EVALUATION OF NORM CONTENT FROM COLTANT MINING IN NIGERIA PRIOR TO EXPORT

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Abstract

Coltant has global demand for variety of application due to its qualities of being good heat conductor, corrosion resistant, but usually associated with NORM during mining process prior to export. The aim of this study was to assess NORM level emanating from coltant shipments from Nigeria, using RDS-31S/R Multi-purpose survey meter, Radionuclides Identifinder and Sodium Iodide detector. The dose rate measurement from the coltant samples ranges from (0.23±04 and 8.44±03) μSv/hr which was above maximum dose rate of 1 μSv/hr at 1m from the package surfaces. The analyzed specific activity concentration of NORM from coltant product were ^{226}Ra, ^{232}Th and ^{40}K found to be (335±195 - 15,786±9,164) Bqkg^{-1}, (152±18 - 15,201±1,738) Bqkg^{-1}and (16±10 - 142±21) Bqkg^{-1}, respectively. The evaluated GDR was with a mean value of 7959 nGy/hr higher than world mean of 59 nGy/hr. The outdoor and indoor AEDR estimated were 9.76 mSv/yr and 39.05 mSv/yr respectively higher than world mean of 0.420 mSv/yr; the estimated ELCR was 3333 higher than world mean value of 0.29 × 10^{-3} as reported in UNSCEAR 2000. The radiological risk assessment from this investigation reveals workers and public in such mining areas and other biota will definitely be overexposed leading to radiation health effects over long term. It is recommended that there should be effective regulatory control of mines and mining Coltant products to determine NORM content prior to export to avoid regulatory infractions between exporting and importing countries.

Keywords: Coltant, NORM, Activity Concentration, Export and Radiological risk

1. INTRODUCTION

Coltan is a combination of columbite and tantalites which is a gloomy black metallic mineral, which has qualities of highly resistant to heat, corrosion and a good conductor, making it quite useful in several applications like in electronics, medical devises, optical lenses, aerospace engines cutting tools, capacitor, resistor, coil, transformer, mobile phones, super alloy for nuclear reactor etc [1]

Nigeria is endowed and has a large and exceptional deposit of tantalite /Coltant, which is found in the several parts of Nigeria found in granite complexes in Jos –Plateau, leading to commercial exploitation for economic purposes. It has contributed immensely to socio-economic benefits and accounts for 0.3% Nigeria's GDP [2,3].

The unrestrained, haphazard and unregulated coltan mining, mostly open pit type leave behind burdens of tailings of technically enhanced Natural Occurrence Materials (NORMs) at the earth surface, usually associates with high concentration of primordial radionuclides (^{238}U, ^{232}Th and ^{40}K) which increases environment radioactivity levels. Also, the varying concentration of ^{238}U, ^{232}Th and ^{40}K present and associated with mined coltan is attributed to perhaps geographical and geological formation [4,5.6]. There is therefore a huge damaging effect of these technical enhanced NORMs to ecosystem, consequently resulting in environmental radiological health hazards of host community, leading to radiation sicknesses, through several pathways exposures [7,8,9].

This investigation was prompted due to reported circumstances of delays, denials and impoundments of coltant consignment originating from Nigeria either at shipping port or importing countries Regulatory Body (RB), due to radioactive material concentration associated with coltant mining ores containing amount required for safeguard declaration purpose. The objective was to evaluate NORM concentration level of coltan from Nigeria prior to export, proffer recommendations to exporters to demonstrate adequate compliance to international requirements and provisions on transport packages and dangerous goods declarations to forestall future contraventions [10,11,12].

