Environmental and Safety Education in Brazil: Preventive Measures to Avoid Contamination with U and Th

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Abstract. This paper presents the Environmental and Safety Educational Campaign on the care in the small mining “garimpo” with radioactive ore of uranium and thorium. These radionuclides are the major source of radioactive material present in certain mineral from rocks for example, tantalite/columbite, granites with cassiterite coal, phosphates, zirconite and rare-earth elements. The occurrence of radioactive ores in some sites has risen especial attention from CNEN such as in Borborema Mountain, where Uranium and Thorium are found scattered in pegmatite bodies from Seridó region between Rio Grande do Norte and Paraíba states, and in Amapá state, in the Amazonian forest region, where thorianite was being illegally mined. Besides work accident risks inherent to this activity, there are radiological risks, showing the need to adapt measures and actions aiming at the health and safety of the small miners and population in general. The campaign involves cooperatives, trade unions, schools, non-governmental organization, entities involved in national security and others take part. The objective is to foment actions of radiological safety, in order to guarantee the protection and safety of the workers, their families and population.

KEYWORDS: Environmental Education, Small mining sites, NORM, TNORM

1. Introduction

The National Nuclear Energy Commission – CNEN, establishes the safety and radiological protection requirements in mining-industrial facilities wich handle, process, as well store ores, scoria and/or wastes containing radionuclides from natural uranium and thorium series that may cause undue exposition of workers, the public and environment. Through carrying out regular inspections and audits, taking into account all working conditions that may results in risks.
It also inspects all the activities that involve natural exposition to radiation whose control is required, once that in the Earth’s crust uranium (U) and thorium (Th), are the major source of radioactive material present in certain mineral from rocks for example, ores like tantalite/columbite, granites with cassiterite coal, phosphates, zirconite and rare-earth elements.
However in Brazil there is the activity of small mining “garimpo” that is a consequence of proper features given to the utilization of small deposits. In this activity is not feasible to carry out previous research works and the installation of mining enterprise. But, as it occupies an important space in the mining economy, the government is trying to develop political initiatives in order to confer status of mining company to small miners co-operatives using law 7805 of 18th July 1989 which regulates the permission of prospecting mine, defining and standard conditions and rules for this activity.
In some sites, the occurrence of ores with high uranium and thorium contents has risen especial attention from CNEN such as in Borborema Mountain, in pegmatites from Seridó region between Rio Grande do Norte and Paraíba states, where uraninite was being illegally mined. Besides work accident risks inherent to this activity, there are radiological risks, showing the need to adapt measures and actions aiming at the health and safety of small miners and population in general.
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The possibility of radiation exposition and internal contamination is high, because miners are not aware of the danger nor use protection equipments, and handle ores with radionuclides before they eat, or even smoke, without washing their hands. They also take a bath in sites that have radioactive ores, besides other situations that may bring risks to health.
Considering of the discussed above it was designed the ELUCIDATION CAMPAIGN: “RISKS OF PERSONAL CONTAMINATION IN SMALL MINING BY RADIOACTIVE ORES:
URANIUM AND THORIUM”, that has been developed since 2004 in these areas, aiming to orientate small miners about cares that must be taken in prospecting, storage and transport of ores containing radioactive materials.

The campaign explains that is important to adopt some simple procedures to prevent a possible contamination, avoid contamination of other people, by showing that the main contamination way is through inhalation of powder containing uranium and thorium, and that the powder spread can stick on clothes used by the worker, and be a second way of contamination.

It is also emphasized that another potential risk is the inhalation of Randon Gas (emitted by the ore) and its short half-life progeny that may occur in underground mines with deficient ventilation or if the ore is stored in a closed room.

With this project, CNEN has strengthened actions related to prevention of a possible contamination by radioactive ores in small mines and, at the same time, has established partnerships with different entities which are working as campaign multipliers, forming an ENVIRONMENTAL EDUCATION NET.

