuals, etc.

St.Petersburg State Institute of Technology already undertook some steps on this way. Specially:

(1) To improve planning stage of restoration activities, the project on "Methodology of Decisions Making on Radioactively Contaminated Installations and Territories" (SBC N43-94) was initiated and started in January 1994.
(2) To strengthen coordination and to optimize information connections, it is planed to prepare "Expanded Directory of Organizations Involved in Identification, Characterization and Restoration of Radioactively Contaminated Sites" and "Catalogue of Modern Methods and Technologies". Corresponding questionnaire was distributed in December 93 - January 94, and 34 organizations already (as of March 1994) supported these initiatives.
(3) To meet objective requirements to the professional qualification of the specialists involved in environmental restoration, advanced educational programme was eloborated in SPbIT. General phylosophy used and the detailes of this programme will be presented at international conference "SPECTRUM-94" in the paper entitled "Modern Trends in Education of Radiochemists-Technologists" (reg. NI-0454). Special training courses on practical aspects of decontamination of radioactively contaminated sites will be organized

within the Institute this year at the request of the Environmental Restoration Division of Municipality.

(4) To raise "radioecological culture" of population, some simplified cources for schoolchildren are under preparation and discussion.

All these projects are open for any interested persons both in Russia and abroad. In turn, we are ready to participate in corresponding projects of the IAEA or any other national and international organizations.

REFERENCES

[1] NECHAEV, A.F., VASILIEV, I.A. Identification and characterization of radioactively contaminated sites in Russia (paper presented at the 1-st Workshop / TC Project RER/9/022, October 1993, Budapest).

[2] SOROKA, Yu.N., KRETININ, A.V., MOLTCHANOV, A.I.Recultivation of territories contaminated with radioactive wastes, Atomic Energy, 72 (1993) 148-155 (in Russian).

[3] TCYPIN, S.G., LYSENKO V.V., ORLOV Yu.V., KORYAKIN, O.A.Radiation evaluation of atomic submarines intended to decomissioning, Atomic Energy, 75 (1993) 230-232 (in Russian).

[4] KRUGLOV, A.K., SMIRNOV, Yu.V. Nuclear disasters,their consenquences and perspectives of nuclear power development, CNII atominform, Moscow (1992) 177 pp. (in Russian).

[5] EMEL'YANKOV, A., POPOV, V.,(Ed.) Atom without secrecy: points of view, HP Druck, Moscow-Berlin (1992) 144 pp (in Russian).

[6] MINISTRY OF ATOMIC POWER OF RUSSIAN FEDERATION, Status of environmental protection at establishments of the branch in 1992, Minatom, Moscow (1993) 48 pp (in Russian).

[7] General description of nuclear legacy of the former USSR (Doc. for AGM on Radiation Safety of the Biosphere, October 4-5, 1993), IIASA, Luxemburg (1993).

[8] RUSSIAN STATE COMMISSION OF EXPERTS ON ECOLOGY, The List of Normative Documents on Protection of Atmosphere from Radioactive and Toxic Substances, Min. Environm., Moscow (1993) 17pp (in Russian).

[9] Annotated Bibliography of Normative and Methodical Documents on Territories Contaminated with Radioactive and Chemical Substances, All-Russian R&D Inst. of Chem. Tech., Moscow (1993) 44 pp (in Russian).

[10] INTERNATIONAL ATOMIC ENERGY AGENCY, Clean up of Large Areas Contaminated as a Result of Nuclear Accident, Technical Reports Series No 300, IAEA, Vienna (1989)

[11] GOVERNMENT OF THE RUSSIAN FEDERATION. Decree on Unified State System of Ecological Monitoring, No 1229 of 24 November 1993, SM, Moscow (1993) (in Russian).

[12] ARUTYUNYAN, R.V., BOLSHOV, L.A., et. al. System-Analitical and Information Support of the State Programmes Aimed at Social Protection of Population and Rehabilitation of Territories, Suffered from the Accident at Chernobyl NPP and Other Radiation Catastrophes, Preprint NSI-20-93, NSI, Moscow (1993) 57 pp (in Russian).

[13] Conception of Raliological Protection of Population and Economic Activities at Radioactively Contaminated Territories, Ministry of Health, Moscow (1993) (in Russian).

[14] THE CONGRESS OF PEOPLE'S DEPUTIES AND SUPREME SOVIET OF RUSSIAN FEDERATION. Law on Sanitary-Epidemiological Prosperity of Population, Bulletin CPDSS, N20 (1991) chapt.641 (in Russian).

[15] KRYSHEV, I.I. Ecological Criteria of Radiation Protection

in Nuclear Power, Atomic Energy, 74 (1993) 321-327 (in Russian).

[16] IL'IN, L.A., GLEBOVA, L.F., ALEXAKHIN, R.M., et. al, Substantiation of the Concept of Ecological Safety of NPPs and Other Nuclear Fuel Cycle Facilities, Atomic Energy, 74 (1993) 316-320 (in Russian).

[17] KULAKOV, V.M., POLEVOY, R.M., PROTASOV, V.M. "On conceptual basis of rehabilitation of territories contaminated with man-made radionuclides", Nuclear Energy and Human Safety (Proc. 4-th Annual Conf. of Nucl. Soc., 1993), Vol.1, Nizhny Novgorod (1993) 76-78 (in Russian).

[18] VLASOV, O.K., YATCALO, B.I., BROVKIN, V.A., et.al. "Elaboration of information-expert system for decisions making on effective contramesures in agro-industrial complex at radioactively contaminated territories", ibid., 186-188 (in Russian).

[19] TCYTTCER, O.Yu., DOSKOTCH, Ya.E. "Conception of the land usage at radioactively contaminated territories", Radioecological and Economic and Legal Aspects of the Land Usage After Chernobyl Accident (Proc. Sci. Conf., 1991), UAS, Kiev (1991) 29-35 (in Russian).

[20] Temporary Permissible Levels of Cs-134/137 and Sr-90 Content in Food Products, Decree of SCSES N7 of 21.07.1993, GN2.6.005 - 93, SCSES, Moscow (1993) (in Russian).

[21] Norms of Radiation Protection (NRP-76/87) and the Main Sanitary Rules of the Work with Radioactive Substances and Other Sources of Ionizing Radiation (MSR-72/87), Energoatomizdat, Moscow (1988) 160 pp (in Russian).

[22] Sanitary Rules on Radioactive Waste Management (SRRWM-85), Moscow (1986) 54 pp (in Russian).

[23] Temporary Criteria for Decisions Making on Management of Soils, Solid Building, Industrial and Other Wastes Conta-

minated with Gamma-Emitted Radionuclides, Doc.01-19/5-11, SCSES, Moscow (1992) (in Russian).

[24] Limitation of Radiation Exposure to Population from Natural Sources of Ionizing Radiation. Temporary Criteria for Decisions Making and for Organization of Control, Ministry of Health, Moscow (1990) (in Russian).

[25] BALONOV,M.I. "Overview of Doses to the Soviet Population from the Chernobyl Accident and the Protective Actions Applied", The Chernobyl Papers. Vol.1. Doses to the Soviet Population and Early Health Effects Studies (MERWIN,S.E.,BALONOV M.I.,Ed.),Research Enterprises, Publishing Segment, Richland (1993) 23-45.

[26] MINISTRY OF ENVIRONMENT AND NATURAL RESOURSES. Criteria for Evaluation of Ecological Situation Aimed at Revealing of Zones of Extraordinary Ecological State and Zones of Ecological Calamity, Moscow (1992) 58 pp (in Russian).

[27] The Rules of the Soil Protection in St.Petersburg. Regional Normative, St.Petersburg (1993) 23 pp (in Russian).

[28] SOROKIN, N.D. (Ed.) Ecological Situation in Saint-Petersburg in 1992, St.Petersburg (1993) 218 pp (in Russian)

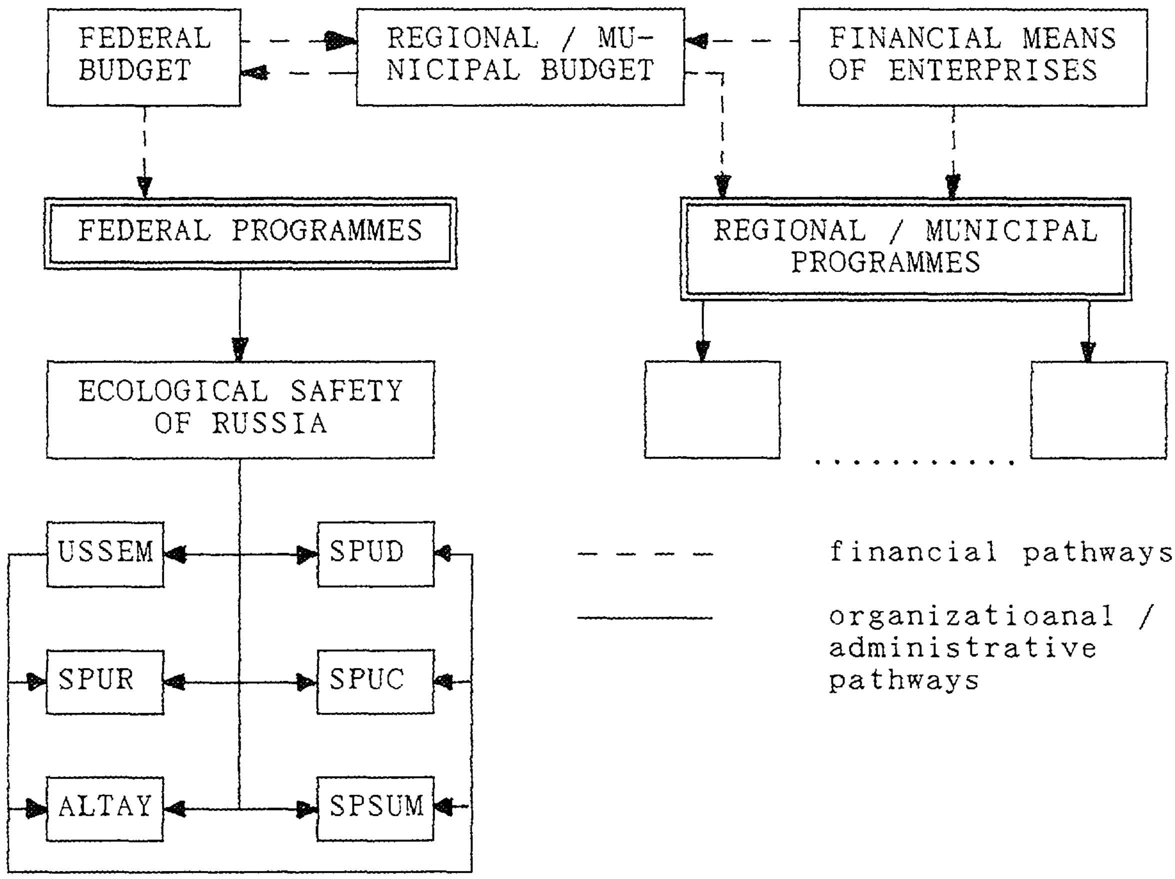
[29] RUZYAK, V.N., ZAITCEV, E.E., PA "Stavropolneftegaz", Neftecumsk, personel communication, 1992.

[30] MULLER-NEUMANN, M. (Ed) Radiological Protection Principles Concerning the Safeguard, Use or Release of Contaminated Materials, Buildings, Areas or Dumps from Uranium Mining. Recommendations of Commission on Radiological Protection with Explanations, G. Fisher, Stuttgard - Jena - New York (1992) 198 pp (in German and English)

[31] STATE COMMITTEE ON NUCLEAR SAFETY SUPERVISION UNDER THE PRESIDENT OF RUSSIAN FEDERATION, Information Bulletin of the North-European District, Arsenal, St. Perersburg (1992) (in Russian)

ANNEX 1

PRINCIPAL PROGRAMME STRUCTURE OF ENVIRONMENTAL RESTORATION ACTIVITIES IN RUSSIA



USSEM - Unified State System of Ecological Monitoring

SPUD - State Programme for Management of Radwaste and Spent Nuclear Materials, their Utilization and Disposal for the Period of 1992-1995 and in Perspective till 2005

SPUR - State Programme on Radiation Rehabilitation of the Ural Region and Measures on Rendering Help to the Population Affected by Radiation for 1992 - 1995

SPUC - State Programme on Social Protection of Population and Rehabilitation of Territories Damaged by Chernobyl

SPSUM - State Programme on Special Underwater Works

ALTAY - Federal Programme on Evaluation of Consequences of Semipalatinsk Radioactive Trail at the Territory of Altay.

PLANNING FOR ENVIRONMENTAL RESTORATION IN SLOVAK REPUBLIC

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Abstract

The restoration in the Slovak Republic concerns to the contaminated banks of the waste water recipient of the Bohunice NPP. The identified contamination, consting of mainly from ^{137}Cs, is a result of two accidents on the CO_2 - cooled and heavy water moderated NPP - A1 unit of NPP Bohunice complex.

Two type of radiation risk scenarios, namely the bank use and contaminated soil (from bank) use scenario were investigated in relation to decision making on the planning for restoration of the contaminated banks. Results of dose assessments and the approach to planning for restoration of contaminated banks are summarized in the paper. Some details from the worked out technical design of the contaminated soil removing from the banks its safe disposal in a subsurface isolated basin are introduced in the paper too.

1. INTRODUCTION

The environmental restoration in The Slovak Republic concerns one ^{137}Cs contaminated site, which includes 18 km banks of the Manivier canal - Dudváh River system as a result of the Bohunice NPP-A1 accidents in 1976 and 1977. Up to 1992, this system got out the waste water from the Bohunice NPP (A1 and V1) to the Váh River, as it is seen in Fig.1.

Since 1992, the all waste waters from NPP Bohunice, containing some radionuclides, have been carried out directly to the Vah River through a specially constructed 15 km long pipeline (Fig.1).

A detailed radiological survey of the main part of this contaminated site was carried out in 1992. The obtained radiological characteristics of the contamination on the banks are given in an earlier paper [1]. In average, 6300 Bq ^{137}Cs/kg earth was identified on the 18 km long affected bank surfaces.

When decision making on remedial measures (including restoration), two different types of scenarios have to be considered:

- the first one with normal use of the banks (without any displacement of contamined earth) and
- the second one, considering specificity of potential earth displacement from the banks into environment during maintenance and reconstruction scheduled of the flow banks.

The second type of scenarios for a critical resident with a house and a garden with (displaced) contaminated earth (from the banks) is, naturally, much more significant than the first one from point of view of the individual dose, although its likelihood is very small.

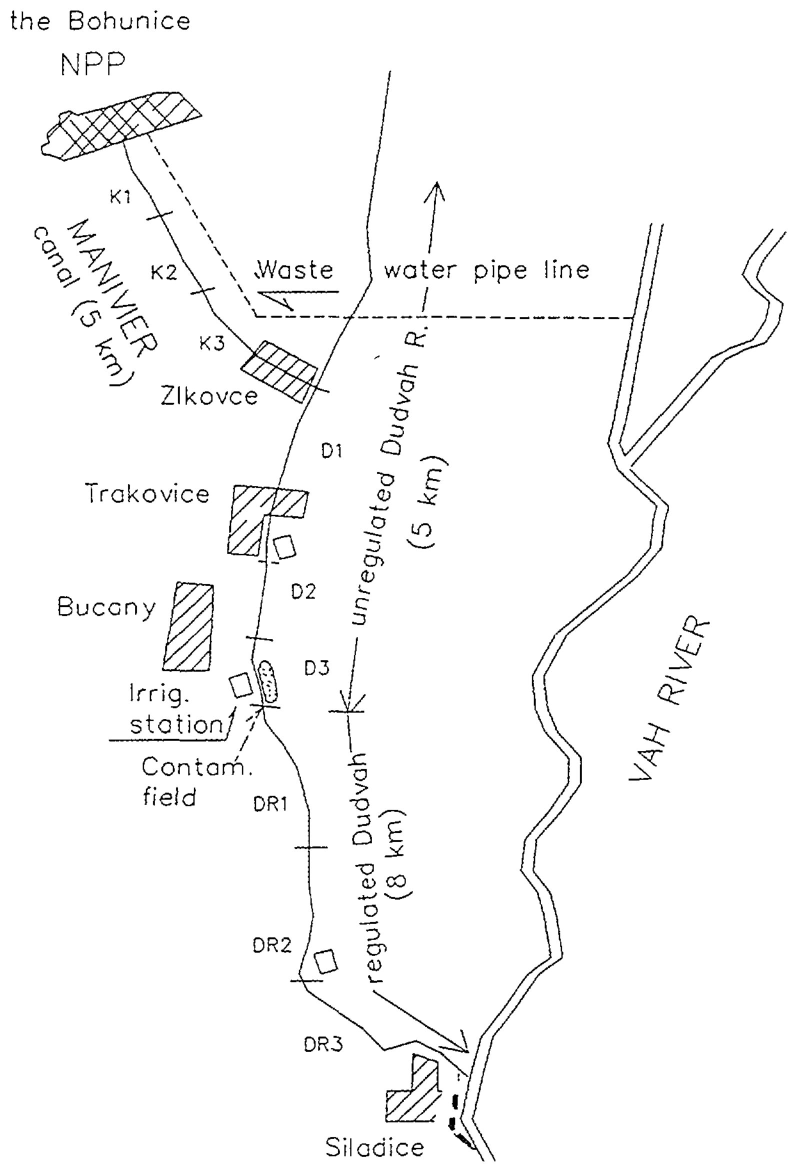

FIG. 1.a. Scheme of the water system taking out the waste water from the Bohunice NPP to the Vah River.

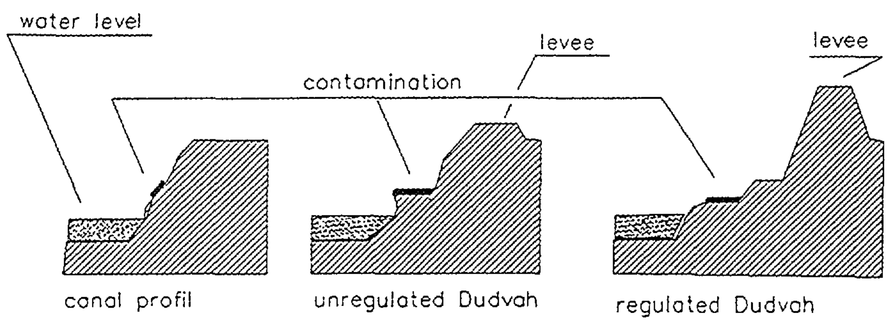

FIG. 1.b. Width profiles and location of contamination in typical sections of flow.

However, in context of future human activities on the flow banks (flood control project implementation, construction of some bridge in the future etc.), this probability can not be considered as zero one, and just this scenario (together with the limitation of individual doses) can give reasons for a radiological cleanup of the contaminated banks in this site.

Unengineered part of the bank. Reconstruction of the banks at the above mentioned section (this section, in Fig.1, is marked as unregulated one) is unavoidable from the point of view of a flood control. The affected water flow flows directly through two villages. To deepen the bed and to widened the profile of the banks, so that a 100 year flood water could flow away, are objectives of the scheduled reconstruction.

At this reconstruction whose design works have already begun, removing of large volumes of (contamined) earth from the banks and their release into the environment is required. However, this reconstruction has been stopped due to the ^{137}Cs contamination found on the banks. The most sure way, in this unengineered section, seems to combine the scheduled reconstruction with a beforegoing radiological restoration of the contamined banks with removing and safe disposal of the contaminated earth from the banks.

However, this type of restoration belong to a very cost consuming remedial measures, the net benefit from this measure, directly influenced by the volume of earth need to be removed and disposed, would be properly take into account. The volume of earth is indirectly predetermined by the used cleanup criteria which would be to develop with help of a proper optimization aproach.

In this context, principles of the ICRP dose limitation system and the recomended primary dose limit value (1991) 1 mSv/y for population can be used as a start point. Determination of suitable parameters of the exposure pathway scenario to a critical resident together with these ICRP principles enable to develop due derived intervention levels (DIL). These DIL can be used as for contamination acceptability levels, as well as for due cleanup criteria determinations.

Bohunice Nuclear Power Plant (NPP) and the competent authorities decided, as a first step, to support the restoration of this unengineered part of the affected flow banks. Technical project of the restoration has, already, been worked out for this 10 km long section (Fig.1).It assumes removing the contaminated surface soil layer from the banks and their disposal (preliminarly about 5000 m^3) on a subsurface isolated concrete basin inside the Bohunice NPP area.

Re-engineered flow banks. In the remaining lower 9 km long part of the Dudváh River (in Fig.1a marked as regulated part), the banks had been already reengineered (1978), i.e. the bank and bed profile was widened and deepend to enable flow away the 100 year's flood water planed. The banks in this zone are, also contaminated [1], probably, as a result of relocation of the contaminated bottom sediments from the bed to the mounted terraces of these banks during the mentioned flood control project implementation in 1978 (after the accidents).

No large relocation of the contaminated soils from this engineered banks to the surrounding environment is expected. As human usage of the affected banks assumed to be not too heavy and therefore the resulting effective doses to individuals are estimated to be not too high (see later), only administrative, or costly unextensive remedial measures, probably, sufficient to be applied in this zone.

But the final decision concerning the remedial measures for some highly contaminated part of this zone has not been made, and it will also be strongly influenced, by the public opinion in the locality and the future political (green movement) and societal considerations.

The two goal of the paper are to:

- summarize the carried out dose assessments and describe the approach to the evaluation and planning for restoration of the contaminated places on the accidentally affected banks and
- give some details of the worked out restoration project plans emphasising the cost and radiation safety aspects.

2. THE CONTAMINATED BANKS NORMAL USE SCENARIO

2.1. Effective individual doses

In the upper, unengineered part of the affected flow, the canal or river flows directly through 2 villages with 2100 inhabitants. The third village Bu_any with 2 000 inhabitants is situated 200 to 500 m from the Dudváh River.

In the remaining lower part (Fig.1) with engineered banks there is, only, one village (Siladice, 800 inhabitants) situated close to the Dudváh River. Along the overall canal-river system, in a 3 to 4 km wide strip, there are 9 villages with about 11.000 inhabitants. Thus the resulting average density of population, along the contaminated banks, has been estimated as about 900 persons per 1 km of the flow (or 450 pers./km of bank).

Two scenarios were chosen for radiological impact assessments estimating the present affect of the contaminated banks on the nearby population. The parameters of both a generic and a site specific scenario are given in Tab.1 together with the exposure pathways, identified as critical one.

The first scenario is a pessimistic one and assumes a maximum individual exposure time on the bank of 500 h/y. The second one for more realistic evaluation of each integral, typically contaminated sections, as marked in Fig.1 (Ki, Di, DRi) assumes a maximum stay, T_{max}, on the banks depending on the distance of the partial section from the nearest willage. For the determination of the effective doses to critical individuals, the maximum direct exposure rates, found in these sections by monitoring [2], has been utilized.

The considered food pathways are, also, given in the Tab.1. The dilution factors R_{ing} for contaminated grass from banks, supposed to be utilized for feeding of a small farmed live-stock, are assumed to be 0.5 (pessimistic scenario) or equal to a bank profile contamination fraction, in the case of the site specific scenario. For the contaminated field, near Bu_any, an effective consumption of 110 kg/y of potato , as a most critical case, has been used at calculations.

The transfer and dose factors, according to Safety Series No 57, and the calculated concentration related dose factors for identified critical food pathways and 1 Bq/g of ^{137}Cs in contaminated soils from the banks are given in Tab.1a.

The relation factors, marked as "$^{137}Cs+1/50\ ^{90}Sr$" in Tab.1a, also include the radionuclide mixture identified on the contaminated banks ($A[^{137}Cs]/A[^{90}Sr]=50$). The resulting values from Tab.1a have been utilized as for the individual as the collective dose assessment calculations, results of which for each individual bank section, are introduced in Tab.2.

As can be seen from Tab.2, the effective doses to a critical individual (IDE) in any section of banks do not exceed 0.7 mSv/y for the case of pessimistic scenario and 0.44 mSv/y in the

Tab.1 The contaminated banks usage scenarios for the canal Manivier and Dudváh River

Source	Individ. doses		Collective doses			
	T_{max} [h/y]	R_{ing} [1]	V(r) [1]	r [km]	T_a [h/y]	P_{Ving} [1]
a. Generic scenario						
each sect.	500	0.5	1	0	80	1
b. Site specific scenario taking into account the position and specifics of each source						
K1	50	0.40	0.01	3.0	8	0.2
K2	50	0.40	0.07	1.8	8	0.2
K3	400	0.50	0.64	0.3	64	0.8
D1	400	0.33	0.47	0.5	64	0.8
D2	100	0.33	0.60	0.4	16	0.6
D3	200	0.40	0.60	0.4	32	0.8
D-po	100	1.0	0.60	0.4	16	0.8
DR1	50	0.30	0.05	2.0	8	0.6
DR2	50	0.30	0.10	1.5	8	0.6
DR3	400	0.50	0.47	0.5	64	0.8

notes:

- *$W(r) = e^{-kr}$ position factor reducing the number of concerned population at estimated density 900 pers. per 1 km of flow, ($k = 1.5\ km^{-1}$)*
- *r average length of source from nearest village*
- *R_{ing} dilution factor* (contaminated width/owerall width ratio)
- *P_v using factor for contaminated products (grass)*
- *T_{max}, T_a maximal and average duration of the stay*
- *Critical exposure pathways:*
  - *K1,K2,DR1,DR2: exposure on bank harvesting the grass*
  - *K3,DR1,DR3 : recreation stay on the banks*
  - *D2 : fishing - children, fisherman*
  - *D-po : tilling on the field*
  - *Elsewhere : Ingestion of 30 kg rabbit meat and 100 l of milk (cow, goat), fed by grass, see tab.*1a
  - *D-Po : Ingestion of 110 kg potatoes, see tab.*1a

Tab.1a Transfer and dose relation factors for choosen bank use scenario (Tab.1) and 1 Bq/g specific activities in soil

Parameter/ radionuclides	^{137}Cs	^{90}Sr	
Activity concentration ratios [5]			
Grass (dw)/ soil CF_T [1]	0.08	1.2	
Grain / soil CF_{GR} [1]	0.007	0.02	
Potato(fw)/ soil CF_{PO} [1]	0.03	0.3	
Other vegetables CF_{VE} [1]	0.03	0.3	
Transfer factors			
Meat (cow)/grass dw k_F $[d.kg^{-1}]$	0.03	0.002	
Milk (cow)/grass dw k_M $[d.dm^{-3}]$	0.007	0.001	
Meat(rabbit)/grass[1] k_{FRA} $[d.kg^{-1}]$	6.9	0.46	
Doses factor, D_A [µSv/Bq]	0.014	0.036	
Dose factors for IDE, adult $[\mu Sv.y^{-1}/Bq.g^{-1}$ of soil]			**Cs+ +Sr/50**
Meat(rabbit) ID_F	15.9	42.0	17.6
Milk (cow) ID_M	11.0	60.0	12.2
Meat+milk ID_{F+M}	26.9	102.0	29.8
Potato, vegetables ID_{PV}	46.2	1188	70.0
Dose factors for KDE_{max} $[10^{-6}$ man $Sv.y^{-1}.m^{-2}/Bq.g^{-1}]$			
Grass - rabbit KD_{RA}	0.010	0.026	0.011
Potato, vegetables KD_{PV}	0.84	21.6	1.3
Site specific yield U_i $[kg.m^{-2}.y^{-1}]$			
Grass 0.13 Rabbit* 0.018 Potato 2			

Notes: * - $U_{RA} = M_{RA}.U_{grass}/(100.Q_{RA})$; $Q_{RA}=0.07$kg d.w./day

1 - $k_{FRa} = k_F.M(cow) / M_{ra}$, $M/M_{ra}=230$; $M_{Ra}= 1.0$ kg

- $ID_{RA} = 1000.CF_T.Q_{RA}.k_{FRA}.D_A.(30kg/y)$

- $ID_{PV} = 1000.CF_i.D_A.(110kg/y)$

- $KD_{RA}= U_{RA}.ID_{RA}/(30\ kg/y)$

- 1/50 Bq/g of ^{90}Sr is assumed in the contaminated soils 1Bq/g of ^{137}Cs [1]

case of the realistic one. These maximum IDEs belong to the DR3 section of the Dudváh River (Fig.1), where the direct exposure creates 60 (scenario "a") or 70 % ("b") of the estimated total doses.

