

Radiological assessment of zircon processing in Nigeria

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Abstract. Processing of zircon along with monazite, ilmenite and magnetite as a by product of the mining and processing of cassiterite and columbite have been taking place in the Jos Plateau area, Nigeria for several decades. The processing in a typical mill involves dry mill separation of the heavy mineral concentrate won from alluvial deposits into cassiterite, columbite, zircon, monazite, ilmenite, magnetite and unsorted tailings after going through a combination of magnetic (low and high intensity) and electrostatic separators. The zircon product is important because of the radiological hazard it poses, with average ThO₂ and U₃O₈ concentrations of 8 wt% and 0.50 wt% respectively and radiation dose levels of 70–100 μSv/h. Radiological assessments of the processing sites and activities were carried out to justify remedial action, with the justification criterion based on regulations of the Nigerian Nuclear Regulatory Authority (NNRA).

1. Introduction

Alkaline rocks or the so-called Younger Granites occur in central Nigeria as ring structures with a sequence of volcanic phase followed by a series of granitic intrusions. These rocks are the source of commercial quantities of cassiterite, columbite, zircon, monazite, thorite, molybdenite and pyrochlore. Cassiterite and columbite mining, mostly from alluvial deposits, and processing of the ores have been taking place for over a hundred years, mostly centered on the Jos Plateau in central Nigeria. Associated with this activity are extensive mine tailings that have been generated over the years and these tailings are left either unsorted or separated into zircon, monazite and ilmenite.

The wide dispersal of the alluvial deposits containing the ores favoured exploitation by a large number of operators, ranging from small scale miners to those that are large and highly mechanized. Dredging and gravel pump methods are applied in the mechanized mining of cassiterite and associated minerals including zircon in the Jos plateau area of Nigeria. Dredging involve spreading the ore-containing material on revolving or oscillating screens and disaggregating using high pressure water jets. The undersize portions, which contain the heavy minerals, are separated after passing through jigs. The concentrates are then taken to processing mills where the ores are separated from the tailings through the use of shaking tables, magnetic and electrostatic separators. A typical processing mill occupies an area of about 1000 m² with an office block and the mill shade housing separating tables, magnetic and electrostatic separators. With increasing depletion of the soft ore-containing materials there was an increasing use of simple tools by the local population to dig out the ores in hand dug pits and use panning methods to recover the ores. The processing activities for the recovery of the concentrates take place in their households and backyards. All the separation processes obviously lead to increases in the specific activity of the source material.

Over the years there has been a growing concern over the radiological impact of the tailings from the processing and mining activities from both the large and small scale operators since it has been established that these tailings are rich in zircon, monazite, xenotime and thorite. The radiation levels have long been considered to be much higher than the annual dose limit for members of the public [1–3] and the radiological impact is not only arising from the enhanced radiation levels from the processing of the ores but also from the haphazard disposal of the tailings in the affected areas. This work reports the radiological assessment of zircon, the mineral with the reported highest radioactivity levels, from the mineral processing activities in the Jos area, central Nigeria.

2. Radiological assessment of mining and processing sites

Radiation monitoring was carried out in some selected mining and processing sites and settlements. These comprise four processing mills and five mining and processing community settlements. All the sites are located near Jos, central Nigeria.

An external dose rate ($\mu\text{Sv/h}$) survey was performed with a calibrated portable survey meter manufactured by RADOS[®] (RDS-120 Universal). The instrument has a scintillation probe in addition to two external probes, a GM probe and an alpha pancake probe. Ten measurements were averaged at each site. The five community settlements covered by the survey are Shafa, Litiya, Fahapa, Rayfield and Bisichi. Most of the measurements were taken from tailings piles that can be found all around these settlements. Background values were in the range of 5–8 $\mu\text{Sv/h}$, while the tailings piles exhibited dose rates in the range 10–30 $\mu\text{Sv/h}$. For the processing mills, measurements were made at James Dung, Dadin Kowa and two mills belonging to the former Amalgamated Tin Mines. The process lines at each of the mills were followed in the course of the survey and the dose rate values were found to be in the range 10–80 $\mu\text{Sv/h}$. The highest values were for the heaps of processed zircon.

The average dose rate of 25 $\mu\text{Sv/h}$ for most of the tailings piles corresponded to an annual dose of about 50 mSv for people in the vicinity, assuming a 2000 hour working year. This by far exceeds the 1 mSv dose limit for members of the public [4]. This was cause for alarm since the tailings are not well managed or contained.

3. Intervention and remediation measures

In general, exposure to NORM in the environment is not regarded as being subject to the requirements for practices. The concept of intervention is now largely accepted in addressing this radiological hazard. Interventions are human activities that seek to reduce existing radiation exposure, or the existing likelihood of incurring exposure. A three step system can be adopted in addressing the radiological hazard arising from the processing of zircon in the Jos area after identifying work activities that may lead to increases in exposure. The first is monitoring of the work areas and worker exposures, the second is implementing corrective measures as needed and the third step is full or partial implementation of radiation protection measures for practices.

Towards achieving these measures the Nigerian Nuclear Regulatory Authority (NNRA) has now a regulation governing TE-NORM which is backed by government policy and strategy for radioactive waste management. The programme of action for intervention includes an awareness campaign, radiation survey and monitoring, sample collection and analysis and some remediation action based on the results of the survey and the analysis of collected material.

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