2. Objectives

The project aims to:
- Identify the localization of small mining of tantalite/columbite, granites with cassiterite, coal, phosphates, zirconite and rare-earth elements with content of associated U and Th, through in situ radiometric survey and collecting samples of these minerals and water.
- Develop actions to promote the prevention of personal contamination risks through distribution of didactic material and lectures previously designed regarding the target audience.
- Assess actions of small miners in considered areas, especially those that have higher risks factors, to formulate several safety items.
- Detect storage site of ores containing radioactive material and define a storage solution.
- Define which will be the best structure to implement a radiological control system of small miners.

3. Methodology

The methodology consists of the creation of an Environmental Education Net where co-operatives, trade unions, schools, Non-Governmental Organization entities involved in national security and other representative entities participate, whose objective is to foment actions of radiological safety, in order to guarantee health of workers, their family and population, as a whole, allowing synergism and higher efficiency of efforts made by net members.

Its creation has show a great relevance since the small miners are not permanent, (this kind of mining is seasonal), and depends on weather and economic factors, therefore with the net, we guarantee the continuity of work through multipliers that are formed.

4. Products

The production of the project consists in:
- Paperback and banner “Care in Small Mining of Radioactive Ores: Uranium and Thorium” (Fig. 1).
- Evaluate the distribution of the pegmatite bodies with a higher concentration of radioactive minerals and their proximity with sources of water supply and population nuclei, based on a Geographic Information System (GIS).
5. Actions

1. Implementation of the Elucidation Campaign in towns whose mineral extraction brings radiological risks
2. Previous survey of the town’s potential resources.
   - Which institutions can help with campaign dissemination and also provide logistic support – Provincial and Municipal Departments, miners Co-operatives, schools, Health Centers, among others.
   - Survey of the number of means that will be distributed during campaign implementation (paperbacks and posters) and how many lectures will be pronounced

   Usually a previous contact is made with City Halls and Small Miners Co-operatives to define a programme and work schedule, the average period for each expedition being fifteen days.
3. Distribution of the paperback “Care in Small Mining of Radioactive Ores: Uranium and Thorium”, in sites of small mining and Co-operatives, reading it together with the miner and their families, in Municipal and provincial Schools for primary and secondary students, through technical lectures (Fig. 2).
4. Distribution of the poster: “Care in Small Mining of Radioactive Ores: Uranium and Thorium”, in inns, bars and other places attended by small miners, containing informations about basic cares that must be taken during mining; libraries; trade-unions, among other important ones in the area.
   - The use of the paperback and poster aim to act in capacity of visual memorization, since small miners, mostly, are not sufficiently educated.
5. Interviews in televised and written press.
6. Presentation of lectures and seminars about radioactive ores and which methods of risks prevention due to exposition and contamination, which are prepared in function of the target public.
   - Small Miner Co-operatives
   - Agriculture Co-operatives (as activity is seasonal, the small miners also work in agriculture)
   - Teachers and students from Primary and Secondary Education
• Trade-unions of Provincial and Municipal Teachers
• Environmental Federal Police
• Environmental Military Police Battalion
• Civil Defense
• Fire Brigade
• Workers from Provincial and Municipal Health centers
• Workers from Mineral Production National Department/DNPM
• Workers from Environment and Renewable Natural Resources Institute /IBAMA
• Municipal and Provincial Environment Bureau

In schools, lectures have a simple language, yet direct, aiming to use children as multiplier agents in their families, by orientating their parents and also because they will be getting new knowledge, in case they are small miners.

- For teachers and secondary education students, the lectures are technical and aims to explain natural radiation, expressions from the nuclear area, paperbacks containing basic concepts of Radiation Protection, the CD of digital paperback and bibliography for consultation are also distributed. Usually, they are held for 4 to 6 hours.
- For Institutions of National Security, Environment and Mineral Production, 40 hours seminars of about Radiation Protection and Nuclear Safety, orientating, mainly, about initial measures required in situations of seizure, radiological incidents and/or accidents involving radioactive ores (Amapá State) are prepared.
- For Health Institutions, 40 hours seminars about Radiation Protection and Nuclear Safety, are held and became vitally important, as when we give interviews about the existence of radioactive ores in these regions, panic situations always arise, where people believe that radiation will reach the city, bringing risks to population and so they go to health centers, as they think that they have symptoms coming from radiation (Amapá State). Thus, lectures are mainly focused on biological effects of radiation.

