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MEASUREMENT OF RADON CONCENTRATION IN SOIL SAMPLES OF MAZAT AND KAFI-HABU MINING SITES, PLATEAU, NIGERIA

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ABSTRACT

Radon and its short-lived progenies contributed significantly to natural background radiation. Long-term exposure to such radiation increases the probability of lung cancer to persons. To assess the radiological hazards associated with the inhalation of radon gas from ore dust in Mazat and Kafi-Habu mining sites of Plateau, Nigeria, 12 soil samples from an abandoned tailing dump ground were collected and analysed for radon using RAD-7 electronic detector. The dose rate of each sampling point was directly measured using RADOS RDS -120 portable survey meter. The results gave a mean radon concentration ranging from 771.51 ± 21.9 Bq/m^3 to 5666.13 ± 28.8 Bq/m^3 with 3451.13 ± 42.9 Bq/m^{3}as the average value for all measurements. The average concentration of measurements from Mazat and Kafi-Habu is 3671.6 ± 41.2 Bq/m^3 and 3010.16 ± 46.5 Bq/m^3 respectively. The average values obtained from the analysis are significantly higher than the upper limit of 300 Bq/m^3 set by the International Commission on Radiological Protection (ICRP) suggesting quick remediation on the host communities. The geometrical mean value of Dose Rate (DR) and Annual Effective Dose Equivalent (AEDE) were 870 nGy/hr and 1.04 mSv/yr respectively. Again, these values are above the global average limits of 59 nGy/hr and 1 mSv/yr. The result indicates that miners working in those sites and dwellers of the study areas are at higher risk of getting exposed to radon and need to employ protective measures. This work is useful in monitoring and control of radon level for the on-site workers and the host communities.

Keywords: Radon, mining, radiological hazards, annihilation dose

INTRODUCTION

Mining and processing of tin ores have been taking place for about a century in Jos and its environs (Sambo 2013). Most of the mining and milling activities are carried out by locals and are artisanal. The miners use manually-intensive methods, working with hand implements. The radiation emanated from rocks, soil, and minerals that are exposed through mineral exploration poses health threats and increases the natural background radiation level (WHO 2004, Dragović, Janković et al. 2006, HPS 2015). The local miners perform almost all their mining activities locally for a good number of hours in a day, ranging from digging pits which are 50-60 ft deep down the ground, parking the minerals when found out of the pits, down to washing or separation of the ores from the sand. Looking at all these processes, one is at a higher risk of acquiring a large amount of dose into their system. Previous studies revealed that exposure to radon gas in miners induces gene mutation, chromosomal aberrations, and lung cancer (Al-zoughool and Krewski 2009, EPA 2019). Radon contributes to about 50% of the annual effective dose to the population due to natural radiation (UNSCEAR 2010) and has three naturally occurring isotopes namely: ^{222}Rn (Radon), ^{220}Rn (Thoron) and ^{219}Rn (Actinon) (Ishimori, Lange et al. 2013). It can be very harmful when inhaled into the lungs because it releases energy that could damage the DNA (Wiwanitkit 2008). Radon-222 (^{222}Rn) which has a half-life of 3.8 days is the most important isotope due to its higher abundance and enriched neutron. It decays by emitting 5.49 MeV alpha particles and generate radioactive progeny, two of these progenies are ^{214}Po and ^{218}Po, which are alpha emitters and they contribute about 90% to the total radiation dose received due to radon exposure (Komal, Rohit et al. 2010). The inhalation of short-lived daughter products of naturally occurring radon which finds their way into the air is a major contributor to the dose exposed subjects (HPS 2015).