Tab.2 **Maximum individual and collective doses from the usage of the contaminated canal and Dudváh River banks, according to the choosen scenarios in Tab.1.**

Source-sect.	length of source [km]	A_{ef} Cs 137 soil [Bq/g]	$IDE_{ext+int}$ a.	$IDE_{ext+int}$ b. [µSv/r]	$KDE_{ext+int}$ a.	$KDE_{ext+int}$ b. [manmSv/r]
Canal Manivier banks						
K1	4.0	6.7	285	163	28	0.2
K2	2.3	16.2	606	386	26	0.4
K3	3.9	2.0	122	109	18	9.6
Dudváh - unadapted banks						
D1	0.81	1.8	97	70	1.6	0.6
D2	1.05	3.5	165	79	4.8	0.4
D3	1.85	4.7	360	198	14.2	3.6
Field near Bučany						
D-po*	0.1	2.5	282	172	1.1	0.2
D-po**		2.5	344	234	6.0	4.0
Dudváh - adapted banks						
DR1	3.96	1.9	125	40	9.6	0.1
DR2	2.3	3.2	257	78	15.1	0.3
DR3	4.2	9.6	689	440	81.2	31.0
Overall sections			**Σ KDE**		**206**	50.4

NOTE: IDE- individual, KDE- collective dose equivalents from internal(int) and external(ext) direct exposure

- $IDE_{ing} = ID_{F+M} \cdot A_{ef} \cdot R \,/\, Su$

  ID_{F+M} = 29.8 $\mu Sv.r^{-1}/Bq.g^{-1}$*dw of soil - from Tab.1a*
  Su = 0.85, *dry soil content*

- $KDE_{ing} \ll KDE_{ext}$, *excluding the contaminated land field*

* : IDE_{ing} *from meat and milk trough grass fromk bank, R=1*

**: IDE_{ing} *from potato raising on the field, R=1*

a.,b., - generic and site specific scenarios from Tab.1

The magnitude of the assessed total effective doses to critical individuals from normal bank use does not exceed anywhere the ICRP primary dose limit 1 mSv/y, thus, the limitation of radiation doses to the critical individuals from normal bank use does not justify any cost consuming remedial or protective actions. Despite this, optimization of health and non radiological detriment (i.e. flood control) to population need to be take into account. The collective dose to the nearby population from bank usage has been investigated for this purposes, in more detail, too.

2.2. Collective effective doses (CDE)

Although the earlier estimated population density is relatively high, 900 inhabitants/km of flow, the investigated canal and river banks belong to typical limited-use areas. Realistic collective dose assessment is very complicated for such a site due to the absence of sufficiently accurate data, concerning the exposure time of population on the contaminated banks. In an earlier work [2] an attempt to assess this quantity was made according to a scenario, parameters of which are given in Tab.1a. The results of this assessment are given in Tab.2.

The average stay of population T_a on the banks was estimated, in this work, only, according to a formally established log-normal distribution (median T_g = 50 h/year, geometric variance σ_g = 2.66) with a resulting average stay duration T_a=80h/year (Tab1). An empirical position factor has also been introduced in the case of the site specific scenario (see note under Tab.1), which has exponentially reduced the total exposure time of population on the competent bank section, depending on an average distance from the nearest village.

The resulting value of annual collective dose, according to Tab.2 (scenario b), is 0.050 manSv for the overall bank sections and 0.031 manSv for the mostly exposed DR3 section. But, these values are considerably overestimated due to the direct exposure component and a too long estimated exposure time on the banks. After more detailed investigation of the data one can find that in the scenario, an average entire day stay of 2.5 people for each 1 km of the banks was assumed (22.000 h/y per 1 km of flow), which is too far from the reality.

More truthful estimation of the average exposure time on the banks T_a would be a value at least by one order of magnitude lower than the before used value, e.g. T_a=8 hours. Revised, less conservative estimation of the collective doses from the banks usage is given in the following Tab.2a

Tab. 2.a Revised estimation of the collective doses from the canal and Dudvah River banks use at assumed value of T_a = 8 hours, other parameters see Tab. 1 - site specific scenario (b)

Section	Collective doses [man mSv/y]		
	external	ingestion	total
DR3	3.0	0.9	3.9
D-Po (field)	0.1	2.9	3.0
Remaining sec.	1.2	1.9	3.1
Overall sec.	4.3	5.7	10.0

As it can be seen from Tab.2a, the revised collective dose, from normal bank use, to nearby population is very low (10 man mSv/y for overall sections), as it is expectable for a limited use contaminated areas. It means that the health detriment to the population or, what is the same, the radiological benefit expectable from some planned measures, will be also very small.

Thus, the population health detriment optimization to normal bank use does not also justify implementation of any cost consuming remedial actions such as bank restoration is. Specific nonradiological benefits, such as resulting from a flood control project implementation, are generally high and no one doubts their need.

The flood control project must be considered as a planned human activity due to which releasing of radioactivity into the environment would occur. The impact of released contaminated soil must be kept on the levels as low as reasonably achievable. But, due to the high cost of the bank restoration and limited volume of the contaminated soil, probably, the higher ranges of permitted values of the ICRP dose limitation system would be properly applied.

3. RESIDENTIAL SCENARIO FOR USE OF SOILS REMOVED AND RELOCATED FROM THE CONTAMINATED BANKS.

During the construction of a flood control project on contaminated flow bank, moving of a large amount of the contaminated soil will be unavoidable. As a worse case, the contaminated soils can assumed to be relocated and to be used as a fill and spread uniformly on the site surface around some resident's living houses.

A site specific residential scenario can be used for the assessment of the effective annual dose critical to individuals. The resulting thickness of the spread soil is assumed to be 20 or 30 cm. Thus, a large source (^{137}Cs) with an effective dose rate value (1 m above the surface), given in Tab.3 for two investigated cases, is created around the critical house.

After the spreading is completed, an individual is assumed to live in the house an entire year and raise vegetables in a garden with the same soil. He is assumed to spend 20% of his time outdoors. Inside the house a shielding from 20cm of concrete in the basement is assumed to reduce the external exposure. Oztunaly's occupancy factor [7] is used in the case of more realistic scenario -(b) (Tab.3).

The dilution of the filled contaminated soil that would result during it tilling, in the garden, is assumed to be 0.8 (20cm/25cm) or 1. Half of the entire year's vegetables (represented by an effective potato consumption), meat (rabbit) and milk (goat, cow) consumption is assumed for food pathways contribution.

A summary of the assigned parameter values used in calculations, and the calculated annual effective doses for individual pathways in two variants are given in Tab.3.

The effective doses, in Tab.3, has been calculated for unit specific activity of ^{137}Cs (1 Bq/g), also including in the case of food pathway, the assumed ^{90}Sr content in the radionuclide mixture in the bank soil, according to the evaluated monitoring results [1]. The inhalation of $^{239,240}Pu$ in the respirable soil particles, with an enhanced factor of 2,0, is considered, too.

As it can be seen from Tab.3, the direct exposure pathway creating about 60% of the total annual dose, is dominant in this scenario. The milk and inhalation pathway contributions are in negligible range (6%), only.

The resulting total annual effective dose related to 1Bq/g of ^{137}Cs in the soil from the affected bank is, according to Tab.3, 0.33 mSv/y, in case of pessimistic, and 0.228 mSv/y in case of

Tab.3 Proposed residential scenario and the resulting doses for 1 Bq/g of ^{137}Cs in the removed contaminated soils from the banks

	a	b
Direct exposure from the soil		
Dose rate, H_E, uniform distr. µSv/h	0.118	0.111
Exposure duration, outdoor, h/y	1800	
indoor, h/y	6960	
Attenuation factor outdoor	1.0	
^{137}Cs indoor	0.01	
Occupacy f. (Oztunally) outdoor	1.0	0.67
($1000\ m^2$) indoor	1.0	0.24
External dose out+in mSv/y	**0.225**	**0.142**
Internal exposure [c]		
^{90}Sr content in soil, 1/50 of Cs137	0.02 Bq/g	
Ingestion from food pathways in		
(contaminated garden [d])		
Dilution factor, tilling, FD_T	1.0	0.8
110 kg/y of potato and vegetab.	0.070	0.056
30 kg/y of meat (rabbit)	0.018	0.014
100 l/y of milk, goat (as cow)	0.012	0.01
Ingestion dose [mSv/y]	**0.100**	**0.080**
Inhalation of soil particles		
^{239}Pu cont. in soil, 1/2000 of Cs137	0.5 Bq/kg	
Dust concentration, average	10 µg/m^3	
Enhanced factor	2	
Inhalation dose, [mSv/y]	**0.008**	**0.006**
Total effect. dose, TD, [mSv/y]	0.333	0.228
Dose rel. factor for ^{137}Cs, 1/TD in $[(Bq.g^{-1})/(1mSv.y^{-1})]$	3.0	4.4

a - thickness of soil layer spread in a large area is 30 cm
b - thickness of soil layer spread in a 1000 m^2 area is 20 cm (effective dose rate $H_E(0.7)$ for adult depending on the thicness according Cocher [7] is given in both cases
c - Dose relation factors for ingestion (^{137}Cs, ^{90}Sr) are taken from Tab.1a
d - Half of the year consumption is expected to be consumed from the grown potato and vegetables in the garden

more realistic variant of residential scenario. The reciprocal of these value (D= 3.0 or 4.4 Bq/g of ^{137}Cs per 1 mSv/y) can be used for the establishment of the competent contamination acceptability levels (CAL).

It can be seen from Tab.3 that parameters such as the assumed size of the resulting source [7] and the dilution factor value used (it is connected with the spread soil thickness) in the scenario, have a significant influence on resulting CAL. Therefore these parameters must be clearly declared and agreed before their use for CAL determination.

3.1 Contamination acceptance level for ^{137}Cs concentration in the contaminated soil removed from the banks

The contamination acceptance level for the soil may be given as derived intervention level DIL for an average ^{137}Cs concentration in a large volume of soil. If, for example, the described residential scenario could be considered as a proper one with non zero probability in the presence time, the respective **CAL** belonging to the dose limit of 1 mSv/y would equal to CAL=DIL = 3.0 or 4.4 Bq ^{137}Cs/g of soil, depending on the assigned parameters of the residential scenario (Tab.3).

The specified sections, in Fig.1 (approximately the same character of contamination [1]), seems to be appropriate to investigate the compliance of the average ^{137}Cs contamination (it is given in Tab.2) with the proper DIL value. As it can be seen from Tab.2 the ^{137}Cs contamination in some sections is higher than the above mentioned CAL values. It means that the potential radiation risk from use of the soil from some sections of the banks is higher than 1 mSv/y and that the residential scenario, and the dose limit of 1 mSv/y could justify also a costly extensive restoration of the unengineered bank sections with the over-limited contamination.

More detailed clean up criteria will have to be developed during working out the plans of final restoration project implementation, also including influence of removing technology and radiation detector used.

The goal of the bank restoration project would thus to be to reduce the declared over limited radiation risks from the use of contaminated earth from the bank to such an extent, that the future reconstruction or maintenance of the bank and possible relocation of the remaining contaminated soils will not result in exceeding the properly established individual dose limit.

Up to now, the more sophisticated cleanup criteria, as well as the proper radiation risk scenario has not been agreed with the competent authorities. It will be necessary to clearifie if the dose limitation system for planned activities or for a recovery of an accidentally affected site will be applied for this contaminated place. It can be noted that clear legislation has, up to now, been absent, in this field, in the Slovak Republic.

4. RESTORATION PROJECT FOR THE CONTAMINATED, UNENGINEERED BANKS

Technical design of the bank restoration, including cleanup of the bank and disposal of the removed soil, has, already, been worked out. The plans for the technical project have sequentially been concerned about the different activities as follows:

- marking out the contaminated sections on the banks in compliance with a working reference level 1 Bq/g of ^{137}Cs, given by the hygiene authorities
- estimation of the volume of the removed contaminated soils from the banks
- selection of the site and technical design of a subsurface disposal facility for the contaminated soils in the NPP Bohunice area
- personnal resources and the budget of the project implementation
- pre-operational safety analysis for the contruction of disposal facility and cleanup the banks including,

i) radiation safety analysis for the workers doing restoration,
ii) and impact assessment of the disposed contaminated soils to the environment.

The preliminar reference level 1 Bq/g of ^{137}Cs given by the national authorities before starting the works, has been understood as an interim contamination acceptance limit. In compliance with this working level of the CAL, it would be necessary to remove and store about a 15 to 20 cm thick soil layer from a 1 to 2 m wide strip on the lower part of the bank and 450 m^3 of soils from the contaminated land field (100x15x0.3m) nearby Bu_any. The total volume of the contaminated earth, need to be removed and disposed, has been estimated in the project as 5130 m^3.

The disposal site selection, in the Bohunice NPP area, was influenced, mainly by the local municipal authorities who had not approved burial of the contaminated soils in their own land register. The average transporting distance by trucks is estimated to be about 5 km.

Other data and the procedure of estimating the dose received by workers, doing the cleanup and disposal, are summarized in Tab.4. As it can be seen the individual effective doses to persons has been estimated as 0.17 mSv for cleanup and 0.58 mSv for sequential burial of the contaminated earth.

The respective collective doses to persons doing these works has been estimated to be about 6,3 manmSv including the monitoring and sampling works on the banks which have already been completed.

5. SUMMARY AND CONCLUSIONS

The stage of the evaluation of the contaminated banks and the planning for restoration of these banks in the Slovak Republik may be summarized, as follows:

1. No generic derived acceptance limits are developed for the contaminated sites.
2. Two different type of contaminated zones (unengineered and engineered bank profiles) must be investigated relating the restoration of the banks and development of due cleanup criteria for this site.
3. Maximum acceptance level of ^{137}Cs for large volume of soil has been estimated, in this paper, as 3000 or 4400 Bq/kg (1 mSv/y) in dependence on the residential scenario parameters chosen for description of the radiation risk from use of the contaminated soils.
5. The projected cost of the restoration has been estimated in average as 1194 K_s (37 $US) per 1 m^3 of disposed earth.
6. The detriment to persons doing the restoration is estimated to be small (6 manmSv) in comparison with the detriment to population using the banks (350 manmSv).
7. The implementation of the restoration project has not, up to now, been finally approved due to licensing of the disposal site in the NPP Bohunice area.

Tab.4 **Some data about the plannig for restoration and the dose burden of persons doing the cleanup and disposal**

Group of persons	CANAL+DUDVÁH	DISPOSAL
Volume of removed/ /disposed earth	5130 m^3	5130 m^3
Average ^{137}Cs concentration	6200 Bq/kg	6200 Bq/kg
Duration of implementation, monthes	9	10
Number of persons involved [1]	15	6
Percentage of hour working	90 %	90 %
Real exposure time, 1 person	1530 h	1700 h
Assumed fraction of time in contact with radiation	0.67	0.67
Average exposure time, 1 person	920 h	1020 h
Average direct exposure rate	0.18 µSv/h	0.55 µSv/h
Effective individual dose including internal exposure	0.17 mSv	0.57 mSv
Effective collective dose, manmSv	2.55	3.42
Total effective collective dose including monitoring, manmSv	2.85	3.45
Average cost, mil. crowns (1992)[2]	2.97	3.15
Average cost, crown/m^3 (1992)[3]	580	614

Note: [1]- Given number of persons involved does not include 5 (Dudváh) + 2 (disposal site) persons doing the specialised monitoring works and whose collective dose was astimated as 0.33 manmSv.

[2]- The transportation cost is included in cleanup cost

[3]- The cost in crowns from 1992 year may be recalculated to US dol. costs using the relation 30 cr.=1 US dol.

REFERENCES

[1] O.SLÁVIK, J.MORÁVEK, Identification and Radiological Characterization of Contaminated Sites in the Slovak Republic, I. IAEA Workshop "Restoration of Contaminated Sites in Central in Eastern Europe", 4.-8 October 1993, Budapest

[2] J.MORÁVEK, O.SLÁVIK, Radiological Impacts Assessment of the Bohunice Surroundings Contamination, Report of NPP RI No 163/92, J.Bohunice, Dec. 1992 (in Slovak)

[3] Exemption of Radiation Sources and Practices from Regulatory Control, IAEA -TECDOC-401, Vienna, 1987

[4] M. VLADÁR, Z.MELICHAR, Optimization of Remedial Measures for Reducing of Dose Burned to Inhabitant with help of Cost/Benefit Analysis, NUPSESO -1004/01/92, Bratislava, November, 1992 (in Slovak)

[5] Generic Models and Parameters for Assessing the Environmental Transfer of Radionuclides from Routine Releases, Safety Series No 57, IAEA, Vienna, 1982

[6] O.SLÁVIK,J.MORÁVEK, Pre-operational Safety Analysis for the Construction of Long Term Disposal Facility for Low Level Contaminated Soils in NPP Bohunice area, NPP RI report No 92/93, Trnava, Aug. 1993 (in Slovak)

[7] COCHER, D.C, Dose rate conversion factors for external exposure to photon emitters in soil, Health Phys. 48 No 2 (1985) 193-205

PLANNING FOR ENVIRONMENTAL RESTORATION OF CONTAMINATED SITES IN SLOVENIA

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Abstract

Compared to the large extent of contaminated sites in other countries, this problem arises in Slovenia only on a small scale. After World War II there were some attempts to exploit uranium from mercury ore residues and from coal ash, both with moderately enhanced U contents. The subject of this paper is the contaminated sites belonging to the former uranium mining and milling operation at Žirovski Vrh. The general features of the former Žirovski Vrh uranium mine (uranium production ceased after 5 years of operation, in 1990) were presented already at the 1st Workshop in Budapest. Main attention in this paper is focused on planning of environmental restoration. A large project covering all aspects of decommission of the mining and milling facilities has been prepared. Some additional studies and decisions should still be made before starting the restoration activities. In parallel, a regulatory framework is in preparation, to set authorized limits for emissions from tailings and wastes and for residual environmental radioactivity, including all categories of contaminated sites, even radioactivity deposited from non-uranium related practices. The first priority will be given to decommissioning of the U-mine area and the restoration should actually start at the beginning of next year. The environmental monitoring program, the data base for dose calculation for members of the public, started in 1985. The general approach in the mine impact assessment was to cover radioactive contamination through all the pathways and in all media of the living environment. A comparison of results was then made with reference levels and/or preoperational levels where extant. Public exposure was determined according the current practice. The Žirovski Vrh uranium mine does not represent a serious problem on an absolute scale, but it could have some meaning as a case study. It shows that even the relatively small dimensions of the contaminated sites could cause a appreciable dose contribution to the critical group. Nowadays, in the close-out period, there is a need to find suitable and relevant restoration of the site. Some results of studies, concerning radon exhalation from tailings, the covering of tailings and waste rock deposit, transmission through clay barriers are presented. Levels of outdoor radon, being evidently the essential contributor to public exposure, should be reduced after restoration according to the proposed authorized levels. Recent investigations showed that most of the thorium-230, the predecessor of radium and radon, remained in layers of so-called red mud, which was deposited like a sandwich in between layers of mine spoil. This feature should have some influence on the long term prediction of environmental contamination and on future remediation measures.

1. INTRODUCTION

Although the radiological characterization of the uranium mining area was discussed already at the 1st workshop in Budapest, some basic facts are again presented for further understanding of the planning of environmental restoration in Slovenia.

The former uranium mine at Žirovski vrh is situated in the small village of Todraž, in northwest Slovenia, 35 km distant from the Austrian and Italian borders and 30 km from Ljubljana, the capital. The mining area lies in a subalpine region of the country, in a deep valley with frequent temperature inversions (about 50 % of time of the year). Some hundreds of people live in the area within a radius of 2 km from the mine.

Relatively low grade ore was excavated and treated (less than 0.1% U_3O_8) in the period 1985-1990. Radioactive wastes, such as chemical tailings of about 600,000 tons were deposited on the slope of a hill, about 100-150 m above the small and narrow valley. The waste rock deposit (1.5 millions tons of spoil, with a content of 70 ppm U_3O_8) and a temporary deposit of some thousand tons of uranium ore are located near the bottom of the main valley. *(Figure 1)*. These two sites are now planned to be

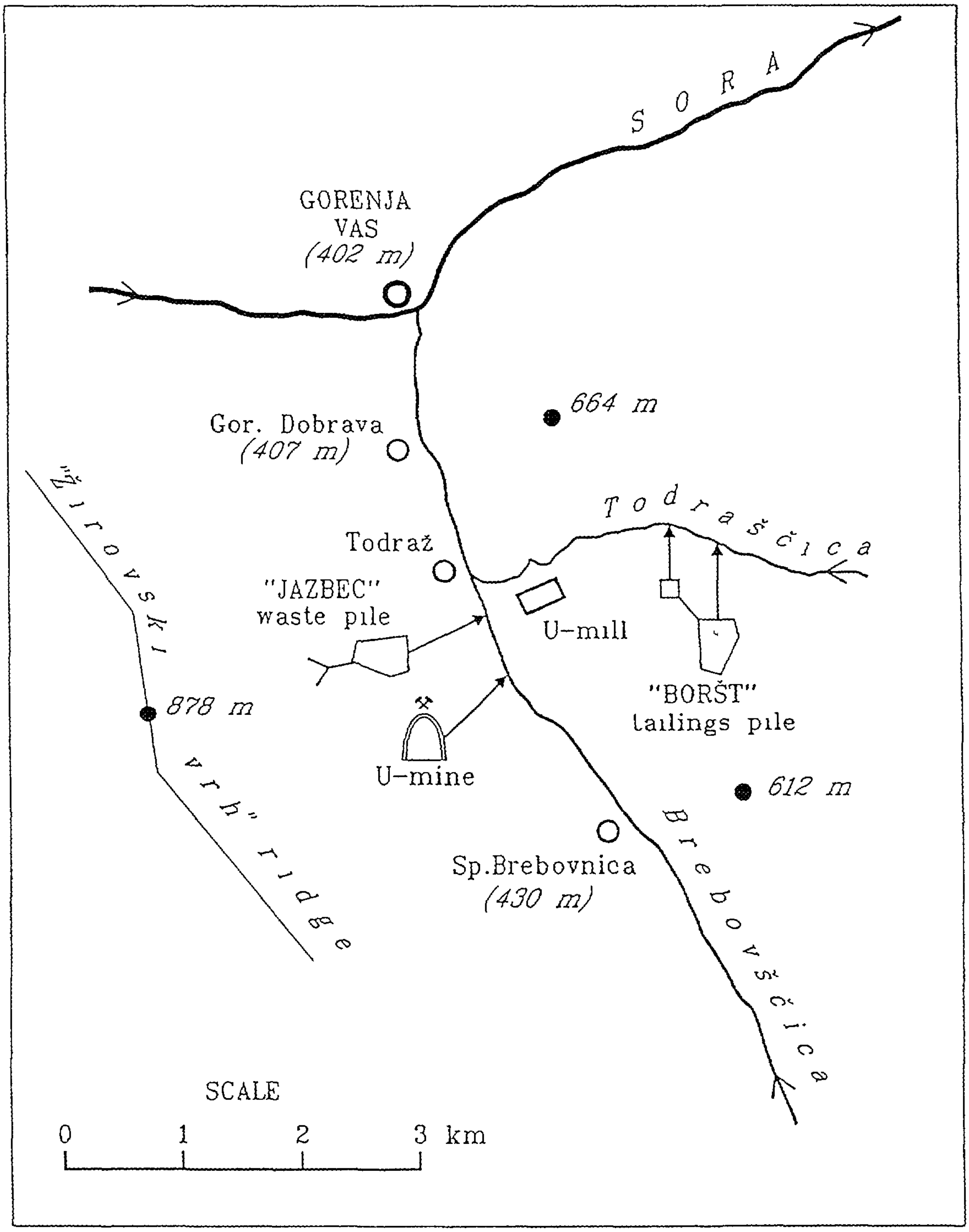


Figure 1

restored. It is not yet finally decided in the decommissioning project if part or most of tailings are to be returned back into the mine.

In succeeding chapters the impact on the environment in terms of enhanced radioactivity and the related dose calculation is presented. Other points of presentation will not be the decommissioning project as a whole, but only related activities, concerning field studies, a regulatory framework and long term considerations.

2. ENVIRONMENTAL CONTAMINATION AND DOSE ASSESSMENT

The regular environmental monitoring programme, based mainly on US Regulatory Guide No.4.14, started in 1985 and has covered all the critical pathways. After cessation of mining and milling, during the close-out period, the surveillance program has been running continuously, together with dose assessment. Generally, the most important consequences of uranium mining and milling are usually observed as a contamination of surface- and ground waters with U, ^{226}Ra, ^{230}Th and ^{210}Pb. In the case of the Žirovski vrh mine it was found that the main radiological impact to the critical group appears to originate from inhalation of radon and its short-lived daughters.

The most important pathways considered are inhalation of enhanced levels of radon and its short lived progeny, inhalation of dust particles with long-lived radionuclides, ingestion of food and water biota and exposure from external radiation.

Measurements of environmental radioactivity were performed at numerous places in the nearby vicinity and also at points distant from the mine. Results obtained were compared with those measured simultaneously at reference point(s), lying beyond the influence of the mine sources. On this basis the contribution of the mine radioactivity to the environment was estimated. There were no complete and relevant radon data available from the pre-operational period.