2. MATERIALS AND METHOD

2.1 Study Areas

The study areas of Jos Plateau is located within coordinates of 09°46'02N and 008°51'39E. It is bounded with Bauchi State – at north east, Kaduna State – at north west , Nasarawa State – to south west, Taraba State – to south east, and is geographically exceptional in Nigeria due to elevated altitude of about 1279 m. It is considered as highest plain amongst surrounding ones in Nigeria which results in a near temperate climate with an average temperature of between 13 and 22 °C even though in the tropical zone. Plateau State geological formation is basically Precambrian basement complex rocks as well as Jurassic younger granites (Biotite granites) and the tertiary quaternary volcanic rocks (basalts, pumice, lava flows and ash deposits. The younger granite province is where mineral deposits of coltant, tin etc is normally found in Jos Plateau [2,9]. Figure 1 presents a Map describing geological formations of Jos insert in the Plateau State, Nigeria.

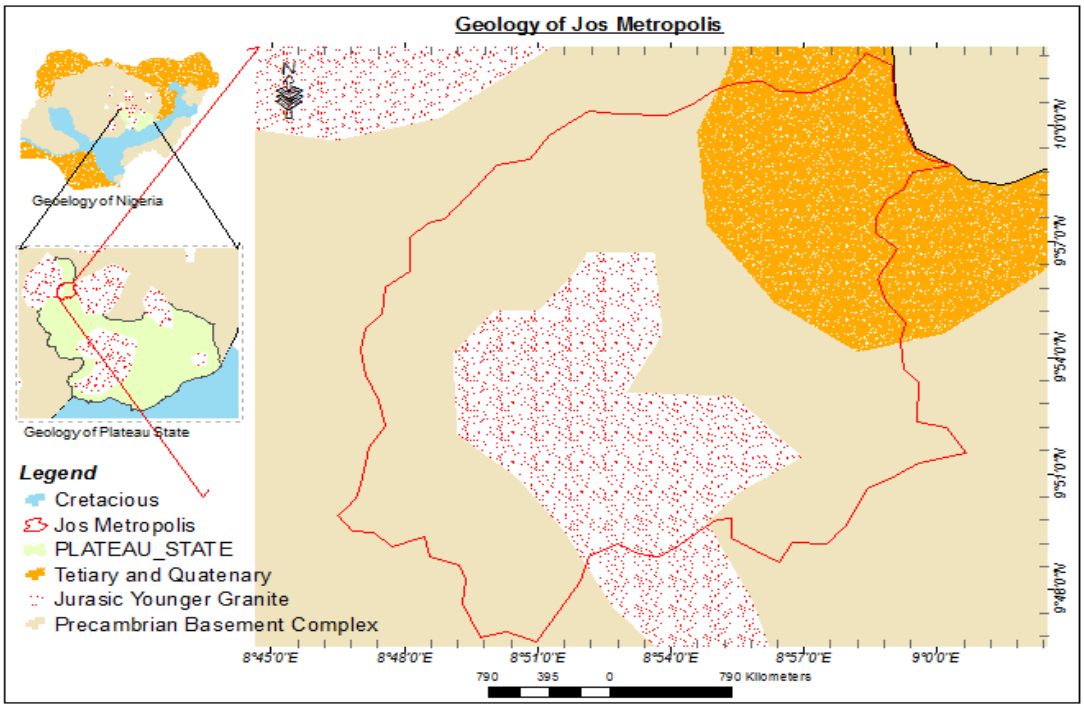

Fig. 1: Map presentation of Jos Plateau State, Nigeria showing its geological formations.

2.2 Equipment

The global positioning system (GPS) – GARMIN Etrex 10 (Serial number 3964) was used to locate coordinates of mine sites, warehouse. Radiation measurements and qualitatively radionuclides identification were done with RDS-31S/R Multi-purpose survey meter with serial number 2100372, measuring a dose range of 0.01 uSv/hr to 10 mSv/hr and a Radionuclide Identifinder (RID) respectively. The RID was able identify radionuclides or elements present in coltant material ores to about 100% certainty with corresponding dose rate measurements. To ensure adequate equipment performance, a pre-operational/ functionality and quality checks prior to dose rate measurements were performed on the equipment to ensure their effective, accurate and perfect working conditions [13].