7. Collection of ores and water samples in working sites and use of analysis results to take programmatic decisions.
8. Interviews with small miners, since many of them have been working for more than 30 years in small mining.
9. Monitoring and constant assessment of all collected data – laboratory analyses, observation of behavior in work, storage sites, among other, identification of problems and to look for prompt solutions.
10. Assessment of these contour conditions so that “Radiological Procedures” which must be applied by the co-operatives, when small mining activity will be legalized by the concerning federal agencies, can be applied.
12. Return after one year of implementation to evaluate the campaign is progress.

6. Cases

6.1. AMAPÁ STATE

In July, 2004 the Federal Police (PF) seized a contraband of thorianite ore (Fig. 3), coming from Navio Hill (Amazon Forest far from any population concentration), whose mineral analysis carried out in a CNEN laboratory indicated that the ore had 75% of Thorium, 7,5% of Uranium and 10% of Lead Oxide in its composition.

Thorianite is plentifully found at a river bank in Navio Hill under the form of an alluvial deposit. Federal Police suspects that it is used in a Tantalite mixture extracted in the region, due to its high density. Later, there were other seizures and in each, CNEN made the seizure and the seized ore is in a deposit at CNEN.

The Thorianite from Amapá shows a high Thorium concentration, each material kilogram reaches 80 grams of uranium and 750 grams of Thorium and so the dose rates are high (890 kilograms correspond to 1 mSv/h), then there are risks of exposition and contamination.

Due to this illicit traffic it was decided to start immediately with the Elucidation Campaign, not only for involved risks, but also for the great repercussion on the national media.

The first campaign action was through the media where technicians gave interviews to becalm the
population, and when seizure was spread there was panic, since they thought they were irradiated as well as contaminated, since some seizure took place in dwellings.

In these interviews the technical team said that Thorianite extraction could bring about high risks to the worker and his family due to ore storage in dwelling, but it would not bring risks to population in general, and they also said this ore is government monopoly and its prospection is illicit.

In television programmes the team chose for a practical demonstration using a radiation detector and a small amount Thorianite to show that dose decreases as a function of distance, since at certain experience time the equipment did not give out anymore (beeps), showing that it was not possible to have any risk for the town, once the mineral deposit was in forest at a distance of many kilometers.

Following actions were to give lectures to safety and environment agencies, involved in the seizure, guiding them about basic radiation protection procedures (it was granted a radiation detector was given to the Federal Police), and to teachers and students in schools.

The campaign was developed in 08 towns, each with small mining, until 2006, but the work was not completely concluded.

**Figure 2:** Presentation of lectures in a small miner co-operative in Lorenço Town (small miners and their families)

**Figure 3:** Thorianite

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6.2. RIO GRANDE DO NORTE STATE

Seridó-Borborema Pegmatitic Province has been a common subject in geological bibliography from the Northeast for more than half century, since when minerals from pegmatites were eagerly sought to supply needs of the allies in Second World War.

It is situated between Rio Grande do Norte and Paraíba states, comprises 22 towns (Fig. 4) and shows an appreciable amount of pegmatite bodies (about 4000), that spreads for an area around 6000 Km², whose small mining activity occupies a vital space in the municipal economy, as minerals of great
importance from an economic aspect are extracted, emphasizing beryllium and aquamarine, tantalite/columbite, cassiterite, amblygonite and bismuthinite, besides blue turmaline, opal, kaolin, feldspars, micas and quartz. 