Several measuring techniques were used. Air particulates were collected on filters and counted with a high resolution gamma spectrometer. Radon determination was performed with nuclear track detectors and charcoal canisters, and for radon daughters we mainly used continuous measurements by alpha spectrometry. Uranium in water was determined by neutron activation analysis and chemical separation, and radium by the sorption-emanation method. Radioactivity in soils and sediments was measured by gamma-spectrometry, and low level of radionuclides in food and crops using a well-type germanium detector. We use thermoluminescent dosemeters (TLD) and portable instruments for measuring outdoor gamma radiation levels.

A summary of the results obtained is shown in Table 1. In the column indicated as mine environment, results from the operational and close-out periods are presented. For most samples, with exception of air particulates, the radioactivity is still relatively constant.

2.1. Dose calculation

The general approach in dose calculation was a realistic assessment of dose, according to the recommendations. All enhanced levels (the differences between the levels in the mine surroundings and at reference point) were supposed to be the contribution of the mine.

Air particulates: the methodology used for dose assessment was taken from US.RG 3.51, taking into account equilibrium in the uranium decay subseries (^{238}U-^{230}Th) and (^{210}Pb-^{210}Po). The contribution of the crushing mill and processing plant became essentially reduced after 1990 when the plant was closed. The corresponding annual effective dose from inhalation of long-lived radioactivity in particulates is nowadays of the order of magnitude of 1 μSv/a, being higher in the operational period (3 μSv/a).

Much more attention is paid to the estimation of dose from radon and radon daughters. The exposure from radon gas represents only 2 % of the dose from inhaled radon progeny. The effective dose equivalent is about 5 μSv per year. To get this figure we estimated the enhancement of radon concentrations in the nearby environment (due to the mine contribution), to be around 5-10 Bq/m^3, GM = 7.5 Bq/m^3 (log-normal plot in *Figure 2*). Average radon concentrations at reference points are near 20 Bq/m^3, and in the mine vicinity 25-30 Bq/m^3 *(see Figures 3 and 4)*.

Radon daughters seemed to be the main radioactive pollutant at "Žirovski vrh" uranium mine, from the dosimetric point of view. To support this, are some basic features about radon dispersion from emission sources at Žirovski Vrh. Measurements showed the geographical extent of the mine's influence and confirmed meteorological predictions: during a period of temperature inversion, radon could not disperse immediately, the air stream is laminar and is channeled along the valley. Concentrations remain almost constant along the air trajectories *(Figure 5)*, even up to distances of 2-3 km downstream from the mine. The wind rose *(Figure 6)* shows steady winds in prevailing directions and a low velocity of air movement (0.6-0.9 m/s). People in the critical group are exposed to the "industrial" component of radon which obviously has a lower equilibrium factor than natural radon. The slightly decreasing concentrations of radon down the valley and the increasing equilibrium factor of radon from the tailings result in maximum radon progeny concentrations (in terms of EEC) at a distance of 1.5 km from the site:

$$C_{Rn} = 7.5\ \mathrm{Bq/m^3}, \qquad F = 0.4, \qquad EEC = 3\ \mathrm{Bq/m^3}.$$

TABLE 1. ENVIRONMENTAL CONCENTRATIONS IN THE SURROUNDINGS OF MINING AREA AT ŽIROVSKI VRH

Sample	**Radionuclide**	**Mine environment**	**Reference point**
Air particulates	^{238}U	0.03-0.12 mBq/m^3	0.015 mBq/m^3
	^{226}Ra	0.01-0.08 mBq/m^3	0.010 mBq/m^3
	^{210}Pb	0.5-1.3 mBq/m^3	0.5 mBq/m^3
Radon	^{222}Rn	10-40 Bq/m^3	10-25 Bq/m^3
Rn-progeny	EEC ^{222}Rn	5-25 Bq/m^3	5-15 Bq/m^3
Surface water	uranium	10-30 mg/m^3	0.5 mg/m^3
	^{226}Ra	12-30 Bq/m^3	5 Bq/m^3
	^{210}Pb	2-10 Bq/m^3	2 Bq/m^3
Sediments	uranium	15-35 mg/kg	5 mg/kg
	^{226}Ra	250-600 Bq/kg	50-60 Bq/kg
	^{210}Pb	250-600 Bq/kg	60 Bq/kg
Fish	^{226}Ra	1 Bq/kg	0.2 Bq/kg
	^{210}Pb	0.5-1 Bq/kg	0.2 Bq/kg
Agricult.prod.	^{226}Ra	0.05-0.5 Bq/kg	0.02-0.3 Bq/kg
	^{210}Pb	0.1-1 Bq/kg	0.03-0.3 Bq/kg
Soil	uranium	4-6 mg/kg	4-5 mg/kg
	^{226}Ra	50-70 Bq/kg	50-60 Bq/kg
	^{210}Pb	60-150 Bq/kg	60-90 Bq/kg
Ext.dose-rate	on tailings	2.0-3.5 μGy/h	0.1 μGy/h
	at fence	0.5 μGy/h	0.1 μGy/h
	100 m distant	0.1-0.2 μGy/h	0.1 μGy/h
	on waste rock	0.3-0.5 μGy/h	0.1 μGy/h
	at fence	0.2 μGy/h	0.1 μGy/h

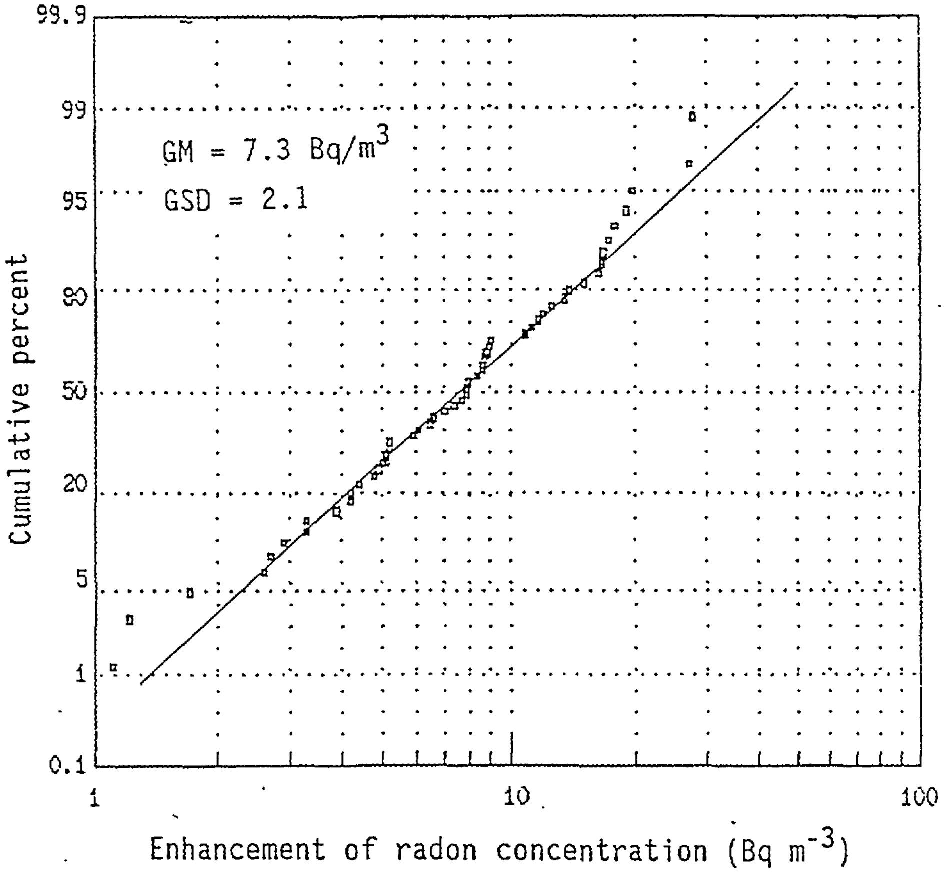


Figure 2

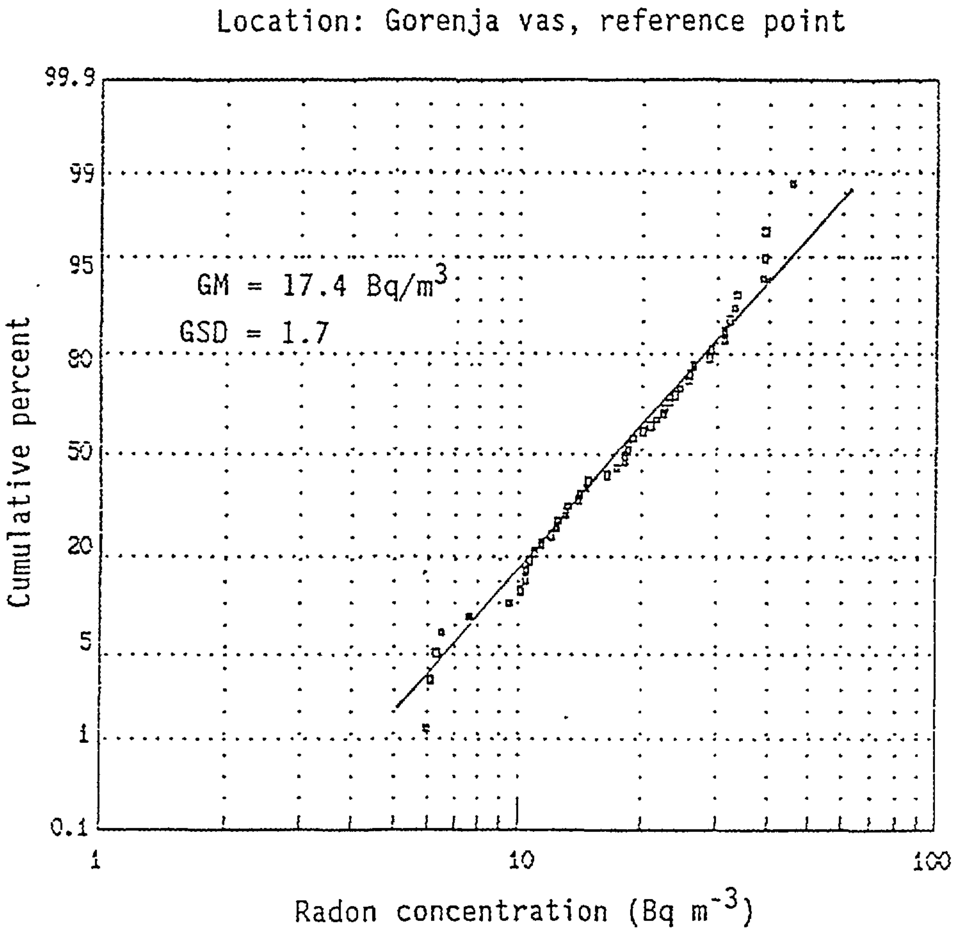


Figure 3

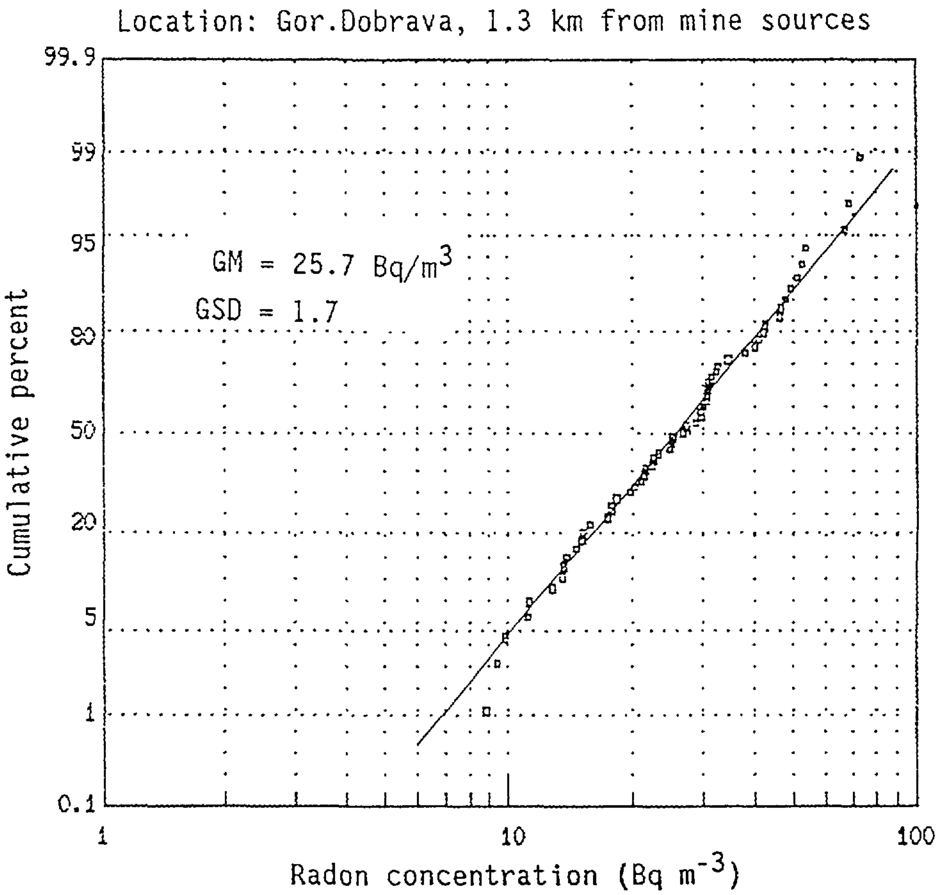


Figure 4

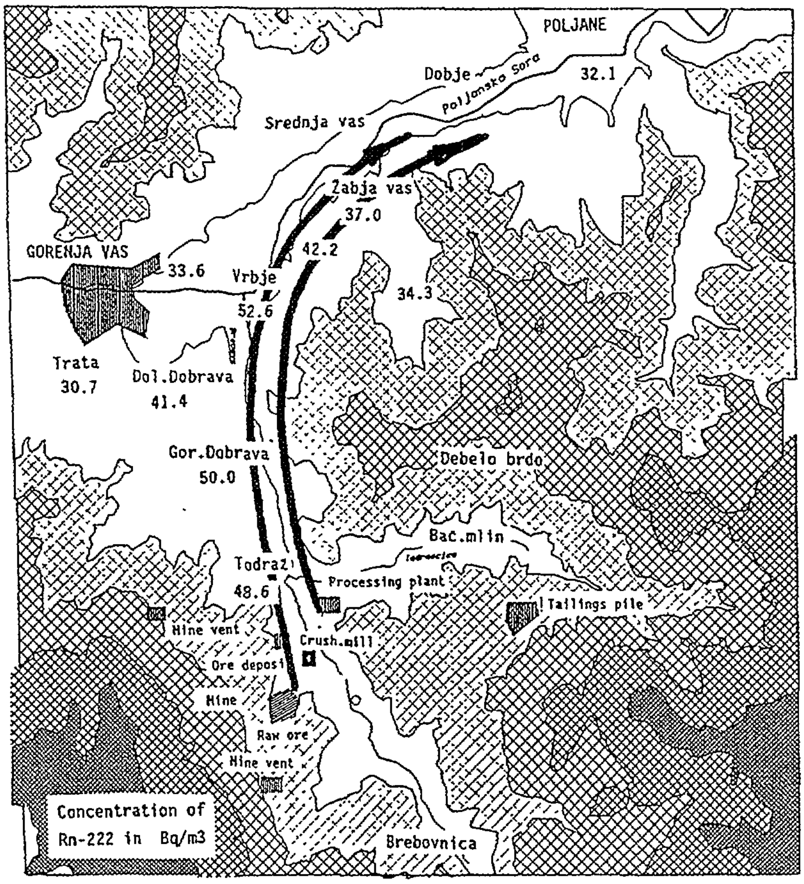


Figure 5

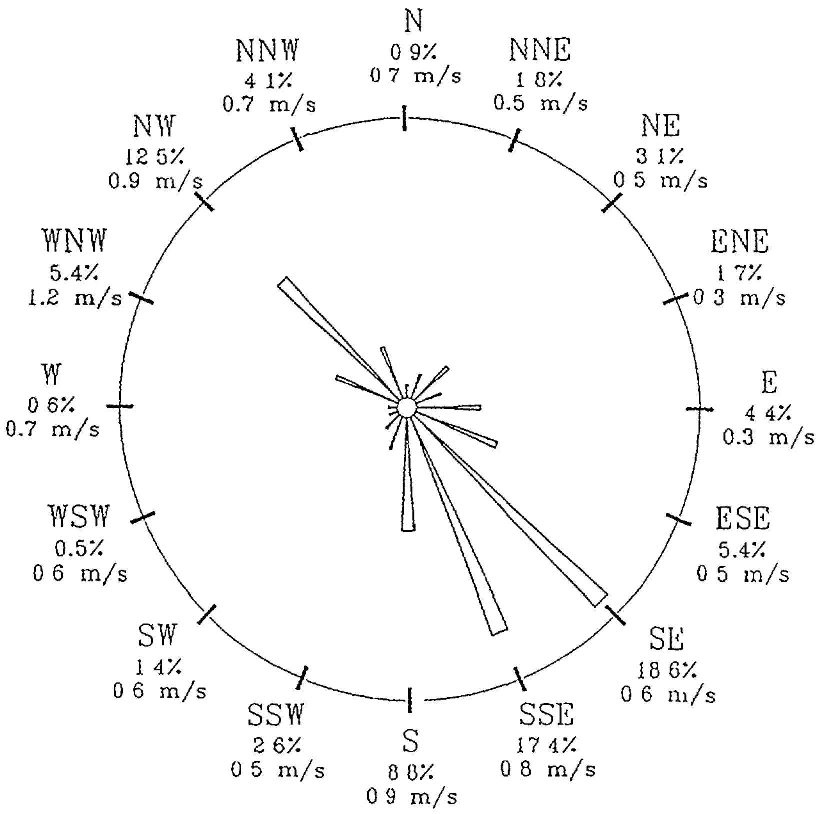


Figure 6

The proof of the existence of fresh radon (with low equilibrium factor F) in the vicinity of waste pile is seen in the alpha spectra of radon daughters, recorded at the center of controlled area, at the foot of the pile (F=0.1-0.2). The time series of EEC show intensive dynamic changes of temporary air contamination *(Figure 7)* and the alpha spectra of ^{218}Po and ^{214}Po confirm the origin of the incoming radon *(Figure 8)*.

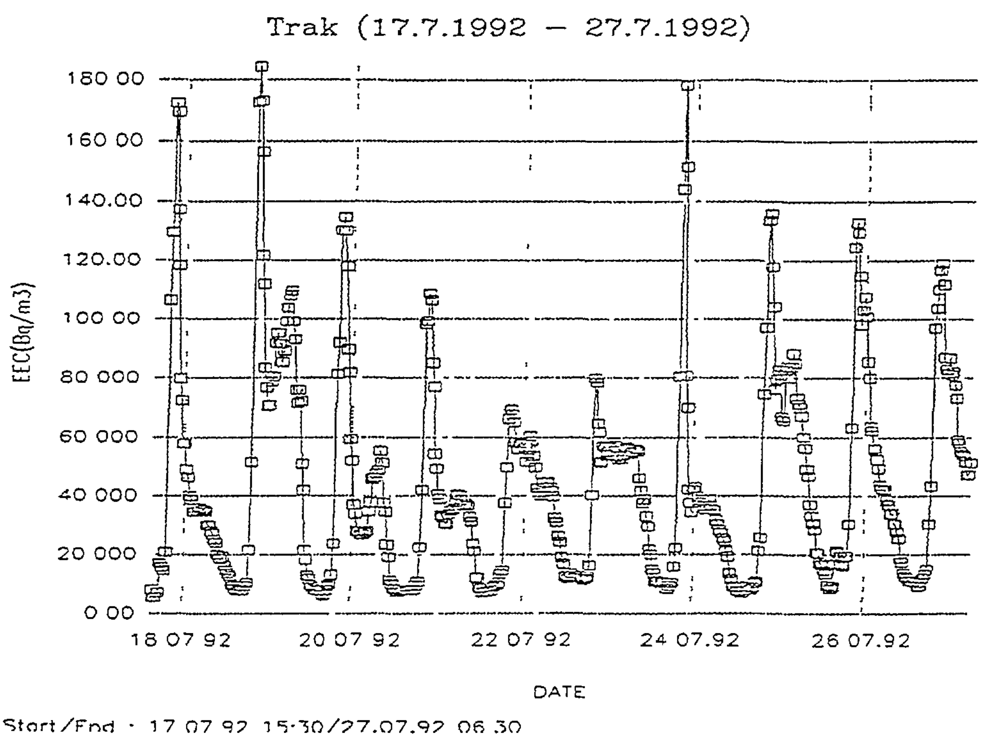
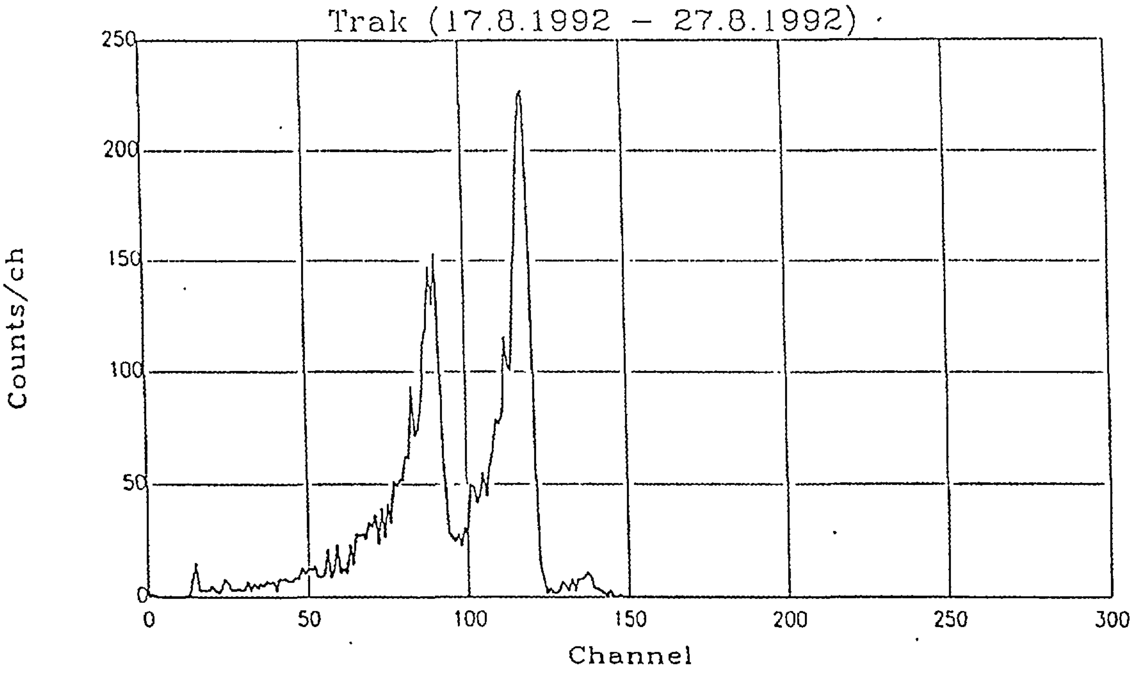


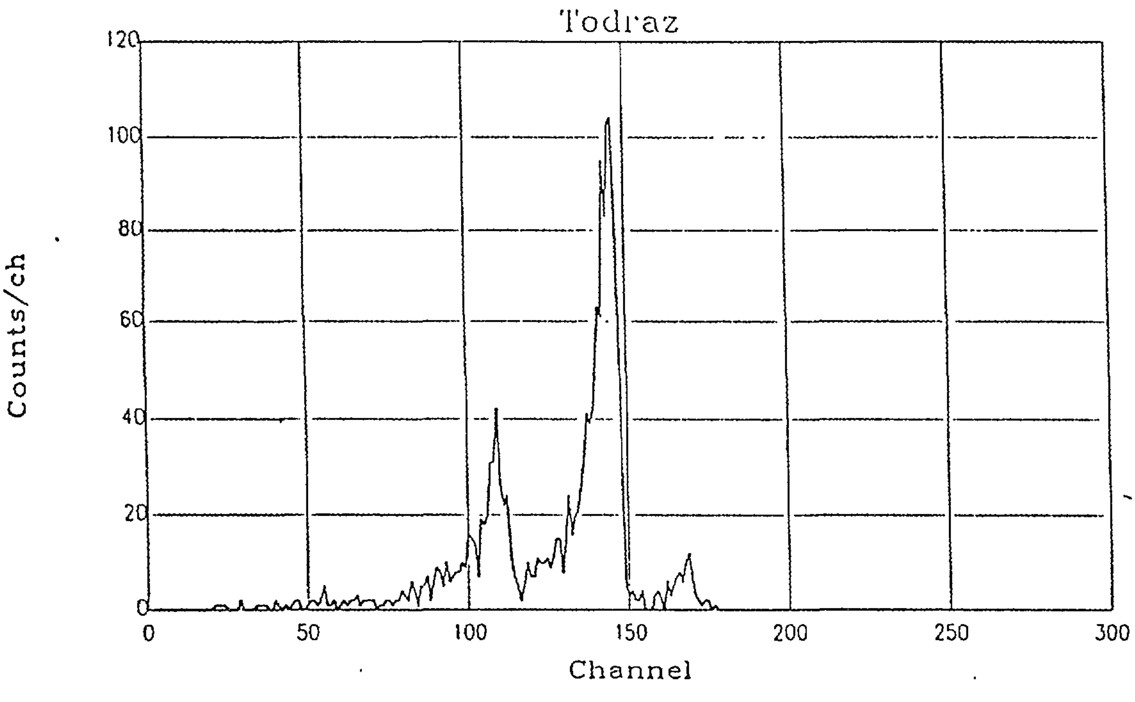
Figure 7



Start/End : 0/255
EEC : 51.2 [Bq/m3]
TEMP. : 19.9 C
DATE : 18.08.92 18:00

Po :	LC	RC	Counts
218:	110	195	1788
214:	146	195	1
212:	196	255	0

Ratio 218/214: 1.79E+0003



Start/End : 0/255
EEC : 20.9 [Bq/m3]
TEMP. : 29.9 C
DATE : 18.08.92 19:00

Po :	LC	RC	Counts
218:	110	195	958
214:	146	195	319
212:	196	255	0

Ratio 218/214: 3.00E+0000

Figure 8

The most exposed members of the public are farmers. We supposed they live and work in an enhanced-radon atmosphere all day, outdoors and indoors. The time period of vigorous (outdoor) working activities coincides with the period of lowest daily concentrations and vice versa. Publication ICRP 50 suggests different conversion factors at different breathing rates - see diagram on *Figure 9*. Breathing rates are taken as 0.45 m^3/h for resting, 0.75 m^3/h for light and 1.2 m^3/h for medium activity.