Also, the analysis of the coltant samples using Sodium Iodide (NaI) detector with 80% Efficiency and Resolution of 2.4 keV at ^{60}Co was carried out at the Secondary Standard Dosimetry Laboratory. This detector is well shielded by a lead shield, to protect from environment external radiation interference during measurement. The calibration of the HpGe detector was performed using IAEA calibration Multi-Gamma Ray Standard (MGS6M315) standards, to acquire spectrum peaks of radionuclides spanning through energy lines of ^{241}Am at 59.5keV to ^{208}Tl at 2614keV, with which all other unknown radionuclides were dully detected and identified [14,15].

2.3 Measurements and coltant samples collection

The engaged method was judgmental random sampling, since the locations were already predetermined being Coltant Export Company (CEC) sites and warehouses where the impounded coltant product originated from. The coltant material ores samples were collected through grab method at the same locations as given in Figures 2 – 3, the dose rates and preliminary measurements were conducted at mine sites, warehouses and where some packages were ready for export as given in Figures 4 - 5. These samples were bag into a polyethylene and sealed, carefully labelling with codes names for proper identification and conveyed to the laboratory.

Figure 2: TENORM Zircon sand dump mine site

Figure 3: Air drying of coltant at warehouse

Figure 4: Coltant products storage at warehouse

Figure 5: Coltant processing at warehouse

2.4 Analysis of coltant samples

The coltant sample were open air dried, subsequent oven dried at about 50°c - 150°c to obtain constant weight, stony samples crushed, pulverised through 500 μm mesh sieve for homogeneity and increase surface area and reduce much attenuation. Coltant samples were packaged in Marinelli beaker and placed vertically on a detector and counted for 18,000 seconds. Gamma spectroscopy method employing a Sodium Iodide (NaI) detector with 80% Efficiency and Resolution of 2.4 keV at ^{60}Co was used to analyzed coltant samples to acquire spectra on its Region of Interest (ROI), which identifies the radionuclides present qualitatively, and counts obtained with corresponding uncertainties to quantitatively determine the activities of radionuclides.

2.5 Theory

Activity Concentration (A_c) can be calculated from analyzed sample data using Equation (1) [16]:

$$\boldsymbol{A_c = \frac{C_{net}}{\varepsilon_\gamma \times I_\gamma \times m}} \quad (1)$$

where mass of the sample is denoted as *m* in the expression. The unit of activity concentration of soil sample is given as Bqkg^{-1}.

In determining the absorbed dose rates (D), conversion factors were applied. These factors used in Equation 1 are of postulation that all the progenies of ^{226}Ra and ^{232}Th are in radioactive equilibrium with their parents radionuclides [17.18].

$$\mathbf{D = 0.461A_{Ra} + 0.623A_{Th} + 0.0414A_K} \quad (2)$$

An Annual Effective Dose Rate estimations are derived from Gamma Dose Rate, a conversion factor of 0.7 Sv/Gy of absorbed dose in air to effective dose an adults receives with 20% time out-of-doors (80% indoors) is given in Equation 3 (Al-Sulaiti, 2009; UNSCEAR, 2000) [16,17]:

$$\mathbf{AEDE_{\mu Sv} = D_{nGy/h} \times 8760_{h/y} \times 0.2 \times 0.7_{Sv/Gy} \times 10^{-3}} \quad (3)$$

For relative purposes, assessing the hazard associated with material containing different concentrations of ^{226}Ra, ^{232}Th and ^{40}K, Radium Equivalent Activity can be estimated by the expression in Equation 4 [19,20].

$$\boldsymbol{Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.007A_K} \quad (4)$$

Excess Life Cancer Risk is determined from the Annual Effective Dose Rate with Duration of Life (DL, 70 years for children and 50 years for adult), Risk Factor (RF, 5%) for public exposure considered to produce stochastic effect is given in Equation 5 [21,22].

$$\mathbf{ELCR_{mSv/y} = AEDE_{mSv/y} \times RF \times DL} \quad (5)$$

3. RESULTS AND DISCUSSIONS

3.1 Results

The dose rate measurements and activity concentration of coltant products samples collected from Coltant Export Company (CEC) Jos, Nigeria are presented in Table 1.

