Legal aspects related to the phases of decommissioning, operation, and construction of uranium mines in Brazil owned by Indústrias Nucleares do Brasil - INB

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Abstract. Indústrias Nucleares do Brasil – INB is a Brazilian company active in the states of Minas Gerais, Bahia, Ceará, through its uranium mining and milling plants, each in a different phase of licensing. The Caldas facility in Minas Gerais is the first uranium mine to be decommissioned. The Caetité facility in Bahia is in operation and INB is currently seeking to license the changed mining method from open pit to underground mining, the first ever in Brazil. The Santa Quitéria Project, in the implementation phase, is also unique because the deposit is characterized by the presence of uranium associated with phosphate, and its economic feasibility is contingent upon the exploitation of the associated phosphate. The licensing conduct and requirements for these plants are the subject of a study and work, by both the project owner and the regulatory bodies. But in the presented cases, the licensing process has not shown to be sufficient to prevent questions about the project by the affected community. Facts occurred in connection with INB have evidenced the necessity for significant investment to be made in environmental education and for conducting an important work on risk perception and communication, so as to facilitate integrating the project owner with the neighboring community.

1. Introduction

Uranium mining and milling plants in Brazil are licensed by the National Nuclear Energy Commission (CNEN) and by Environment and Natural Renewable Resources (IBAMA). The licensing procedure conducted by CNEN involves all steps of the project: from its setting out after site authorization, through construction, operation and decommissioning. The entire process is governed by specific rules for nuclear facilities dealing with each of these phases.

In parallel, IBAMA's environmental licensing procedure comprises the granting of the following licenses: Prior License awarded during the planning phase of the project; Installation License authorizing construction on basis of the approved detailed design; and Operating License authorizing the start of the licensed activity and the operation of pollution control equipment.

In the course of the licensing procedure, a number of documents are requested by the environmental agency, the most important ones being:

- Environmental Impact Study (EIS) and the corresponding Environmental Impact Report (EIR) at the setting out of the project;
- Detailed design at the installation of the project;
- Detailing of environmental programs with project operation;
- Plan of Rehabilitation Degraded Area, at project decommissioning.

This paper is intended to present the uranium mining and milling facilities run by Brazil, the licensing step they are in, their pioneering role in this country, and the project owner's difficulties in managing the licensing process issues and the technical challenges according to scientific, legal, social, environmental, political, and economical viewpoints.

With the resumption of the Brazilian Nuclear Program, an increase is planned in the domestic production of uranium concentrate with new projects under construction and in operation. This entails the need to conduct environmental remediation activities simultaneously with the operation of the mine and to acquire know-how for decommissioning the facility at the end of its useful life. Also, it will be necessary to build up solid competence to cope with the demands and difficulties of a technical, scientific and legal nature existing not only in the setting up, operation, and decommissioning of the facilities, but also in connection with public acceptance of the nuclear activity.

2. Description of the industrial mining projects of Indústrias Nucleares do Brasil

2.1. Caldas facility – Minas Gerais

The former Poços de Caldas Industrial Complex – CIPC belonging to Indústrias Nucleares do Brasil is located in the city of Caldas/ Minas Gerais and was the first Brazilian facility to produce uranium in industrial scale (Fig 1). It started producing uranium concentrate (yellow cake) in 1982 and was temporarily closed in 1997.

FIG. 1. Caldas facility.

Currently known as Ore Treatment Plant, the facility is in an area of 3.2 thousand hectares and has a 2 km diameter open pit; in addition to 108 million tonnes of mining overburden and 2.4 million tonnes of tailings from the ore treatment plant. It involves a constructed area of 30 thousand square meters, where equipment used in the past for uranium concentrate production is still present. Today, the facility has no production activity, and many of its employees have been transferred to the facility in operation, located in the state of Bahia.

Many of the activities now being carried out in the facility involve remediation of degraded areas, mainly heaps of overburden, drainage basins and storage places for industrial waste from uranium processing. The presence of sulfide ores, mainly pyrite (FeS_2), causes the formation of acid drainage from heaps and the consequent production of a large volume of water containing high concentrations of stable and radioactive isotopes. Continuously treating such waste throughout these years means a high cost for the company

Anticipating the decommissioning of the facility, INB has been developing a series of mitigation measures, such as reducing the volume of acid drainage water. Because of the smaller volume of water to be treated, this has brought about significant savings of electric power and lime consumption, and has made possible a more effective operating control within the facility's capacity limit.

2.2. Caetité facility – Bahia

To the southwest of Bahia, near the municipalities of Caetité and Lagoa Real, one of the most important uranium provinces of Brazil is located. The implementation of the Industrial Uranium Mining Complex, originally called Lagoa Real Project and currently titled Uranium Concentrate Plant – URA, was started in 1998 (Fig 2).

The commercial-scale operation started in 2002, when the extraction of uranium ore with an average content of approximately 2 900 ppm in equivalent U_3O_8 was started through an open-pit mine on the Cachoeira deposit. Mineral beneficiation in the industrial facilities comprises the following steps [1]: uranium extraction by heap leaching; concentration and purification by the counter-current solvent extraction method; and production of the corresponding concentrated ammonium diuranate (ADU). The current annual production of ADU is 400 metric tonnes of equivalent U_3O_8.

FIG. 2. Caetité facility.

Of the 35 deposits explored so far, the site selected for development was the Cachoeira deposit, which concentrates the highest average content – 3 500 ppm U_3O_8 geological. By applying economic parameters, the mine is an open-pit development project to the depth of 140 m so as to produce ore with an average content of 2 900 ppm recoverable U_3O_8 for beneficiation.

The next phase of the project, currently in the course of licensing, is the shift to underground mining for a better economic development of the ore site. It will be the first Brazilian uranium underground mine. INB's planning of activities for the Lagoa Real uranium province includes the economic development of other deposits, in principle 3 among the 35 known deposits.

2.3. Santa Quitéria facility – Ceará

The Santa Quitéria Project, in the early implementation process, is located in the central region of the State of Ceará, about 45 km southeast of the city of Santa Quitéria. The deposit is characterized by the presence of uranium (reserves of the order of 80 thousand metric tonnes U_3O_8 associated with phosphate (reserves of the order of 9 million tonnes P_2O_5) and, although it is the largest uranium reserve existing in Brazil, its economic feasibility is contingent upon the exploitation of the associated phosphate [2] (Fig 3). The average contents found are 11% P_2O_5 and 0,1% U_3O_8. This means that uranium extraction is conditioned on the production of phosphoric acid, the input used in the production of fertilizers and mineral salt. This fact determines unique particularities in the licensing process for that facility.

FIG.3. Santa Quitéria Colophonite.

The project comprises open-pit mining, mineral beneficiation/ processing for phosphoric acid, and further processing of phosphoric acid for production of fertilizers, mineral salt and uranium concentrate from uranium by-product in a separate plant.

The area containing the deposit is a very poor region, it being estimated that the project will represent a large positive impact on regional development from the generation of 3 000 jobs – direct, indirect and associated – with the attraction and settlement of people in the region.

3. Current licensing status of INB projects

3.1. Caldas facility – Minas Gerais

The closure of the CIPC mine, with the decommissioning of the facility and environmental remediation of degraded areas, will be pioneering in Brazil and will happen after implementation of the PRAD − Plan for Rehabilitation of Degraded Areas. The PRAD is part of the agreement entered into by INB and IBAMA and CNEN, the licensing and oversight agencies with jurisdiction over the company's activities. This is called for in the overall plan for facility decommissioning, covering the closure and remediation approaches for the tailings ponds, mine pit, heaps of overburden and waste from uranium chemical processing, industrial areas and others.

Since 2004, when the regulatory body presented the Term of Reference, a number of factors hindered and delayed the hiring by INB of a company with the necessary technical qualification to prepare such document [3]. Three attempts were unsuccessful, and this year (2009) new contracting proceeding is under way. The main hindrances have to do with Brazil's lack of practical experience and skills in uranium mine remediation and decommissioning, plus legal and bureaucratic difficulties for a government-owned company to hire service contractors, mainly with international organizations. The cost of preparation of the PRAD is in the order of 2 million dollars.

3.2. Caetité facility – Bahia

The uranium mine and mill site in Caetité, State of Bahia, has been in commercial operation since 2002. Its Initial Operating Authorization was granted by CNEN for renewable periods, the facility's production being limited to 400 metric tonnes of uranium concentrate.

At present, the facility has an Operating License granted by IBAMA. The conditions for maintaining and renewing the facility's environmental license are as follows: continue the proposed environmental programs and the mitigation measures indicated in the environmental studies and submit relevant annual progress reports. These include: Fauna and Flora Management and Conservation; Monitoring and Mitigation: Monitoring of Air Quality; Monitoring of Underground Water Quality; Biological Monitoring; Monitoring of Effluents and Wastes; Control of Solid Wastes; and Socioeconomic Aspects: Social Communication and Environmental Education.

Another demand of the license is an Epidemiological Study, in progress, on the possible occurrence of diseases related to genetic damage and malignant neoplasms in the area of influence of the URA.

The need to shift to underground from open-pit mining was already acknowledged in the project's detailed design. Notwithstanding, a new license application was recently filed for the project with CNEN and IBAMA. Initially, only the construction of the access ramp was authorized. Under the environmental licensing procedure, IBAMA required INB to prepare an Environmental Study within the scope established by the regulatory body. This includes a description of the mining method; an explanation of the systems installed for environmental protection and control and occupational safety; reviews of Risk Analysis, Emergency Plan, Radiation Protection and Environmental Protection Plan; in addition to planning of actions for facility decommissioning.

In connection with nuclear licensing, the regulatory body required that a new socio-economic research within the project's area of influence (15 km radius), be conducted 7 years after the previous one in order to update the information on the community's land and water use patterns. Such research is nearing completion and, upon the opinion of the regulatory body, the review of the facility's Safety Analysis Report will be started.

In addition, complying with the regulatory body's requirement, INB is reformulating its Environmental Education Program in order to involve the neighboring community in the facility's production activity through a participative approach that includes an evaluation of public acceptance of the project, and aspects related to risk communication, regional insertion, etc. The Environmental Education Program is expected to involve employees, family members and the community of municipalities within the unit's area of influence.

3.3. Santa Quitéria Project – Ceará

The licensing history of the Santa Quitéria Project shows that it represents a particular case in this country. Since 2005, it has been a subject of study and discussion by INB - the project owner - the regulatory bodies CNEN and IBAMA, the environmental agency of the State of Ceará, where the deposit is located, in addition to the state and federal levels of the Judicial Power. The fact is that INB adopted the strategy of separating the project into two Units: a Phosphate Facility for production of phosphoric acid and fertilizers; and a Uranium Facility, responsible for the production of uranium concentrate. In this case, mining and mineral beneficiation activities belong to the Phosphate Facility.

INB chose to obtain the environmental license for the Phosphate Facility from the environmental agency of the State of Ceará, as established by the Brazilian legislation on mining activity in general. At the same time, INB started the environmental and nuclear processing of the Uranium Facility. In this case, the project being a nuclear facility for production of uranium concentrate is, by force of law, a monopoly of the federal government; accordingly, the licensing of its operations belongs to IBAMA and CNEN. The debate was then focused on the boundary of what would be a nuclear facility and, therefore, the subject of licensing by these federal agencies.

INB already has the official documentation from the parties involved in the process agreeing to the adopted licensing strategy; still, the company is not yet free from some challenges by those who oppose the chosen method.

Currently, the Phosphate Facility's installation license from the State of Ceará is in the process of renewal, and the Uranium Unit is in possession of the Term of Reference prepared by the federal environmental agency IBAMA for the project's Environmental Impact Study. CNEN, the nuclear regulatory body, has yet to issue a position on Site Approval, the first step of nuclear licensing.

It should be stressed that although the Environmental Impact Study refers to the Uranium Facility, it has a wide scope that covers the entire project because, as the federal environmental agency understands it, the environmental impact evaluation cannot be a fragmented effort.

On this project, for its particularities ensuing from the uranium-phosphate association, where phosphate it the preponderant element, and for the necessity of a partnership between INB and a private entity to make the project feasible, a longer delay is perceived in the steps to be completed under the administrative procedure of licensing.

4. Process difficulties and challenges: Decommissioning, operating and implementation of uranium mines

The former Poços de Caldas Industrial Complex – CIPC, located in Caldas/ Minas Gerais, was built and started producing uranium concentrate (yellow cake) in 1982, prior to the enactment of environmental legislation in Brazil. Therefore, many of the currently popular environmental remediation techniques were not practiced at that time, and the environmental issue was left to be addressed at the end of the project's useful life. Today, there is an environmental liability to be settled and a Rehabilitation Plan for Degraded Areas to be prepared as part of the actions for facility decommissioning. This country lacks practical experience in this area, because such facility is the first uranium mine to be decommissioned, and the challenges are many. The first one, from a technical viewpoint, given the characteristics of the environment, is that a number of studies, simulations, use of computational models are needed, which means time and cost for the project owner. A second challenge would be of a sociopolitical nature, with the need to have the stakeholders engaged in the process of defining and accepting the environmental remediation techniques.