The radioactivity measurement of Jos tin mine tailings is reported elsewhere (Ibeanu 1999, Mangset and Sheyin 2009, Usikalu, Anoka et al. 2011, Wapwera, Ayanbimpe et al. 2015). Their results showed the activities of Naturally Occurring Radionuclide Materials (NORMS) varied from one site to another. In the Ibeanu (1999), it was shown that the ^{226}Ra radionuclide contributed about 96.09 % of the risk in the external scenario with only 3.09% from the ^{232}Th while in the internal ^{226}Ra contributed only 70.38% from the 60 analysed soil samples. It is observed that no information about the radioactive gas (radon) associated with the Radium presented in their studies. Also, the results reported can not be relied upon to assess the level of radon exposure in other mining sites as the radiological exposure from tailings depends on many factors including geology, mineral ore types, lithology, and a host of other factors as reported elsewhere (Kobeissi, El Samad et al. 2008, Nasirian, Bahari et al. 2008, Lu, Li et al. 2013, Duggal, Rani et al. 2014, Amin 2015, Elzain 2015, Bala, Kumar et al. 2017, Abo-Elmagd, Saleh et al. 2018). It should be noted that the inhalation aspect has not been addressed in the aforementioned studies. The annihilation aspect is an important radiation exposure pathway due to the presence of radioactive ore dust/radon gas in the atmosphere and should not be ignored in the radiological assessment.

Although, previous studies have developed and adopted different verified methodologies on the measurement of radioactivity from a different environmental sample of Jos Plateau mining areas, studies that considered the potential radiological impact of Radon are very limited and there is hardly found in the literature the radiological assessment related to Radon for the areas under investigation (Mazat and Kafu Habu villages). Only a few specific evaluation data on radon emission for Barkin Ladi town (nearby community) is reported by Abdulwahab, Asuku et al. (2020). Most attention has been focused on the activity measurement of NORMS and chemical toxicity. The relevant radiological data related to radon gas reported outside Nigeria have been described elsewhere (Komal, Rohit et al. 2010, Ramsiya, Joseph et al. 2017, Shilpa, Anandaram et al. 2017).

This study is aimed at measuring the radon concentration using RAD7 electronic detector to the dwellers of two local mining areas of Mazat and Kafu Habu villages of Barkin Ladi L.G.A, Plateau State, Nigeria with a view to estimate the potential radiological health risk and hazards from the Radon gas release. The sites were newly discovered and the miming activities are presently ongoing. To the knowledge of the current research, there is no reference radiological data related to radon for the study areas signifying a data gap. They were found to have rock mineral potentials and are well known to miners for their natural gift of tin and columbite deposits. Locals were competing to beat one another to establish their mining points.

Experimental Method

Study Area:

Mazat and Kafi–Habu are two local communities located at the outskirt of Barkin Ladi town of Plateau state Nigeria. Mazat and Kafi-Habu villages are geographically situated on Longitude 9o 28′ N and 9o 27′ N and Latitude 8o 56′ E and 8˚22′ E respectively. The two areas have an estimated population of about 6000 and are roughly 3 kilometers apart. They are characterised with the wet and dry type of weather (Olowolafe 2008), underlain by five bedrock formations broadly classified under geological groups namely Younger granites of Jos Plateau, basement complex of Precambrian age, and Volcanic rocks of quaternary and tertiary ages as reported (Abba, Hassan et al. 2018).

Sample and Data Collection: A total number of 12 soil samples were collected randomly from different mining pits, 8 from Mazat (X) and 4 from Kafi-Habu (Y) mining areas. The positions of the sampling points were taken using Global Positioning Systems (GPS) and are summarized in Table 1. Each sample was carefully sealed in a plastic bag at the point of sampling and was coded before analysis with RAD 7 electronic detector at the Centre for Energy Research and Training (CERT), Zaria. The sample codes B1 – B8 represent the soil samples obtained from Mazat (X) while B9 – B12 are those obtained from Kafi-Habu (Y) artisanal mining sites. The dose rate (μSv/hr) of each sampling point was then measured in situ 1 meter using a RADOS RDS -120 survey meter.

Sample Analysis: Radon concentration from each sample was measured using RAD7 electronic detector shown in Figure 1. This detector converts alpha radiation directly to an electrical signal and determines the energy of each alpha particle. In this study, the detector was connected to a kit containing the soil sample which enables it to remove radon gas from the soil sample into the air in a closed loop. Within the closed loop is a desiccant to dry the air before entering the detector for radon concentration measurement. Each sample was assayed for 30 minutes for each cycle. A total of 48 cycles were attained for each sample, thus making 24 hours for a complete run in line with the standard procedure. The experimental setup is depicted in Figure 2.