The average additional exposition to radon daughters was calculated from actual measured data and the corresponding behavior model; we found it to be on average about 0.042 WLM (6,7.10^4 Bq.h/m^3) per year. Using conversions from ICRP 50, the calculated effective dose equivalent is about 0.30 mSv per year. People in the critical group employed far from the affected area are less exposed, 0.036 WLM (5,7.10^4 Bq.h/m^3), and receive yearly only 0.24 mSv, and small children (the dose conversion factor should be multiplied by 1.5) are the most exposed segment of the population (0.065 WLM or 1,04.10^5 Bq.h/m^3, this means nearly 0.44 mSv). According to the new ICRP 65 publication (1994), the dose from inhaled radon progeny will be re-estimated, leading to lower values.

The exposure from the ingestion pathway was probably over-estimated because of using data for the most contaminated (^{226}Ra, ^{210}Pb) local agriculture food samples (milk, eggs, meat, cabbage, potato, wheat flour, fruit) and fish (trout). A great number of products originate from the surroundings of the air particulate emission sources (tailings pile, crushing mill). The additional committed dose equivalent due to intake, based on conversion factors from the IAEA Safety Series, is evaluated to be less than 0.050 mSv, i.e. within the interval of natural local variations.

The local streams are in fact used neither as drinking water nor for watering or irrigation, and are - due to realistic assessment - not included in dose calucation for the critical group. However, if drinking water were to be included in the dose assessment, the contribution from direct ingestion of local stream water would amount to 0.034 mSv/y. According to current Slovenian limits, environmental contamination of surface waters could reach up to 20 % of derived limits for drinking water.

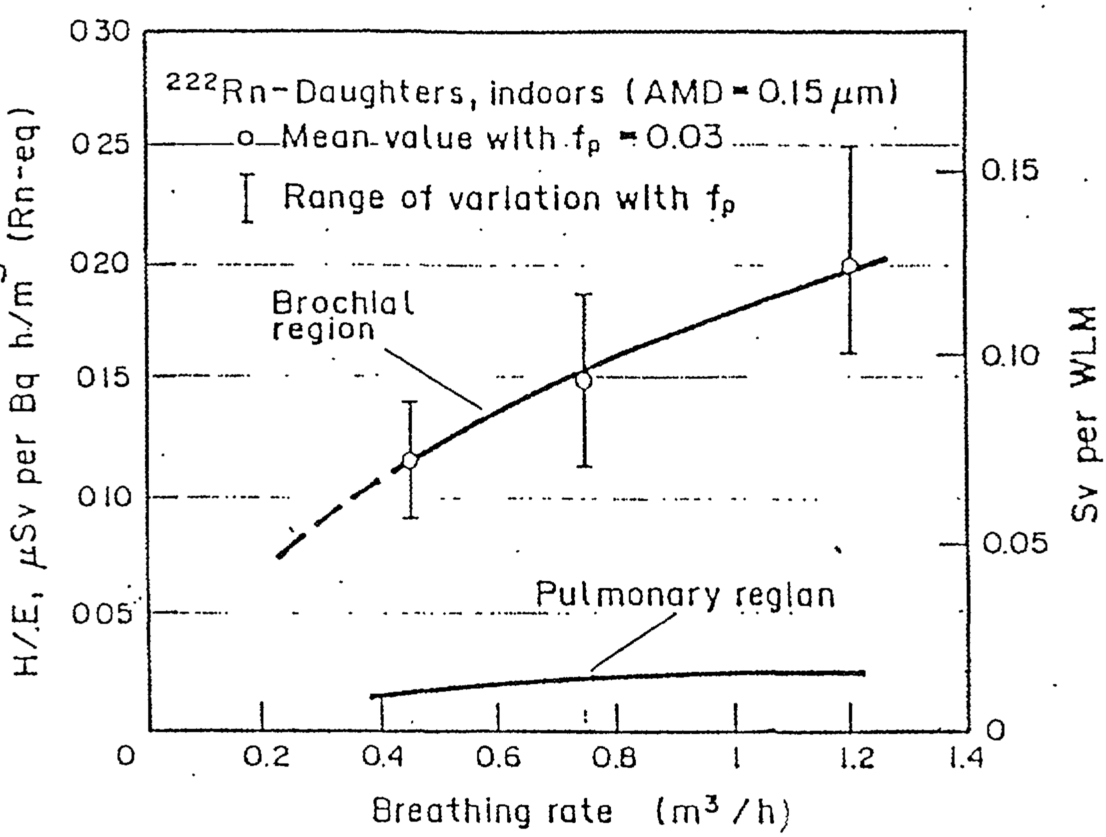


Figure 9

External exposure was estimated as a sum of dose contributions for air immersion in a radon progeny atmosphere and for direct gamma exposure from their dry deposit and temporary wash-out, and for direct gamma exposure from waste piles. This dose is small and is estimated to be around 0.01 mSv per year.

TABLE 2. ANNUAL EFFECTIVE DOSE EQUIVALENT - THE CONTRIBUTION OF THE ŽIROVSKI VRH U-MINE

Pathway	Detailed description, important radionuclides	Annual effective dose equivalent (mSv)
Inhalation	aerosols (U, ^{226}Ra, ^{210}Pb)	0.001
	^{222}Rn (gas),	0.005
	Rn short-lived progeny	0.266
Ingestion	drinking water (U, ^{226}Ra, ^{210}Pb),	-
	water biota (^{226}Ra, ^{210}Pb)	< 0.005
	agriculture products (^{226}Ra, ^{210}Pb)	< 0.05
External radiation	Rn progeny (immersion, deposition),	0.004
	long lived radionuclides,	-
	direct radiation from waste piles	0.005
Total annual dose equivalent (rounded)		**0.34 mSv**

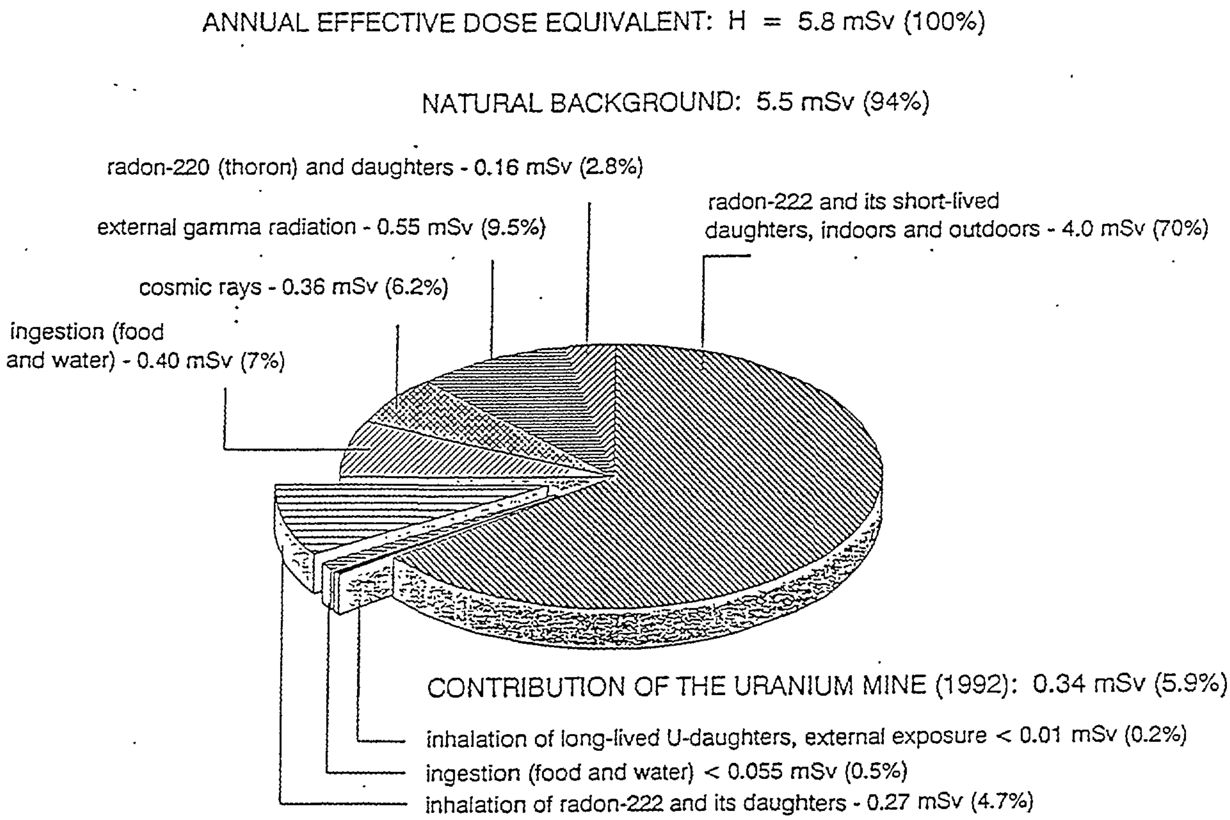
Natural background radiation around the mine area was also investigated. It was found early on that radon concentrations in the majority of old houses were quite high, even up to 1000-2000 Bq/m^3 in some cases. The log-normal distribution plot showed a geometric mean of about 250 Bq/m^3 while, in new buildings the level is essentially lower. However, on average the annual exposure due to indoor radon progeny is near 4 mSv, and thus the overall effective dose from natural sources lies around the value of 5.5 mSv per year *(Figure 10)*.

3. PLANNING OF RESTORATION OF CONTAMINATED SITES

A large project was elaborated in 1993 by the agency "ELEKTROPROJEKT LJUBLJANA" in collaboration with the University of Ljubljana, Faculty of Natural Sciences and Technology, covering all aspects of decommissioning of mining and milling facilities. The general project is called "The programme of permanent cessation of uranium ore exploitation and permanent environmental protection at Žirovski Vrh uranium mine" and consists of the following sub-projects:

- project for permanent shut-down of the uranium ore mining,
- project for cessation of yellow cake production,
- project on restoration of mine waste piles and mill tailings pile, with permanent environmental protection against the consequences of disposal and storage

Environmental monitoring after restoration of the site is also included in the project. The time schedule, manpower and costs of closing down are also important parts of the project.



Dose from medical use of radiation and from Chernobyl contamination are not included.

Figure 10

Some additional studies and decisions should still be made before starting restoration activities. In parallel, a regulatory framework is in preparation, to set authorized limits for emissions from tailings and wastes and for residual environmental radioactivity, including all categories of contaminated sites, even deposited radioactivity from non-uranium related practices. The first priority will be given to decommissioning of the U-mine area. The restoration of sites should actually start at the beginning of the next year and will last five years.

The further discussion in this paper is concerned with the technical basis for setting limits of environmental contamination and public exposure. Some practical and interesting experiences in preparing restoration at Žirovski Vrh are presented in next pages.

3.1. Regulatory framework - setting the authorized limits

Restoration projects need many technical parameters to fulfill the regulatory requirements. We started from the site specific and radiological characteristics of the site, taking into account topographical and meteorological conditions, radon emissions, geographical extent and spatial position of the waste piles, as well as outdoor levels, dispersion and distribution of radon, the main pollutant. The annual effective dose for members of the critical group was also considered in planning restoration.

Different measurement techniques were used in this research, mostly related to radon: the charcoal canister technique for radon measurement (exhalation and concentration) and continuous measurement of Rn-daughters. In this way we could follow steady-state conditions and dynamic impacts on the environmental levels.

The recent IAEA proposal recommended dose constraints from 0.1-0.5 mSv per year for members of public, the exact choice being dependent on the location and nature of the controlled source. The primary limitation is related to the level for the effective dose, the basis for deriving limits for all other quantities: radon exhalation rates and radon concentrations, content of radionuclides in ground layers, gamma dose-rate, and others.

In the case of Žirovski vrh, the primary dose limitation was proposed to be 0.10 mSv per year. This is in fact 3-4 times lower value than the actual value, assessed during the operational and close-out period (0.30-0.35 mSv). The main contribution from existing contaminated sites at Žirovski vrh comes from inhalation of radon progeny, so the main effort should be made to reduce exposure through this pathway. Since the main radon sources are area sources, they have to be covered efficiently.

Parameters for covering the bare surfaces of the waste piles were acquired and main results of this research are given below.

The radon flux from the bare tailings pile and from the mine spoil was measured in various weather conditions, for a period of almost one year. At same time we measured the environmental concentrations of radon and radon daughters within the affected areas and in the nearby environment. We also checked the homogeneity of tailings and of spoil by measuring the gamma dose-rate on the surfaces of both piles and by analyzing samples by gamma-spectrometry.

On the tailings pile at Boršt, with an area of about 38,000 m^2, the radon flux was found to average about 5 $Bq/m^2.s$ (from 1-10 $Bq/m^2.s$, theoretically predicted 5-7.5 $Bq/m^2.s$). In the same period we recorded the radon concentration profile on a longitudinal cross-section of the pile and its surroundings, trying to estimate the possible contributions to environmental concentrations *(Figure 11)*. A summary of the results and the estimated enhancement of radon concentrations are shown in Table 3.

The average radon concentration at the foot of tailings pile is 60-70 Bq/m^3, the enhancement in the valley estimated to be 7 Bq/m^3, say 5-10 Bq/m^3. The exhalation rate was 5 $Bq/m^2.s$, say 5-7 $Bq/m^2.s$. If we reduce the exhalation rate from the tailings pile at Boršt by an order of magnitude (i.e. from 5-7 $Bq/m^2.s$ to the EPA **recommended limit** value for **radon flux of 0.74 $Bq/m^2.s$**), the level of radon should drop from 5-10 Bq/m^3 to 0.5-1 Bq/m^3. The corresponding dose for members of public, living in that lateral valley, will be obviously reduced to 0.02-0.04 mSv per year.

Let us now consider the other waste pile, i.e. mine waste rock pile (spoil) at Jazbec. The same program of measurements was performed as in the previous case: an average radon flux 0.75 $Bq/m^2.s$ (0.2-1.4 $Bq/m^2.s$) from the bare surface was measured. The measured radon concentrations along the longitudinal profile has different shapes, depending on the cold or warm period of the year *(Figures 12 and 13)*. The summary of results is shown in Table 4. The first four results in the table are taken from the real concentration profile over the waste pile, and the last column refers to the value at the reference point. Results indicated with bold letters are measured in the area where members of the critical group are living.

It is not surprising that high local radon concentrations exist close to (measured 1.5 m above the surface of spoil) mine waste pile at Jazbec *(see Figure 12)* and are even higher than those close to area of the tailing pile, yet in spite of that, the total emission from the tailings pile is about 5-times higher than the emissions from the mine waste area *(Figure 14)*. The resulting excess concentrations are the same in both cases. The reason lies in the different topographical position of the two piles; the tailings pile lies on the slope of a hill, well above the average inversion layer (at 500 m). The mine waste pile is located only some tens of meters above the bottom of the main valley and below the inversion layer. So the latter has the dominant impact on environmental levels of radon. This means it would be necessary to reduce radon the exhalation rate from 0.7-0.8 $Bq/m^2.s$ by approximately one order of magnitude, i.e. to below 0.1 $Bq/m^2.s$.

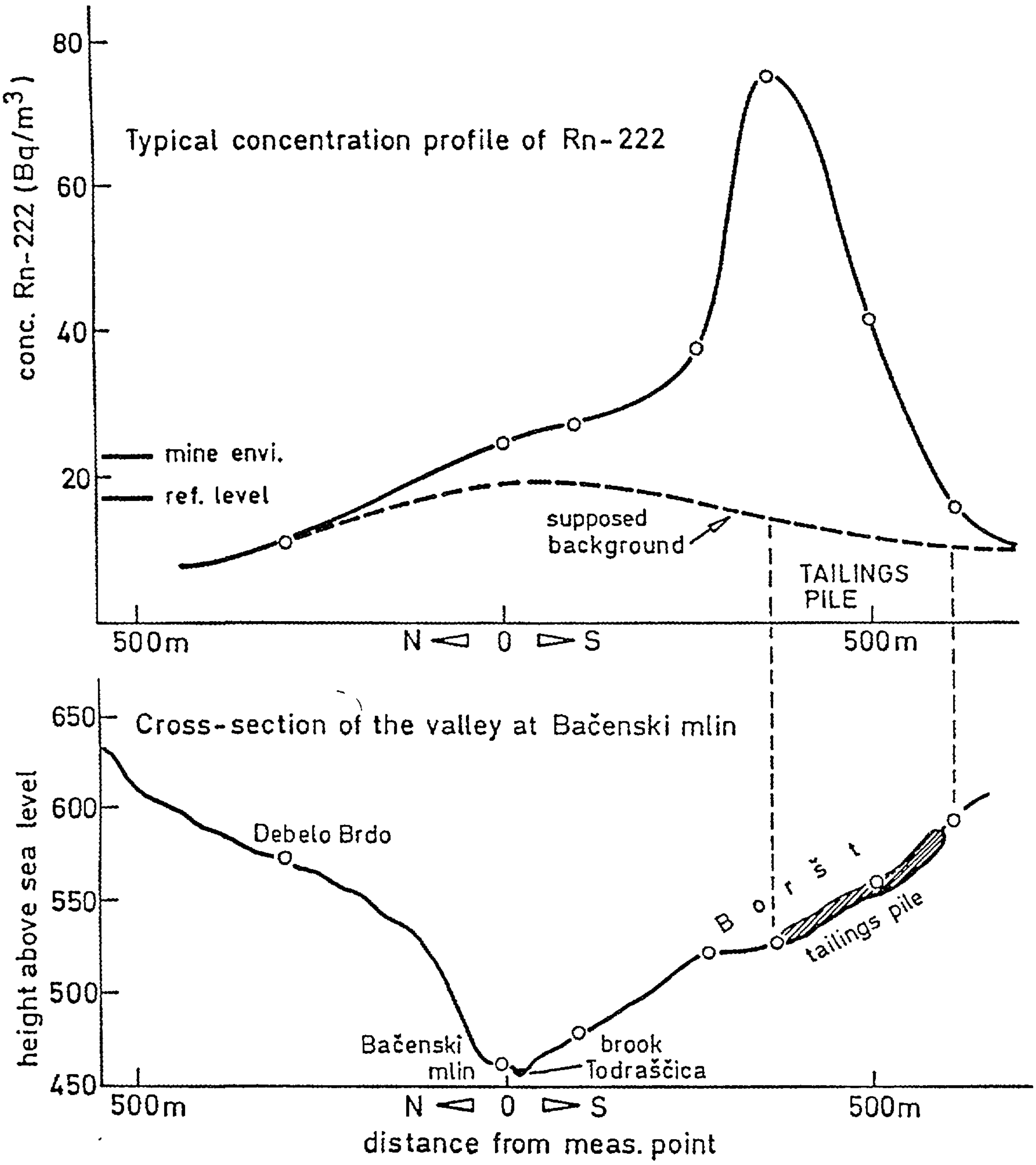


Figure 11

TABLE 3. AVERAGE CONCENTRATIONS OF THE ^{222}Rn AT THE TAILING PILE

	Average radon concentration at the tailings pile and in the surroundings (Bq/m^3)					
Distance(*)	50 m	100 m	150 m	300 m	500 m	900 m
Total	22	42	80	40	27	22
Background	16	17	17	18	20	12
Enhancement	**4**	**25**	**63**	**22**	7	-

(*) Zero distance in the table is set at the distance of 100 m above the upper edge of the tailings pile

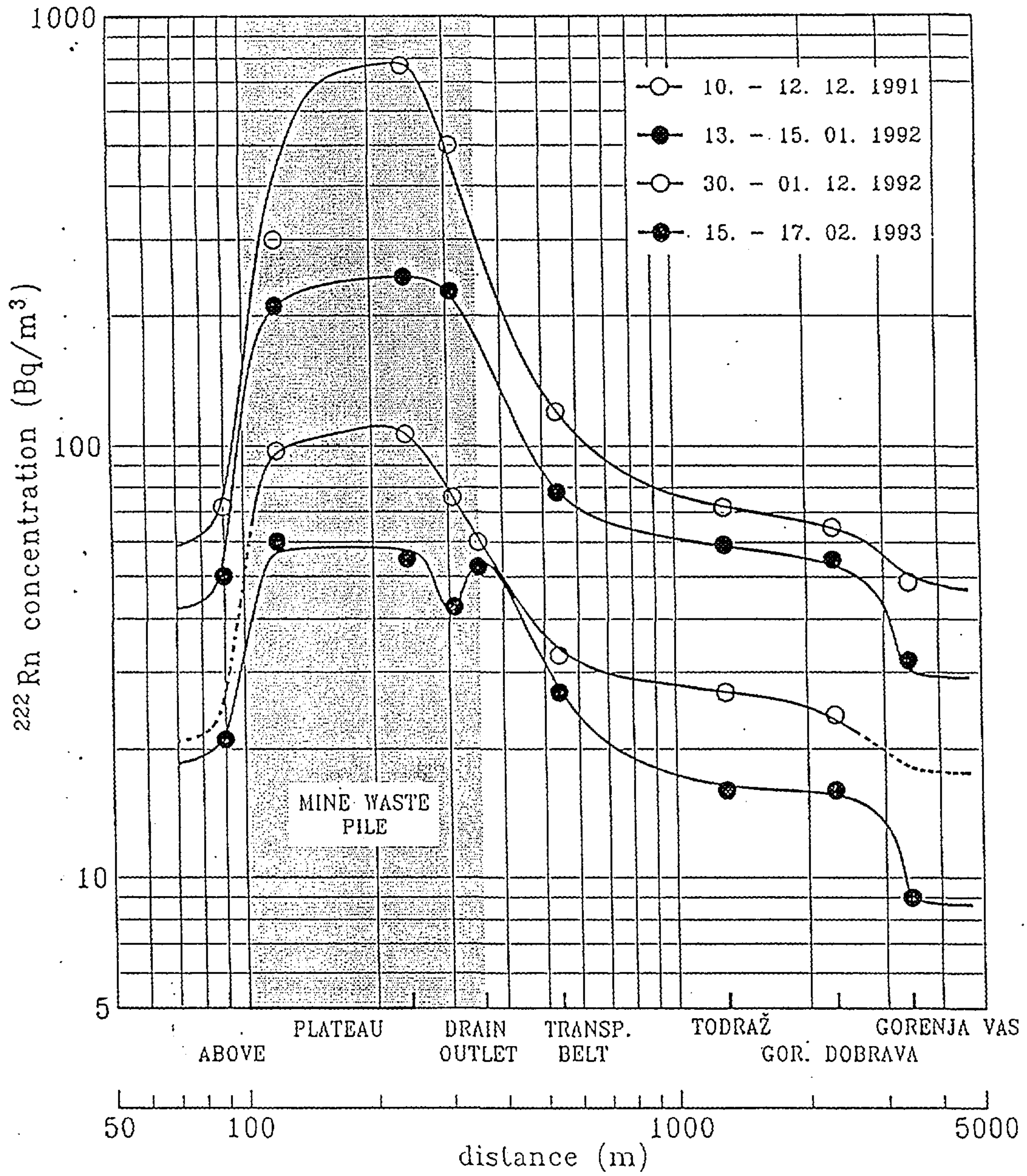


Figure 12

3.2. Derivation of authorized limits for radon emission

A simple and rough calculation, related to enhanced levels of radon and exposure of the public enables the setting of the authorized limits. From the previous section we have the relation: 7-8 Bq/m^3 of average enhancement of radon concentrations results in an exposure of the public of approximately 0.3 mSv per year. If now we set a dose constraint for total exposure from the decommissioned sites to 0.10 mSv per year, the radon concentrations should be reduced to the average yearly values down to 1-2 Bq/m^3. This means the **limiting** value of **radon flux** on the mine waste pile has to be not higher than **0.1 Bq/m^2.s**.

For this particular case, the experimental basis (radon concentration profiles and realistic impact assessment) for the decision on authorized limits was created as shown in the summary table.