In the case of the uranium mine in operation in the State of Bahia, Brazil, its uniqueness is highlighted today by the shift to underground mining, away from the open-pit method. Although underground mining operations exist in Brazil, this project will be the first ever underground uranium mine to operate in this country, and has, therefore, brought an even stricter control on the part of regulatory bodies for the granting of licenses. Since the start of commercial-scale operation of the Caetité/Bahia URA in 2002, with the open-pit mine and the mineral processing facility, INB has worked to meet all requirements of the regulatory bodies and satisfy all demands of the licenses. The company's experience shows that this has not been sufficient. The URA adopts environmental remediation techniques and conducts rehabilitation of the area while still in operation, so that by the end of the project's useful life the actions needed for decommissioning will be well planned and minimized. Notwithstanding, recent developments show that there are many difficulties to be overcome in the process, mainly in connection with the knowledge and understanding of the activity and its acceptance on the part of the project's neighboring communities. In this connection, opponents of the nuclear industry, such as Greenpeace, the local Church and other opinion makers created and placed technically ungrounded news items in national network. This was widely explored by the media and caused damage to the company's image until it was finally cleared up.

Finally, with respect to the uranium-phosphate mine being established in the State of Ceará, once the legal difficulties are overcome, the approach will drew on the experience and challenges faced in the course of the two other projects, one in operation, and the other being decommissioned. Thus, theoretically, some situations are prevented from happening, which means savings in material and human resources at the end of the process. From the viewpoint of a uranium mining and milling operation, we must anticipate ourselves; this means being conservative and conducting whatever studies are required, whether of a technical, socio-environmental, or political-economic nature, etc. At the same time, it is important to adopt relevant policies and get world recognized certifications for usual systems like Integrated Quality, Safety, Environmental Management, and Social Responsibility.

And, in fact, the current juncture has raised the interest of the industry as a whole for the so-called Social License.

5. Conclusion

The three presented cases of uranium mining and milling facilities in Brazil, namely the first in decommissioning, the second in operation, and the third in the implementation phase are unprecedented and pioneering situations in this country. This has entailed a greater effort by INB to meet the licensing requirements, with higher costs and longer time schedules.

INB has worked toward acquiring and expanding the knowledge necessary for the studies demanded by the regulator, by hiring consulting firms and promoting exchanges with international organizations and other companies of known experience in the related areas, besides training programs conducted locally or abroad, and technical visits.

Still, the licensing process for the facilities has not proven sufficient to prevent questions about the project by the community concerned. The facts happened to INB evidence the need for extensive investment in Environmental Education and an important work to be done in risk perception and communication. This is intended to facilitate integration of the project owner with the neighboring community and prevent the biased media exploration of ungrounded accusations by those who, for different reasons, come forward against the nuclear activity, and therefore work to mess up the process.

Social and Environmental responsibility actions with the parties concerned should be part of the project owner's routine, regardless of the phase the project is in, and the ideal is that such efforts be worked on from a strategic and operational viewpoint. The Brazilian experience has shown that, in this context, mining is in the lead and the nuclear industry in Brazil is expected to follow this trend, given the setting favorable to the growth of its activities.

REFERENCES

[1] INDÚSTRIAS NUCLEARES DO BRASIL S.A, Relatório Final de Análise de Segurança – Unidade de Concentrado de Urânio – URA rev. 02 (2007).

[2] INDÚSTRIAS NUCLEARES DO BRASIL S.A, Estudo de Impacto Ambiental – Projeto Santa Quitéria – Unidade de Fosfato (2005).

[3] IBAMA- DF, Termo de Referência para Plano de Recuperação de Áreas Degradadas (PRAD) - UTM Caldas (2004).

Licensing process for a uranium ore mining and milling facilities located in the state of Bahia, Brazil

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Abstract. The Uranium Concentrate Plant – URA – is a plant engaged in uranium ore research, mining and milling activities. The plant aims at producing natural uranium concentrate in the form of ammonium diuranate – ADU, used as raw material for fuel production for nuclear plants. This paper discusses the aspects related to nuclear installation licensing, featuring all steps of the process and emphasizing the requirements of control agencies. It also approaches the epidemiological study required by IBAMA during the process of environment licensing, in order to define possible influences of URA's activities on the neighboring population's health.

1. Introduction

Brazilian legislation establishes that nuclear activities in Brazil be subject to an extensive, detailed licensing process, both from the nuclear viewpoint – with the National Nuclear Energy Commission (CNEN), and from the environmental viewpoint – with the Brazilian Institute for the Environment and Natural Renewable Resources (IBAMA), which evaluates the positive and negative impacts of such activities on workers, the public and the environment.

The licensing process consists of defined steps that are to be adhered to on pain of rendering any granted licenses invalid. By an analysis of the documents submitted in the course of the process, all possible impacts from the would-be licensed activities are evaluated. Not until the completion of all specified steps will licenses and permits be issued for the functioning of the facilities. As necessary, demands and requirements are established for adherence by the owner/ operator, so as to minimize the negative impacts from the activities and thus provide a safe operation.

This paper will discuss the formalism of existing licensing procedures, with emphasis on the environmental licensing of a uranium mining and milling facility owned by Indústrias Nucleares do Brasil S.A.

2. Project description

Cachoeira farm, where the Cachoeira deposit (Deposit/Anomaly LR-13) is located, was the first rural property acquired by INB [1]. Originally called Lagoa Real Project – LRP, this is a mining industrial complex currently called Uranium Concentrate Plant – URA, located in the municipality of Caetité, State of Bahia, Northeast Brazil.

This project defines the opening and operation of an open-pit mine located on the Cachoeira deposit (Deposit/Anomaly LR-13), for extraction of uranium ore with an average content of approximately 2 900 ppm in equivalent U_3O_8, with milling operations being done in industrial facilities built for uranium extraction by acid heap leaching, concentration and purification by counter-current solvent extraction, and production of the respective concentrate in the form of ammonium diuranate (ADU).

The period of open-pit mining is estimated at approximately 12 years for an annual ADU production of 400 tonnes.

The Cachoeira Deposit was selected for initial operation for it presents the main geological and economical parameters (highest average content of geological uranium – 3 500 ppm, mineralized thickness, volume and morphology) more favorable for industrial use among the 35 deposits/anomalies surveyed to the present day in the region. The mine overburden and waste ore from the leaching piles are disposed of conjointly nearby the pit in a place adequately chosen aiming at minimum environmental impact.

FIG. 1. URA- Uranium concentrate plant.

It is worth stressing that, at the time of project inception, a key aspect that led INB to start exploiting that region's ore deposit was the low investment – in the order of US $23 million − needed to make the project feasible. In addition, the uranium is found in deposits that allow a modular exploitation method. INB is currently in the process of obtaining the relevant license for exploiting the same anomaly through underground mining.

Additional uranium resources can be found at the Lagoa Real Uranium Province, Constituted by 12 deposits, from which 7 of those have the surveys partially concluded, have evolved to the mineral deposit category. On the other side it is believed that the potentiality presented by the 23 uranium anomalies yet not evaluated through boring might add considerably to those resources

At present, as an extension program, the URA is establishing other projects for extraction (underground mining) and processing of uranium concentrate (dynamic leaching), while carrying on exploitation on the same deposit. Subsequently, plans contemplate the development of other deposits that make up the Lagoa Real Uranium Province.

The plant occupies an area of approximately 870 hectares, where the facilities of the complex are distributed, as shown in Fig. 1.

3. Licensing pocedures

The items below describe the licensing procedure for a nuclear facility.

3.1. *Nuclear licensing*

Every nuclear facility in Brazil must undergo a licensing process with the National Nuclear Energy Commission-CNEN [2], whose guidelines are unique in dealing with radiological parameters. Their provisions include requirements on equipment design and size; civil engineering and industrial erection; systems and devices for industrial, radiation, and environmental safety, and property security of nuclear facilities.

The process is regulated by CNEN Rule NE 1.13 –Licensing of Uranium/Thorium Mining and Milling Facilities and the CNEN Rule NE-1.04 – Licensing of Nuclear Facilities, applicable to the activities associated with the siting, construction, and operation of nuclear installations, covering the following steps:

* **Site Approval** – whereby CNEN approves the site proposed for a particular nuclear facility.

* **Construction Permit (full or partial)** – a permit CNEN authorizes the construction of a nuclear facility after verifying the technical feasibility and the safety concept of the project and its compatibility with the approved site.

* **Authorization for the Use of Nuclear Material** - AUNM– the granting by CNEN of written permission for use of nuclear material in a nuclear facility.

* **Authorization for Initial Operation** - AIO– authorization granted for the initial operating phase of a nuclear facility, upon:

    - verification that construction is substantially completed;

    - evaluation of the Final Safety Analysis Report and of the pre-operational test results;

    - verification of inclusion of all supplemental safety conditions required by CNEN during the construction phase.

* **Authorization for Permanent Operation** - APO– authorization for a nuclear facility to operate on a permanent basis, after completing the phases of initial operation and operation at nominal capacity in normal conditions during a continuous time interval set by CNEN.

3.1.1. Nuclear licensing - background

The nuclear licensing of this facility goes back to the nineties when, after submitting the required documentation to CNEN, it obtained site approval in October 1997. At present, the URA has the Authorization for Initial Operation (renewal) granted by CNEN on 4 September 2007.

The construction license was obtained in September 1999 and afterwards the URA plant received the pilot test authorization.

The first Authorization for Initial Operation (AIO) was granted in 2000 and it has been renewed ever since. The last AOI was released in 4 September 2007 and is valid through 24 months.

By means of constant inspections CNEN, monitors URA’s operation whenever necessary for the preparation of additional work to inquire into some technical detail deemed important for clarification.

Additionally, in compliance with the rules issued by CNEN, INB keeps a series of Plans documented and approved by CNEN. These are: Environmental Monitoring Program, Occupational Radiation Protection Plan, Physical Protection Plan, Emergency Plan, Nuclear Material Control Plan, Fire Protection Plan.

3.2. Environmental licensing

All project phases are also licensed with the Brazilian Institute for the Environment and Renewable Natural Resources – IBAMA.

Environmental licensing [3] is a rather complex procedure that involves several steps. There is even a constitutional provision for some mandatory procedures to be followed for the licensing of activities that potentially degrade the environment, such as the necessity (Art. 225, Par. 1, V) to prepare a preliminary environmental impact study. Art. 9, IV of Law 6938/81, establishes that "the licensing and review of effectively or potentially polluting activities" are instruments of the National Policy on the Environment.

The main legal document [3] dealing with environmental licensing in the federal sphere is Decree nº 99274 of 6/6/90, where the licensing of activities using environmental resources is governed by articles 17 onwards.

The environmental licensing procedure comprises the granting of the following licenses:

* **Prior License (LP)** – granted in the preliminary phase of activity planning. It constains basic requirements to be met in the siting, installation, and operation phases, in accordance with the municipal, state or federal plans on soil use.

* **Installation License (LI)** –Authorizes the start of site preparation according to the approved detailed design specifications.

* **Operating License (LO)** –A document authorizing, after the necessary verifications, the start of the licensed activity and the operation of pollution control equipment in line with the provisions of the prior and installation license.

In order to clarify the environmental licensing process, CONAMA (National Council for the Environment) Resolution 237/97 (Art. 10) established a minimum road map to be followed in the process, namely:

- Definition by the appropriate state environmental agency, together with the project owner, of the documents, design papers, and environmental studies necessary for starting the licensing process corresponding to the license sought;

- Environmental license application by the project owner, supported by the relevant documents, design papers, and environmental studies; to be publicized on the media;

- Analysis by the appropriate state environmental agency under the National System for the Environment – SISNAMA, of the submitted documents, design papers and environmental studies, and conduct of technical inspections, as necessary;

- Clarification and supplemental information one-time request by the appropriate state environmental agency under SISNAMA, as a result of the analysis of submitted documents, design papers and environmental studies, if any. Such request may be repeated if the clarification and supplemental information are deemed to be inadequate;

- Public hearing, if any, in accordance with the relevant regulation;

- Clarification and supplemental information request by the competent environmental agency as a result of public hearings, if any. Such request may be repeated if the clarification and supplemental information are considered to be inadequate;

- Issuance of conclusive technical opinion and, where appropriate, legal opinion;

- Approval or denial of license application, to be publicized on the media (Resolution CONAMA nº 06/86).