Radiological Hazards parameters

In this study, the Dose Rate (DR) and Annual Effective Dose Equivalent (AEDE), and radon concentration are reported. The DR of each sampling point was directly measured by the portable survey metre (RADOS RDS -120) while the AEDE received by the inhabitants of the two mining areas were estimated from Equation 1 (UNSCEAR 2010).

$$\text{AEDE (mSv/yr)} = \text{DR (nGy/hr} \times 0.7\ \text{Sv/Gy} \times \text{OF} \times 8700\ \text{hr} \times 10^{-6} \qquad (1)$$

where DR is the measured dose rate for each sampling point given in Table 1, 0.7 is the conversion factor to convert the absorbed dose rate to effective dose equivalent in air received by an adult (ICRP 1993), OF is the occupancy factor equal to 0.2 for outdoor activities (UNSCEAR 2010), 8700 hr is the number of hours in a year, and 10^{-6} is the conversion factor between nano and milli.

Fig 1: RAD-7 Radon detector (RAD7 User Manual)

Fig 2: Experimental set-up for radon measurements

RESULTS AND DISCUSSIONS

The radon concentrations at various sampling points are presented in Figure 3. The figure indicates that the concentration ranges from 771.81 Bq/m^3 to 5666.13 Bq/m^3, with B10 (771.81 Bq/m^3) and B4 (5666.13 Bq/m^3) showing the minimum and maximum value respectively. The average concentration of all measurements from Mazat and Kafi-Habu is 3671.609 ± 41.2 Bq/m^3 and 3010.158 ± 46.5 Bq/m^3 respectively. The mean measurement for all samples is 3451.42.9 Bq/m^3. Comparing the above concentrations with the recommended maximum reference level value of 300 Bq/m^3 set by the International Commission on Radiological Protection (ICRP), it is seen that except for sample B10, all other values exceed the ICRP limit. This indicates that the miners in the two sites are at higher risk of getting exposed to radon and its progeny. The higher level of radon concentration may not be unconnected to anthropogenic activities in the two areas. The data reported in this study is quite greater than 651 ± 22.85 Bq/m^3 and 250 ± 11.355 Bq/m^3 for Barkin Ladi and Jos South respectively as reported (Abdulwahab, Asuku et al. 2020). The reason for variation in the reported radon concentration for these areas may be attributed to their geology (Vaupotic, Krizman et al. 1994), climatic condition (Vaupotič, Kobal et al. 1998), uranium grade and complex effects of host rock, uranium ore grade as well as uranium mineralogy (Fleischer 1983, Morawska and Phillips 1993).

The dose rates (nGy/hr) for the twelve sampling locations measured with RADOS RDS -120 survey meter are shown in the last column of Table 1. It is seen that dose rate measurements from Mazat (X) give much higher values with 3250 nGy/hr as a maximum at B7 and 450 nGy/hr as the lowest at B2. A mean value of 1081.25 3250 nGy/hr is calculated for this area. For Kafi-Habu (Y), the highest dose rate of 880 nGy/hr is recorded at B10 and the lowest (210 nGy/hr) at B9. The geometrical mean value of the dose rate for all the data points is 870 nGy/hr. The dose rates recorded in both measurements are significantly above the worldwide average outdoor dose rate of 59 nGy/hr (UNSCEAR 2010). It is pertinent to note that the recorded dose rates are even greater than the cited reference data of about 300 nGy/hr for areas with elevated radiation dose levels. The only exception is at B9 and B11.