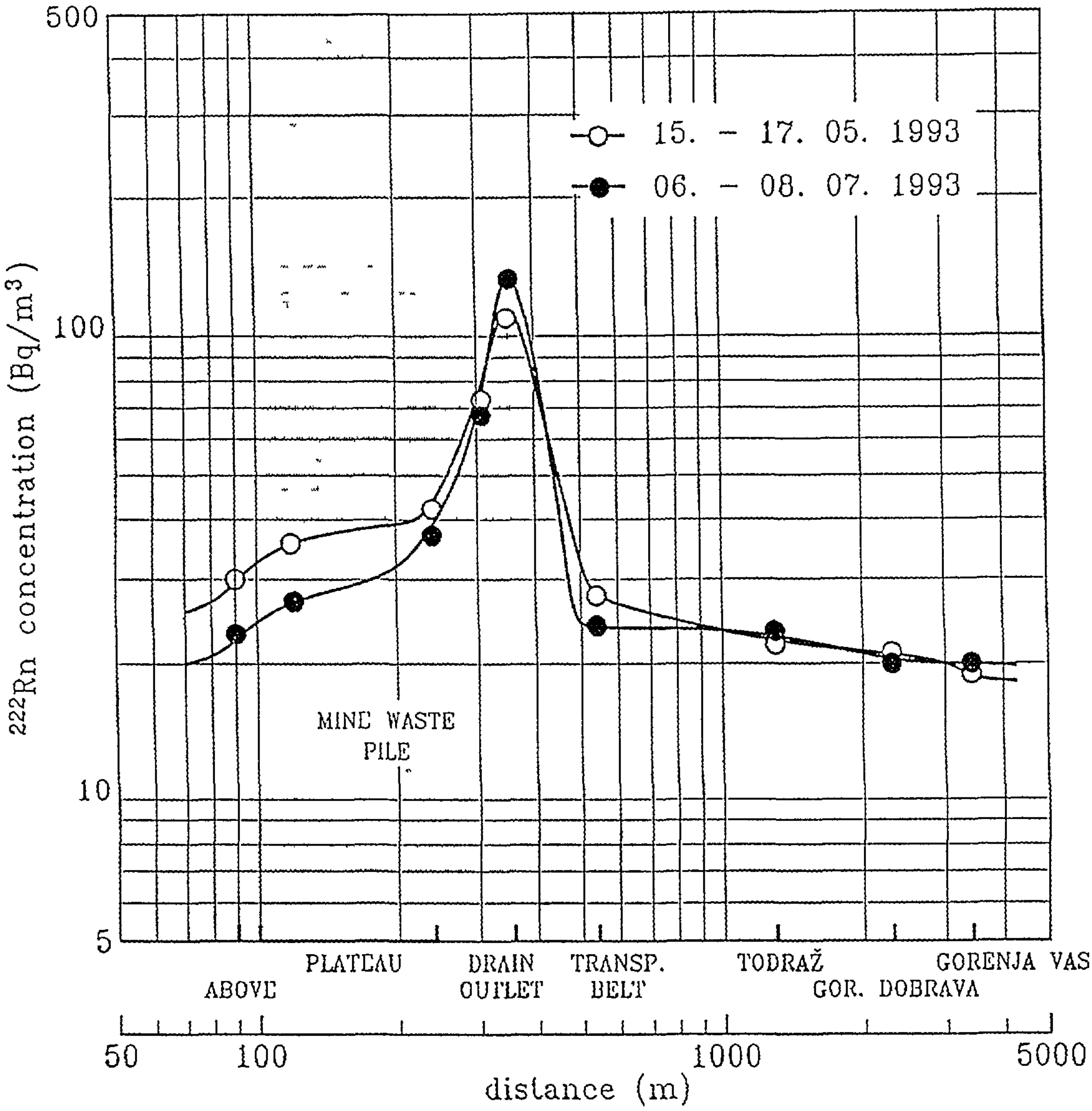


Figure 13

TABLE 4. AVERAGE CONCENTRATIONS OF ^{222}Rn AT THE MINE WASTE PILE AND IN THE VICINITY

	Average radon concentrations at the mine waste pile (spoil) (Bq/m^3)					
Distance(*)	50 m	200 m	300 m	500	1500 m	3000 m
In winter	30	155	115	55	35	25
In summer	35	47	115	28	21	16
Annual average	33	101	115	42	28	20
Background	15	18	21	21	21	20
Contribution	**18**	**83**	**94**	**21**	7	-

(*) Zero distance in the table is set at the distance of 100m above the upper edge of the tailing pile

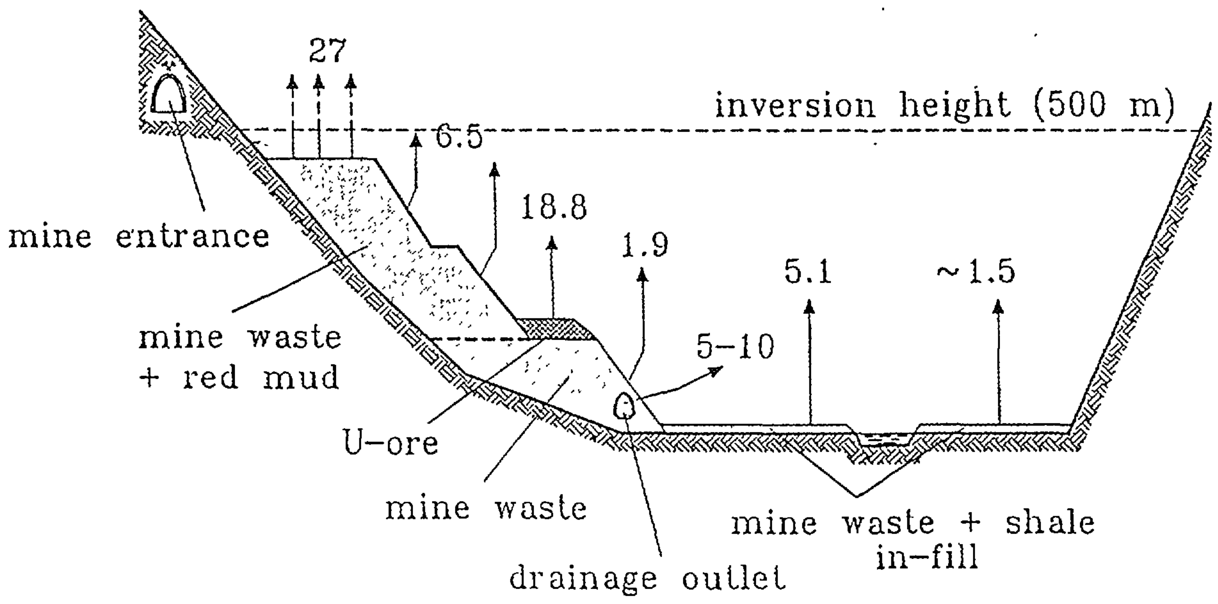


Figure 14. RADON EMISSION FROM MINE WASTE AREA (in units kBq/s)

TABLE 5. PROPOSAL FOR AUTHORIZED LIMITS FOR CONTAMINATED SITES AT ŽIROVSKI VHR URANIUM MINE

	Dose constraint (mSv)	Rn-enhancement (Bq/m^3)	Rn-flux ($Bq/m^2.s$)
Mine waste pile	**0.10**	1-2	**0.1**
Tailings pile	**0.10**	1-2	**0.74**

The proposals for other authorized limits, such as for contaminated soil (including top covering materials), intended for further agriculture use, are not verified yet, but probably will be set to:

1. **Soil contamination**: the highest content of long-lived radionuclides should be limited to 100-200 Bq/kg (^{226}Ra, ^{228}Ra)

2. **Gamma dose-rate** on the restored surface: maximum 0.10 μGy/h above background or additionally up to 100 % of level of native background

3.3. Covering the waste piles: design and experiments

Once (the proposal for) the regulatory framework was established, the parameters needed for covering the waste piles could be determined. A field experiment was carried out in order to test the protective radon barrier. A clay covering with various thicknesses, namely from 0.20-0.50 m in steps of 0.10 m was built on the surfaces of the tailings pile and on the waste pile separately. Measurements of radon transmission were periodically performed over a year. Results showed that the particular clay used in the experiment, will reduces the radon bare flux very efficiently: 30 cm of clay material (with normal humidity) could reduce the radon flux up to 95-98 % or even 99 %. Results were also verified by a model simulation and are presented in the diagram on *Figure 15*.

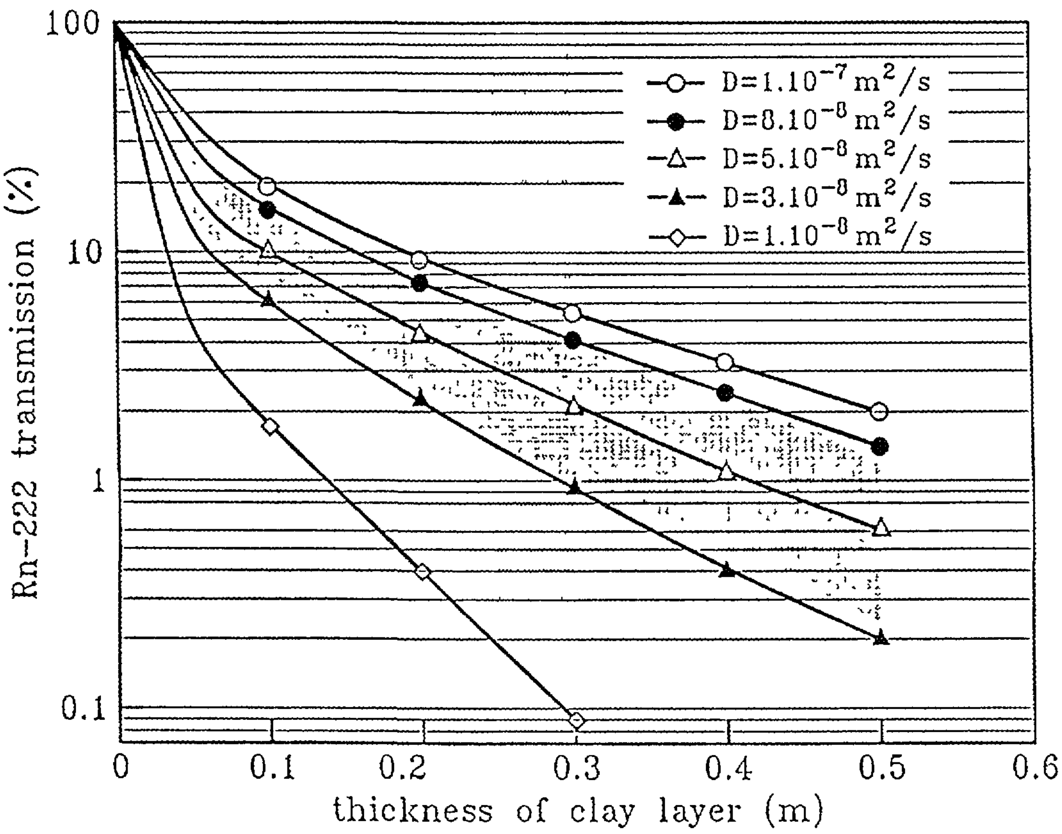


Figure 15. ATTENUATION OF RADON FLUX THROUGH CLAY COVER

The thickness of the clay radon barrier needed on the tailings pile was estimated to be at least 0.30 m. The analogue cover of the mine waste pile could be a little thinner, i.e. 0.25 m. The proposed layer thicknesses would fulfill the requirements for exhalation limits and for the dose limit.

The construction of the total covering is more complex and needs to be thicker, ensuring among other things, protection against freezing of the clay layer *(Figure 16)*.

2.4. Long-term considerations

Concerning the long-term prediction of public exposure, during the required research studies, a very unusual feature was discovered. As the consequence of unsuitable practice in the past, this will have probably a strong influence on future migration of radionuclides into the environment.

Namely, laboratory analysis of deposited materials and the balances of masses and activities showed that the majority of ^{230}Th, the predecessor of ^{226}Ra, was not deposited on the tailings pile but remained in so-called red mud. This neutralization by-product in the process of solvent extraction of uranium, containing high contents ^{230}Th, was deposited on the mine waste pile at Jazbec. Having the greatest impact on environmental radon concentrations, most ^{226}Ra will grow in at the Jazbec tip. This ingrowth of ^{226}Ra over the next several thousands years means enhanced potential of radon, able to some extent to emanate into atmosphere. The elevated concentrations of its short lived progeny will increase the radiation exposure of members of public as well as leaching of ^{226}Ra into surface and ground waters. The time dependance of radium ^{226}Ra activity, deposited in the waste pile, could, according to theoretical predictions, more than double the exhalation rate from the pile in the next thousand years *(Figure 17)*.

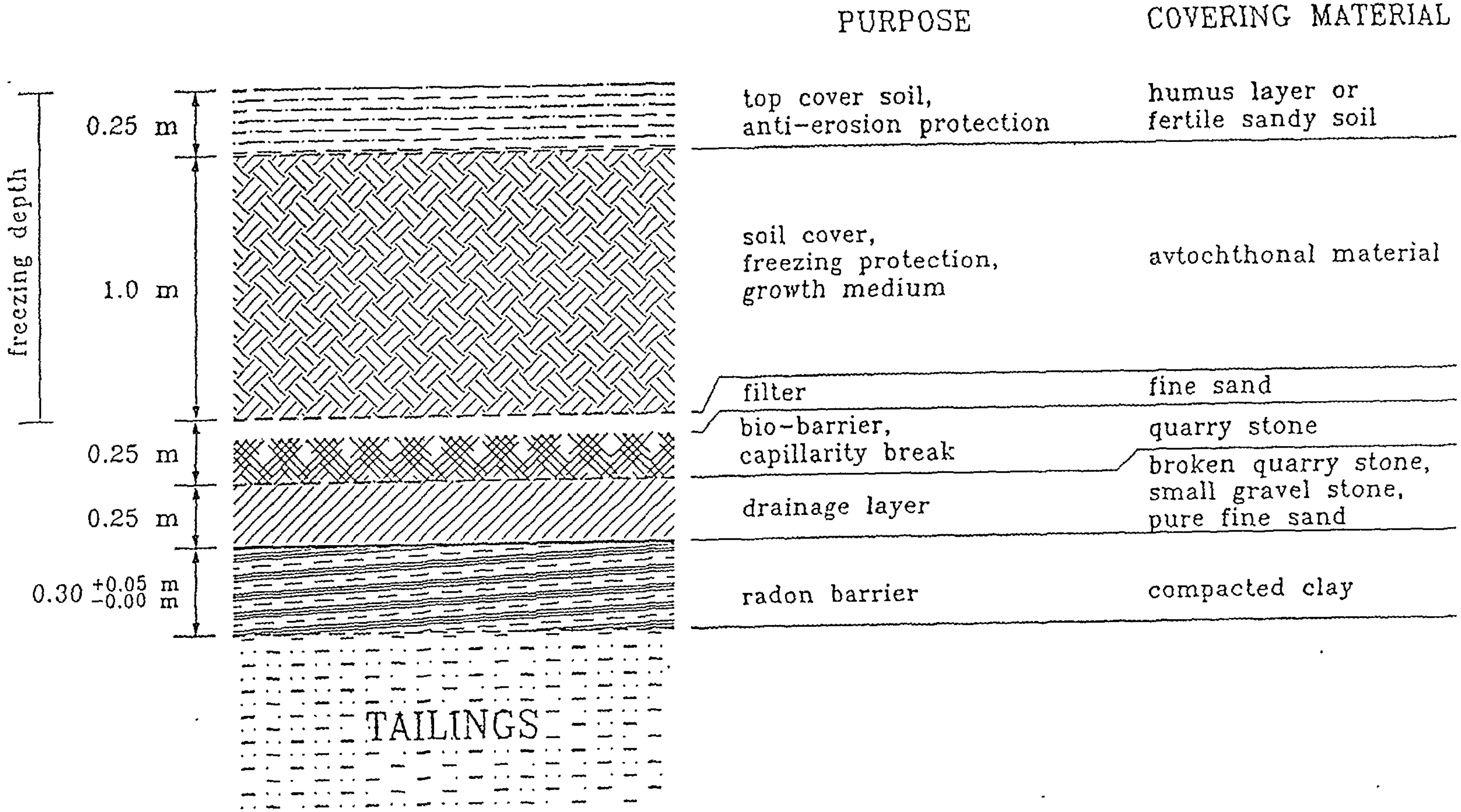
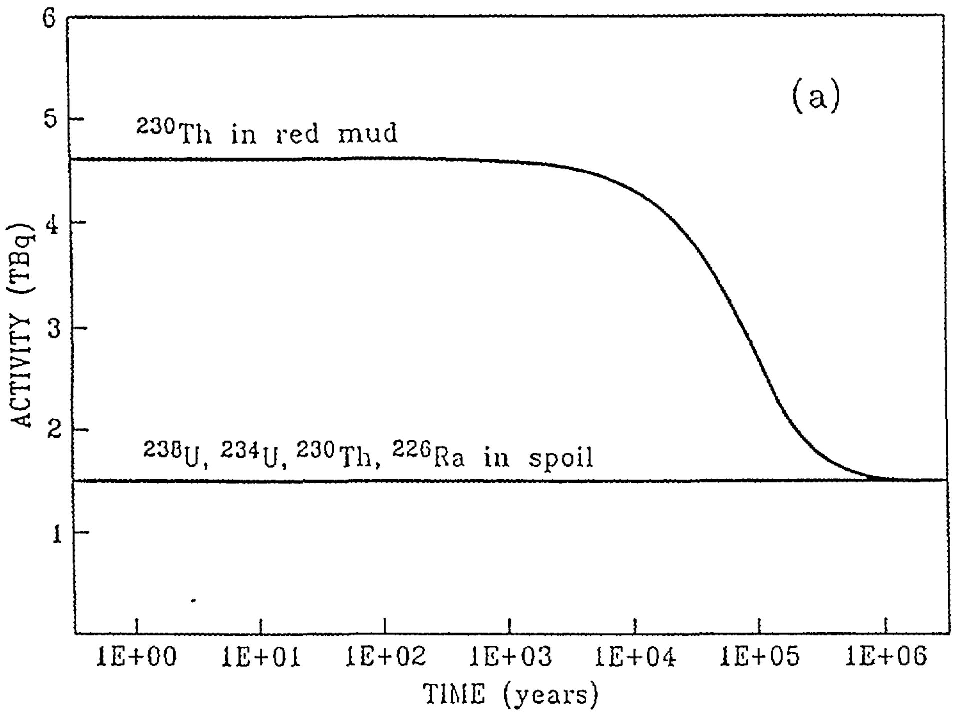


Figure 16. PROPOSED CONSTRUCTION OF COMPLEX COVERING LAYER



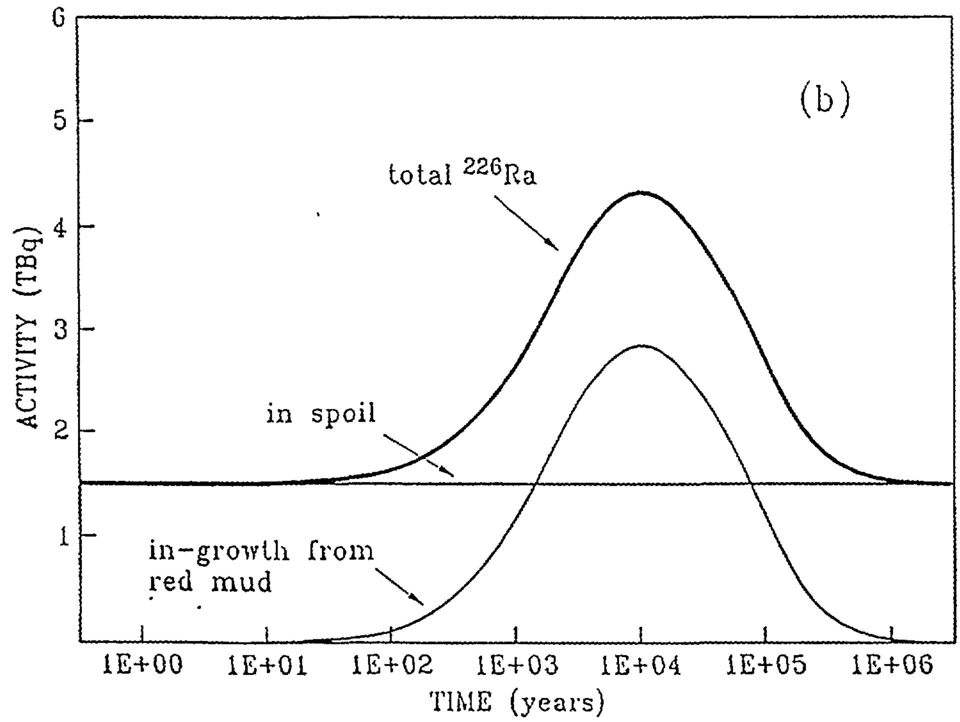


Figure 17. (a) - DECAY ACTIVITIES OF RADIONUCLIDES IN WASTE PILE AT JASBEC; (b) - ACTIVITY OF RADIUM-226 DEPOSITED IN WASTE PILE AT JASBEC.

3. CONCLUSION

Until now, no final solution on the restoration of contaminated sites at Žirovski Vrh has yet been accepted. There are three variant solutions projected. Returning the tailings back to the mine, in total or only partially (1/4), depends on countermeasures against slippage on the slope of the hill called Boršt. The third solution, to move all the tailings to the mine waste pile (over the spoil) at the Jazbec site, will be most probably rejected. In this case, the tailings would cause, as it was found in previous studies, too high dose levels for members of the public, far beyond the recommended dose constraints. Whatever will be accepted, the technical basis and regulatory framework for restoration, from the radiological point of view, is prepared.

Other cases of tailings of radioactive material in Slovenia are not uranium production related and are not considered in this paper. In the town of Idria, the mercury mining district, residues of ignited mercury ore and the mine vents (in the closing phase but still in operation) cause high outdoor concentrations of radon in the town (up to 50-100 Bq/m^3), comparable or even higher to those in the vicinity of the former U mine. Indoor radon concentration in one reached 15.000 Bq/m^3. Similar features were observed in the town of Kočevje, an old coal mining district: the highest outdoor values in Slovenia were measured, with daily averages of about 80 Bq/m^3, and hourly maxima of about 150 Bq/m^3. These high values are probably related to the large amounts (some millions of cubic meters) of radioactive coal and coal ash (^{226}Ra 400-2000 Bq/kg) deposited on an area of 1.5 km^2 at the edge of the town. Indoor radon concentrations also show high levels (up to some thousands of Bq/m^3). These two cases of contaminated areas also need further investigations. The cancer statistics shows the highest levels of incidence of lung cancer in Slovenia in both communities.

A regulatory framework is also in preparation for non-uranium cycle related tailings and for other technologically enhanced and deposited radioactivity.

REFERENCES

(1) Hinton, T.G., Whicker F.W., A Field Experiment on Radon Flux from Reclaimed Uranium Mill Tailings, Health Phys., Vol.48, No.4, pp.421-427, Pergamon Press, USA, 1985

(2) Busigin A, Nathwani J.S., Phillips C.R., Attenuation of Radon Flux from Uranium Mill Tailings by Consolidation, Health Phys., Vol.36, pp.393-399, Pergamon press, 1979

(3) Mathews M.L., Remedial Actions at Inactive Uranium Mill Tailings Sites, Proceedings of Internal Conference "Radiation Hazards in Mining", ed.M.Gomez, Publ.Soc. of Min.Eng., New York 1981

(4) Levins, D.M., Davy.D.R., Management of Wastes from Uranium Mining and Milling, Document IAEA-CN-43/147, Int.Conf. on Radioactive Waste Management, Seattle, USA, May 1983

(5) Morris. R.C., Fraley L.Jr., Effects of Vegetation, a Clay Cap and Environmental Variables on Rn-222 Fluence Rate from Reclaimed U Mill Tailings, Health Phys, Vol.56, pp.431-440, Pregamon Press, USA, 1989

(6) IAEA Technical Reports Series No.209, Current Practice for Confinement of Uranium Mill Tailings, IAEA, Vienna, 1981

(7) US NRC 10 CFR, Chapter 1, Appendix A to Part 40, Criteria Relating to the Operation of Uranium Mills and the Disposition of Tailings or Wastes Products by the Extraction or Concentration of Source Material from Ores Processed Primarily for Their Source Material Content, NRC (1-1-89 Edition).

(8) US NUREG Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers, Nuclear Regulatory Guide 3.64, Washington D.C., June 1989

(9) Canadian Uranium Mill Waste disposal Technology, A.Mc G.Robertson, R.A.Knapp, L.A.Melis, N.A.Skermer, CANMET, Ottawa (1987)

(10) IAEA Technical Reports Series (Draft version), The Decommissioning of Uranium and Milling Facilities and the Closeout of Tailings Impoundments, Vienna, March 1992

(11) Australian Government Department of Home Affairs and Environment, Code of Practice on Management of Radioactive Wastes from the Mining and Milling of Radioactive Ores, (3rd set Additional Guidelines), Canberra 1983

(12) IAEA Technical Reports Series (Draft version), Measurement and Calculation of Radon Releases from Uranium Mill Tailings, Vienna, July 1991

(13) Rogers,V.C., Nielson K.K., Multiphase Radon Generation and Transport in Porous Materials, Health Phys.Vol.60, No.6,pp.807-815, Pergamon Press, N.Y.1991

(14) Strong.K.P., Levins D.M., Effect of Moisture Content on Radon Emanation from Uranium Ore and Tailings, Health Phys., Vol.42, No.1, pp.27-32, Pergamon Press, N.Y. 1982

(15) Regulations on mode of collecting, keeping records, processing, storing, final deposition and discharging of radioactive waste materials into living environment, Federal official gazette, No. 40/86 (in Slovene)

(16) Health and environmental protection standards for uranium and thorium mill tailings, CFR 40, Chapter I - EPA, Part 192, Subpart A, B, D in E, Washington, July 1, 1991

(17) Strahlenschutzgrundsatze fuer die Verwahrung, Nutzung oder Freigabe von kontaminierten Materialen, Gebaueden, Flaechen oder Halden aus dem Uranerzbergbau, Empfelunen der Strahlenschutz Kommission mit Erlauterungen, Bonn, April 1992

(18) Strahlenschutzgrundsaetze fuer die Verwahrung und Nutzung von Berghalden, Empfelungen der Strahleschutzkommission, Bonn, Oktober 1991

(19) NEA, Long-term Radiological Aspects of Management of Wastes from Uranium Mining and Milling, NEA OECD, September 1984,

(20) IAEA Current Practice and Options for Confinement of Uranium Mill Tailings, Technical Report Series No.209, Vienna, 1981

(21) Holmes R.W. and Chambers D.B., Probabilistic Assessment of the Long-term Effects of Uranium Tailings, paper presented at the 2nd Int.Conf. on Radioactive Waste Management, Winnipeg, Manitoba, Sept 7.-11. 1986

(22) US NRC, Methods for Estimating Radioactive and Toxic Airborne Source Terms for Uranium Milling Operations, Reg.Guide 3.59, Washington D.C., March 1987

(23) Nielson K.K. et al., Prediction of Net Radon Emission from a Model Open Pit Uranium Mine, NUREG/CR-0628 Rev.PNL-2889, Battelle, Pacific Northwest Laboratory, Richland, WA, 1979

(24) NN 89, Final EPA rules set 10 mrem/yr dose level, Nuclear News, Amer.Nucl.Soc.Publ., Vol.32, La Grange Park, Ill., December 1989

(25) M.Križman, P.Stegnar, Environmental Radioactivity in the Žirovski Vrh Uranium Mine and the Impact Assessment in 1992, Report, IJS DP-6750, Ljubljana, May 1993 (in Slovene)

(26) M.Križman, P.Stegnar, D.Konda, Testing of covering materials on uranium tailings pile at Boršt, and determination of the structure and thickness of covering layer, IJS Report DP-6431, Ljubljana, March 1992 (in Slovene)

(27) Križman M., Stegnar P., Environmental impact of the Žirovski Vrh uranium mine on the enhancement of outdoor radon concentrations, Rad.Prot.Dos. Vol.45 1/4 pp.723-728 (1992)

(28) Križman M., Stegnar P., Atmospheric radon concentrations in the environment of uranium mill tailings in Slovenia, Proceedings of Austrian-Italian-Hungarian Radiation Protection Symposium, Obergurgl/Tyrol (28-30 April 1993), Austria, publ.OVS, Seibersdorf, 1994

(29) Križman M., Byrne A.R., Benedik L., Distribution of Th-230 in milling wastes from the Žirovski vrh uranium mine (Slovenia), and its radiological implications, (submitted to Journal of environmental radioactivity)

(30) Križman M., Stegnar P., Konda D., Study of parameters for restoring of mine waste pile at Jazbec (The Žirovski Vrh Uranium mine, Slovenia), Report, IJS DP-6950, Ljubljana, February 1994 (in Slovene)

(31) ICRP 60, 1990 Recommendations of the International Commission on Radiological Protection, Pergamon Press, Oxford, 1991

(32) ICRP 65, Protection against Radon-222 at Home and at Work, Pergamon Press, Oxford, England, 1994

(33) Basic Safety Standards, (draft versions in years 1992-1993), IAEA, Vienna

(34) Bajželj U., Zabukovec I., Kvaternik K. The programme of permanent cessation of uranium ore exploitation and permanent environmental protection at Žirovski Vrh uranium mine, Report B103/9, Elektroprojekt Ljubljana, Ljubljana, February 1993 (in Slovene)

DECOMMISSIONING PLAN FOR ANDUJAR URANIUM MILL FACILITIES

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Abstract

The milling of radioactive ores results in contaminated buildings and facilities which must be decommissioned, and large quanties of tailings which must be managed safely so that residual environmental and health risks do not exceed aceptable levels. In the south of Spain on the outskirts of the town of Andujar an inactive uranium mill facility in under decommissioning. Mill equipment, buildings and process facilities have been dismantled and demolished and the resulting metal wastes and debris have been placed in the pile. The tailing mass is being reshaped by flattening the sideslopes and a cover system will be placed over the pile. This paper describes the safety aspects and technical approaches which are being used for the remediation and closure of the Andujar mill site.