- Additionally, Article 10, Par. 1 establishes that the environmental licensing proceedings shall mandatorily include a City Hall statement certifying that the site and type of project or activity are in accordance with the applicable legislation on soil use and occupation and, where appropriate, with the authorization for vegetation removal and water use issued by the competent bodies.

In short, during a licensing process, the main documents requested are:

- Environmental Impact Study (EIS) and corresponding Environmental Impact Report (EIR) prepared according to a specific Terms of Reference document issued by the environmental agency;

- Detailed design of the facility

- Basic Environmental Plan with the detailing of all required environmental programs.

Such documents are to be submitted in the course of the process. Still, after review thereof, changes and supplemental information may be requested by the environmental agencies.

3.2.1. Environmental licensing – history

The environment licensing process for subject facility began in 1996, when INB requested from IBAMA the Prior License for project installation. IBAMA then required the preparation of the Environmental Impact Study (EIS) and the corresponding Environmental Impact Report (EIR).

The EIR must contain a summary of the information included in the EIS in a readily intelligible language in order to provide a clear understanding of the project being licensed.

According to the legislation in force at that time, INB hired an independent firm for preparing the EIS/ EIR. On 28 May 1997, IBAMA makes public that it had received the documents and calls a public hearing scheduled for 4 July 1997.

To enable a wide publicizing of such documents, in addition to the copies distributed to the oversight bodies, INB made copies of the EIR available to a number of city halls in the region, namely: Caetité (EIS/ EIR), Livramento do Brumado, Ibiassucê, Caculé, Rio do Antônio, Lagoa Real, Igaporã, Guanambi. Copies were also furnished to: the School of Philosophy, Sciences and Letters of Caeitié; the District Attorney's Office of Caeité; the Diocese of Caeitité and the City Council of Caetité.

In the period from the delivery of the EIS/ EIR to the Public Hearing, INB conducted a series of lectures in the municipalities of Caetité and Lagoa Real for the purpose of disclosing and making available the information contained in the EIR.

Such lectures provided information on:

- nuclear fuel cycle, use of nuclear energy and the existing potential of the uranium province in that region;

- presentation of the process of acquisition of areas of interest to INB for project implementation;

- presentation of the process that would be used to obtain the uranium concentrate;

- presentation of the activities involving licensing, and environmental and occupational control.

In connection with the acquisition of the area needed for project implementation, it should be noted that, due to the existence of several proprietors, INB had to establish a program in order not to cause a great impact on the local society.

In Caetité, INB did not use the instrument of judicial expropriation [4] in the process of acquiring the project land as usually done in implementing large public or private projects. Instead, INB used the "involuntary indemnification" rule. That is, land owners were indemnified in their possessory interest on the land and improvements (crops) ensuing from their working and tilling of the land during the time of their occupation. A value was attributed to the supposed loss of profits, and another to the relocation expenses. The assessment of all such indicators provided the "actual and final value" to be paid the land surface owner for his/her property, by way of compensation. Such value was not only the local market value, but also a historical and cultural value, where nearly all efforts of that rural worker/farmer were assessed and included in the final price of the property.

Therefore, the company's policy was to negotiate with each inhabitant, assessing his/her property at the actual market value so as to enable all to be able to settle down somewhere else, with no financial loss.

The public hearing held on 4 July 1997 was attended by 974 people representing several segments of the local community. Such event can be considered a landmark for the municipality, inasmuch as it allowed an ample discussion of a project that would contribute to improving the living conditions of the region.

INB then received the Prior License in October 1997 and, after submitting the documents required by the environmental agency, the Installation License on 30 April 1988.

Operating License 274/2002, issued on 29 October 2001, presented conditions on the continuation of social and environmental programs. In addition, the constant concern about possible health problems to the population as a result of the installation of the Uranium Concentrate Plant in the municipality of Caetité, led IBAMA to require that Operating License 274/2002 include a mandatory epidemiological study with the following characteristics:

a) the company to be hired for conducting the study is to work in partnership with the Caetité Secretariat of Health and Regional Health Directorate, which are the competent agencies to enforce the program requirements;

b) the work is to include transversal and longitudinal epidemiological studies for identification of carcinogenic effects on the health of the potentially exposed population, making correlations with the reference municipality, with data from the federal government and the state of Bahia covering the period from 1995 to 2006;

c) the contractor is also to compare the occurrence of neoplasms in the Uraniun Concentrate Plant's area of influence against another region having similar characteristics from a socio-demographic viewpoint but which do not include the presence of natural radiation sources;

d) the second phase of the effort consists in monitoring the original work for a period of five years (up to 2012), the contractor being required to generate corresponding annual reports.

The first phase of this work is nearing completion and expected to be submitted to IBAMA by the end of June 2009.

4. Conclusion

As one can see from the preceding items, the licensing of a nuclear facility is a complex process that develops in the course of years, and where the existence of parallel proceedings (CNEN/ IBAMA) makes it even slower and more expensive to the project owner.

Additionally, one has noticed the tendency to transfer to the project owner the handling of issues that belong to the government. This is a matter that deserves a serious discussion with society at large, because complying with all demands may easily make a project unfeasible.

At present, whereas nuclear licensing maintains a primarily technical approach, environmental licensing has, in turn, sought to incorporate more and more complex demands from the project's neighboring communities.

Such concern, however, is not new to INB, which has always included safety and control principles into its projects and activities, so as to prevent damage to workers, the environment, and the general public. In fact, as it includes society in decision-making pertaining to activities that may possibly affect society directly or indirectly, the environmental licensing process has been shown to be an opportunity for publicizing the work done by the company, giving it more transparency and, from the viewpoint of the communities, making it more reliable.

Also, it should be noted that licensing is a constant process involving the company, because of the necessity to comply with all requirements of the oversight bodies so as to maintain the licenses obtained and/or to gain license extensions or additions for plants.

For example, INB is now seeking to license a change to the URA mining process, which will shift from open-pit to underground mining. Accordingly, by requirement of CNEN/ IBAMA, INB is revising all environmental studies/ safety analyses and expanding projects dealing with environmental education and regional insertion.

REFERENCES

[1] INDÚSTRIAS NUCLEARES DO BRASIL S.A.,Relatório Final de Análise de Segurança, Unidade de Concentrado de Urânio, URA [translation: Final Safety Analysis Report – Uranium Concentrate Plant] (licensing document),

[2] COMISSÃO NACIONAL DE ENERGIA NUCLEAR, CNEN, www.cnen.gov.br.

[3] ANTUNES, P.B., Direito Ambiental, Editora Lumen Juris, Brazil (2008).

[4] ALVES, M.R., Efeitos da Implantação do Projeto Lagoa Real na Qualidade de Vida das Famílias da Áreas Atingindas: Um Estudo de Caso, Monografia [translation: Effects from the implementation of the Lagoa Real Project on the quality of life of families in the affected areas], Universidade do Estado da Bahia, Salvador de Bahia, Brazil (2005).

Radiation safety and environmental protection issues of uranium mines and mills in Brazil

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Abstract. In 1971 an immense uranium ore deposit was discovered in Caetité, Bahia, at the Northeast region of Brazil, estimated to have about 100 thousands tonnes of uranium concentrate (U_3O_8). Up to 1995, Brazilian needs were restricted to feed the nuclear reactor Angra 1, then supplied by the first Brazilian mine located in Caldas, Minas Gerais. When the Government decided to finish the next reactor, Angra 2, it became necessary to have larger supplies of uranium concentrate. Therefore, the project of producing uranium in Bahia was elaborated by the Indústrias Nucleares do Brasil - INB, complying with all the strict national and international safety and environmental protection regulations. Considering the mineral characteristics and the very dry weather conditions of the region, it was decided to use the heap leaching process to extract the uranium ore. After been crushed, the ore is piled and irrigated with a sulfuric acid solution. This technique spares the milling, mechanic agitation and filtration phases, allowing, besides a substantial investment reduction and operation at smaller costs. The extraction process accomplishes the uranium concentration by organic solvents, followed by separation by precipitation, and drying. One of the characteristics of the process is that it can be carried out without the need for liberation of effluents to the environment. Recently, the Brazilian Government announced the decision to resume the construction of Angra 3, and there are plans for the construction of four other new nuclear plants. Accordingly, projects for the expansion of the current uranium production capacity in Caetité were developed, and comprise going for underground mining and shifting to conventional leaching. This paper summarizes the present status of radiation safety and environmental protection activities that are in place in and around the uranium mine and milling facilities of Caetité. It describes the workforce radiation protection measures, including dose assessment for direct exposition and incorporation, over the years of operation, and measures envisaged to comply with the future expansion of the enterprise. The environmental protection programme is presented, detailing the continuous monitoring of up to 30-kilometer area around the unit, including the control of: underground and rain water, air, soil, grass, agricultural products and milk. Reference is made to the request made by INB for hosting the IAEA Uranium Production Site Appraisal Team (UPSAT) programme mission, in order to provide assessment of the status of present operational safety and operational practices for both mining and milling at Caetité.

1. Introduction

The Caetité Uranium Concentrate Unit, also known as URA, owned by the Indústrias Nucleares do Brasil – INB [1], is the uranium mine and mill facility in operation at the present moment in Brazil. Located on a mineral rich province with 100 000 tonnes of uranium (U_3O_8) reserves, it is installed in an area of 1 780 hectares, in the municipality of Caetité, Southeast of Bahia state (13°56'36"S and 42°15'32"W). Project construction began in 1998, exploring the Cachoeira ore deposit (Fig. 1), and involved investments of about US $20 million. Production activities started two years later, based upon the open pit mining of uranium ore, with the average uranium content of 2 900 ppm. The crushed rocks, with particle sizes down to 12 mm or less, are mounted in heap leaching piles of about 25 000 to 35 000 tonnes of mineralized material, irrigated with a sulfuric acid solution. At the processing plant (Fig. 2), the uranium liquor is collected and prepared to have about 2 g/L of uranium, as U_3O_8. After clarification and filtration of the liquor, the uranium is extracted by means of an organic solvent.

Uranium is then stripped with a NaCl solution, from which it is precipitated as ammonium diuranate (ADU), dried and stocked in drums, ready to be sent abroad for conversion to UF_6.

All the activities of the Caetité Unit are licensed and inspected by the Brazilian Regulatory Authorities: CNEN for nuclear issues and IBAMA for environmental issues, each one with its specific laws and regulations.

FIG. 1. Caetité unit – open pit mine, at present.

FIG. 2. Milling of uranium – processing plant.

2. Occupational radiation safety

Being a nuclear facility and complying with federal regulations, the Caetité Unit has a Radiation Protection Service (RPS), managed by the Radiation Protection (RP) Officer certified by CNEN. There are several activities and controls developed by the RPS, in order to ensure the proper protection of the health and safety of the workforce, of the people and the environment. Among these, concerning the Occupational Radiation Safety, we may remark:

- *Training of the workforce and other individuals* – all workers and any visitors are subjected to a RP training programme, upon their arrival at the URA. The duration and content of the programme depends on the specific activity to be developed. Workers follow annual retraining programmes.

- *Restricted access to Controlled Areas* – there is the need for an express written authorization, given by the RP Officer, in order to enter any Controlled Area. There are specific procedures to follow upon entrance and exit. Each Controlled Area has a station with full time RP personnel, comprising with the overall inspection, permanence control and dose records, worker protection equipment, as well as area and individual monitoring. The worker protection equipment may include helmets, boots, gloves, protective clothing, mask with filters, more or less stringent depending on the activity pursued.

- *Occupational Monitoring Programme* – there is a comprehensive monitoring programme, approved and inspected by the regulatory body, in order to assess the radiation field levels and the occupational exposure. A summary of the radiation monitoring devices used, or methods, is presented in Table 1, separated as external exposure, internal exposure and surface contamination, either for individual or workplace assessment.

Table 1. Occupational monitoring devices and methods

Occupational Monitoring	External Exposure	Internal Exposure	Surface Contamination
Individual Monitoring	TLD	Personal Air Sampler with Alpha/Beta Spectrometry	Geiger Mueller with External Pancake Probe
	Electronic Personal Dosimeter	Internal Dosimetry Excretion Analysis	Personal Hand and Foot Radiation Monitor
Workplace Monitoring	Dose Rate Meter	High-Flow Air Pump Kit with Alpha/Beta Spectrometry	Surface Scratching with Filter
	Geiger Mueller Counter or Gamma Ray Scintillometer		Geiger Mueller with External Pancake Probe

As a result of the Occupational Monitoring Programme, there is full compliance with the dose limit for occupational exposures, established as 20 mSv per year, as required by the Radiation Protection Regulation [2] issued by CNEN (2005). Figure 3 summarizes assessed dose for workers, during the past years. The comparison with production figures illustrates the effectiveness of the continuous optimization procedures, in the last 4 years of operation.