In Figure 4, the values of AEDE (as a function of sampling points) computed using Equation 1 is depicted. It can be seen that the annual dose equivalent for sampling points in Mazat ranges from 0.63 mSv/yr to 3.95 mSv/yr while those from Kafi-Habu ranges from 0.33 mSv/yr to 0.94 mSv/yr respectively. The resulting average annual effective radiation dose to the public for the two sites were 1.33 mSv/yr and 0.51 mSv/yr respectively. The data indicate that the mean value of 1.33 mSv/yr for Mazat is slightly higher than the maximum recommended outdoor radon gas exposure limit of 1mSv/yr. The computed mean AEDE for Kafi-Habu (0.51 mSv/yr) is within the threshold values of 0.3 – 1 mSv/yr as suggested in the regulatory report (UNSCEAR 2010). The foregoing explanation signified that the public radiological exposure from the radon release is significantly higher at the Mazat mining site than in Kafi-Habu. The three computed radiological hazard parameters such as radon concentration, dose rate, and AEDE are significantly above the world average values reported by the ICRP and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

Table 1: Location and dose rate of sampling points

S/N	Sample	Position of sampling points		Place	Dose Rate (DR) (nGy/hr)
		Longitude	Latitude		
1	B1	N09˚28′ 44″	E008˚56′ 34 ″	X	600
2	B2	N09˚28′ 40″	E008˚56′ 35″	X	450
3	B3	N09˚28′ 45″	E008˚56′ 34 ″	Y	770
4	B4	N09˚28′ 04″	E008˚52′ 53 ″	X	1540
5	B5	N09˚28′ 04″	E008˚56′ 34 ″	X	520
6	B6	N09˚28′ 40″	E008˚56′ 35″	X	650
7	B7	N09˚29′ 04″	E008˚32′ 53 ″	X	3250
8	B8	N09˚29′ 04″	E008˚52′ 53 ″	X	870
9	B9	N09˚27′ 28″	E008˚22′ 36 ″	Y	210
10	B10	N09˚29′ 04″	E008˚52′ 53″	X	880
11	B11	N09˚27′ 28″	E008˚22′ 36 ″	Y	250
12	B12	N09˚28′ 43″	E008˚56′ 35 ″	Y	450