1.- INTRODUCTION

Empresa Nacional de Residuos Radiactivos, S.A. (ENRESA) is remediating an inactive uranium mill facility in the town of Andújar in the south of Spain. The Andújar plant became operational in 1959 and continued in operation until 1981. All solid waste generated during the operation of the plant are contained in a tailings pile, which covers an area of 9.4 hectares and has a total volume of about one million cubic meters. The pile was constructed in five cells by upstream construction to a height of 20 meters in the central and eastern parts and to a height of 10 meters in the western part. This paper summarizes the criteria used for the remediation and closure of the Andújar mill site and discusses the safety aspects associated with the decommissioning of the mill facilities.

2.- MILL FACILITY CHARACTERISTICS

The Andújar Uranium Milling Plant is in the province of Jaén (Andalucía) on the southern floodplain of the Guadalquivir river at 1.5 kilometers south from the urban center of Andújar. The location of the site is given in Figure 1. The site is trapezoidal in shape, covers and area of approximately 17.5 hectares and is contained within a peripheral wall, which is about 150 m from the course of the river.

The plant was designed for processing low grade uranium ore (0.15% of U_3O_8) and produced 80% concentrate of U_3O_8 in the form of sodium and ammonium uranate at a rate of 60 to 80 tons per year. The plant became operational in 1959 and continued in operation until 1981. During this period 1.2 million tons of uranium ore were processed to produce 1350 tons of U_3O_8 with a fineness of 80-85%. Recovery of the uranium involved sulphuric acid leaching followed by ion exchange or by tertiary amine/Kerosene extraction. Solid wastes were stored in the tailings piles and liquid wastes were treated before disposal to the Guadalquivir river.

The configuration of the Andújar mill site is shown in Figure 2 and includes the following areas: the tailings pile, the processing plant, the waste water treatment area, the auxiliary and administrative buildings and the housing area.

All solid waste generated during the plant's operation (1.2 million tons) are contained in the tailings pile, which sideslopes vary from 25 to 35 degrees and has a total activity of 4500 Ci.

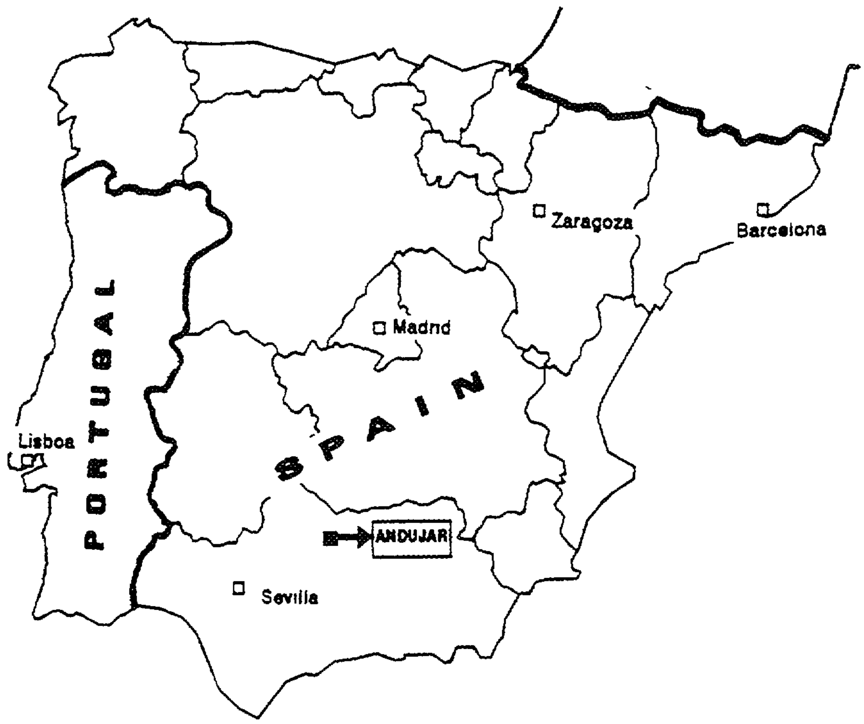

FIG. 1. Site location.

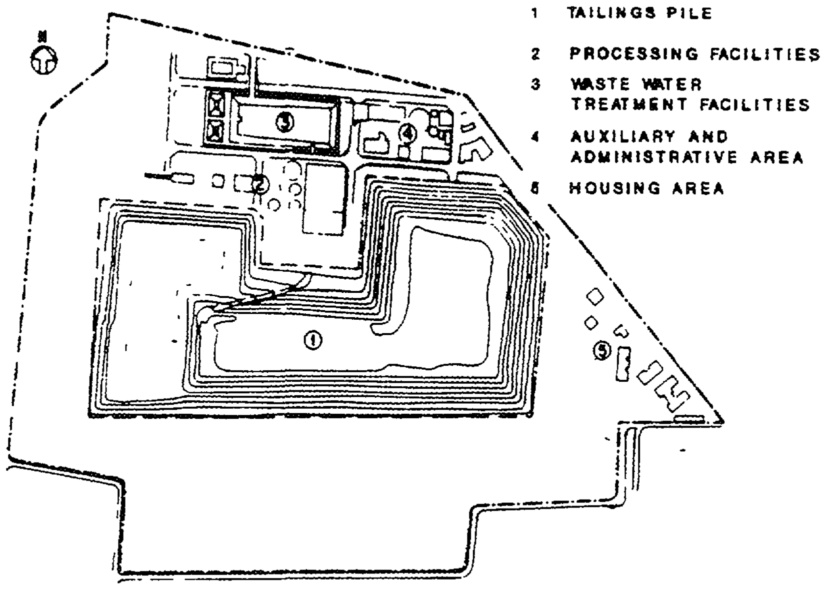

FIG. 2. Present configuration Andujar mill site.

3.- SAFETY ASSESSMENT

Safety analyses were carried out to determine the short term and long term consequences (risks) to humans and the environment associated with the inactive milling site and the proposed decommissioning actions. Risks may arise from the tailings pile, the mill facilities and buildings and the contaminated soils around the site and may be generated by events such as:

. Humans actions associated with intrusion into tailings or removal of contaminated materials.

. Dispersion of contamination via air/water pathways.

. Massive migration of tailings/contaminated materials as a result of structural failure or degradation of the pile and/or the buildings.

Scenario analyses were performed in which release and transport scenarios for radiactive pollutants were defined, followed by consequence analyses in which the radiological effects of the releases to the environment were evaluated.

The various scenarios considered for the Andujar mill site are shown in Figure 3. Important release mechanisms include: radon emanation, seepage and uncontrolled release of contaminated water, structural or seismic instability, wind and water erosion or dispersion, unauthorized removal of tailings and/or contaminated soils or materials.

Major risks associated with the decommissioning of mill facilities are listed below:

. Direct gamma radiation produced by radioactive decay series of the U-238.

. Tailings dispersion due to wind or water erosion and human or animal intrusion.

. Contamination of surface waters due to water erosion and surface runoff wich result in the dispersion of radioactive particles in the waters.

. Groundwater contamination as a result of seepage of rainfall water through the tailings and the substratum and contaminant migration to underlying aquifers.

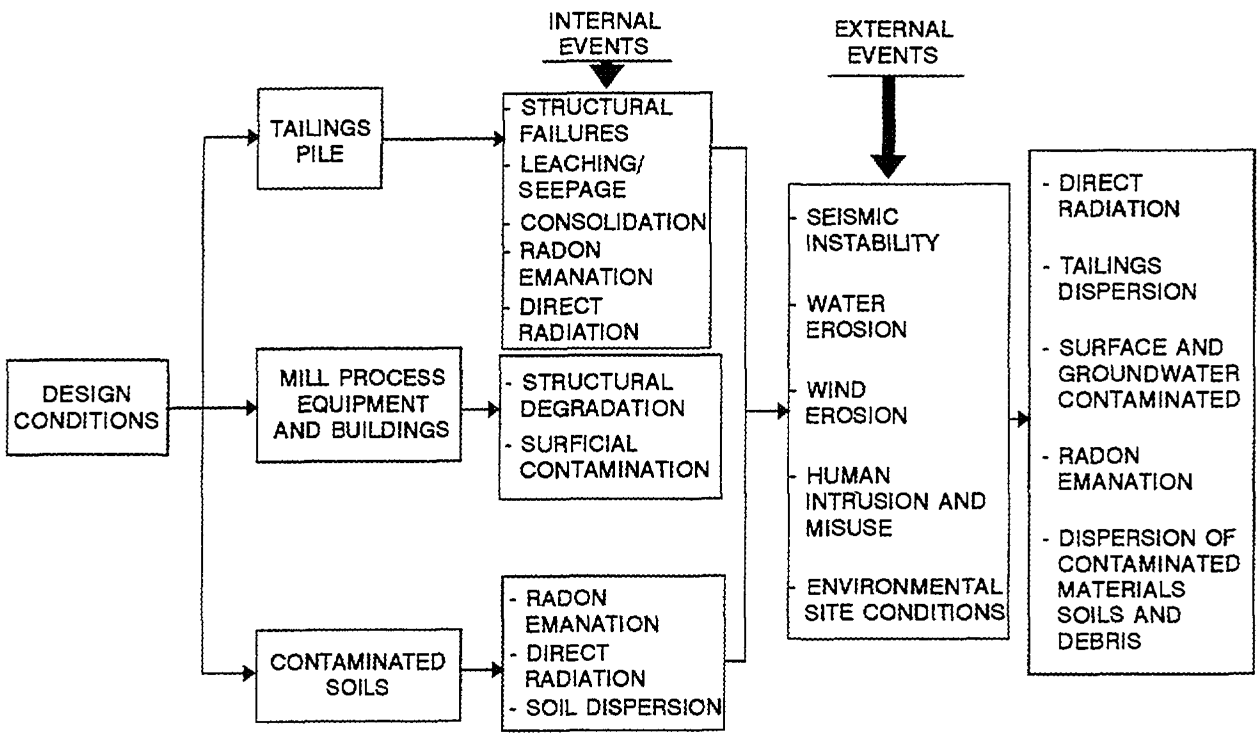

FIG. 3. Potential risks associated with inactive mill facilities.

. Radon emanation produced in the radioactive decay sequence of Ra-226.

. Dispersion of contaminated materials and/or soils by wind, water erosion, human or animal intrusion.

Major pathways by which the released pollutants can reach the environment and humans are as follows:

. Atmospheric pathways which lead to irradiation by inhalation of radon and its daughters, inhalation of airborne radioactive particles and external irradiation.

Atmospheric and terrestrial pathways which can cause doses due to ingestion of contaminated foodstuff and external irradiation

Aquatic pathways which can results in the ingestion of contaminated water, foods produced using irrigation, fish and other aquatic biota, and though external irradiation

To ensure that risks were adequately controlled, a set of fundamental safety and design criteria were established, as shown in Figure 4 Primary objectives were the following

Dispersion and stabilization control to ensure confinement and long-term stability of tailings and contaminated materials

Erosion control to prevent surface water contamination and ensure long-term integrity of the closed-out facility

Radon control to reduce radon emissions

Groundwater protection to prevent groundwater contamination by rainfall waters infiltrating into the tailings

To achieve these objectives, the following design elements were incorporated into the decommissioning plan (Fig 4)

Stabilization against extreme events by slope flattening and pile reshaping

Dismantling and demolition of mill facilities and buildings and placement of metal wastes/debris in the pile

Placement of a cover system including a radon barrier, an infiltration barrier, a biointrusion barrier and an erosion protection barrier

4.- REGULATORY AND DESIGN OBJECTIVES

The regulations and standards that govern the remediation activities at Andujar have been established by the Spanish Nuclear Safety Council (CSN), taking into account the recommendations of international organizations (ICRP, IAEA and OECD/NEA), the standards promulgated by the U S Environmental Protection Agency for the remediation of uranium mill tailings, and the Spanish regulations, specifically

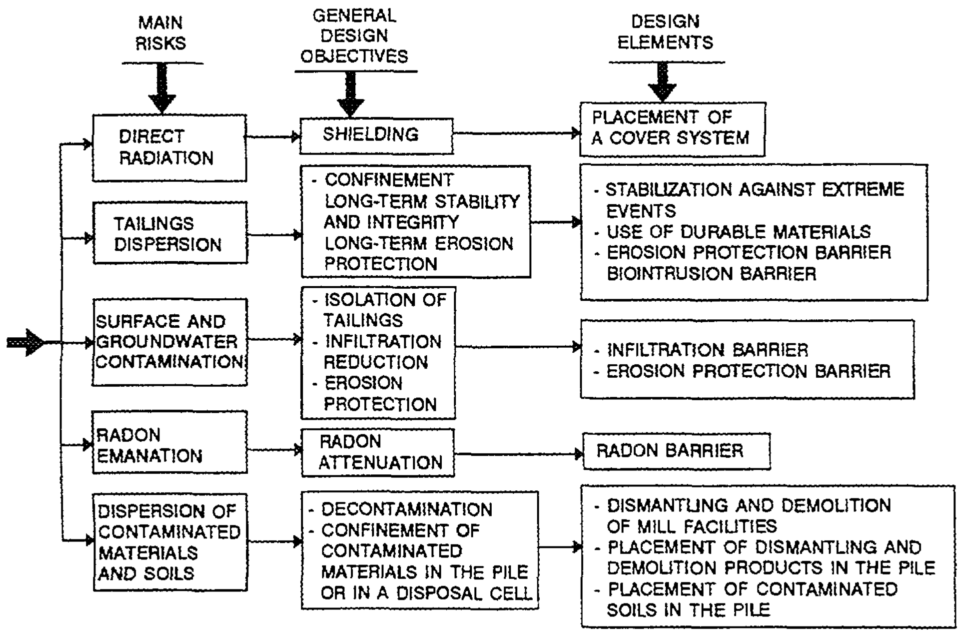

FIG. 4 Objectives and design elements.

those related to groundwater protection and the long-term disposal of radioactive wastes. These regulations may be summarized as follows:

* Dispersion Control: Prevent inadvertent human intrusion and dispersion of contaminated materials by wind and water erosion.

* Long-term Radiation Protection: Achieve an effective equivalent dose to the individual in the critical group below 0.1 mSv/year.

* Design Life: Remain stable for 1000 years to the extent reasonably achievable and in any case for at least 200 years.

* Soil Cleanup: Reduce the residual concentration of radium-226 in land, averaged over an area of 100 m^2, so that the background level is not exceeded by more than 5pCi/g (averaged over the first 15 cm soil) and is less than 15 pCi/g (averaged over 15 cm thick layers of soil more than 15 cm below the surface).

* Radon Control: Reduce radon flux over the surface of the final pile to an average release rate of less than 20 pCi/m^2 s.

* Groundwater Quality Protection: Control groundwater contamination so that background water quality or maximum concentration levels (in accordance with Spanish regulations and CSN guidelines for radioactive constituents) are achieved in the long-term. These maximum levels are: combined radium-226 and radium-228 0,18 Bq/l (4,86 pCi/l), combined uranium-234 and uranium-238 1,2 Bq/l (32,4 pCi/l) and gross alpha activity, excluding radon and uranium, 0,5 Bq/l (13,5 pCi/l).

* Long-term Maintenance: Minimize the need for long-term maintenance.

* Construction Works: Minimize hazards to the workers and the environment.

* Regulations: Comply with other applicable and relevant spanish regulations governing air and water quality in non radiological aspects.

With regard to groundwater quality protection, it is also required that for short-term conditions the cover system be designed to limit infiltration to ensure that, at the end of the compliance period (minimum 10 years), the combined uranium-234 and uranium-238 concentration in groundwater complies with the two following conditions:

* Be less than 6.15 Bq/l (166pCi/l) at the point of compliance, at the downgradient boundary of the disposal site.

* Be less than 3,5 Bq/l (94,5 pCi/l) at the wells in the vicinity of the site.

In addition to the above design standards, a performance standard has been established for Andujar: groundwater quality must be monitored during the compliance period (minimum 10 years) to confirm adequate performance of the cover and compliance with the maximum concentration limits established for short-term conditions.

5.- REMEDIAL ACTION PLAN

The remedial action plan proposed for Andujar mill site, involved stabilizing and consolidating the uranium mill tailings and contaminated materials in place. The actual tailings pile were reshaped by flattening the sideslopes to improve stability. Tailings from sideslope flattening were relocated around the existing pile and on the top of the lower pile. Mill equipment, buildings and process facilities were dismantled and demolished and placed in the tailings pile. Off-pile contaminated soils were excavated and placed on top of tailings pile in order to reduce the radon flux.

The final pile configuration, as shown in Figure 5, was designed to minimize the movement of tailings and the size of the restricted disposal area. The pile was constructed with four percent topslopes and 20 percent sideslopes which provide static and dynamic slope stability without requiring excessively large rock to resist erosion. Protection against upland watershed runoff is provided by channelling runoff around and away from the pile via drainage diversions wales along the perimeter of the pile. Protection against floods associated with the Guadalquivir river is provided by a rock apron around the perimeter of the pile and riprap layers on the sideslopes.

Decommissioning of mill facilities and buildings involved the dismantling of the facilities, the demolition of the buildings, the reduction of metal wastes and demolition debris to manageable pieces, the cementation of the metal wastes and the disposal of dismantling and demolition wastes in the tailings pile. *Special containers* were used *to* facilitate handling, transportation and cementation of the metal wastes. Cementation proved to be a cost-effective operation and provided a more stable structure to the wastes than the conventional alternative of mixing and compacting with the tailings.

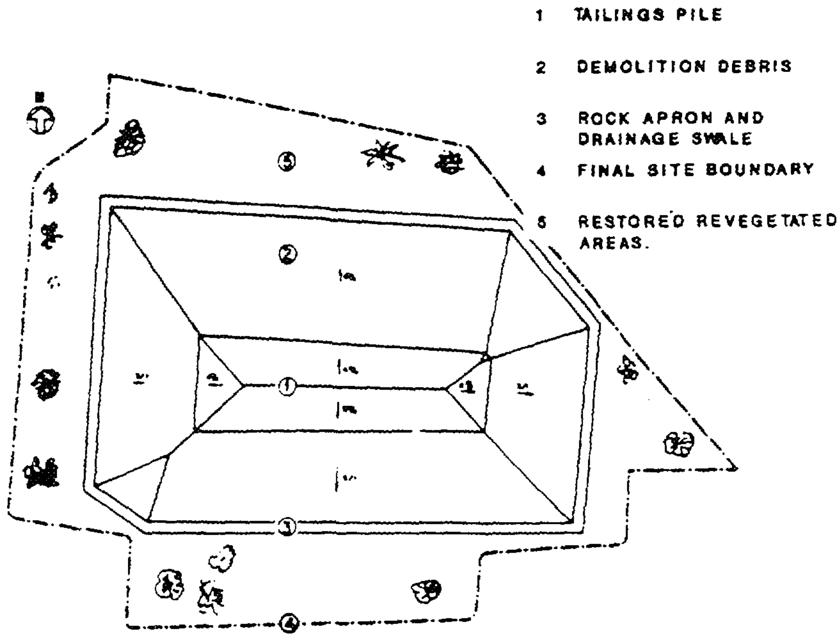

FIG. 5. Andujar site after remediation.

The pile will be covered with a multilayer system to meet the three simultaneous demands of erosion control, infiltration and radon control. In order to comply with the standards, the following design elements are incorporated into the cover system:

* Stabilization control for up to 1000 years: Only natural materials are used and the cover is designed to resist extreme events such as probable maximum precipitation, probable maximum flood, maximum credible earthquake.
* Dispersion and intrusion control: erosion protection layers and biointrusion barriers within the cover.
* Soil clean-up: Remove contaminated soils and incorporate them within the tailings underneath the cover system. This reduces the thickness of the radon barrier.
* Radon control: a radon barrier of natural soils.
* Protection of groundwater quality: a multiple redundant cover system to limit infiltration. This system includes soil/vegetation layers, drain layers and a low permeability infiltration barrier.
* Long-term maintenance: a rooting medium for the establishment of climax vegetation.

Major activities involved in the remedial action (Fig. 6) are listed below:

. Preparation of the site including construction of a new waste-water retention basin to protect against release of contaminants, a decontamination pad to wash down equipment, field offices, and shower/change facilities.

. Construction of drainage control measures to direct generated waste-water and contaminated storm-water runoff to the retention basin during construction activities.

. Dismantling of processing facilities and burial of contaminated materials in the tailings pile.

. Demolition of mill buildings and structures and burial of debris in the tailings pile.

- Reshaping the existing tailings pile and excavating, transporting and placing off-pile contaminated materials on the tailings pile.

- Construction of the final cover system over the tailings to inhibit water infiltration, radon emanation, and wind and water erosion.

- Restoration of the excavated areas, to ensure proper drainage.

- Revegetation of the pile and excavated areas on and adjacent to the processing site.

- Construction of the final fencing.

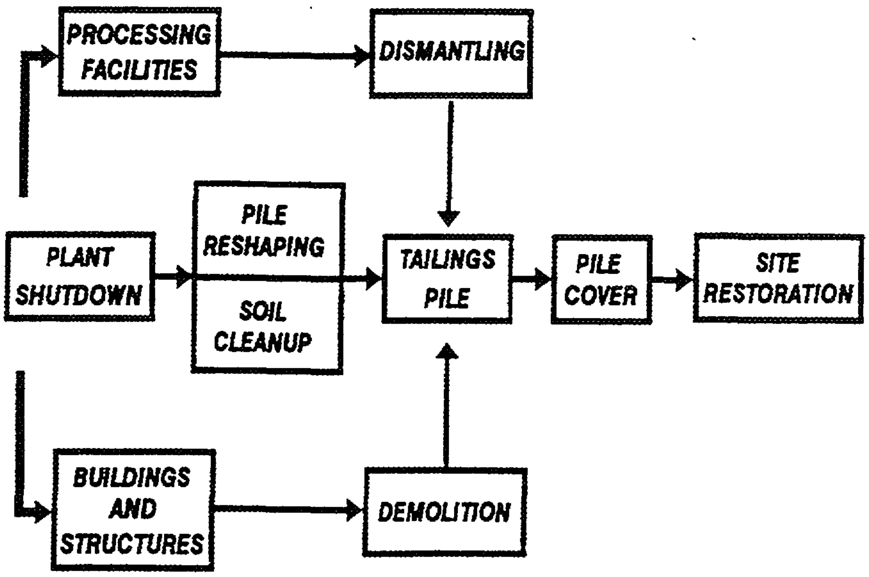

FIG. 6. Remedial action plan.

Fig. 7 shows the cover components for top and sideslopes of the final disposal cell. The topslope consists of, from top down.

- 50 mm erosion barrier of mixed gravel and soil

- 500 mm vegetation growth and desiccation protection zone of random soil.

- 250 mm filter of clean sand.

- 300 mm biointrusion barrier of coarse rock.

- 250 mm drain of clean sand.

- 600 mm radon and infiltration barrier of silty clay.

The most significant benefits of this cover are its ability to deal effectively with vegetation and to reduce infiltration to the cell because of effective evapotranspiration.

From the top down, the sideslope cover consists of:

- 30 mm of soil to migrate into the rock and help support vegetation.

- 300 mm erosion barrier of soil/rock matrix.

- 500 mm vegetation growth and desiccation protection zone of random soil.

- 250 mm filter of clean sand.

. 300 mm biointrusion barrier of large rocks.

. 250 mm drain of clean sand.

. 600 mm radon and infiltration barrier of silty clay.

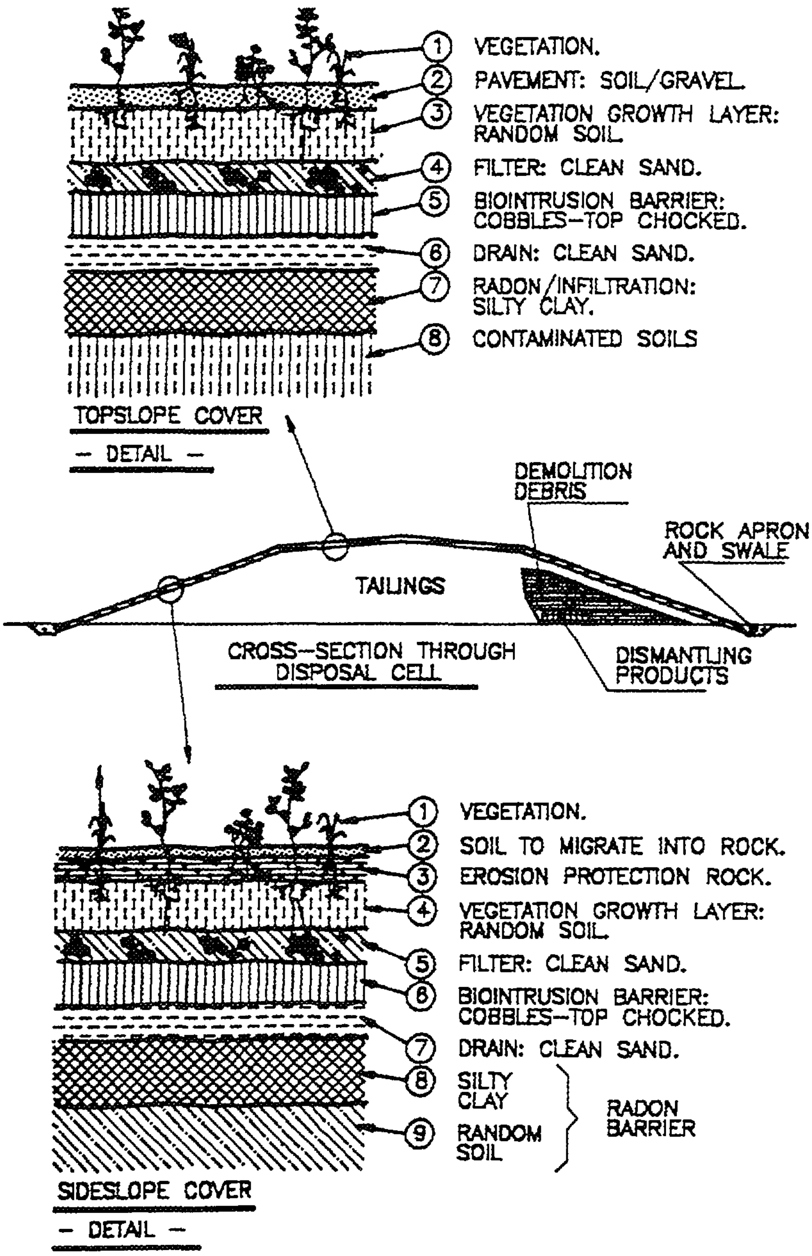

FIG. 7. Cover design for Andujar tailings pile.