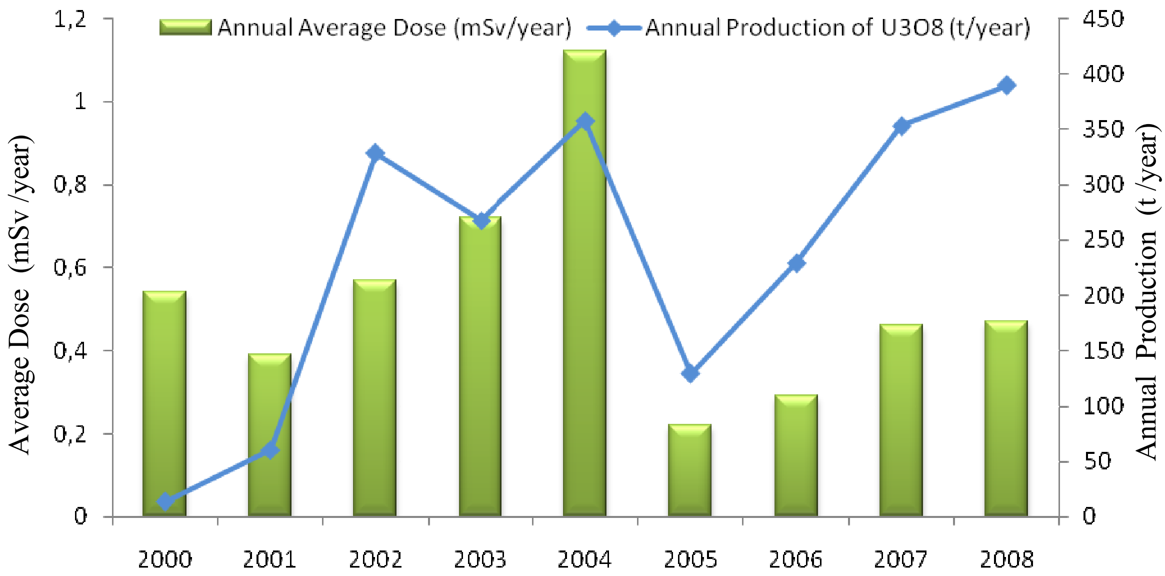

FIG. 3. Average assessed dose for workers and annual production of U_3O_8 over the past years.

3. Environmental protection programme

The assessment and protection of the health and safety of the members of the public is ensured by means of a rigid Environmental Protection Programme, encompassing the operational (as well as the pre-operational) monitoring of the waste management facilities and the environment.

For the URA Unit, the potential radiation sources are: atmospheric sources– due to open pit detonation, to ore crushing and to heap leaching pile mounting; aquatic sources – due to rainwater run-off or percolation among the solid rock waste deposits, to treated liquid effluent tailing impoundments and to the surface water sedimentation basins; and solid sources – basically due to the solid rock waste deposits. For liquid (surface and underground water) or solid effluents the activity concentration of the following radionuclides is determined: U-238, U-234, Th-230, Ra-226, Pb-210, Th-232 and Ra-228. For air sampling, Rn-222 soil exhalation and atmospheric concentration is also monitored.

The Environmental Monitoring Programme encompass a 30 km radius around the site, and measurements are compared with background levels and pre-operational measurements, taken over a 10 years period before beginning of production. Farm products are taken in the neighborhood, including black beans, corn, manioc, palm (local cactus) and cow milk. Soil and pasture grass at these locations are also collected, together with air sampling.

Table 2 summarizes the monitored matrix, accounting for the number of different sampling points, the monitored parameters and the total average number of results per year, depending on their measurement frequency. Physical-chemical parameters and concentration of stable elements are also determined, for several liquid samples.

Detailed mathematical calculations are used to model the radionuclide transport over the different environmental compartments, starting from each source, in order to achieve reliable assessment of potential contamination and committed doses. Mathematical models and conversion coefficients are based on CNEN regulations, and therefore compatible with ICRP Recommendations and IAEA Safety Standards.

As a result of the Environmental Protection Programme, there is full compliance with the dose limit established as 1 mSv per year, for the relevant critical groups of members of the public, as well as the dose constraint of 0.3 mSv per year, established as the optimization of the Radiological Protection and Safety activities [2].

Table 2. Environmental monitoring programme matrix.

Monitoring Type	Number of Monitoring Points	Monitored Parameters [(a)]	Number of Monitoring Results per Year
Radon	26	Radon Concentration in Air	104
Gamma Radiation	26	Rate of Kerma in Air	104
Aerosol	7	Radionuclides	140
Rain Water	7	Radionuclides and pH	126
Surface Water and Sediments	12	Radionuclides and pH	216
Underground Water	70	Radionuclides, Physical and Chemical Parameters	8,484
Soil	14	Radionuclides	70
Farm Products, Grass	14	Radionuclides	70
Crushed Ore	2	Radionuclides	60
Liquid Effluents	21	Radionuclides, Chemical Parameters, pH and Conductivity	1,962
Total per Year	199		11,336

[(a)] Monitored Parameters:

Chemical parameters: Mg^{++}, Ca^{++}, Ba^{++}, Mn^{++}, Fe^{++}, Al^{+++}, SiO_2, SO_4, F^-, Na^+, K^+, Cl^-, NO_3.
Physical parameters: pH, Conductivity, Hardness, Alkalinity, Color, Turbidity, Acidity.
Radionuclides: U-238, U-234, Th-230, Ra-226, Pb-210, Th-232 and Ra-228.

4. Near future plans and conclusion

Projects for the expansion of the current uranium production capacity in Caetité, from annual 400 tonnes to 800 tonnes, are being developed. On the uranium milling, plans are to shift from heap leaching to the more efficient conventional leaching. Pilot tests are being carried out. As for the Cachoeira Mine, plans comprise going for underground mining, scheduled to begin in 2011. Open pit mining is predicted to operate until 2012. Corresponding adaptation of the Occupational Radiation Safety and Environmental Protection Programmes are under way. For the underground mining, ventilation issues and real time radon and daughters monitoring are on top of the concern list, taken by the risk assessment analysis. As for the mid term planning, new ore deposits are under investigation in the Caetité region, envisaging exploration: Engenho Anomaly (about 27 000 tonnes of uranium) and Rabicha Anomaly (about 23 000 tonnes of uranium).

With all this increasing activities running at the URA Caetité Unit, and confident on the Radiological Safety and Environmental Protection Programmes being properly conducted, INB decided to request for hosting an IAEA Uranium Production Site Appraisal Team (UPSAT) programme mission [3], already this year. The purpose is to provide improved assessment of the status of present operational safety and operational practices, for both mining and milling at Caetité, in order to favor a solid ground for the upcoming uranium enterprises of INB, not only in Caetité, but also as a reference for future developments, for example, those planned for Santa Quitéria, in Ceará state.

REFERENCES

[1] INDÚSTRIAS NUCLEARES DO BRASIL S A – INB, http://www.inb.gov.br

[2] COMISSÃO NACIONAL DE ENERGIA NUCLEAR – CNEN, Norma CNEN-NN-3.01 - Diretrizes Básicas de Proteção Radiológica (2005), http://www.cnen.gov.br/seguranca/normas/pdf/Nrm301.pdf

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, The IAEA Uranium Production Site

Appraisal Team (UPSAT) programme,
http://www.iaea.org/OurWork/ST/NE/NEFW/nfcms_rawmaterials_UPSAT.html

Radiological safety in mining of low grade uranium ores: four decades of monitoring and control in Indian mines

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Abstract. The first uranium mine in India commenced operation in 1967 and is now operating up to a depth of about 905 meters. Subsequently, three underground and an opencast mines were opened in the same region. Another underground mine is being developed in the same region and one in southern state of Andhra Pradesh. Workplace monitoring for radiological parameters in each mine commenced right from the beginning of the operations. Monitoring methodologies and ventilation system have undergone several improvements over a period of time. Modifications in ventilation had positive impact of reduction in radon concentrations; consequently the average doses have shown a downward trend. This paper gives an overview of the monitoring for external radiation, radon and the long-lived alpha emitters in the mines. The trend of doses in Jaduguda mines is given for the last four decades and recent data for the other mines are summarised. Efforts made to increase the ventilation and the impacts on radon control are also discussed.

1. Introduction

Many low grade uranium ore deposits have been identified in India. After initial exploratory work, the first uranium mine in India commenced commercial scale operations at Jaduguda in 1967. Subsequently other mines were opened for production in nearby locations [1][2]. Currently four underground and an opencast mines are in operation; two underground mines are in different stages of development. These mines employ large work force. Radiation exposure of mine workers is essentially due to the external gamma radiation from the ore body and internal radiation from inhalation of radon with its short-lived progeny. Exposure to long-lived alpha activity from the airborne ore dust is small. The radiation monitoring and evaluation of dose to workers are regularly carried out in these mines from the beginning of the operations [3][4]. As a matter of policy radiological and environmental safety surveillance is carried out by the Environmental Survey Laboratories of the Bhabha Atomic Research Centre. A brief description of the mines, ventilation system, monitoring methodology and radiation exposure estimates for the workers are given. Impact of ventilation up gradation on radon concentration and dose to workers is also presented. Average annual radiation doses to workers for the last five years in the operating mines are presented. A summary of the average annual exposure of Jaduguda uranium mine workers since the beginning of the operations is also presented in this paper.

2. Mines and the ventilation system

There are four underground and one opencast uranium mines currently operating in the Singhbhum Thrust Belt of eastern India. Another underground mine is being developed at Tumalpalle in the southern state of Andhra Pradesh. The Jaduguda mine was developed in three stages over the years to reach the deepest ore deposit [1]. A central shaft serves as entry for men and material and as main ventilation intake route. A system of exhaust fans located in adits at the top provides adequate air to ventilate the mine workings. The ventilation system is continuously upgraded to provide air quantity commensurate with the operations. The initial ventilation rate of about 78 $m^3.s^{-1}$ in early years was increased to 90 $m^3.s^{-1}$ in 1990s. As deeper levels were developed the ventilation rate was increased further to 125 $m^3.s^{-1}$ in 2002. This was achieved by widening the ventilation routes and increasing the fan capacities.

Initially the series system of ventilation was in vogue where the fresh air entered the lowest levels and travelled to upper levels progressively ventilating the workplaces and finally discharged to open atmosphere through the exhaust fans located in two diagonally opposite adits about 30 metres above ground in isolated locations. This had the disadvantage of contaminating the air during its travel to workplaces in upper horizon. It was later modified to a parallel system of ventilation such that adequate quantity of fresh air enters each haulage level. After ventilating the workplaces the contaminated air joins the return air stream. The fresh air requirement for each haulage level was calculated by taking in to account the emanation rate from the host rock and broken ore stockpiles generally present in the production zones. Taking into account the radon concentration entering a particular haulage level and that in the return air from the most productive zone, the fresh air required for each haulage level of Jaduguda mine was calculated to be 20 $m^3.s^{-1}$ [5]. The total quantity for the mine was evaluated depending on the number of haulage levels operating simultaneously and giving due regard to possible leakages.

The Bhatin mine is a relatively small mine developed through adits and winzes to reach the ore body. Entry is through an adit which also serves as intake route for ventilation air and transport of the excavated ore to the surface. An exhaust fan of capacity 50 $m^3.s^{-1}$ provides air for ventilation.

Narwapahar mine is one of the most modern mines in the country with a combination of trackless mining through decline and a vertical shaft to reach the deeper ores. Three large fans with a total capacity of 225 m^3s^{-1} provide ventilation to the mine workings [4]. Turamdih mine is also designed for operation with a combination of decline and shaft for production and ventilation purposes. In the initial stages the ventilation rate for this mine is 84 $m^3.s^{-1}$. The ventilation in all mines is reviewed periodically and augmented to meet the requirements.

3. Monitoring methodology

3.1. Radon monitoring

A radiation monitoring programme is in operation in all uranium mines and processing plants. The main sources of radiation exposure of workers in low ore grade underground uranium mines are identified as external gamma radiation from the ore body and inhalation of radon (^{222}Rn) and its short-lived progeny.

Long-lived alpha activity due to airborne ore dust in mines is evaluated by sampling air through high efficiency filters and counting the alpha activity after allowing sufficient time for complete decay of radon progeny. It is observed in the region of 5 – 10 $mBq.m^{-3}$. Its contribution to the total dose is very small due to the low grade of ore [6][7].

Radon is monitored at all working locations using pre-evacuated scintillation cells. Radon daughter concentrations are also occasionally monitored along with radon to evaluate the equilibrium factor (F). The equilibrium equivalent radon concentrations ($Bq.m^{-3}EER$) for different workplaces are obtained from the measured radon concentration and the equilibrium factor. The radon progeny concentration in units of working level (WL) is obtained by dividing the equilibrium equivalent concentration of radon by 3 700. Although radon concentrations in mines strongly depend on the ventilation rate, factors such as distribution of fresh air, presence of varying quantities of broken ore, radon released by the mine water during its flow through the galleries and auxiliary fans in new development headings make the system rather complex. New development faces are ventilated by auxiliary fans in the initial stages until they are joined with the main ventilation stream. This also has important bearing in the overall average radon concentration in the mine.