These dose rate measurements reported in Table 1 Column 3 ranged (1.29±0.9 - 8.44±0.4) μSv/hr, and higher than 0.2 μSv/hr of the global average and above recommended transport index that should be on packages during transportation [17,12].

Also, the preliminary site analysis with RID presented in Table 1 Column 4, from all the coltant samples except for J-KW showed qualitative description of ^{226}Ra and ^{232}Th progenies which also corroborated initial suspecting report from RB at the Airport that led to the coltant consignment impoundment.

Furthermore, radionuclides concentration from laboratory analysis of coltant samples derived from Equation 1 are reported in Table 1 Column 5. These activity concentration were found to ranged (335±195 - 15,786±9,164) Bqkg^{-1}, (152±18-15,201±1,738) Bqkg^{-1}and (16±10 - 142±21) Bqkg^{-1}, for ^{226}Ra, ^{232}Th and ^{40}K respectively. These activity concentration far exceeded the global average of 33 Bqkg^{-1}, 45 Bqkg^{-1} and 420 Bqkg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K respectively [17]. These high activity concentration recorded were due to minerals ore mined from Jos, Plateau are usually associated with TENORMs.

Table 1: Dose rate measurements and activity concentration of Coltant products samples collected from Coltant Export Company Jos, Nigeria

Sample Codes	Dose Rate (μSv/hr)	RID Result	Activity Concentration (Bq/kg)		
			K-40	Ra-226	Th-232
J- KN	4.10±0.5	57% Th-232; 52% Te-132	ND	5155±2993	18422±2.106
J-KW	4.35±0.7	50% Mn-54; 47% Be-7	123±11	4931±2863	7044±806
J-TL	4.70±0.8	71% Th-232; 45% Ru-103	ND	6339±3680	10830±1238
J-TR2	4.80±0.6	58% Na-22; 56% Bi-207	16±10	817±475	1185±138
J-ZS	8.44±0.4	64% Ra -226; 55% Y-88	ND	15786±9164	7480±857
J-BL	3.56±0.9	60% Na-22; 56% Pb-214	ND	335±195	152±18
J-C63	1.29±0.9	57% Zr-95; 54% La-140	ND	13493±7832	2407±276
J-C64	1.29±0.9	59% Bi-207	95±39	7401±4296	15201±1738
J-TR1	2.90±0.6	58% Na-22; 56% Bi-207	142±21	3239±1881	9692±1108

J – Jos; Packages - TR1&2, ZS, C63&64, BL, TL, KN and KW

3.2 Discussions of Results

It was evident that in both the preliminary measurements with RID and laboratory analysis, ^{40}K was found in only three (3) of the coltant samples with activity concentration below admissible limits, but were not found in the other six (6) coltant samples as stated in Table 1, Columns (3-4), and which may be attributed to perhaps geographical or geological formation [6].

The maximum dose rate measurement and activity concentration result from laboratory analysis of the investigation study, corroborates with maximum dose rate of 8μSv/hr and activity concentration of 2,400±400 Bq for ^{232}Th, 4,900±700 Bq for ^{238}U in a 381.0 g conducted on the impounded CEC coltant consignment, at the Airport by the RB. Also, these values were above Regulatory requirement of Quantity for Notification ($1x10^4$ Bq) and which the aggregate of these samples put together for export/shipment likely to exceed 20 tons of the international safeguards requirements for declaring such shipment [23,10,12]. This high NORM concentration was regarded as gross violations of regulatory requirements and ICAO-TI provisions, as there was no adequate transport index labelling and declaration on packages containing fissile materials, ore and radioactive substances [10,11,12]. This had led to impoundment of the five (5) pieces of CEC, Jos Nigeria coltant products at the transit Airport by RB.