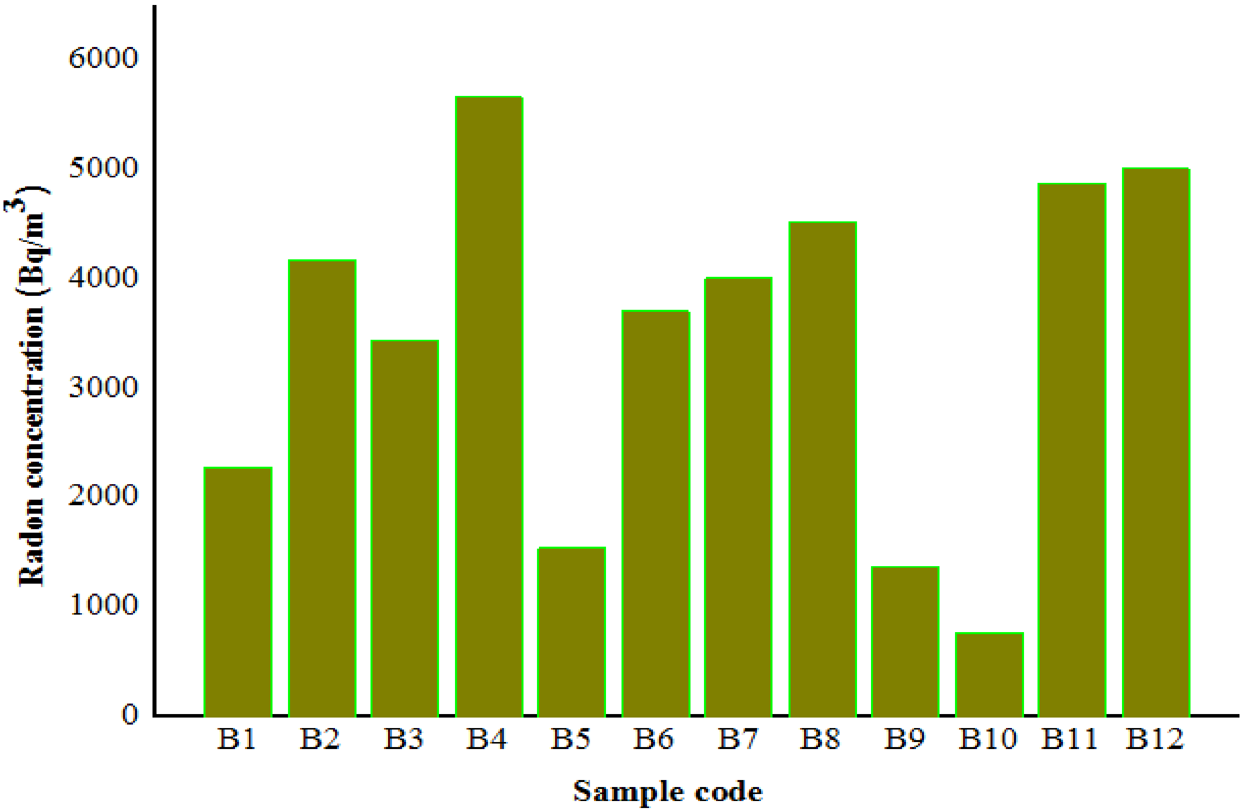

Fig 3: Radon concentration as a function of location

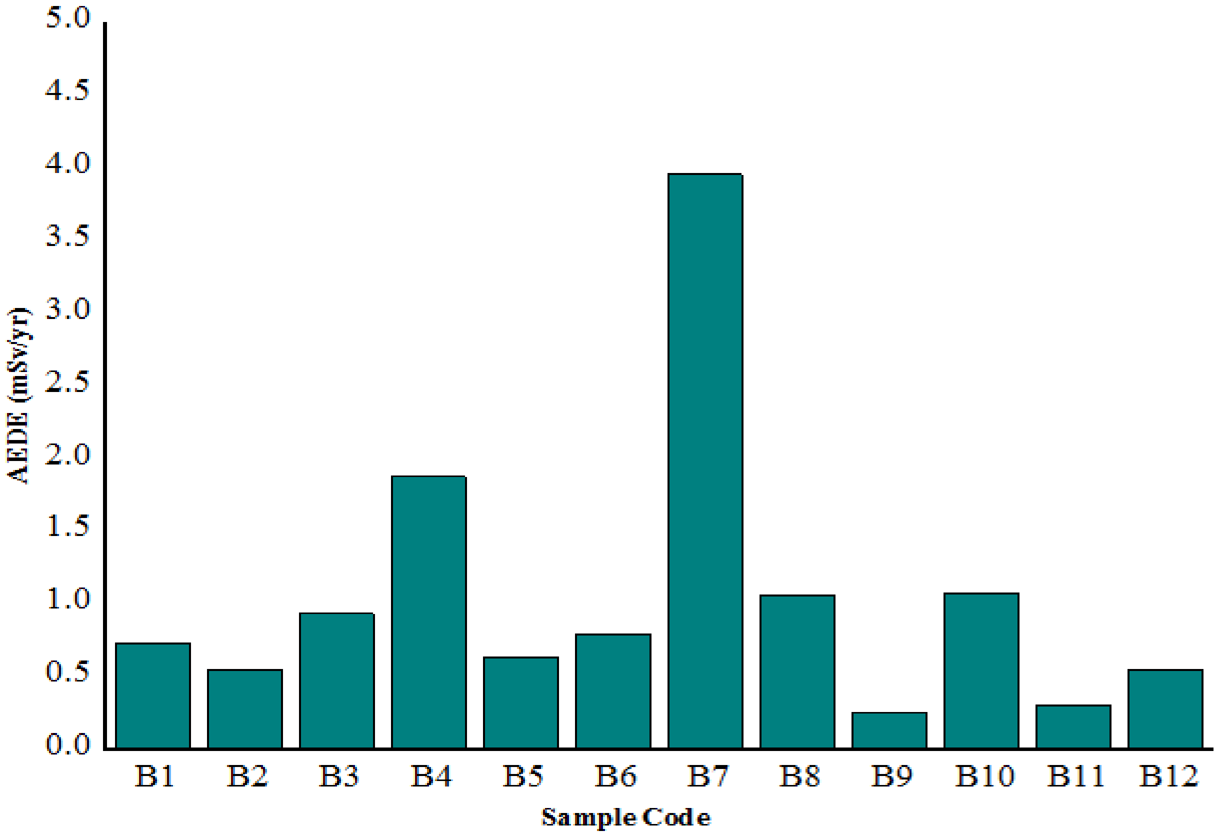

Fig 4: AEDE as a function of location

CONCLUSION

Radon concentrations from soil samples of Mazat and Kafi-Habu mining sites of Jos Plateau, Nigeria are investigated by deploying a RAD-7 electronic detector. The dose rates of twelve selected sampling points were measured using the RADOS RDS -120 portable survey meter. The average concentration of radon for Mazat and Kafi-Habu is 3671.6 ± 41.2 Bq/m^3 and 3010.16 ± 46.5 Bq/m^3 respectively. The geometric mean value of radon for all measurements is 3451.13 ± 18.6 Bq/m^3. The mean dose rate and computed AEDE for Mazat were 1081.25 nGy/hr and 1.33 mSv/yr while for Kafi-Habu were 335 nGy/hr and 0.51 mSv/yr respectively. The mean DR and AEDE value computed for all the data points were 870 nGy/hr and 1.04 mSv/yr. The computed radiological hazard parameters are significantly above their corresponding global average values signifying that workers are at a higher risk of getting exposed to radon. To mitigate the consequences of radiation overexposure to the on-site workers and inhabitants via direct inhalation of radon gas and its progeny, intervention measures in terms of protective respiratory equipment should be employed by the workers, and a remediation programme should be conducted on the areas. It is recommended that the on-site workers should undergo medical examinations periodically to know how fit they are for the work, and when they are due for termination.

REFERENCES

Abba, H. T., W. M. S. W. Hassan and M. A. Saleh (2018). "Evaluation of environmental natural radioactivity levels in soil and groundwater of Barkin Ladi, Plateau state, Nigeria." Malaysian Journal of Fundamental and Applied Sciences **14**(3): 338-342.

Abdulwahab, M. B., A. Asuku, Y. A. Ahmed, Ishola O. Okunade, A. Umar, S. John and A. R. Abubakar (2020). Assessment of Natural Radioactivity and Radon Emanation Rate at Jos Tin Mine Tailing Sites, Jos, Plateau State, Nigeria. Science Forum (Journal of Pure and Applied Sciences), Faculty of Science, Abubakar Tafawa Balewa University Bauchi.