Advantages of this cover include protection of the radon infiltration barrier from dessication and the existence of a controlled zone-the random soil- for vegetation that might establish through the riprap and help reduce the visual impact of the remediated pile.

PLANNING FOR THE RESTORATION OF THE CLOSED-DOWN URANIUM MINE IN RANSTAD, SWEDEN

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Abstract

Different studies were performed during the 1970's and 1980's to find effective ways for reducing the leaching processes. The aim of the investigations was to find methods for reducing the infiltration of rain water and entrance of oxygen into the tailings. Among other things a test pile, consisting of 15 000 tonnes of the mill tailings, was constructed in 1972 for studying the effect of different cover systems. In 1985 the planning of the restoration started with general planning and investigations including collection of available information and completion concerning maps, geology, hydrology and water quality. A detailed plan for the restoration was submitted to the County Administration in October 1988. After reviewing the authorities granted permission for the project to be started in January 1990. The demands from the authorities were that a release and recipient control programme for the concentration of uranium and radium as well as heavy metals as e.g. cadmium, copper and nickel should be performed. The groundwater levels within and in the surroundings of the tailings should also be measured as well as the groundwater quality. Besides a quality assurance programme for the cover system of the tailings should be established. The aim is to get close to the natural background values of the Ranstad area. However, no fixed limits have so far been decided. Exposure rates and radon emanation should also be measured during the covering of the mill tailings area.

1. BACKGROUND

The uranium mine in Ranstad (Fig. 1) was opened as a part of the Swedish Nuclear Power Programme. Uranium was extracted by percolation leaching with sulphuric acid from the alum shale, which has a grade of about 300 g/t. The shale also contains about 22 % of organic matter and about 15 % of pyrite. A geological section at Ranstad is presented in Fig. 2. The plant was operated from 1965 to 1969 with open pit mining. During this period, 1.5 Mtonnes of alum shale were mined and 215 tonnes of uranium were produced.

As the operation licence for the Ranstad plant expired in 1984 discussions about the final restoration started. At that time the leachate from the mill tailings, that were covered by a 0.5 m thick layer of moraine, was collected and purified before it was released to the recipient river Flian. The open pit mine was kept dry by pumping. The environmental consequences were not critical but the continuous pumping and treatment of leakage water was costly. Consequently, a plan for final restoration had to be prepared.

2. RATIONALE AND GOAL FOR THE RESTORATION

The aim of the restoration of the Ranstad site is to make all future maintenance unnecessary. When it is fully completed it is anticipated that the area will comply with environmental legislation without any further intervention.

3. RE-RESTORATION CHARACTERIZATION OF THE AREA

The content of the alum shale in the Ranstad area is presented in Table 1. As the total amount of the tailings is about 1 million cubic meters there is about 100 tonnes of uranium and 5×10^{12} Bq or radium-226. The tailings cover an area of 250 000 m^2.

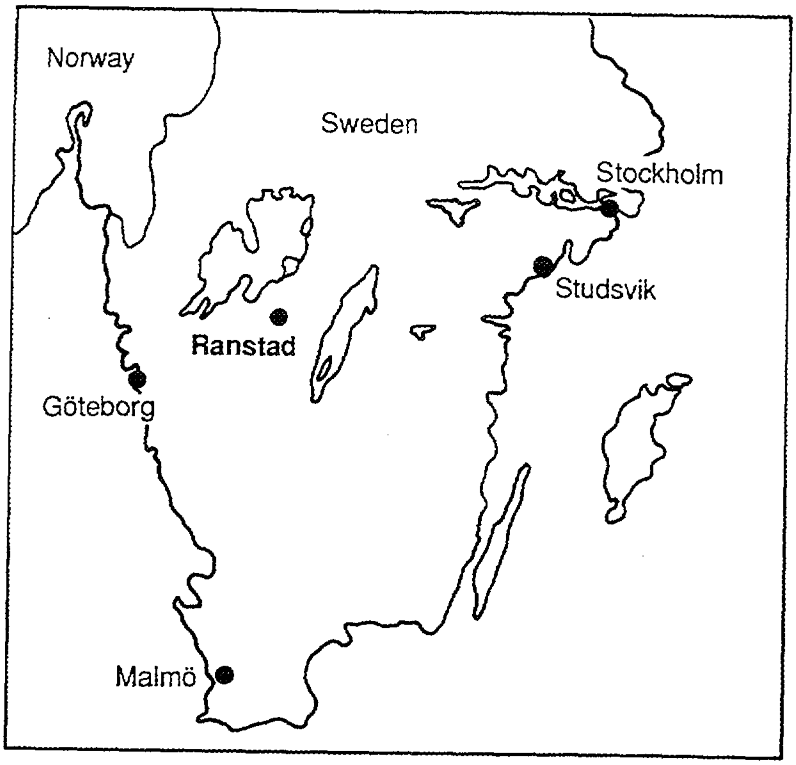

Fig. 1 The location of the Ranstad site.

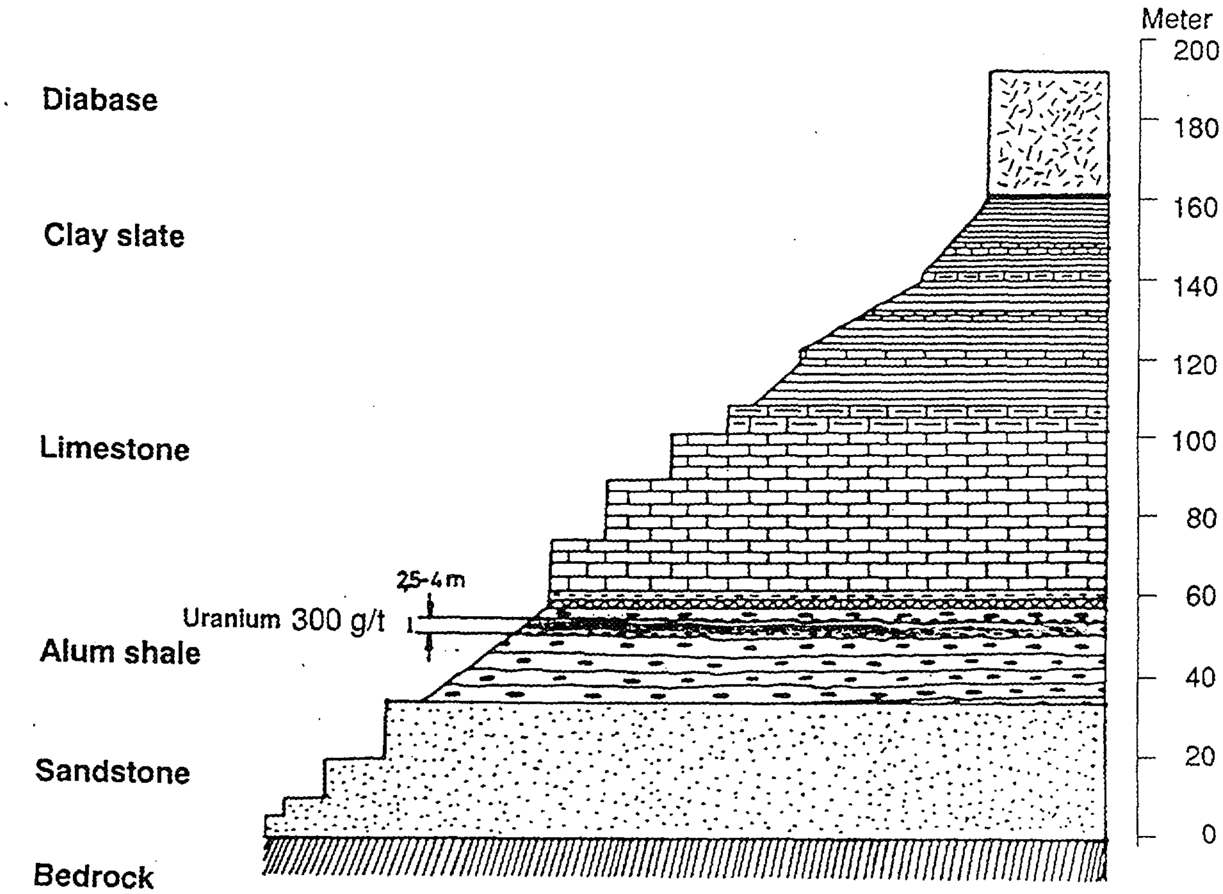

Fig. 2 The geological section of the Ranstad area.

The size of the open pit mine was in a form of a 2 000 m long, 100 - 200 m wide and 15 m deep trench. The open pit was kept dry until November 1991 when the pumping was stopped. The concentration of uranium and radium-226 in the released water was as an average 75 μg/l respective 25 mBq/l.

Except for the control of the leakage water from the tailings the radiological conditions on top of the deposits area were investigated. This was performed by radon emanation and exposure rate measurements. The radon emanation in 1987 - 1988 was 10 mBq/s m^2 on the tailings, while the emanation was about 25 mBq/s m^2 in the surroundings [1]. In end of the 1980's the tailings had a cover of 0.5 m moraine. The results indicated that this relatively thin cover of the tailings had a reducing effect on the radon releases.

The exposure rate in 1987 - 1988 was as an average 0.078 μSv/h on the tailings, while it was 0.074 μSv/h in the surroundings indicating small differences between the two types of area.

These results gave important information of the planning of the cover system of mill tailings.

Table 1

Elemental composition - Ranstad, Sweden.

Unit: ppm

Element	Alum shale	Mill tailings
Ra-226 (Bq/kg)	3 500	
U	300	64
Mo	340	330
V	750	650
Al	66 000	60 000
Fe	60 000	56 000
K	40 000	38 000
Na	2 100	2 000
Mg	4 900	3 700
Ca	9 000	9 000
As	106	102
Cd	2.2	0.6
Cr	320	300
Cu	110	110
Hg	0.3	0.3
Mn	250	110
Ni	200	130
Pb	14	13
Sb	5	5
Ti	3 800	3 800
Zn	130	100
REE	410	330
C (organic)	151 000	150 000
S (total)	70 000	74 000
SiO_2	450 000	450 000
CO_3	13 000	
PO_4	2 500	500
SO_4		15 000

A long-term study of a test pile, consisting of 15 000 tonnes of mill tailings, was started in 1972. Two types of cover systems were studied. Half of the pile was covered by a 0.3 m thick sealing layer of crushed limestone followed by a 0.9 m thick moraine layer and finally a top soil layer of 0.3 m. The sealing layer of the other half consisted of a mixture of moraine and bitumen (2.5 %). This long-term study showed that the infiltration through the cover layers could be minimized to less than 5 % of the precipitation. The oxygen penetration was also effectively stopped by these types of cover. This is very important for the type of tailing that is present in Ranstad, because it consists of easily weathered pyrite. This weathering causes released of hazardous heavy metals. These heavy metal releases are the most serious problem concerning the Ranstad mill tailings. Thus, the environmental impact is more of a mixed waste problem than a pure radiological one. Lower radon release was observed from the test pile compared to the surroundings.

The Ranstad site is situated in a sparse populated farming land. The distance to the closest village, Stenstorp (2 000 inhabitants) is about 5 km.

A comprehensive release and recipient control program has been performed since the early 1960's. The concentration of uranium in water within the mill tailing area as well as in the open pit mine area is shown in Figs. 3 and 4 as an example of the changed conditions during the operation period and the years afterwards until present days.

4. PLANNING FOR RESTORATION

4.1. The remediation plan

The situation in 1984 was not critical from the environmental point of view. The leakage from the tailings had to be purified before it could be released to the recipient. However, continuous pumping and treatment is costly and cannot be carried out indefinitely. Moreover, the open pit mine was a wound in the landscape on the hillside of the mountain Billingen.

Since 1989, the restoration project has been a part of the Swedish programme for the management of research waste from the government funded development of nuclear power in Sweden. These activities are financed by a fee charged to the utilities on the current production of nuclear energy. This funding is now administrated by the Swedish Nuclear Power Inspectorate. Studsvik AB is now part of one of the

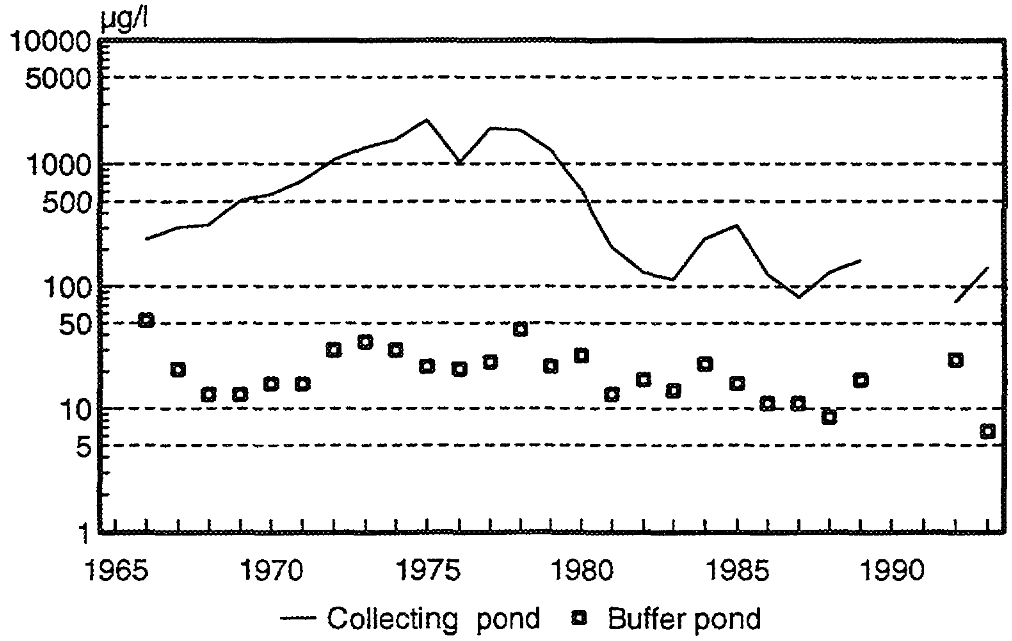

Fig. 3 Uranium concentration in Ranstad. Mill tailing area 1965 - 1993.

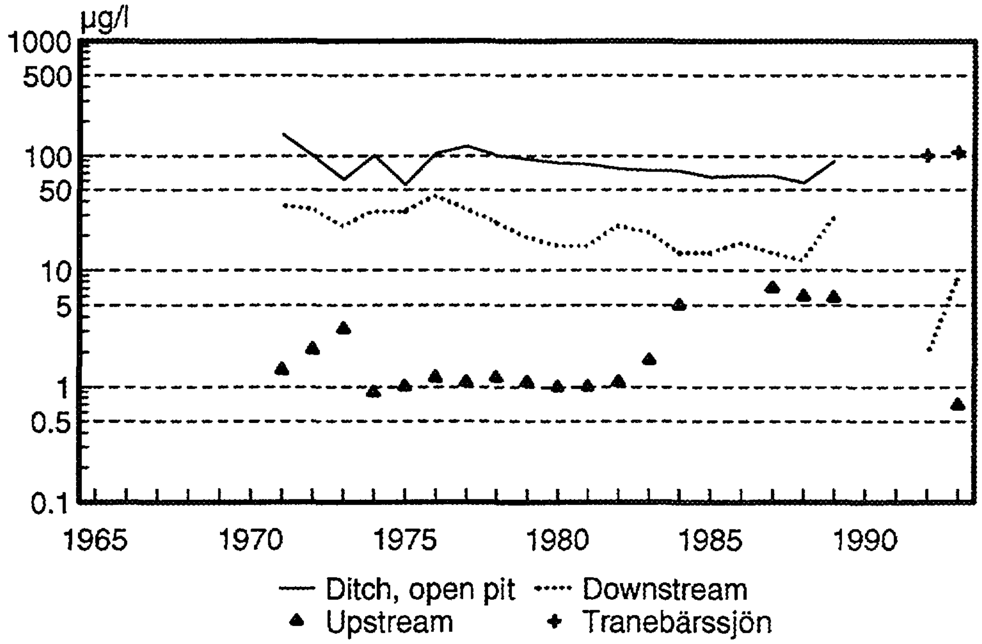

Fig. 4 Uranium concentration in Ranstad. Open pit mine area 1965 -1993.

nuclear facilities, Vattenfall. The utilities have recently set up an organization, AB SVAFO, for the implementation. Studsvik Eco & Safety AB is engaged in the project on behalf of AB SVAFO.

4.2 Project phases

Already from the beginning, the plans for restoration were divided into several phases according to the section below, see also Fig. 5.

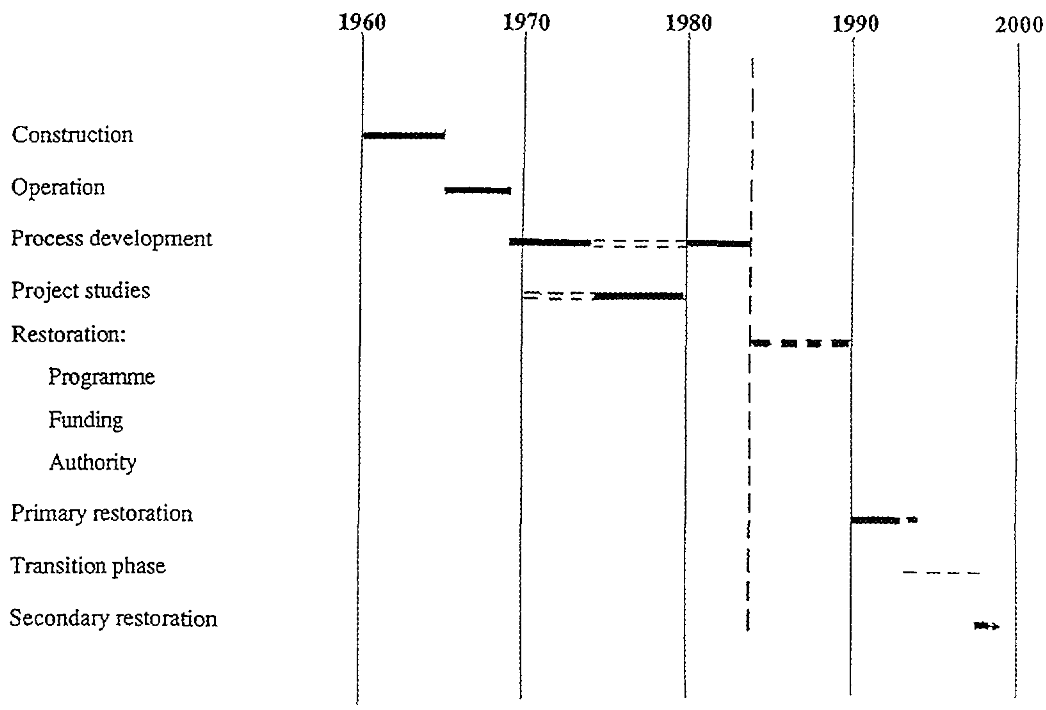

Fig. 5 The time schedule for the uranium mine project of Ranstad.

1. General programme, collection of information
2. Investigation phase, field and laboratory tests, evaluation
3. Restoration plan, acceptance of the authorities
4. Design and tendering procedure
5. Primary restoration
6. Transition phase
7. Secondary restoration
8. Follow-up phase

The *general programme* provided information concerning the plant and the mining history, environmental protection requirements, remediation alternatives, necessary studies and investigations, legal conditions and formalities for further work and a suggested time table. In 1987 funds were granted for the next stage.

The aim of the *investigation phase* was to collect site-specific data and to elaborate a scientific and technical basis for planning and the restoration. This included the collection of available information and complementations concerning maps, geology, hydrology and water analysis.

A *detailed plan for the final restoration* of the Ranstad site [2] was submitted to the County Administration in October 1988. After a comprehensive review, the County Administration granted permission for the project to be started in January 1990.

The Swedish Radiation Protection Institute is responsible for supervising all radiation related questions. Radiation levels and radon releases were measured within the tailings as mentioned above. As the conditions were the same on the tailings in the surroundings the institute has not found any need for additional protection measures.

Based on the restoration plan, detailed *design and specifications for tender* documents were elaborated.

The last four phases of project concern the realization of the project. At present, April 1994, we are in phase 6, the transition phase, with decreasing releases of radionuclides and heavy metals. But purification must still be continued for some years. The former open pit mine has been transformed into a lake.

5. ENVIRONMENTAL CONTROL

The aim of the restoration is to reduce the effects of the mining activities to levels that are close to the observed background values of the Ranstad area.

The present water system is illustrated in Fig. 6. The leachate from the mill tailings is collected in surrounding ditches (sampling sites 1 and 2) that are drained into the collecting pond. The water is purified in a treatment plan (sampling site 3) and released into a buffer bond (sampling site 5). From that pond the water is pumped through a pipe over the Billingen mountain and released into the river Flian.

The release and recipient control programme provided water quality for predictions of the future water quality after restoration. The present water quality and the proposed cover system were used as input to the prediction model. The model system is presented in Fig. 7, where the different boxes represent different recipients and associated sediments. The arrows between the boxes represent the transfer of radionuclides and heavy metals in the water system in the Ranstad area.

The input data of the model is water flow, water volumes, water depth, sedimentation rate, suspended matter, water content in the sediment, density of the sediment and sorption capacity, described by a distribution coefficient, of the different elements.

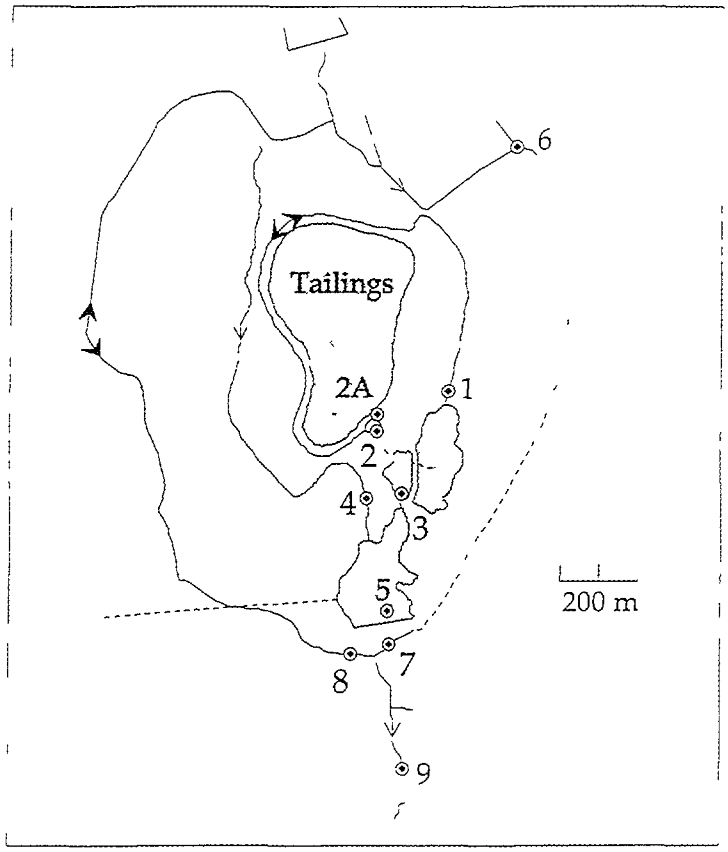

Fig. 6 The mill tailing area and the surrounding water system.

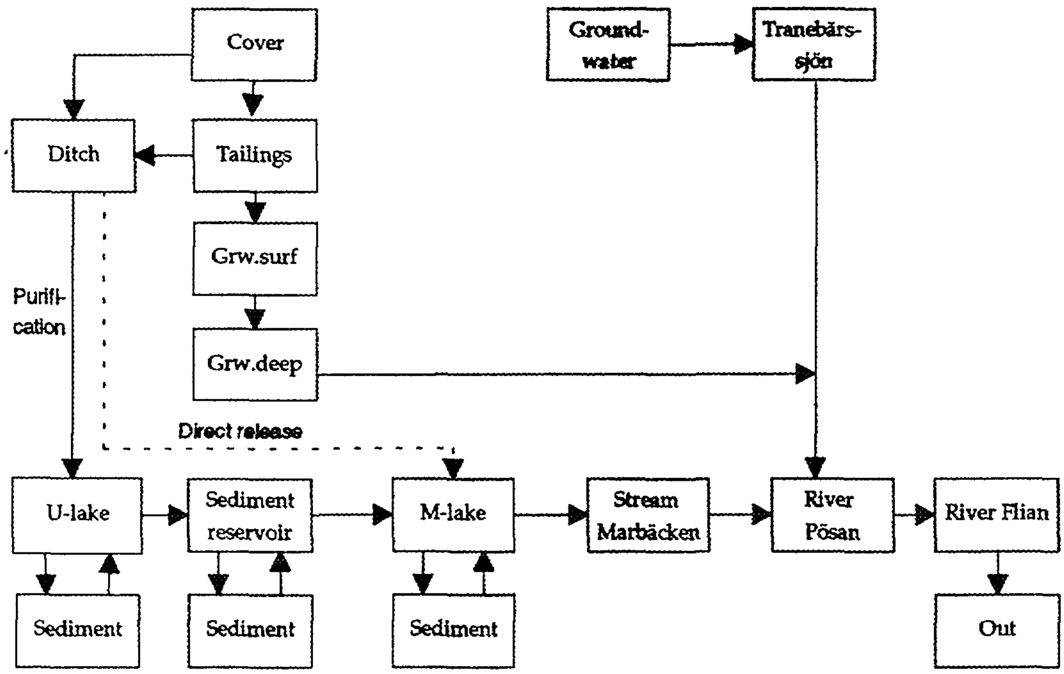

Fig. 7 The model system of the Ranstad site.