**Figure 4 : Seridó-Borborema Pegmatitic Province**

The problem lies in the fact that in most of mining sites pegmatitic bodies with radioactive ore are found, due to uranium spread in these minerals, and also the presence of primary and secondary uranium minerals (gummite, autunite, pitchblende, torbenite, uraninite, among others).

According to current bibliography, the total of small mining in the Province reaches values between 400 and 800 active prospecting fronts, and only in Rio Grande do Norte, radioactive occurrence were found in 18 sites at least, with about 50 active and inactive prospecting fronts.

Most small mining are prospected by hand made and intermittent ways and the presence of radioactive ores in isolated or associated structures were observed. First there was a survey work of contour conditions from which it was concluded that the risk due to exposure is not relevant, since radioactive occurrences are local and rare (nodular formation), and the internal contamination is the main concern. When miners look for prospecting other minerals and precious stones from these pegmatites, they clearly follow a wrong procedure, such as working in galleries with low ventilation and without wearing protection equipment. Miners can inhale particulate containing radioactive ores, besides Radon gas.

Other cases likely to produce internal contamination were also detected, since many miners store radioactive samples in sites near streams, consume water coming from springs in the Pegmatite Province, store samples in their dwellings, use pits for bath and store waste containing radioactive ores beside lodgings.

The field work in this region has observed that miners are aware of uranium and give names that identify it by its characteristic color- yellow (Fig. 6), usually they call it “blond” or “urânia”, however they are not aware of the risks involved. Also Tantalite/Columbite with high content of U are extracted as detected by analyses made in 2004 (Fig.7).

**Figure 6: Uraninite**
The first actions were lectures in small miners co-operatives up involved risks in mining and prevention procedures for personal contamination that may occur in the mining processes, and to warn about radon gas emitted by the ore, since the miners use water coming from Pegmatite for subsistence.

The orientation was that is extremely important to boil water before consumption, not only to avoid contamination by bacteria, but also to give off radon gas, which is soluble in water.

The following actions were lectures for primary and secondary students, and seminars for teachers and workers from the health area.

During lectures, once more it was observed that at first the information of the presence of radioactive ores in the region cause a great impact and panic in population, and to minimize the problem, interviews were given in press as well in TV media.

7. Developed Actions

![developed-actions-graph]

8. Partial Results

- State government showed to be an excellent partner allowing lectures involving Education, Health and Environment Departments.
- Partnerships with Federal Agency of Mineral Production/DNPM and Environment/IBAMA
- In the visited towns, the town hall and the co-operatives have been excellent partners and made possible lectures in auditorium providing the required infrastructure, working in advertisement and involving all the institutions that can be multipliers.
In schools the subject radioactive ores has been discussed among teachers and students, and a science workshop took place and showed many workers whose subject was Nuclear Energy and its benefits.

Women have showed to play a fundamental role, since they have not allowed any ore to be stored inside dwellings, in view of risks to children’s health.

Illicit traffic in Amapá State decreased substantially, according to informations of the Federal Police, and miners have not more stored ores, such as Tantalite/Columbite, which is abundant in dwellings in this state.

In lectures given in Small Miners Co-operatives, information was given about radioactive occurrences in prospecting fronts, that was later confirmed by the team, as in the case of a feldspar mine in Paraíba State, Santa Luzia town, where mineral analyses showed high thorium content in collected samples.

The samples of minerals - feldspar, tantalite, amazonite, quartz, opal – originated descendant from different pegmatites from Equador – Parelhas regions between Rio Grande do Norte and Paraíba State have uranium and thorium in expressive amounts. This fact, surely contribute in contamination of aquifer that furnishes the towns water. However until this time, it is not knowledge about amount background of radioactive elements in water. Town’s water will be collected to evaluate possible contamination.

Many entities have asked for lectures that will be schedule in future.