Abo-Elmagd, M., A. Saleh and G. Afifi (2018). "Evaluation of radon-related parameters in environmental samples from Jazan city, Saudi Arabia." Journal of Radiation Research and Applied Sciences **11**(1): 104-110.

Al-zoughool, M. and D. Krewski (2009). "Health Effects of radon: A review of the literature." International journal of radiation Biology **85**(1): 57-69.

Amin, R. M. (2015). "A study of radon emitted from building materials using solid state nuclear track detectors." Journal of Radiation Research and Applied Sciences **8**(4): 516-522.

Bala, P., V. Kumar and R. Mehra (2017). "Measurement of radon exhalation rate in various building materials and soil samples." Journal of earth system science **126**(2): 31.

Dragović, S., L. Janković, A. Onjia and G. Bačić (2006). "Distribution of primordial radionuclides in surface soils from Serbia and Montenegro." Radiation measurements **41**(5): 611-616.

Duggal, V., A. Rani, R. Mehra and R. Ramola (2014). "Assessment of natural radioactivity levels and associated dose rates in soil samples from Northern Rajasthan, India." Radiation protection dosimetry **158**(2): 235-240.

Elzain, A.-E. A. (2015). "Radon exhalation rates from some building materials used in Sudan." Indoor and Built Environment **24**(6): 852-860.

EPA (2019). Radiation Health Effects. USA, United States Environmental Protection Agency.

Fleischer, R. L. (1983). "Theory of alpha recoil effects on radon release and isotopic disequilibrium." Geochimica et Cosmochimica Acta **47**(4): 779-784.

HPS (2015). Background Radiation, Fact Sheet, Health Physics Society Specialists in Radiation Safety.

Ibeanu (1999). Assessment of Radiological Hazards of Tin Mining and Ore Processing in Jos, Nigeria. International Symposium on Restoration of Environments with Radioactive Residues. Arlington, Virginia, USA, International Atomic Energy Agency**:** 86-91.

