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Radiogenic and Dosimetric Characterization of Columbite-Tantalite Mineral Extraction and Processing to Assess Occupational Radiation Exposure in Artisanal Mining in Rwanda

Background
Unregulated artisanal mining of columbite–tantalite (coltan) which is widespread in Eastern Africa is growing rapidly due to increased demand for tantalum, a rare refractory metal that is highly resistant to corrosion and a good conductor of heat and electricity.Such mining works that involve naturally occurring radioactive materials (NORM) are however sources of radiation exposures; and, from the environmental point of view the immobilized discharges (mine tailings and mine waste waters) of the [now] technologically enhanced (TE)-NORM) are radioactive wastes. A screening survey of artisanal mining in three regions (Muhanga, Ruli and Ngoma) of Rwanda was undertaken motivated by the need to provide data for development of evidence-based regulatory frameworks for artisanal mining and a method for quality assurance of the mineral.

Methodology
Dose rates in the field were measured using the Sensor Meter (Model G/B) survey meter. Radiogenic and dosimetric characterization of the coltan extraction and processing was done by HpGe-based gamma-ray spectrometry combined with recommended (UNSCEAR) computational, as well as multivariate modeling based on principal components analysis (PCA) utilizing ore gamma-ray spectra as geochemical fingerprints. The various artisanal exposure scenarios and pathways were studied and the results used to estimate the occupational exposure.

Results
The mean activity concentrations of 238U and 232Th in the extracted tantalum were 513 Bqkg-1 and 57 Bqkg-1 respectively; while that of 40K was 267 Bqkg-1. The measured absorbed dose rates ranged 518.34 - 796.92 nGyh-1, 522.4 - 820.7 nGyh-1 and 563.8 - 845.7 nGyh-1 in Muhanga, Ruli and Ngoma respectively: these values are ⊠11 times higher than the world average (value of 60 nGyh-1) thereby delineating Rwanda's coltan mining belts as high background areas (HBRA). The activity concentration of 238U was 15 times higher than world average. Compared with the dose rates obtained from model computations using radionuclide activities the values were twice as high: the effective doses ranged 0.0173 - 0.272 mSvy-1 in Muhanga, 0.013 - 0.525 mSvy-1 in Ruli and 0.022 - 0.255 mSvy-1 in Ngoma - indicating the significance of radioactive dust and radon in the occupational radiation exposure: dust inhalation accounted for 98 % of the exposure. Processing of the coltan ore was observed to enhance the concentration of 232Th and 238U by a factor of 3 and 2 respectively, while it reduces that of 40K by a factor of 15. The processed coltan samples were uniquely source-apportioned to their respective mining regions using PCA modeling utilizing radionuclide activities and gamma spectral signatures as model inputs. Multivariate modeling by PCA also successfully discriminated extracted from processed coltan.

Conclusion
Radiogenic fluxes due to NORM in the artisanal extraction and processing of coltan in Rwanda were quantified and the occupational dosemetric attributes due to the practice derived. Dosimetrically significant multivariate relations were gleaned from the radiometric data. Although analyses of the effluents showed the mining practices do not radiogenically impact the environment, interpreted together with the dosimetric data, the study raises occupational exposure as well as quality assurance concerns of artisanal columbite-tantalites from Rwanda.

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