A related studies come to an agreement with this investigative having same elevated NORM concentration level due to mining activities in Jos, Plateau where the impounded coltant product emanated. Soils and food crops (yam) samples from coltant or tin mining areas were analysed to determine NORM concentration contents. The ^{40}K, ^{238}U and ^{232}Th radionuclides concentrations ranged (60 – 494) $Bqkg^{-1}$, (0 – 48) $Bqkg^{-1}$ and (0 – 17) $Bqkg^{-1}$ respectively. The ^{40}K was found to be the highest contributor than other radionuclides in the analysed food products, and this high concentration was attributed to the mining activities [24]. Also, evaluations of NORM tailings were conducted to determine the activity concentrations of the samples. The ^{40}K was below detectable limits while ^{238}U ranged (17.1 x 10^2 - 16.6 x 10^3) $Bqkg^{-1}$ with means of (72.2 x 10^2) $Bqkg^{-1}$ and ^{232}Th ranged (52.9 x 10^2 to 47.5 x 10^3) $Bqkg^{-1}$ with means of 16.8 x 10^3 $Bqkg^{-1}$ which exceeds world mean [25]. These studies reveals that materials of products gotten from mining areas are largely associated with NORM concentrations.

3.3 Discussions of Radiological Health Parameters

Table 2 presents the radiological hazards considerations of activity concentration from the coltant analyzed samples of Table 1 were evaluated using Equations (2-5).

The estimated GDR arising from terrestrial gamma of activity concentration from the samples of the investigation area was with a mean value of 79 nGy/hr were found to be higher than world mean value of 59 nGy/hr [16,27]. More so, the AEDR estimated from both terrestrial outdoor was with mean value of 9.76 mSv/yr, whereas the evaluated indoor AEDR was with mean value of 39.05 mSv/yr also higher when compared with world mean value of 460 mSv/y The rationale behind outdoor AEDR lower than that of AEDR indoor is because more time is spent indoors than outdoors. Furthermore, the estimated ELCR was with the mean value of 3333 higher than world mean value of 0.29×10^{-3} [26,27]. This means that the possibility of infant of adult becoming a cancer patient in the study area is very high.

The radiological hazards indices evaluation of the dose rate measurements from the site and warehouses translated to between (2.58 – 16.88) mSv/yr which is far above public acceptable annual effective dose without constraint of 1mSv/yr for the purpose of safety, and with constraint of 0.5 mSv/yr [16,27]. The implication of these radiological risk assessment from the study investigation is that, there is likelihood of overexposures leading to radiation health hazards over long term. First to workers who spends more than 2000 hours in a year working without any protective measures, also to the public through external exposures on elevated radiation level, through pathways of inhalation of re-suspended TENORMs particles in air, ingestions through various food chain, and finally to other biota.

Table 2: Radiological hazards indices of Coltant products collected from Jos, Nigeria

Sample	GDR (nGy/hr)	Ra_{eq} (Bq/Kg)	AEDR (O) (mSv/y)	AEDR (I) (mSv/y)	ELCR
J-KW	6666	15004	8176	32704	28616
J-BL	249	552	306	1222	5.22
J-TR1	7537	17099	9244	36974	161
J-KN	13853	31498	16989	67959	298
J-C64	12886	29139	15803	63214	275
J-C63	7719	16935	9468	37870	160

J-TL	9669	21826	11859	47434	206
J-ZS	11937	26482	14640	58560	250
J-TR2	1115	2512	1368	5472	24
Mean	**7959**	**17894**	**9761**	**39046**	**3333**
World Mean	59	370	0.46	0.46	0.29

4. CONCLUSION

The coltant mining in Nigeria is economically viable, but not without environmental burdens due to abandon tailing on earth surface usually associated with variety NORM concentrations, thereby increasing radiation exposure level. Some coltant samples collected from CEC were analyzed and the activity concentrations of primordial radionuclides were found to exceed the admissible global limits, and which translate to radiological health hazards to port workers, public during transportation due to improper packaging and labelling. In these regards, to forestalling future contraventions of international regulations, there is need for exporters to conduct both radiometric and elemental analysis on coltant products from Nigeria to determine NORM concentrations. Furthermore, a uniform ICAO-TI guidelines be used to conduct inspections at coltant shipping port of origin and apply appropriate labelling/ packaging and declaration prior to export.

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