ICRP (2018). Protection Against Radon-222 at Home and at Work, International Commission on Radiological Protection.

Ishimori, Y., K. Lange, P. Martin, Y. S. Mayya and M. Phaneuf (2013). Measurement and Calculation o Radon Releases from NORM Residues. Vienna, International Atomic Energy Agency Vienna.

Kobeissi, M., O. El Samad, K. Zahraman, S. Milky, F. Bahsoun and K. Abumurad (2008). "Natural radioactivity measurements in building materials in Southern Lebanon." Journal of Environmental Radioactivity **99**(8): 1279-1288.

Komal, B., M. Rohit and R. G. Sonkawade (2010). "Measurement of radon concentration in groundwater using RAD7 and assessment of average annual dose in the environs of NITJ, Punjab, India." Indian Journal of Pure & Applied Physics **48**: 508-511.

Lu, X., N. Li, G. Yang and C. Zhao (2013). "Assessment of natural radioactivity and radiological hazards in building materials used in Yan'an, China." Health physics **104**(3): 325-331.

Mangset, W. and A. Sheyin (2009). "Measurement of radionuclides in processed mine tailings in Jos, Plateau State." Bayero Journal of Pure and Applied Sciences **2**(2): 56-60.

Morawska, L. and C. R. Phillips (1993). "Dependence of the radon emanation coefficient on radium distribution and internal structure of the material." Geochimica et Cosmochimica Acta **57**(8): 1783-1797.

Nasirian, M., I. Bahari and P. Abdullah (2008). "Assessment of natural radioactivity in water and sediment from Amang (tin tailing) processing ponds." Malays J Anal Sci **12**(1): 150-159.

Olowolafe, A. E. (2008). "Land use effects on the properties of an Alfisol on the Jos Plateau, Nigeria." GeoJournal **71**(2-3): 83-91.

Ramsiya, M., A. Joseph and J. P..J. (2017). "Estimation of indoor radon and thoron in dwellings of Palakkad,Keral, India using solid state nuclear track detectors." Journal of Radiation Research and Applied Sciences **10**: 269-272.

Sambo, I. (2013). Assessment of occupational and public exposure arising from Tin processing industries in Jos-Central Nigeria. Ph.D, Ahmadu Bello University, Zaria, Nigeria.

Shilpa, G. M., B. N. Anandaram and T. L. Mohankumari (2017). "Measurement of 222Rn concentration in drinking water in the environs of Thirthahalli taluk, Karnataka, India." Journal of Radiation Research and Applied Sciences **10**(3): 262-268.

UNSCEAR (2010). Sources and Effects of Ionizing Radiation United Nations Scientific Committee on the Effects of Atomic Radiation, UNSCEAR 2008, Report to the General Assembly with Scientific Annexes. New York United Nations Scientific Committee on the Effects of Atomic Radiation. **1:** 235-236.

Usikalu, M., O. Anoka and F. Balogun (2011). "Radioactivity measurements of the Jos Tin mine tailing in Northern Nigeria." Archives of Physics Research **2**(2): 80-86.

Vaupotič, J., I. Kobal and J. Planinić (1998). "Long-term radon investigation in four selected kindergartens in different geological and climate regions of Slovenia." Journal of radioanalytical and nuclear chemistry **238**(1-2): 61-66.

Vaupotic, J., M. Krizman, J. Planinić, J. Pezdic, K. Adamic, P. Stegnar and I. Kobal (1994). "Systematic indoor radon and gamma measurements in kindergartens and playschools in Slovenia." Health physics **66**(5): 550-556.

Wapwera, S. D., G. M. Ayanbimpe and C. E. Odita (2015). "Abandoned Mine, Potential Home for the People: A Case Study of Jos Plateau Tin-Mining Region " Journal of Civil Engineering and Architecture **9**: 429-445.

WHO (2004). Guidelines for drinking water quality. Radiological aspects Geneva World health organization.

Wiwanitkit, V. (2008). "Minor heavy metal: A review on occupational and environmental intoxication." Indian J Occup Environ Med. **12(3): 116–121.**(3): 116–121.