3.2. *Gamma radiation monitoring*

The gamma radiation levels are monitored at all workplaces using radiation survey meters as well as by thermoluminiscent detector based personal dosimeters. Gamma radiation level in workplace depends on the grade of ore present. As a rule of thumb, the ore grade (% U_3O_8) multiplied by 50 gives the gamma radiation dose rate ($\mu Gy.h^{-1}$) [8]. This relationship is useful in estimating the possible exposure levels in a new mining zone.

3.3. *Dose evaluation*

Using the gamma radiation and radon monitoring data in combination with the average equilibrium factor and occupancy period in different work areas the annual effective dose to the workers is computed as,

$$H(mSv) = \frac{K.A.\sum_{i}^{n} WL_i T_i}{170} + \sum_{i}^{n} G_i T_i$$

where

H = effective dose, mSv
K = conversion factor (1 WLM =5 mSv)
WLi = radon daughter conc. at ith location (WL)
Ti = time spent at ith location (h)
n = no. of locations
A = annual attendance (d/y)
Gi = gamma dose rate at ith location.

The dose evaluation from the area monitoring for radiation and radon with occupancy period is termed as ambient dosimetry. It is supplemented by use of personal dosimetry (PD). The personal dosimeter is an indigenously developed system using thermoluminiscent detectors (TLD) for gamma radiation and solid state nuclear track detectors (SSNTD) for radon measurements. This device comprises of an aluminium chamber of 60 ml volume cylindrical covered with permeable membrane which allows only radon to diffuse in, due to its relatively longer half life, while acting as a barrier for Rn-219, Rn-220 and dust. A 1.8 cm x 3 cm SSNTD film is placed between two TLD chips mounted inside at the other end of the chamber. The TLD and SSNTD in the chamber are replaced every two months. While the TLD chips are processed to give cumulative exposure to gamma radiation and the SSNTD film is etched and electronically counted to give alpha tracks which are correlated to radon exposure. The personal radiation and radon dosimeter is shown in Fig. 1 [9][10].

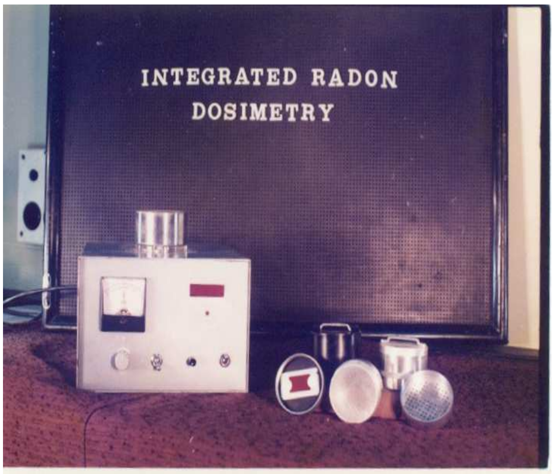

FIG.1. Personal radiation and radon dosimeter.

4. Results and discussions

The average gamma radiation level in Jaduguda mine in 2007 was 2.77 μGy.h^{-1}and radon concentration was 0.24 kBq.m^{-3}. In other mines the average external radiation levels were in the range of 1.3 to 2.3 μGy.h^{-1} and radon concentrations were in the range of 0.32 to 0.57 kBq.m^{-3}, respectively. In the Banduhurang opencast mines the average external radiation level and radon concentration were 0.51 μGy.h^{-1} and 0.03 kBq.m^{-3}, respectively.

The radon monitoring data for Jaduguda mine is summarized in Fig. 2. As the ventilation system was augmented in 2002, the results for the radon measurements are given for 5 years before and after the latest ventilation augmentation. There is a reducing trend in radon concentration due to constant modifications in the ventilation. The trend is not uniform because when new mine faces are developed some areas need to be ventilated using auxiliary fans until the gallery is connected to the main ventilation system.

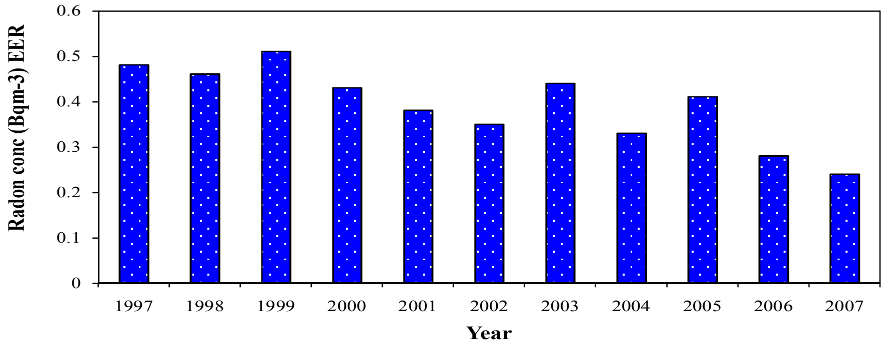

FIG. 2. Trend of radon concentration in Jaduguda mine.

For dose evaluation both the techniques, namely ambient and personal dosimetry, are used. Hence, it is considered appropriate to compare the data obtained by the two systems. A comparison of internal doses due to radon progeny evaluated using the two techniques for different categories of workers is given in Fig. 3. Both techniques are in reasonably good agreement with variations within about 20% [11].

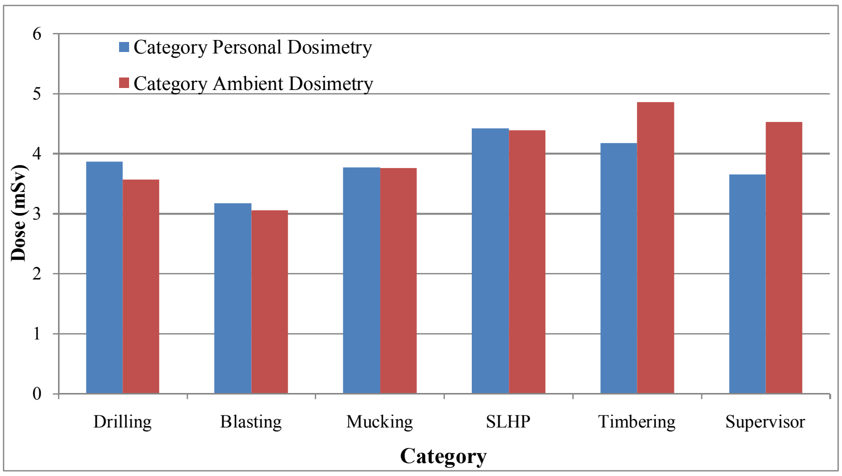

FIG. 3. Comparison of average dose of different categories of mine workers using personal & ambient dosimetry.

The annual average doses to workers in the operating uranium mines during the 5 years from 2003 to 2007 are shown in Fig. 4. The efforts in improving the ventilation to reduce radon concentrations in the mine are reflected in a corresponding downward trend in dose to workers.

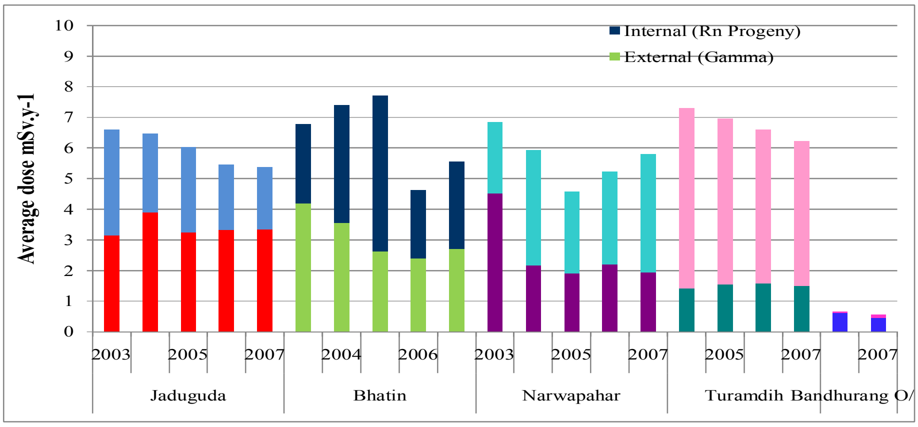

FIG. 4. Average dose to uranium mine workers in different mines (2003–2007).

While the mines at Jaduguda, Bhatin and Narwapahar have been operating for several decades the Turamdih mine came in to operation during the last few years. Banduhurang, also a new mine, is an opencast mine with low grade of ore. There has been overall reduction in the doses to workers of Bhatin and Narwapahar mines also but there are fluctuations. The average doses are currently in the region of 5 to 7 $mSv.y^{-1}$ for most of the workers. A progressive improvement in ventilation with appropriate distribution of air shows a downward trend. This trend is relatively more prominent in Jaduguda and Turamdih mines. The internal and external dose fractions average around 0.45 and 0.55, respectively, in Jaduguda mine.

The dose record of all mine workers is properly maintained for any future reference and analysis. The annual average doses to Jaduguda mine workers for the last four decades, i.e. from 1965 – 2007 are summarized in Fig. 5.

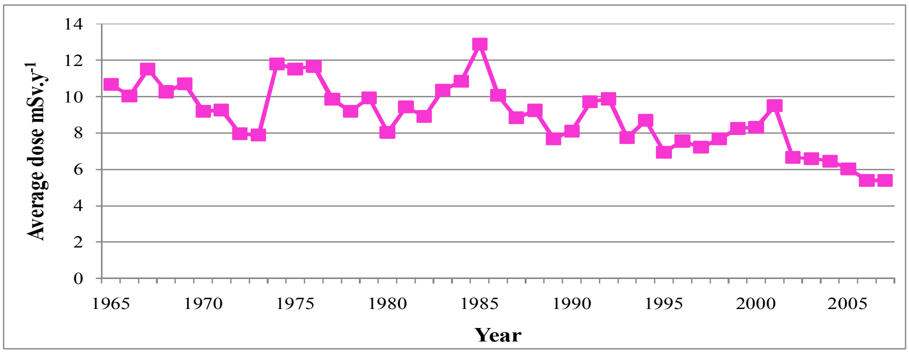

FIG. 5. Average dose to Jaduguda uranium miners during 1965-2007 (mSv/y).

The annual doses to mine workers for over four decades of operations have been well below 20 $mSv.y^{-1}$. It may be seen from the Fig. 5 that during 1980s and 1990s average doses were in the region of about 10 $mSv.y^{-1}$. The continuous improvements and up gradation of ventilation has resulted in reducing the doses in recent years to about 5 – 6 $mSv.y^{-1}$.

Radiological monitoring is also carried out during ore processing operations in the mill, tailings management facilities and the environment. The average dose to mill workers during the last 5 years has been around 1.7 $mSv.y^{-1}$.

Environmental monitoring around the mining facility, especially around the tailings, is carried out regularly by sampling and analysis of effluents and the ground and surface waters to ensure that operation are carried out in compliance with regulatory norms. Analysis of soil, vegetation, plants and local foodstuff is also undertaken periodically. Environmental gamma radiation and radon are also monitored. Impact of mining operations on the environment over the years has been negligible.

New instruments and methodologies are being developed for in-plant and environmental monitoring. Continuous radon monitors have been developed for use as on-line monitors in mines and in the environment.

5. Conclusion

Radiological monitoring and control measures are adopted in all uranium mines in India from the beginning of the operations. As the mines develop and production increases the ventilation system is regularly up graded to supply adequate fresh air to all operating locations to control radon concentrations at workplaces. The radiation doses to workers have been well with in the prescribed constraint of 20 $mSv.y^{-1}$. The data presented for the recent years show that the average doses in all the mines are in the zone of 5 - 6 $mSv.y^{-1}$. The improvements in the ventilation system are reflected in a generally downward trend in doses to mine workers. Record of doses received by mine workers is maintained from the beginning of the operations. Radiation and radioactivity levels in ore processing mill and in the environment are also low.

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REFERENCES

[1] BHASIN, J.L., 'Mining and milling of uranium ore: Indian scenario' Impact of new environmental and safety regulations on uranium exploration, mining, milling and management of its waste, Proc. Technical Committee meeting held in Vienna, 14-17 September 1998, IAEA-TECDOC-1244, IAEA, Vienna (2001).

[2] BHASIN, J.L., ' Radiation Protection in uranium mining and milling', Proc. 24th Annual Conf. Indian Association of Radiation Protection, Kakrapar, India, January 20 -22, 1999.