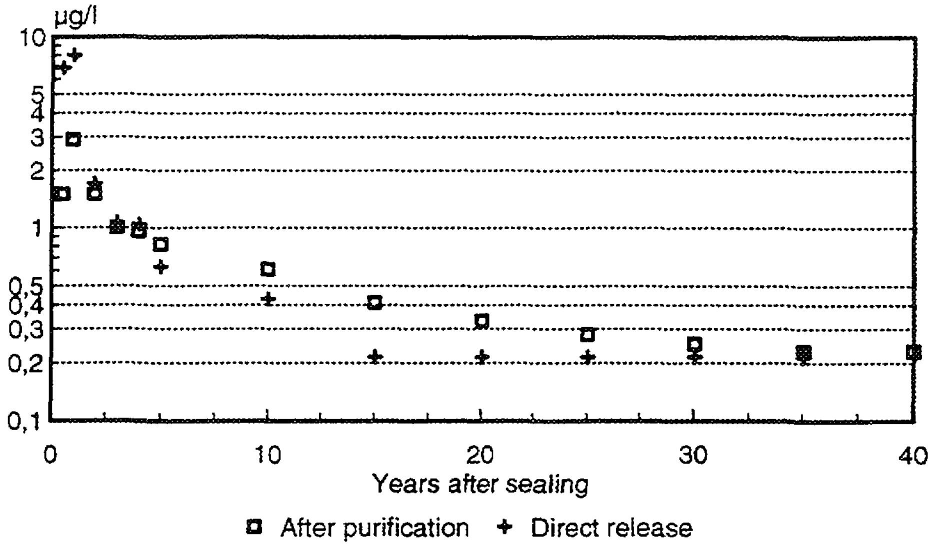

Fig. 8 Prognosis for uranium.

The calculated concentration of uranium above background values in the primary recipient, after the restoration work is finished, is shown in Fig. 8. As can be seen it will take about five years before the concentration of uranium will decrease to a level of 10 % excess above the background value.

The steady-state values of nickel and uranium are presented in Fig. 9 and they are compared with the background values. The nickel concentration is increased with about 30 %, while the uranium increase is much smaller, about 3 %.

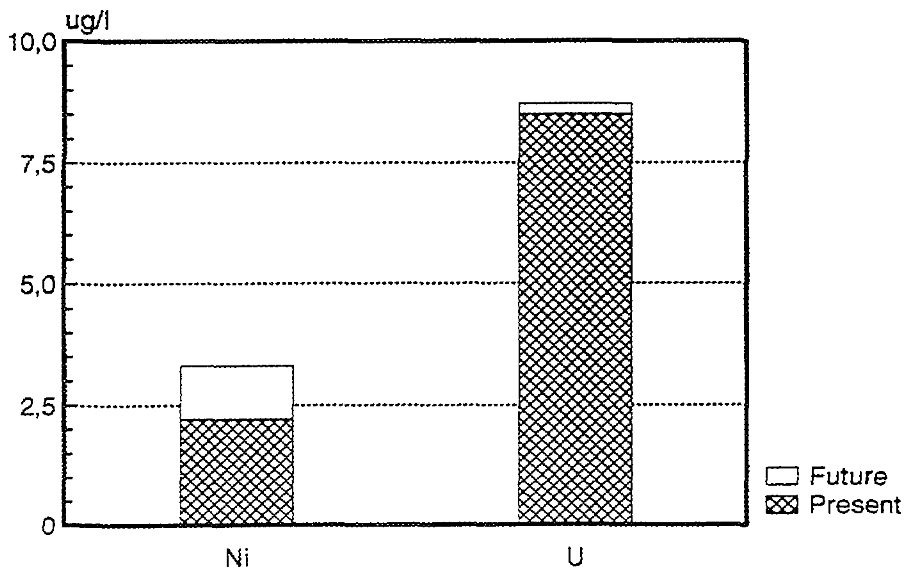

Fig. 9 Comparison between recent and future concentration of nickel and uranium.

6. COST ESTIMATE

The estimation of the cost of the different activities is presented in Table 2.

Table 2

Cost estimate of the Ranstad restoration programme

Activity	Per cent
General programme	0.5
Investigation phase	2.0
Restoration plan	1.5
Design tendering	3.5
Primary restoration:	
- Project management	7.5
- Contractors	70
Environmental control incl. water treatment (1985 - 2000)	15

Today the costs are estimated to 140 MSEK which corresponds to about 18 M$.

7. CONCLUSIONS

The leachate from the mill tailings has continuously been collected and treated since the beginning of the mining operation started in the middle of 1960's. Thus the environmental situation was well under control when the project started, allowing for careful investigations and planning of the remedial actions, including the necessary time for the acceptance by the authorities.

Site characteristics and other available data were collected. A sampling programme was performed and according to the experiences gained during the project, it is better to have an extensive sampling programme rather than a restrictive one.

Predictions of the environmental consequences were an important part of the investigation phase. They gave a scientific base for judgement of the restoration efforts and a possibility for authorities to evaluate the restoration plan.

The technique for preparing a barrier with a low hydraulic conductivity, an appropriate quality assurance and control programme have been well tested and established.

The valuable experiences obtained from the project may be utilized for many applications of other rehabilitation issues.

REFERENCES

[1] ANGEDAL, P.-O., LINDER, P. and TOVEDAL, H., Remediation in Ranstad. Radiological measurements (In Swedish). Studsvik AB, Sweden, 1988 (STUDSVIK)NP-88/61).

[2] Restoration in Ranstad, Remediation plan. Studsvik AB, Oct 1988 (In Swedish).

PLANNING FOR THE ENVIRONMENTAL RESTORATION OF RADIOACTIVELY CONTAMINATED SITES IN THE UNITED KINGDOM

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Abstract

The general approach to investigating and remediating radioactive contamination of sites in the United Kingdom has involved a multi-stage programme. The stages of such a programme are: review of the existing site history and characteristics, radiological investigations, modelling of containments' spread, identification of remediation options, risk assessment and cost-benefit analysis, interactions with regulatory authorities, selection and design of preferred cleanup option, implementation of preferred option, monitoring of achievement of cleanup standards and, lastly, closeout of works. This paper describes also in detail the regulatory framework and interactions among involved parties. Specific information is given on cleanup criteria in the UK and criteria for the selection of appropriate cleanup technologies. Disposal of radioactive wastes is a key element in planning and managing environmental restoration activities: provisions for waste disposal in the UK are also described in this paper.

1 INTRODUCTION

The general approach to investigating and remediating radioactive contamination at sites in the United Kingdom has involved a multi-stage programme. The extent to which each individual stage is necessary or is carried out depends on the state of each site and what work has been carried out previously. The stages of such a programme are:

i) review of the existing history of the site, the radionuclides and other possible contaminants used and present there, the nature of soil and underlying geology, the results of any previous investigations or monitoring;

ii) investigation of the site to determine the nature and extent of the contamination. This should include non-radioactive contaminants, such as heavy metals, toxic chemicals, oils and solvents, asbestos, etc., as well as radioactive contaminants. The investigation will be influenced by the results from i) and usually includes monitoring surveys and general screening for radionuclides. Statistical sampling plans[1] and expert judgement systems[2] are now being used increasingly to optimise this stage. This is usually followed by targetted detailed surveys in specific areas of concern;

iii) development of a conceptual model of the spread of the contaminants. This is particularly important in cases where the contamination is migrating off-site, as a result of infiltration into surface and groundwater sources, dispersion by dust entrainment, etc. This phase can be extended into the development of mathematical models for use in risk assessments, remediation design, etc.;

iv) identification of remediation options. These include;

a) “dig and dump”, where the contamination is simply dug up and removed to a licensed disposal site. Depending on the nature and specific activity of the waste, it may require conditioning prior to disposal. This approach has been the most widely used to date;

b) containment on site using engineered barriers as appropriate. This option is usually used for short-lived or longer-lived, low toxicity and low concentration radionuclides; and

c) “segregate and concentrate”. This approach normally involves physical or chemical treatment to concentrate the majority of the activity into a small volume, so allowing the bulk of the soil and other material either to be reused as inactive material or to be disposed of to a lower quality containment and hence less expensive disposal facility. The concentrated activity is either sent to a disposal site with higher quality containment or is stored. In its simplest form this approach involves very careful removal and sentencing of contaminated soil in individual lots to minimise active volumes.

v) risk assessment and cost-benefit analysis. Risk assessments are undertaken to quantify the hazards posed by the site in its current form and after each of the possible remediation options. These assessments are primarily human health based, but are now being extended to consider general environmental risks. Risk assessments based on considerations of human health are also being used increasingly in justifying clean-up standards to regulatory authorities.

The capital and lifetime operating costs of each remediation option are also determined and then compared on a net present value basis. The latter is determined by discounting at the marginal real rate of return on investment. The costs of additional treatment steps to reduce emissions to the environment can then be compared to the reductions in health detriment achieved to make objective, quantitative assessments of their value.;

vi) interactions with regulatory authorities. The regulatory structure applying to radioactively contaminated sites in the UK is discussed in more detail below. At present, there is no single regulatory authority with responsibility for all aspects of the management of contaminated sites. This can lead to different priorities and even conflicts of requirements between regulatory authorities. Agreement has to be reached with regulatory authorities on the standards to which any site has to be cleaned up, the remediation techniques to be used and the methods for certifying that those standards have been achieved. It has proved to be beneficial to commence interactions with all of the regulatory authorities with an interest in the site, preferably in common meetings, at the earliest possible stage after the site has been determined or is suspected of being contaminated. Their involvement at the site investigation stage enables their possible concerns to be addressed from the outset, so avoiding the need for costly, additional investigations at a later stage;

vii) selection and design of preferred clean-up option. Following agreement with regulatory authorities on the standards and extent of clean-up required, the choice of remediation options can be made. The preferred options are usually the most cost-effective ones which fulfill all of the regulatory criteria. However, in making the choice other factors are considered. These include the results of any risk assessments and cost-benefit analyses of the options; the state of development of the proposed techniques; timescales; degree of interference with other activities on the site; disposal routes for wastes; any emissions to the environment with needs for discharge authorisations; requirements for planning approvals to construct and waste licences to operate any remediation plant which may have to be built on site, public relations, etc. The selected option is designed according to standard codes and practices with appropriate operating instructions and safety cases being prepared;

viii) implementation of preferred option. This involves the construction and operation of any necessary remediation and monitoring plant and the appropriate disposal of all wastes;

ix) monitoring and certification of achievement of clean-up standards; and

x) close-out of works and demobilisation

2 THE REGULATORY FRAMEWORK

2.1 Legislation

The basis of the UK policy for managing radioactive wastes is defined by an Act (law) of Parliament. In particular the Radioactive Substances Act of 1960 (RSA 60) gave the force of law to the recommendations of a Government White Paper (consultation document) "The Control of Radioactive Wastes" (Command 884). In the act the aims for waste management and disposal were given as:

i) to ensure, irrespective of cost that no member of the Public shall receive more than 1/10th of the ICRP level for occupational workers;

ii) to ensure, irrespective of cost that the whole population of the country shall not receive an average dose of more than 1 rem in 30 years; and

iii) to do what is reasonably practical having regard to cost, convenience and the national importance of the subject, to reduce the doses as far as possible below these levels.

RSA 60 provided for controls to be exercised over the use and keeping of radioactive materials and the accumulation and disposal of radioactive wastes. It also required that radioactive substances stored on non-licensed sites for more than 3 months should be presumed to be waste and that the waste could be stored only if authorised and in accordance with the terms of any authorisation given. This part of the Act had important implications for any unlicensed sites contaminated with radioactivity, for there was a requirement for the site to become licensed. The licensing process involves statutory and public consultation. In addition, any soil, etc., contaminated with radioactivity becomes classified as radioactive waste and has to be treated accordingly.

RSA 60 and its amendments by subsequent legislation, including Part V of the Environmental Protection Act of 1990 (EPA 90), have been consolidated into the new Radioactive Substances Act of 1993 (RSA 93). The regulation of radioactive waste treatment and disposal under RSA 93 is broadly consistent with the principles by which processes not involving radioactive materials are regulated under Part 1 of EPA 90. There is a requirement under RSA 93 for operators to consider process options and waste minimisation and to identify and evaluate options for the management of each waste stream through to disposal, including an assessment of its effect on the environment.

An important general principle of the law is that the "polluter should pay". In addition, no organisation can absolve itself from the full responsibility for its wastes by passing these onto a contractor. It is incumbent on the organisation to ensure that the contractor will deal with the wastes in a satisfactory manner, i.e. it has a "duty of care" in respect of its wastes.

Authorisations have to be obtained from Government Departments for the discharge of radioactive wastes, the transport and disposal of solid waste.

A number of materials are specifically exempted by Order from the requirement to under the RSA. These include luminous articles, electronic valves, smoke detectors, phosphatic substances, geological specimens, certain uranium, thorium and radium compounds. etc. The exemptions are, however, subject to detailed conditions designed to ensure that no radiological harm arises. In some of these cases, such as with the uranium, thorium and radium compounds, an effect of the exemption is to allow slightly higher limits on the activity per unit mass of the material to be disposed of before the material has to be regarded as radioactive waste. These higher limits can be very useful when rehabilitating sites, which are contaminated with such compounds as with ore processing sites.

2.2 The Authorising Departments

The Secretaries of State for the Environment, Scotland and Wales have overall responsibility for the development of a comprehensive policy for managing all radioactive wastes. The Department of the Environment (DoE) and the Ministry of Agriculture, Fisheries and Food (MAFF) are responsible, under the Radioactive Substances Act 1960, for:

a) approval of radioactive waste disposal routes and disposal sites;

b) assessment of the radiological implications of disposals and to fix limits for discharges from particular sites;

c) setting other necessary conditions in authorisations and to ensure compliance with the limits and conditions; and

d) to carry out necessary monitoring.

In practice Her Majesty's Inspectorate of Pollution (HMIP) of DoE takes responsibility for authorising the disposal and discharge of radioactive waste, while the MAFF assesses the consequences of discharges on agriculture, fisheries, food and the aquatic environment.

The responsibilities of the Department of Transport are for the transport of radioactive materials. Regulations, made under the Radioactive Substances Act 1948, require a certificate of approval to be granted before a package may be used to transport radioactive materials.

2.3 Her Majesty's Inspectorate of Pollution (HMIP)

HMIP is part of the Department of the Environment. It was established in 1987 by bringing together three existing inspectorates - the Radiochemical Inspectorate, the Industrial Air Pollution Inspectorate and the Hazardous Waste Inspectorate - together with responsibility for controlling seriously-polluting discharges to water. In a further move to unify regulatory control for pollution the Government has announced proposals to create an Environmental Agency by bringing together HMIP, the National Rivers Authority and regulation of waste disposal, which is currently a local authority responsibility. HMIP is currently responsible for:

i) authorisation and regulation of the most complex and seriously polluting categories of industry;

ii) authorisation and regulation of premises which use, store or dispose of radioactive material;

iii) oversight of the work of local waste regulation authorities and the promotion of good standards;

iv) research on pollution control and radioactive waste disposal. It currently funds a programme totalling £8M a year, covering all areas of its regulatory work; and

v) expert advice to Government and industry on a wide range of pollution issues.

HMIP's responsibilities were increased under the Environmental Protection Act of 1990. It now regulates 200 categories of industry, 5,000 major industrial plants and 8,000 premises using or storing radioactive material. Other less polluting processes are regulated by local authorities. HMIP operates in England and Wales with separate organisations operating in Scotland and Northern Ireland.

2.4 The Environmental Protection Agencies

The UK Government has announced plans for the creation of a new independent Environment Agency for England and Wales and a Scottish Environment Protection Agency, bringing together the environmental regulatory functions of different organisations within single national bodies. HMIP will form part of the former and HMIPI part of the latter. They will also include the National Rivers Authority (NRA), which is responsible for the protection of surface, groundwater and coastal waters, and local waste regulation authorities (WRA). HMIP's current responsibilities for implementation of the Radioactive Substances Act will pass to these new agencies. This will enable rationalisation of some of the arrangements for regulating radioactive wastes. The agencies are proposed to provide industry with a single source for authorisations and their formation will represent a step towards deregulation without impairing the effectiveness of present controls.

2.5 Nuclear Installations Inspectorate (NII)

The Nuclear Installations Inspectorate is a separate organisation under the Health and Safety Executive (HSE). It is responsible for overseeing the operations of all significant nuclear facilities, except those operated by the Ministry of Defence. The latter are scheduled to be placed under its jurisdiction by the end of the century. Thus it is responsible for regulating the safety of NPPs, all other fuel cycle facilities, including fuel fabrication, enrichment and reprocessing plants, all waste treatment and disposal facilities and even significant research facilities, such as research reactors. Over 90% of the radioactive waste in the UK is currently stored on nuclear sites licensed by HSE/NII.

The NII is responsible for regulating operational safety. It has to be satisfied as to the safety of a plant at every stage from design through commissioning, operation and ultimately decommissioning, and any changes in the method of operation have to be approved by them. Thus it reviews the safety cases of all major nuclear facilities prior to start-up and at regular intervals during the life of each plant. Its staff carry out regular inspections of nuclear facilities and they have the power to order the immediate shutdown or modification of plants or processes which they regard as unsafe. They also have the power to prosecute plant owners and even individual operatives for any breaches of safety standards.

The HSE/NII has powers under the Nuclear Installations Act of 1965 to direct the operators of any nuclear licensed sites to carry out specified actions in the interests of the safety of workers or members of the public. This includes the power to direct operators to dispose of accumulations of radioactive wastes, where disposal routes are available, to clean-up sites of any radioactive contamination or to decommission plant.

2.6 Consultation and Liaison between the Authorising Departments, the NII and Other Organisations

The responsibilities of the authorising Departments mean that they have to be involved in several aspects of the NII's work. This is in order to be able to ensure that waste management considerations are properly taken into account at consider all stages of the nuclear fuel cycle, and not simply when the stage of ultimately discharging wastes is reached. Liaison and consultation between the NII and the authorising Departments is required in the assessment of the design and inspection of plant and processes, to ensure that waste handling and treatment methods are compatible with disposal routes and that the likelihood of unplanned releases and discharges is minimised.

3 CLEAN-UP CRITERIA

To date it has been the practice is to clean-up contaminated sites, so that the specific activity of the remaining material does not exceed 0.4 Bq/g. This limit corresponds approximately to background levels of radiation. However, clean-up levels are being increasingly determined on the basis of risk-based criteria with the design target being 10^{-6} risk of death or serious harm per year. Where regulators are satisfied that good engineering, science and practice have been adopted by the operator and the estimated risks to the public are below this target, then no further reductions in risk will be sought. If the estimated risk is above this target, then the regulators will only agree to the clean-up if they are satisfied that further reductions in risk could only be achieved at disproportionate cost.

This concept of using risk level as a key component of design criteria was first applied to new facilities for the disposal of radioactive wastes [3]. It has since been adopted by HSE for the design of new nuclear power stations [4] and has been recommended by the UK National Radiological Protection Board (NRPB) for radioactive waste disposal and emissions

[5]. It is increasing being used by HMIP in deriving acceptable levels of emissions and clean-up targets for active and inactive contaminants.

4 CRITERIA FOR THE SELECTION OF APPROPRIATE CLEAN-UP TECHNOLOGIES

HMIP works on the principle of controlling emissions to the environment on a multi-media basis in order to secure the best all-round environmental solution. This is embodied in the concept of 'Integrated Pollution Control' (IPC), which was introduced by the 1990 Environmental Protection Act. IPC is a preventative philosophy which starts with the operator submitting a detailed application to HMIP, giving information on the proposed process, detailed design, raw materials, emissions, environmental impact, monitoring and operating procedures, and waste disposal arrangements. Processes involving radioactive substances have been deliberately excluded from IPC, as they were already highly regulated and subject to integrated regulatory control.

Under IPC the operator must demonstrate that the proposals incorporate 'best available techniques not entailing excessive cost' (BATNEEC). The release of pollutants must be prevented where possible or minimised. The equivalent to BATNEEC under RSA 93 is "best practicable means" (BPM).

Where a plant involves emissions to more than one medium, HMIP assesses the 'best practicable environmental option' (BPEO) and the authorisations set detailed limits and operating standards, covering emissions to all media. BPEO involves the selection of the optimum among a range of available options, whereas BATNEEC/BPM is concerned with optimisation of the selected option itself. Methods for determining what constitutes BATNEEC/BPM and BPEO have been given in a recent HMIP discussion paper [6].

Plants must be kept abreast of new developments in pollution control technology and are subject to complete review at least once every four years. HMIP can amend and tighten the authorisation at any time. Once a plant has been authorised, HMIP ensures compliance with the defined standards through analysis of monitoring data, regular site visits and investigation of problems and complaints. HMIP has powers to revoke authorisations and to halt a process where there is 'imminent risk of serious pollution'. HMIP has powers of enforcement and prosecution for breaches of authorisation standards.

5 THE DISPOSAL OF RADIOACTIVE WASTES

Given the dominant position of the "dig and dump" approach to the remediation of radioactively contaminated sites in the United Kingdom, the disposal of contaminated soil and debris as radioactive waste is a key component of most strategies for the clean-up. This requires a clearly defined system of waste categorisation and appropriate facilities for storing and disposing of wastes in those categories.

Radioactive waste is currently classified under four broad categories in the UK, according to its heat-generating capacity and specific activity.

i) High-level or heat generating wastes (HLW). These are wastes in which the temperature may rise significantly as a result of their radioactivity, so that this factor has to be taken into account in designing storage or disposal facilities. The bulk of these wastes are the cycle 1 raffinates from the reprocessing of spent fuel, the vitrified products from immobilising these wastes and spent fuel. Currently, there are no disposal routes for this category of wastes in the UK. They are all stored in high integrity containment facilities.

ii) Intermediate-level wastes (ILW). These are wastes with activity levels exceeding the upper boundaries for low-level wastes, but which do not require heating to be taken into account in the design of storage or disposal facilities. Wastes in this category are also currently being kept in engineered stores. Disposal facilities are being developed by UK Nirex for this category of waste, but will not be available until the first decade of the twenty-first century.

iii) Low-level wastes (LLW). Wastes containing radioactive materials other than those acceptable for disposal with ordinary refuse, but not exceeding
4 GBq(α)/te or 12 GBq($\beta\gamma$)/te. These are wastes which can be accepted for authorised disposal at the BNFL Drigg disposal site in Cumbria, UKAEA's Dounreay disposal site in Caithness, Scotland or other landfill sites by controlled burial.

The latter relate to suitable landfill sites, which have good containment characteristics, e.g. they are based in several metres of clay strata. The sites may be operated by a local authority or a private operator and occasionally disposals are made to a landfill on the site from which the waste originates. Disposals are only permitted when the waste containment characteristics and performance of the site have been fully assessed and when HMIP or HMIPI are satisfied that the public will be fully protected. The conditions required to ensure safe disposal are specified in authorisations under RSA 93. HMIP or HMIPI arrange for leachates from the sites to be monitored for radioactivity. Currently, there are 27 sites in England and Wales and 12 in Scotland in this category.

This form of disposal is used primarily by non-nuclear industries, which process raw materials containing natural radioactivity, and by major hospitals and universities for their relatively more active waste streams. However, very few nuclear sites dispose of their solid waste in this way. Two exceptions are the BNFL sites at Springfields and Capenhurst, which dispose of waste to a landfill operated by Lancashire Waste Services. BNFL also disposes of very lightly contaminated excavation spoil to a landfill on its Sellafield site.

On-site disposal is an alternative to disposal by special precautions on a local authority regulated landfill or the LLW disposal sites at Drigg and Dounreay. This has some radiological and economic advantages, as it avoids transport of the waste and the public can be excluded from the site making unauthorised salvage less likely. A typical example of this alternative was the authorised disposal of 600 te/a of ferro-niobium slag containing ^{226}Ra [7]. After weathering and crushing, it was mixed with inactive slag to reduce dose rates from 0.05 mGy/h to 0.001 mGy/h and was then buried on-site. Authorisations have also been given for the on-site burial of certain wastes with short-lived activation products from the naval nuclear propulsion programme [7].

iv) Very low-level waste (VLLW). These are wastes which can be safely disposed of with ordinary refuse ("dust-bin" disposal). The limits are for each 0.1 m^3 of material to contain less than 400 kBq($\beta\gamma$) or single items to contain less than 40 kBq($\beta\gamma$). The first restriction is to limit the dose-rate at the surface and the second is to limit irradiation, if the article is salvaged. It has also been usual to:

a) exclude α-emitters and ^{90}Sr; and

b) raise the first limit to 4 MBq in 0.1 m^3 for the weak β-emitters, ^{14}C and ^{3}H, which are commonly used.

For solid waste arisings, which are not suitable for "dustbin" disposal, disposal at a landfill site is still permissible provided that certain precautions are taken. Authorisations for such disposals specify the disposal site, which is chosen after careful consideration of its management, its expected life, the probable subsequent use of the land, whether the site is liable to catch fire, the drainage from the tip and other special features. Before an authorisation is granted in the name of the Secretary of State (Minister) for the Environment, consultation must take place with both relevant local authorities (councils) and the general public.

The limits and conditions normally imposed on such special precaution disposals are:

a) wastes are to be conveyed to the disposal site in sealed, plain unlabelled, plastic or multi-layered paper sacks in closed metal bins;

b) at the disposal site the sacks are to be removed from the metals bins and immediately covered with inactive refuse to a depth of 1.5 m;

c) no sack is to contain more than 4 MBq of radionuclides with a half-life of more than one year and 40 MBq of others. This limit does not apply to ^{14}C or ^{3}H, which have very low radiotoxicities and are readily dispersed by natural processes. For these levels up to 200 MBq per sack are considered acceptable; and

d) no sack shall contain more than 40 MBq of short-lived, i.e. half-life of < 1 year, radionuclides.

The practice of special precautions disposal is also applied to include bulk loads of relatively lightly contaminated rubble and soil, arising from the clean-up and demolition of sites and premises, where work was performed using radioactive substances. Typical examples are luminising works, gas mantle factories and ore processing plants.

REFERENCES

[1] FERGUSON, C. C. The Statistical Basis for Spatial Sampling of Contaminated Land. Ground Engineering, 25, 34-38, (1993).

[2] FERGUSON, C. C. and ABBACHI, A. Incorporating Expert Judgement into Statistical Sampling Designs for Contaminated Sites. Land Contamination and Reclamation, 1, 135-142, (1992).

[3] DEPARTMENT OF THE ENVIRONMENT. Disposal Facilities on Land for Low and Intermediate-Level Radioactive Wastes: Principles for the Protection of the Human Environment.

[4] NUCLEAR INSTALLATIONS INSPECTORATE. Safety Assessment Principles for Nuclear Plant. 1992. HMSO.

[5] NATIONAL RADIOLOGICAL PROTECTION BOARD. Statement on Radiological Protection Objectives for the Land-based Disposal of Solid Radioactive Wastes. 1992.

[6] HMIP. Environmental, Economic and BPEO Assessment. Principles for Integrated Pollution Control. Version 5.0, 1 July 1993. Paper presented at HMIP seminar, 16 July 1993.

[7] DEPARTMENT OF THE ENVIRONMENT. A Review of Cmnd 884: "The Control of Radioactive Wastes". A Report by an Expert Group made to the Radioactive Waste Management Committee. September 1979.

[8] STEARN, S. M. Reclamation of non-nuclear sites contaminated with radioactive waste: A regulator's view. International Symposium on Remediation and Restoration of Radioactive-contaminated Sites in Europe. 11-15 October, 1993. Antwerp, Belgium. Commission of the European Communities.

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