Evaluation of Background Radioactivity In Ogbete Coal Mine Dumpsites In Enugu, Nigeria

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Abstract: The assessment of naturally occurring radionuclides 238U, 232Th and 40K in Ogbete coal mine dumpsites in Enugu were carried out using gamma-ray spectrometry with high purity germanium detector to determine the natural radionuclide in the dumpsites and to evaluate the hazards these might have on the public. The calculated average activity concentration of 238U, 232Th and 40K in the samples were 18.7 ± 2.9 Bqkg-1, 24.4 ± 2.2 Bqkg-1, and 164.4 ± 17.3 Bqkg-1 respectively. The mean activity concentration of 238U, 232Th and 40K in the present study is much lower than the world-wide average values of 33 Bqkg-1, 45 Bqkg-1 and 420 Bqkg-1 respectively. The present study revealed that the calculated average absorbed dose rate, indoor annual effective dose rate and outdoor annual effective dose were found as 31.2 nGyh-1, 0.15 mSvy-1 and 0.04 mSvy-1 respectively. The mean values of the absorbed dose rate, the indoor and outdoor annual effective dose rates are much lower than the world average recommended safety limits. The International Commission on Radiological Protection (ICRP) has recommended the annual effective dose equivalent limit of 1mSvy-1for the individual members of the public and 20mSvy-1 for the radiation workers. Therefore it can be concluded that the present study area is radiologically safe from radiation hazards and will pose no harmful effects to the environmental and the living population.

Keywords: Radioactivity, Gamma rays, Absorbed Dose Rate, Annual Effective dose, Tin mining, Radionuclides, Dumpsites.

1. Introduction

Coal deposits result from the accumulation of drifted wood carried from the land and laid down under water at the mouths of large rivers. Principally, the main elements in coal are carbon, hydrogen, nitrogen and sulphur, (excluding the inherent plant ash). Apart from the major organic and inorganic constituents, coals contain a variable assemblage of elements in trace amounts.

Natural radioactivity is wide spread in the earth environment and it exists in various geological formations such as earth crust, rock, soils, plant and air (UNSCEAR, 2000). Other natural sources of radioactivity in the environment include coal and oil which contain traces of primordial radionuclides. These natural radiation sources are released during fuel extraction and burning particularly in the light fly ash from coal which is released through the exhaust of the plant and from oil when brine is burnt. Phosphate rocks mined for use in fertilizers contain high concentrations of uranium, and radon is released into the environment during mining and processing of the ores. Soil provides a direct source of radioactivity in food chain due to its uptake by agricultural plants. The radioactivity caused by radionuclides can be transferred from soil, water, air to plants, tress and other biological elements and finally to human body. The natural radioactivity of soil samples is usually determined from its ^{238}U, ^{232}Th and ^{40}K contents. It is widely spread in the earth's environment and depends primarily on the geological and geographical

conditions, and appears at different levels in the soil of each region in the world (UNSCEAR, 2000).

Coal was first discovered in Enugu in 1909, and the Ogbete Mine had opened and begun regularly extracting coal by 1916. By 1920, coal production had reached 180,122 long tons. Peak production was in 1960 when the production was at 565,681 long tons. The Nigerian Coal Corporation (NCC) held a monopoly on the mining, processing and sales of coal, lignite and coke products until 1999. As of 2005 coal mining was no longer the major source of income and mines sites became unused. (Nwaobi, 2008). Different types of environmental damage and hazards inevitably accompany the harnessing of this mineral (UNSCEAR 2000). Bye products from mining and processing of coal contain some heavy metals that are highly radioactive which are often dumped in the mining site indiscriminately due to lack of market. De wet, (1996) found that a wide range of agricultural products including milk meat and vegetable from farms near mining areas and polluted rivers contain radium. Exposure to these radionuclides constitutes a health hazard. IARC monographs have concluded that there is sufficient evidence that exposure to radium-226 cause bone sarcomas and mastoid process while radon-222 is a cause of lung cancer (IARC, 2012). Although review of literature revealed that studies have been done on coal (Nwankpa, 2010) but there are generally little or no awareness and knowledge of the radiological hazards and exposure levels to NORMs in mining areas as people still use the dumps either for building or the mining sites for dry season farming. Numerous types of human activities and non-nuclear industries contribute to further concentrate some of the natural radionuclides that can be found in the earth crust affecting the human and the environment. Gamma radiation from the natural radionuclides and cosmic rays constitute the external exposure to humans while those from inhalation and ingestion through foods and drinking water constitutes internal exposure to humans (Masok, et al 2015). The present study is aimed at determining the level of radioactive elements (uranium, thorium and potassium) and corresponding health risk due to exposure to these radionuclides from coal mine soil dumped in Ogbete Enugu.