[3] KHAN, A. H., et al., 'Assessment of Radiation Exposure of Uranium Mine Workers in India, IAEA Intl. Conf. on Occupational Radiation Protection: Protecting Workers against Ionizing Radiation, Geneva, 26 – 30 August 2002, IAEA-CN-91/111, IAEA, Vienna.

[4] KHAN, A.H., SAHOO, S.K., PURANIK, V.D., 'Radiation Protection of workers in mining and processing of uranium ore, Radiation Protection and Environment, Vol.26, No. 3 &4, India (2003).

[5] RAGHAVAYYA, M., KHAN, A.H., 'Radon and uranium mine ventilation', Bulletin of Radiation Protection, Vol.12, No. 1 & 2, India (1989).

[6] KUMAR, R., KHAN, A. H., ' Evaluation of exposure of workers to low specific activity airborne dust during processing of uranium ore', Proc. 24th Annual Conf. of the Indian Association of Radiation Protection, Surat, January 20 -22, 1999.

[7] INTERNATIONAL ATOMIC ENERGY AGENCY, 'Radiation monitoring in the mining and milling of radioactive ores', IAEA Safety Series No. 95, IAEA, Vienna (1989).

[8] RAGHAVAYYA, M., 'Radiation Protection in uranium mining and milling industry', Environmental Geochemistry, Vol. 8 No.1 & 2, 2005 (NSE-14, Hyderabad, India).

[9] JHA, G., RAGHAVAYYA, M., "Development of a Passive radon Dosimeter", Vth National Symposium on Radiation Environment, Nov 2-4, Calcutta (1983).

[10] RAGHAVAYYA, M., KHAN, A.H., JHA, G., 'Dose estimate for Jaduguda mine workers', Bulletin of Radiation Protection, Vol.8 (1986).

[11] SRIVASTAVA, V.S., KUMAR, R., SHUKLA, A.K., KHAN, A.H., 'Estimation of internal

dose to uranium mine workers by personal and ambient dosimetry techniques' Symposium on Radiation Dosimetry and Microanalysis, 2004, DAV College, Amritsar, India.

Temporal changes of radioactive contamination of Ploučnice River Inundation area, Czech Republic

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Abstract. The inundation area of Ploučnice river, Czech Republic, has been contaminated by natural radionuclides during the early mining of the uranium ore deposit in the region of Stráž pod Ralskem. A study of temporal changes of contamination was based on a comparison of airborne gamma-ray spectrometric data from 1991 - 1993 and from 2005. After that, detailed ground gamma dose rate measurements were performed at several chosen areas. The results indicate a decrease of contamination with time in a majority of contaminated areas. Advantages and disadvantages of both approaches to the evaluation of the level of contamination (airborne gamma-ray spectrometry, ground gamma dose rate measurements) are described.

1. Introduction

The inundation area of Ploučnice river has been contaminated by natural radionuclides during the early mining of the uranium ore deposit in the region of Stráž pod Ralskem, Northern Bohemia, i.e. in the seventies and in the eighties of the last century [1]. The evaluation of the level of contamination has faced many problems. During several floods that occurred after the primary contamination, the contaminants were spread to a relatively large territory, but the level of contamination became fairly variable. Large regions have not been affected at all, and measured values of gamma dose rate are comparable with the values of natural background. On the other hand, a higher contamination can be found at small areas, often situated far from the river - for example in catchwater drains. Moreover, many contaminated areas are located in places that are difficult to reach. The topographical orientation is also intricate in such places.

A study of temporal changes of contamination was based on a comparison of data obtained using two different methods: airborne gamma-ray spectrometry and detailed ground gamma dose rate measurements.

2. Method

Airborne gamma-ray spectrometric data from 1991 - 1993 and from 2005 (measured using the same instrumentation) were available for the study. In both cases, the airborne survey was realized with the 256-channel gamma-ray spectrometer GR 820 D. Basic parallel flight paths distanced 250 m with the ground clearance of about 100 m were used to cover the whole territory.

As for the results of detailed ground gamma dose rate measurements, several measurement campaigns have been organized during previous 20 years. However only a part of available data is applicable to the analysis of temporal changes of contamination, because different approaches and different measuring techniques were used in the campaigns. To get an information on the present situation in several chosen „hot spots“, a detailed ground survey was performed in 2008. The gamma dose rate on the ground surface and at the height of 1 m above the ground was determined with the field gamma-ray spectrometer Gamma Surveyor and with the radiometer DC-3E-98, respectively.

3. Results and discussion

As output of the airborne gamma-ray spectrometry, different maps of the region of interest have been created: isolines of equivalent uranium concentration in the upper soil layers (ppm eU), isolines of equivalent thorium concentration (ppm eTh), isolines of potassium concentration (% K), and isolines of calculated gamma dose rate at the height of 1 m above the ground (µGy/h). A composite map of equivalent uranium concentrations from 1991 and from 2005 gives information on temporal changes of radioactive contamination. The original scale of the map is 1:50 000, a detail is shown in Fig. 1. The analysis across the map indicates a decrease of radioactive contamination with time in a majority of contaminated areas. Only one exeption has been found - the locality on the southern outskirts of the city Mimoň. Over time, the sediments have been gradually eroded, moved and re-deposited on another place. The river probably shows some “self-cleaning ability”.

A decrease of contamination was confirmed by detailed ground gamma dose rate measurements in several chosen „hot spots“. Data from two areas, called „Mimoň - bakery“ and „Mimoň - slaughterhouse“, are summarized in Tables 1 and 2.

Table 1. Radioactive contamination at the area „Mimoň - Bakery“- temporal changes. ground survey 1996 and 2008. Gamma dose rate at the height of 1 m above the ground

Parameter / year	**1996**	**2008**
number of measurements	313	29
arithmetic mean	0,42 µGy/h	0,24 µGy/h
minimum	0,10 µGy/h	0,13 µGy/h
maximum	1,2 µGy/h	0,62 µGy/h
median	0,34 µGy/h	0,17 µGy/h
surface area with values higher than 0,2 µGy/h	65 x 40 m	45 x 15 m

Table 2. Radioactive contamination at the area „Mimoň - Slaughterhouse“ - temporal changes. ground survey 1996 and 2008. Gamma dose rate at the height of 1 m above the ground

Parameter / year	**1996**	**2008**
number of measurements	311	27
arithmetic mean	0,29 µGy/h	0,25 µGy/h
minimum	0,11 µGy/h	0,15 µGy/h
maximum	0,58 µGy/h	0,46 µGy/h
median	0,26 µGy/h	0,22 µGy/h

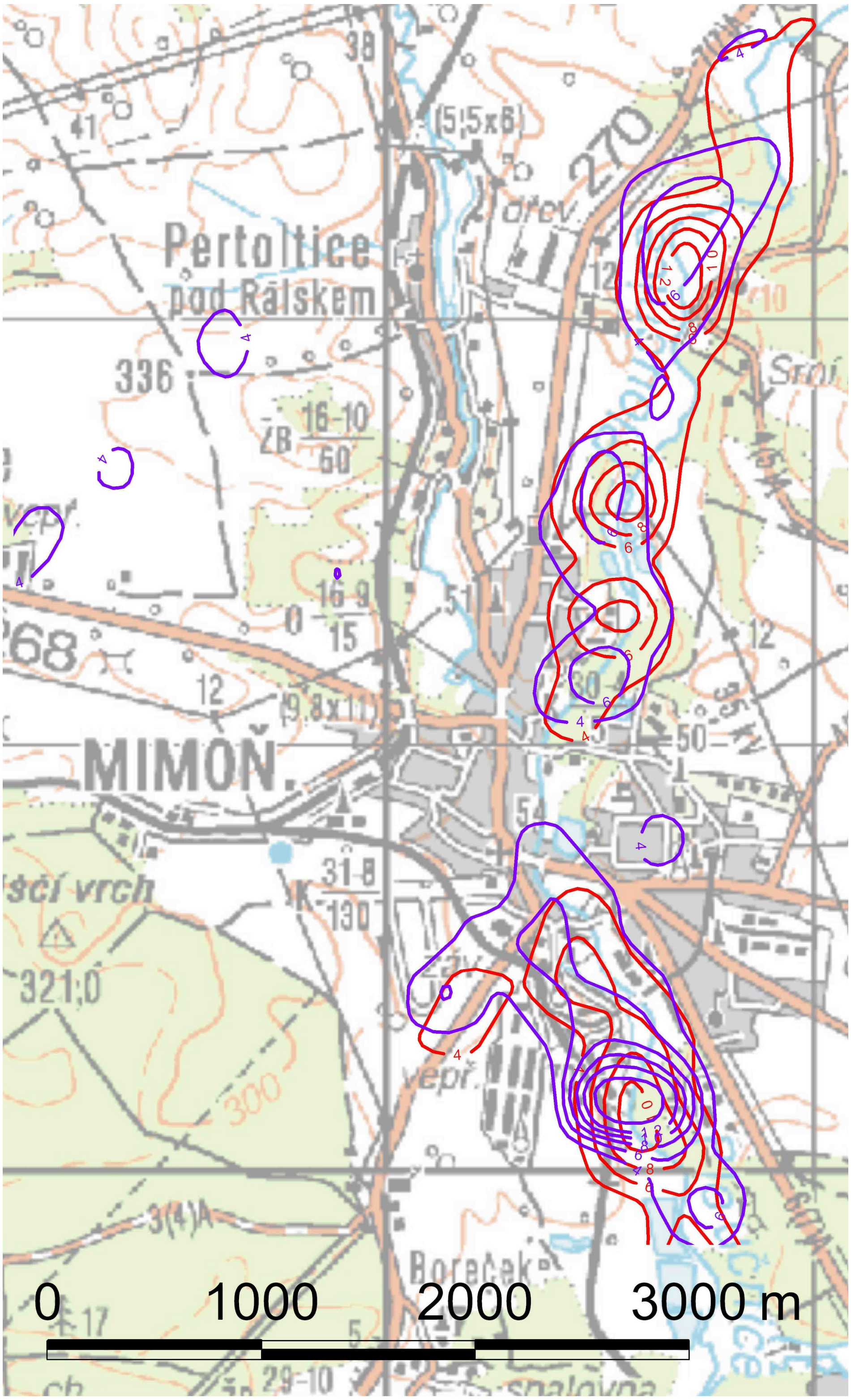

FIG. 1. Radioactive contamination of the inundation area of Ploučnice River - temporal changes. Airborne survey 1991 and 2005. Detail. Equivalent uranium concentration (red isolines - 1991, violet isolines - 2005; isolines: 4, 6, 8, 10, 12 ppm eU).

A detailed comparison of airborne gamma-ray spectrometric data and of ground gamma dose rate measurement results illustrates limitations of the maps derived from the airborne survey. One example is presented in Fig. 2.

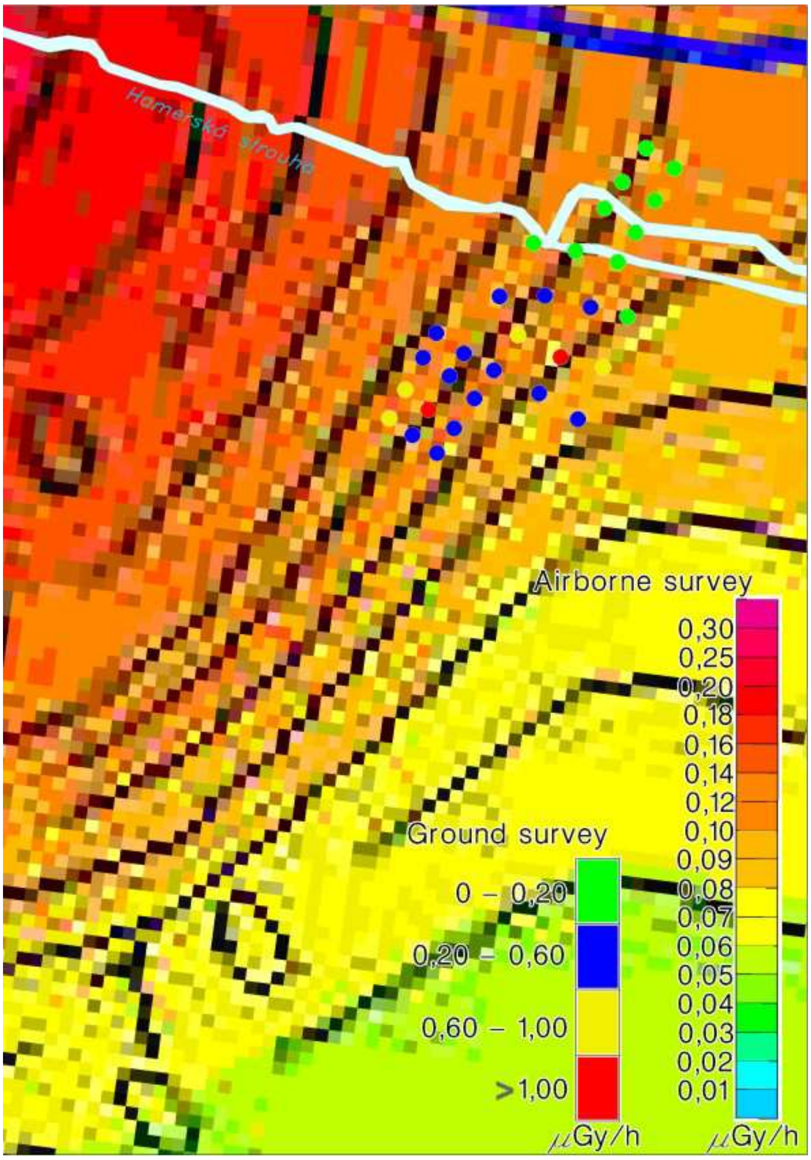

FIG. 2. Airborne and ground surveys - comparison of the results. Detail. Gamma dose rate derived from airborne measurements, 2005 (μGy/h; underlying map; right scale) vs. gamma dose rate measured at the height of 1 m above the ground, 2008 (μGy/h; coloured circles; left scale).