Preliminary considerations of a study accomplished on the radioactive minerals, primary and secondary uranium minerals that occur in the pegmatite of the Seridó Region, State of Rio Grande do Norte, Brazil and their influence on the several sources of water provision and on population nuclei of the area of the municipal district of Parelhas and Equador: In general, the pegmatite from the area of Equador-Parelhas present high environmental radioactivity so much due to the dispersed uranium in the crystalline structure of minerals (albite, microcline, turmaline, lepidolite, phosphate minerals, quartz and apatite), as primary and secondary uranium minerals (uraninite, pitchblende, gummite, autunite, torbernite, and uranium-bearing opal, etc.). These uranium minerals appear associates to the fracture and voids in the pegmatite and in the tourmaline-bearing granite. These minerals were identified by petrography, X Rays diffraction, ultraviolet fluorescence analysis, infrared spectroscopy, radioactivity (HPGe gamma spectrometry), thermal behavior and chemical analysis (ICP-MS and AAS, Microprobe).

Geochemistry and hydrochemistry preliminary environmental studies on the pegmatite bodies from Seridó Region show gamma radiation level which between 150 to 30.000 cps; uranium (U3O8) and thorium (ThO2) content in Columbo-Tantalite (and/or polycrase) varying between 0,3% - 3,0% and 0,1% - 0,5% respectively, and the coating existent in these minerals show uranium contents varying between 20% to 60%. While the soil samples gathered in Equador/Parelhas districts show an average activity of 226Ra, 232Th, and 40K of 27.1/39.1; 33.74/48.5; 260.1/234.8 (Bq.kg-1, dry-weight), respectively, and the corresponding kerma rate (I) in air are 50 and 67 nGyh-1, suggesting that the acid underground waters and others oxidizers attack and dissolve the radioactive minerals from pegmatite, generating solutions rich in U6+ ions (UO22+, UO2OH+, UO2(CO3)22-, UO2(CO3)34+), and these acid solutions, could contaminate the aquifers.

The values obtained of total uranium, 226Ra, 228Ra and 210Pb activity concentration in Drinkwater from Pegmatite Borborema Province run from 0.13 ± 0.1 up to 0.5 ± 0.03 Bq/L; 0.04 ± 0.01 up to 0.06 ±0.01 Bq/L; 0.16 ± 0.1 up to 0.17 ± 0.1 Bq/L and 210Pb range 0.042 ± 0.008 up to 0.054 ± 0.008 Bq/L, respectively. The uranium water activity content is high and superior to the level recommended for the Environment National Commission of Brazil (CONAMA) that is 0.1 Bq/L. Which confirm the existence of water contamination.

Evaluate the distribution of the pegmatite bodies with a higher concentration of radioactive minerals and their proximity with sources of water supply and population nuclei, based on a Geographic Information System (GIS).

6. General Conclusions

In view of obtained and observed data, we can conclude, until now, that the Elucidation Campaign has been efficient to transmit information and the worries is common in visited states.

1. The interest for the subject is great due to the lack of knowledge and worries about health and safety of the small miners as well of their family, the population and federal agencies.
2. Women have showed to play a fundamental role when they did not allowed ores to be stored at home. During lectures, they asked more because they were worried with their children and husbands.
3. Some children in schools are sons of small miners and during lectures it was possible to see their worries about their fathers, to be point that they said that they would read and explain the paperback in order that care should be taken in mineral exploration.
4. During lectures in co-operatives the miners revealed new prospecting fronts, with radioactive occurrences, and that were easily confirmed by the team. (In Rio Grande do Norte State).

7. Future Actions

1. To finish work in Amapá state and make an assessment of campaign efficiency after one year.
2. To continue the work in Serra da Borborema region for longer terms, to better assess the situation and to visit other pegmatites – RN/PB because, it is necessary to visit of certains mining to check the prospecting fronts advance towards other layer containing gummite; to have an assessment of U and Th contents in prospecting fronts followed by a registration of mining activities, such as traders and also exports acting in this region.
3. To apply the campaign in regions of trading ores mining that have associated radioactive ores, but only in small mining.
4. To make a video with basic notions of Radioactivity and Radiation Protection, focusing multipliers.

REFERENCES


