Assessment of Heavy Metal Fluxes and Radiation Exposure due to NORM in the Extraction and Processing of Coltan Ores in Selected Areas of Rwanda

By

NTIHABOSE Léon
B.Sc. (Hons)

A thesis submitted in partial fulfillment of the requirements for the award of Master of Science (MSc) degree in Physics, University of Nairobi.

October, 2010

DECLARATION

This thesis is my own work and has not been examined or submitted for examination in any other university.

NTIHABOSE Léon

Signature.....

Date...26.10.2010...

This thesis has been submitted for examination with the approval of my University supervisors:

1) Prof. J.P. Patel
Department of Physics
University of Nairobi

Signature.....

Date.....26/10/10

2) Dr. H.K. Angeyo
Department of Physics
University of Nairobi

Signature.....

Date.....26-10-2010

3) Mr. D.M. Maina
Institute of Nuclear Science & Technology
University of Nairobi

Signature.....

Date.....27/10/2010

ABSTRACT

The present study quantifies heavy metal fluxes and radiation exposure due to Naturally Occurring Radioactive Materials (NORM) in the extraction and processing of the Columbite-Tantalite (Coltan) mineral in Muhanga, Ruli and Ngoma areas of Rwanda. Heavy metal in samples of Coltan ore, mine sediments and soil from the three areas were analyzed using the Energy Dispersive X-Ray Fluorescence (EDXRF) spectrometry. Activity concentrations of primordial radionuclides ^{40}K, ^{238}U and ^{232}Th in samples of Coltan, sediments and soil were determined by Hyper Pure Germanium (HPGe)-based gamma-ray spectrometry. Multivariate chemometrics techniques, Principal Component Analysis (PCA) and Hierarchical Cluster Analysis (HCA) were used to explore the salient relationships among measured data (heavy metals, radionuclides). The heavy metals were categorized into three classes which may be interpreted as, elements normally associated with coltan; radioactive minerals; and heavy metal toxic elements. Multivariate chemometrics techniques enabled to classify the samples into three coltan types namely; processed coltan, extracted (or unprocessed) coltan, mine sediments and control soil samples. Processed coltan is purified coltan which is obtained after separating soil and coltan by using water. Extracted coltan is the raw ore taken immediately from soil; it is a mixture of coltan and soil. Sediments are the wastes produced after removing coltan. Control soil sample is the soil which was taken from an area within the vicinity but outside the mining site. Coltan ore were also classified according to their origin using principal component analysis (PCA).

The result of elemental analysis showed that the most abundant elements were Tantalum (Ta), Niobium (Nb) and Tin (Sn). These elements are normally associated with Coltan. The highest concentration of Ta (30.6 %), Nb (25.7 %) and Sn (16.4%) were observed in processed Coltan. In some sediment samples Ta (35.6-63.3 $\mu g\ g^{-1}$) and Nb (35.4-83.8 $\mu g\ g^{-1}$)

were also reported but at lower level. Heavy toxic elements such as lead (Pb), manganese (Mn) and zinc (Zn) were also observed in all samples with manganese having the highest concentration (35,155-65,200) $\mu g\ g^{-1}$ and lead having the lowest concentration (548-1655) $\mu g\ g^{-1}$. Radioactive elements (U, Th, K) were detected in all samples with the highest concentration found in processed Coltan (115-569) $\mu g\ g^{-1}$, (281-797) $\mu g\ g^{-1}$ and (15,870-37,900) $\mu g\ g^{-1}$ respectively.

The average activity concentration of ^{238}U (513 Bq kg^{-1}) and ^{232}Th (57 Bq kg^{-1}) in all sample exceed the world wide average of ^{238}U (35Bq kg^{-1}) and ^{232}Th (30 Bq kg^{-1}), while the average ^{40}K (267 Bq kg^{-1}) activity was below the world wide average of 400 Bq kg^{-1}. Absorbed dose was obtained by measurement and models of calculation. In general the measured absorbed dose was found to be 2 times higher than the calculated absorbed dose. The measured absorbed dose varied 507.43-845.71 nGy h^{-1} (average: 665.5 nGy h^{-1}), whereas the calculated absorbed doses varied 63.52-779.07nGy h^{-1} (average: 286.19 nGy h^{-1}). These values are 5-11 times higher than the world wide average absorbed dose reported by UNSCEAR which is 55 nGy h^{-1}. This characterized the sampled areas of Rwanda as High Background Radiation Area (HBRA). Among the exposure pathways considered, inhalation of Coltan bearing dust resulted in the highest doses exposures from crushing and sieving Coltan in the mill; estimated up to 0.53 mSv (98 per cent of the total exposure) per annum on average. Further assessment of radiation exposure due to NORM should be carried out in the whole country and consider not only coltan but also other minerals of economic importance.