The airborne survey area resolution is too low to identify small contaminated areas, or significant changes of the level of contamination on a small scale. The level of contamination can be locally much higher than reported on a map derived from the airborne survey. As can be seen in Fig. 2, two points with the gamma dose rate exceeding 1 μGy/h have been found - the points are marked by red circles. The equivalent uranium concentration in the upper soil layers measured by field gamma-ray spectrometer Gamma Surveyor was higher than 200 ppm eU in these points, but the anomaly is so small that it could not be captured by the airborne survey.

4. Conclusions

The analysis of data indicates temporal changes of radioactive contamination of Ploučnice river inundation area. The changes concern the localization of contaminated areas as well as the level of contamination. A decrease of contamination with time has been observed in a majority of contaminated areas.

The airborne survey represents an effective tool for the evaluation of the level of contamination on a large scale. But there are also some limitations of this approach:

- The airborne survey area resolution is limited. Large contaminated areas - such as the uranium mill tailings in Stráž pod Ralskem - can be determined with a good accuracy. However, contaminated areas in the surroundings of Ploučnice river are typically much smaller (~ 100 m^2, or several hundred m^2), and the level of contamination is highly variable. Results of the ground gamma dose rate measurements therefore often differ from values derived from the airborne survey. Detailed ground spectrometric measurements also give higher estimates of local uranium concentrations in the upper soil layer.

The airborne survey results are partly influenced by meteorological conditions. At unaffected areas, gamma dose rate values derived from the airborne survey in 2005 are generally higher than those derived from the previous survey in 1991 - 1993. This fact can be explained by lower soil moisture during the airborne survey in 2005.

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REFERENCES

[1] HANSLÍK, E., Radium isotopes in river sediments of Czech Republic“, Elsevier, Limnologia 35 (2005) 177-184.

The radiation protection programme at the Nuclear Materials Authority of Egypt

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Abstract. The development of environmental and safety regulation programme at the Nuclear Materials Authority (NMA) of Egypt is described and the impacts of these developments on various phases of the uranium mining and milling are illustrated. Also, the monitoring and dose assessment for the individual and workplace at the mining operations and laboratories were explained. Meanwhile, a radiation protection programme (RPP) may relate to all phases of a practice or to the lifetime of a facility from design through process control to decommissioning. Therefore, the RPP covers the main elements contributing to protection and safety, and is a key factor for the development of a safety culture. The general objective of RPPs is to reflect the application of management responsibility for protection and safety through the adoption of management structures, policies, procedures and organizational arrangements that are commensurate with the nature and extent of risks. Therefore, the RPP may include protection of workers, the public and the environment. Also, implementation of the optimization principle should be the principal driving force to prevent or reduce potential exposures and to mitigate the consequences of accidents. Therefore, upgrade emergency plan should be ready and active beside written procedures should be used as a part of the work planning process as appropriate. Meanwhile, the education and upgrade training programme introduce in regular intervals, annually, which include an information and recommendation of the international relevant organizations and the basic principles of radiation protection against ionizing radiation. The design and implementation of a monitoring programme should conform to quality assurance and quality control requirements, to ensure that procedures are established and followed correctly, and that records are promptly made and correctly maintained. So, the equipment to be used in the monitoring programme should be suitable for the radiation type(s) and the form(s) of radioactive material encountered in the workplace. Also, the equipment should be calibrated to meet appropriate standards. The Radiation Protection Officer should take part in the planning of activities involving significant exposures, and should advise on the conditions under which work can be undertaken in controlled areas.

Key Words: Radiation Protection Programme, Uranium, Thorium, Radon, Uranium Mine

1. Introduction

The Nuclear Materials Authority (NMA) has been developing a national programme for radioactive mineral exploration, especially uranium, in different sites at Sinai and in the eastern desert of Egypt. So, the Radiation Protection Programme is in to parallel with the most projects and activities of the authority, either in the labs and geological field parities. The principle of optimization of radiation protection is a cornerstone of the international system for radiation protection and is the key driver for ensuring that radiation doses are not just maintained below standards, but are kept to the lowest feasible level throughout the life cycle of a practice involving radioactive materials. This principle is also referred to as the ALARA principle: As Low As Reasonably Achievable, economic and social factors being taken into account. The use of risk management to develop a detailed plan for the identification, control and monitoring of radiation exposure and the management of radioactive wastes is necessary to coordinate the system of radiation protection. The preparation of a formal radiation management is intended to document how best practicable technology has been incorporated into the design and operation of the mine and/or processing plant.

The approved radiation management plan for the mines and Laboratories should contain a radiation monitoring programme that requires, amongst other matters, the monitoring of personal contamination levels and external gamma doses [1]. Due to the use of work category averages in dose assessment, any unusually high or low monitoring result may impact on the exposure estimates for all workers in the particular work category. Safe Work Procedures should be written and reviewed periodically for their effectiveness as well as audited for their actual application in practice. These written work procedures should be referenced in the mine's and labs radiation management plan and must be readily available to, and understood by, all personnel involved.

The site radiation safety officer (RSO) is expected to have a good knowledge of the mean contamination levels and gamma exposures that each work category is normally exposed to. Thus, the RSO should be able to provide professional judgments to make an assessment as to whether any monitoring result appears unusual. Investigation and reporting levels have been identified for radiation parameters area such as Gamma Dose Rate, Personal External Dose, Personal Internal Dose, Airborne Radioactivity, Air-borne Dust, and Radon/Thoron in Air, radionuclides in Water, Stack Emissions and surface contamination. Meanwhile, all employees who may be exposed to radiation should be provided with information on the risks associated with radiation exposure, detailed description of sources and pathways of radiation exposure, and safe working methods.

2. Ionizing radiation

Act No.59 of 1960:

Republican resolution Act No. 59 of 1960, concerning the organization of work with ionizing radiation and the prevention of dangers and the decision executive by Minister of Health No. 630 of 1962 decided the following law.

Concerning the organization of work with ionizing radiation and the prevention of dangers:

1. The ionizing radiation which emitted by radioactive substances or X-ray machines as equipment or accelerators and reactors

2. Using of ionizing radiation does not license unless under the supervision of a person authorized to monitor the implementation of the requirements of radiation protection

3. Constitute a decision of the Minister of Health of the Technical Committee for Ionizing Radiation for licensing in this area.

It should be noted that this act of ionizing radiation does not take into consideration the uranium ore mining and milling, because the substances generated from these activities are qualified as not nuclear substances from the point of view of this act. Therefore, some further decrees based on this act are now under preparation .So in the future this act may also be taken into consideration when planning the rehabilitation activity.

3. Radiation dose limits

3.1.Occupational exposure of workers

The occupational exposure of any worker shall be so controlled that the following limits be not exceeded [2].

(a) an effective dose of 20 mSv per year averaged over five consecutive years

(b) an effective dose of 50 mSv in any single year.

(c) an equivalent dose to the lens of the eye of 150 mSv in a year; and

(d) an equivalent dose to the extremities (hand and feet) or the skin of 500 mSv in a year.

(e) For exposure to radon progeny and thoron progeny, the annual limits on potential alpha energy exposure and inhalation of ore dust corresponding to the limits on effective dose are given as the following: [3]

i. radon progeny: 20 mSv corresponds to 14 $mJ \cdot h \cdot m^{-3}$ which equivalent 4 WLM
ii. thoron progeny: 20 mSv corresponds to 42 $mJ \cdot h \cdot m^{-3}$ which equivalent 12 WLM
iii. uranium ore dust: 20 mSv corresponds to an alpha activity intake of 5 700 Bq
iv. thorium ore dust: 20 mSv corresponds to an alpha activity intake of 2 500 Bq

3.2.Public exposure

The estimated average dose to the relevant critical groups of members of the public that are attributable to practices shall not exceed the following limits:

a) an effective dose of 1 mSv in a year;

b) in special circumstances, an effective dose of up to 5 mSv a single year provided that the average dose over five consecutive years does not exceed 1 mSv;

c) an equivalent dose to the lens of the eye of 15 mSv in a year; and

d) an equivalent dose to the skin of 50 mSv in a year.

3.3.Total annual dose limits for workers in uranium mines, mills and labs

An annual limit taking into account the combined risks that must be recorded for each worker.The total effective dose ET is calculated according to the following formula:

$$E_T = H_p(d) + \sum_j e(g)_{j,ing} I_{j,ing} + \sum_j e(g)_{j,inh} I_{j,inh}$$

where $H_p(d)$ is the personal dose equivalent from exposure to penetrating radiation during the year; $e(g)_j$,ing and $e(g)_j$,inh are the committed effective dose per unit intake by ingestion and

inhalation for radionuclide j by the group of age g; and I_j,ing and $I_{j,\text{inh}}$ are the intakes via ingestion or inhalation of radionuclide j during the same period and the following relation should be satisfied.

$$\frac{H_p(d)}{DL} + \sum_j \frac{I_{j,ing}}{I_{j,ing,L}} + \sum \frac{I_{j\min h}}{I_{j,inh,L}} \leq 1$$

where DL is the relevant limit on effective dose, and I_j,ing,L and I_j,inh,L are the annual limits on intake (ALI) via ingestion or via inhalation of radionuclide j.

Potential alpha energy exposures to radon progeny and thoron progeny may be determined by integrating the PAEC over the exposure time; they may also be determined from the concentrations of radon and thoron gas in the air by using the following formulas

$P_{RnP} = 5.56 \times 10^{-6} \times t \times F_{RnP} \times C_{Rn}$
$P_{TnP} = 7.57 \times 10^{-5} \times t \times F_{TnP} \times C_{Tn}$

Where; PRnP , PTnP are the potential alpha energy exposures to radon progeny and thoron progeny, respectively ($mJ \cdot h \cdot m^{-3}$), t is the exposure time (h), F_{RnP} is the equilibrium factor for radon progeny, C_{Rn} is the radon gas concentration (Bq/m^3), F_{TnP} is the equilibrium factor for thoron progeny, C_{Tn} is the thoron gas concentration (Bq/m^3) [3].

4. Radiation monitoring

Workplace conditions, individual exposures, and assessment of the potential impact an operation may have on the environment must be assessed. It is, therefore, necessary to clearly distinguish between monitoring carried out for the purpose of assessing occupational exposure of workers and monitoring conducted to quantify both the potential for environmental impact of the operation and the possible level of radiation exposure to members of the general public. The main purpose of an occupational radiation monitoring programme is to ensure workforce exposure to radiation remains below the reference level.

4.1. Field measurements

For the detection and measurements of external (gamma-dose) and internal hazards radon and its decay products in the mining environments, both active and passive techniques are applied, for each estimation at different locations in the exploration uranium mines. Active technique needs an external power supply for pumps and electronics devices, but passive technique doesn't need a power supply as, it uses track etch detectors such as CR-39, LR-115, etc. or thermo-luminescent detectors (TLD) such as CaSO4: Dy or LiF, …etc. Moreover, active technique used in the routine work gives us spontaneous measurements, while passive technique used in the long run and gives us integrating measurements.

4.1.1. Active technique

This technique involves the pumping of a gas through a membrane filter connected with Lucas cell. Radon-222 and Radon-220 (thoron) gases concentration is determined by counting Lucas cell, and the radon/thoron daughters' products are estimated by counting the filter [4]. There are many techniques for radon and/or radon daughters measurements, for example, the Rolle [5], Kusnetz [6], Markove [7] and Tsivoglou techniques (Tsivoglou et al ,1964). In our study we use Rolle and Kusnetz techniques for one count method and modified Tsivoglou for three count method.

4.1.2. Passive technique

In this technique we use Solid State Nuclear Track Detectors (SSNTDs) such as CR-39 and LR-115 type –II for radon and radon daughter products beside Thermoluminescence Detectors (TLD) for γ – rays. Different authors have investigated the application of SSNTDs for radon dosimeters in mines, in order to build working personnel dosimeter [1][8].

The cup technique is commonly used to study radon emanation from rock materials and radon concentration in mines using track etch plastic detectors. Whereas a plastic cup of about 12 cm height, 7 cm diameter at the open mouth and 5.4 cm diameter at the bottom, is fitted with 1.5 x 1.5 cm^2 plastic track etch detector attached to the inside and out side the cup. The open mouth of the cup is covered with filter, which permits radon gas to enter the cup and prevents the entrance of radon daughters, therefore, radon gas concentration is determined by counting the inside detector and radon daughter by the outside. A calibrated allyl-diglycol carbonate ($C_{12}H_{18}O_7$) known as CR-39 and cellulose nitrate ($C_6H_8O_9N_2$) which is known as LR-115 type–II were used, which they were placed for 30 days, then the detector is etched at optimum conditions and counted by optical microscope for calculating track density, hence radon and radon daughter products could be determined.

4.1.3. Determination of uranium dust ore concentration (Long-lived alpha emitters)

Concentration of ore dust is measured by collecting air samples on high-efficiency filters paper and analyzing the sample by alpha counting. It is important to ensure that airborne concentrations of uranium be minimized as far below the reference limit and can be determined from the following relation [9].

$$C_u = \frac{2.2 x 10^{-7} C}{Evt}$$

Or

$$C_u = \frac{3.4x10^{-7} M}{vt}$$

Cu is U Conc. in µCi/cm^3, C is alpha count per min., M is the mass of U in µg , t sampling time in min., E is the efficiency of the alpha counter and v is the volumetric sampling rate in L/min.

4.2.General rules for radiation safety in the mines, mills and labs

Each person in the mines mills or labs should observe and obey the rules and instructions that reduce or mitigate radiation hazards as the following:

1. The proposed programme for selecting, using and maintaining personal protective equipment

2. The proposed ventilation and dust control methods and equipment for controlling air quality.

3. Good forced ventilation systems in underground mines to ensure that exposure to radon gas and its radioactive daughter products is as low as possible and does not exceed established safety levels.

4. Limiting the radiation exposure of workers in mine, mill and tailings areas so that it is as low as possible, and in any event does not exceed the allowable dose limits set by the ICRP and IAEA.

5. When performing operations that might produce airborne contamination (i.e., dust evaporations, sanding, or grinding, transfers of unsealed powdered or volatile radioactive material), exhaust ventilation approved by the Radiation Safety Committee shall be used.

6. Smoking, eating or drinking shall not be permitted around radionuclide materials (mine, mill and labs).

7. Food, beverages and their containers shall not be permitted in the laboratory.

8. Pipetting by mouth shall not be permitted in radionuclide laboratories.

9. Microwave ovens in radionuclide laboratories shall not be used for heating food or beverages for personal use.

10. Materials and equipment shall be surveyed before removal from a potentially contaminated area

11. Protective clothing appropriate for the work conditions shall be worn when working with radioactive materials. This includes laboratory coats, gloves, and safety glasses, appropriate footwear (sandals cannot be worn when working with radioactive materials).

12. All containers of radioactive materials and items, suspected or known to be contaminated, shall be properly labeled (i.e. with tape or tag bearing the radiation).

13. A radiation survey shall be performed by the radionuclide worker at the end of each procedure involving radioactive materials.

4.3. Personal monitoring

1. For individual dose assessment, we are using film badge, and pocket dosimeter in the labs. In the mines worker used the protective equipments beside personal alpha dosimeter and TLD.

2. The individual dose is recorded in the individual file for each worker beside the previous exposure

3. Some of workers need to health surveillance such as bioassay which includes urine and fecal analysis for determination of uranium and thorium concentration.

4. The medical practitioner should be communicated conclusion in writing to worker and employer

5. All workers should be informed in an appropriate manner for the results of health examination.

6. All safe worker procedures must be clear and easy to be followed by the users.

7. The personal protective equipment should be used to reduce the radiological risk beside the dose record and health surveillance (we apply the recommendation of the safety standard issued by IAEA and ICRP in radiation control).

8. In particular, personal radiation exposure data for all designated employees should be available at any time and regularly updated. This should be facilitated by the use of a computer database.

5. The radioactive waste management

Although the milling process recovers about 95 percent of the uranium present in ores, the residues, or tailings, contain several naturally-occurring radioactive elements, including uranium, thorium, radium, polonium, and radon, beside the solid and liquid wastes that are generated in the mining and milling of ores and which should be managed throughout the lifetime of the mining and milling facilities that include sludges, contaminated materials, waste rock, process water, leaching fluids, seepage and runoff.

The tailings are categorized as radioactive waste, disposal may be undertaken by returning to the mine pit, preferably dispersed in the initial mine tailings, or stored with appropriate safeguards if future economic use is foreseen [10].

In the laboratories the radioactive west should be classified and disposed in the storage. The storage area with radiation level exceeding the permissible limit should be isolated and classified as restricted area and it should be far enough from the office and workers restricted area.

6. Transport of hazardous materials

Package and transport all hazardous materials (radioactive and non-radioactive) – including products, residues, wastes, and contaminated materials – safely, securely, and in compliance with laws and regulations. With radioactive materials, adhere to IAEA Regulations for the Safe Transport of Radioactive Material, relevant IAEA Safety Guides, applicable international conventions, and local legislation. Also, security and safety of Sealed Radioactive Sources and Nuclear Substances should be following up due physical, chemical and radiological properties during transportation, storage and uses. Routine monitoring made at the surface of and at a certain distance from the packages and conveyances should be detailed in the RPP to ensure both that the current authorized limits for radiation levels and surface contamination are met and that the scope of the RPP has been well defined. The equipment to be used should be suitable for the types of radiation encountered and should be calibrated to meet the appropriate performance standards.

7. Decommissioning and site closure

In designing any installation, plan for future site decommissioning, remediation, closure and land re-use as an integral and necessary part of original project development. In such design and in facility operations, seek to maximize the use of remedial actions concurrent with production. Ensure that the long-term plan includes socio-economic considerations, including the welfare of workers and host communities, and clear provisions for the accumulation of resources adequate to implement the plan. Periodically review and update the plan in light of new circumstances and in consultation with affected stakeholders. In connection with the cessation of operations, establish a decommissioning organization to implement the plan and safely restore the site for re-use to the fullest extent practicable. Engage in no activities – or acts of omission – that could result in the abandonment of a site without plans and resources for full and effective decommissioning or that would pose a burden or threat to future generations.

8. The emergency plan against nuclear accidents.

The emergency response programme has three primary objectives. The first objective is to take action at the source of the accident to mitigate or reduce the potential risk. The second objective is to ensure that people will not receive doses high enough to result in deterministic health effects induced by the accident. The third objective is to take reasonable actions to reduce the chance of stochastic health effects. It's obvious that the second and the third objectives are directly related to human health. Therefore, every person participating in emergency response has to know and understand the steps and topics of emergency; and the relationships between radiation physics, radiation induced health effects and radiation protection. Therefore, a periodic training and exercises should be performed in order that the plan should be ready and active.

9. The training programme

All employees who may be exposed to radiation and all persons responsible for the implementation of the RPP beside the radiation protection officers and radiation protection experts should receive appropriate training. Senior management and employees in other departments (such as public relations, human resources, etc) should also be provided with information on risks associated with radiation exposure.

9.1. Employees training

Employees whose work may impact on the levels of radiation exposure should be provided with basic information. Therefore, the training program should include;

1. Basic of radiation and radioactivity (detection, units and measurements)
2. The principles of radiation protection and ALARA concepts.
3. The radiation protection in uranium mines, mills and tailing beside laboratories.
4. Effect of radiation on the biological system
5. Exposure limits
6. Safety Responsibilities
7. Emergency Procedures
8. Regulatory References

9.2. Radiation protection officer training

Beside the employees training topics, training for radiation protection officers will vary considerably depending on the radiation application, but all training should contain a certain amount of common core information on protection and safety. The depth to which each topic is covered should depend on the specific practice in which the person is being trained, and should also take into account the magnitude of the potential hazards associated with the application . Radiation protection officers need to have specific personal attributes, such as communication skills, leadership and analytical skills, human–machine interface skills and multitask management skills, which can be stimulated during training through practical exercises.

9.3. Qualified experts training

Training for qualified experts should provide the broad knowledge of protection and safety. This level of knowledge may be obtained by formal education, specific training and work experience. Additionally, qualified experts need to have a thorough knowledge of specific topics related to their field of expertise and also need to keep abreast of developments in their field. Qualified experts need to have highly developed personal attributes, including communication, analytical and leadership skills, since they provide training and give advice to a wide range of personnel, such as workers, managers, health professionals or staff of government authorities.

10. Quality assurance and quality control

Monitoring and surveillance programmes should be subject to adequate arrangements as regards quality assurance that provides for a disciplined approach to all activities affecting quality, where appropriate, verification that each task has met the objectives and that any corrective action has been implemented. An adequate quality assurance programme for the monitoring and surveillance has to satisfy the basic general requirements established by the regulatory authority for quality assurance in the fields of environmental protection and radiological protection. Therefore, an appropriate quality assurance programme includes:

1. Design and implementation of the monitoring and surveillance programmes which include determination of suitable equipment and procedures, and their documentation.

2. Proper maintenance, testing and calibration of equipment and instruments to ensure that they function properly;

3. Calibration standards that is traceable to national and international standards;

4. Quality control mechanisms and procedures for reviewing and assessing the overall effectiveness of the monitoring and surveillance programme;

5. Uncertainty analysis;

6. Record keeping requirements.

11. General conclusion

The goal of a radiation protection programme is to keep radiation exposures to workers and the general public to levels as low as reasonably achievable (ALARA).Therefore, the key elements necessary to develop an effective Radiation Protection Programme (RPP) should be established. The development and conduct of an effective monitoring and surveillance plan needs continual interaction between the regulatory authority, the affected community and the mine or mill operators. Radiation protection is only one element in ensuring the overall health and safety of workers in operations in the mining and processing of raw materials beside the laboratories safety control. The radiation protection programme (RPP) may relate to all phases of a practice or to the lifetime of a facility from design through process control to decommissioning. The implementation of the optimization principle should be the principal driving force to prevent or reduce potential exposures and to mitigate the consequences of accidents. Therefore, upgrade emergency plan should be ready and active beside written procedures should be used as a part of the work planning process as appropriate. Meanwhile, the education and upgrade training programme introduce in regular intervals, annually, which include an information and recommendation of the international relevant organizations and the basic principles of radiation protection against ionizing radiation. The design and implementation of amonitoring programme should conform to quality assurance and quality control requirements, to ensure that procedures are established and followed correctly, and that records are promptly made and correctly maintained

REFERENCES

[1] CARTWRIGHT, B.G., STIRK, E.K., Nucl. Instr. And Meth. 53 (1978) 457- 460.

[2] INTERNATIONAL ATOMIC ENERGY AGENCY, International Basic Safety Standards for Protection against ionizing Radiation Sources, IAEA Safety Series No: 115-1, IAEA, Vienna (1996).

[3] INTERNATIONAL ATOMIC ENERGY AGENCY, "Occupational Radiation Protection in the Mining and Processing of Raw Materials" Jointly Sponsored by IAEA and ILO, IAEA Safety Standard Series-Safety Guide No.RS-G-1.6, IAEA, Vienna (2004).

[4] COHEN, B.L., CHOE, E.S., "Large scintillation cells for high sensitivity radon concentration measurements". Nucl. Instrr. And Meth. 212 (1983) 403.

[5] ROLLE, R., "Improved radon daughter monitoring procedures". Am. Ind. Hyg Assoc.J 302 (1969) 153.

[6] KUSNITZ, N.L., Radon daughters in mine atmosphere,. A field method for determining concentrations, Am. Ind. Hug. Assoc 1, 17, 85 (1956).

[7] MARKOV, K.P., RYABOV, N.V., STAS, K.N., "A rapid method for estimating the radiation hazard associated with the presence of radon daughter products in air", At.ehnerg. 124 (April 1962).

[8] TOMMASINO, I., "Radon monitoring by alpha track detection", proc. on Int.workshop on radon monitoring in radioprotection environmental radioactivity and earth science, Teriste, Italy (1990) 123-132.

[9] INTERNATIONAL ATOMIC ENERGY AGENCY, Manual on Radiological Safety in uranium and thorium mines and mills, IAEA Safety series No. 43, IAEA, Vienna (1976).

[10] Managing naturally occurring radioactive material (NORM) in mining and mineral processing guideline. NORM_3.2 (2008) Australia, www.docep.wa.gov.au/Resources safety.