Study Area.

The City of Enugu, is located between longitudes 7^{o} 6'E and 7^{o} 54'E and latitudes 5^{o} 56'N and 6^{o} 52'N. The state shares borders with Abia State and Imo State to the south, Ebonyi State to the east, Benue State to the north-east, Kogi State to the northwest and Anambra State to the west. It is 2545m (meter) above the mean sea level, with an area of about 79.25 square kilometers. The soil characteristically consists of hydro-orphic soil which is mineral rich soil and whose morphology is influenced by seasonal water logging caused by underlying impervious shale. The annual rainfall varies between 100 to 200 meters with its peak occurring between mid-March and September. The rainfall average is 1412 millimeters per month, with the lowest rainfall in February. The temperature is generally high throughout the year with monthly maximum temperature ranging between 28.1^{o}C and 32.2^{o}C. Enugu, which literally means hilltop, derives its name from its position among the Udi Hills, which is at an altitude of about 223 meters above sea level. Its intimate association with coal has earned it the euphemistic name of 'Coal city'. (Amalu and Ajake 2014)

2.0 MATERIALS AND METHODS.

2.1 Sample Collection.

Soil samples were collected from different coal mine dumps of the study area using digger and spade. The samples were air dried for several days to attain a constant weight. The samples were then crush and sieved with a 2 mm mesh sieve in order to remove organic materials, piece of stones, gravels and lumps. 250 g each of the sieved soil samples was then transferred to 1-L Marinelli beakers and sealed. The soil samples remained in the sealed 1-L Marinelli beakers for 28 days, which is a sufficient time required to attain a state of secular radioactive equilibrium prior to gamma-spectrometry (Veige *et al*. 2006).

2.2 Gamma Counting and Activity Determination.

The gamma counting using high purity germanium (HPGe) detector was done in the Department of Physics, University of the Western Cape, Cape Town, South Africa. The prepared sealed samples were placed over the HPGe detector respectively for counting. The HPGe detector, Canberra model used is of coaxial geometry with one end open and a closed end-facing window. The detector was operated at a negative bias voltage of 4000 V DC. The detector with the accompanying pre-amplifier, connected to the Multi-channel Analyzer (MCA) was mounted on a vertical dipstick cryostat, model 7500. The detector element is held in place with a holder which is electrically isolated but thermally connected to a copper coldfinger which transfers heat from the detector to the liquid nitrogen reservoir. The mean counting time for each sample was 36000s. Also, an empty 1-L Marinelli beaker was counted under identical geometry as the samples in other to determine the background spectrum distribution. The photo peak of gamma transmission at 1460 KeV was used for the measurement of ^{40}K while the peak at 1760 KeV from ^{214}Bi and 2614 KeV from ^{208}Tl were used for the measurement of ^{226}Ra (^{238}U) and ^{228}Ra (^{232}Th) respectively. The gamma lines from recorded spectra were first assigned qualitatively using the energy calibration curve and then evaluated quantitatively using the efficiency calibration curve. The concentration C_s in BqKg^{-1}, of a nuclide contained in an analyzed sample is given by:

$$C_s = \frac{N(E_\gamma)}{\varepsilon(E_y) M_s P_y t_c} \quad (1)$$

where, $N(E_\gamma)$ is the net count rate of nuclide in counts/secs, $\varepsilon(E_\gamma)$is the absolute efficiency of the detector for the specific nuclide, P_γ is the absolute γ-ray emission probability of the nuclide at the particular energy, M_s is the dried mass of the sample used in Kg and t_c is the total counting time for the sample.

2.3 Absorbed Dose Rate.

The absorbed dose rate in air, D, due to the natural occurring radionuclides (^{238}U, ^{232}Th and ^{40}K) in the soil samples were calculated using (Leung, et al 1990):

$$D = 0.428_{AU} + 0.666_{ATh} + 0.042_{AK} \quad (2)$$

Where, $A_{U,}$ A_{Th} and A_K, are the specific activity concentrations for ^{238}U, ^{232}Th and ^{40}K, (in Bqkg^{-1}) respectively.

Assuming that ^{137}Cs, ^{90}Sr and ^{235}U decay series can be neglected, they contribute very little to the total dose from the environmental background (Leung et al.,1990).

2.4 Annual Effective Dose Rate

To estimate the annual effective dose rate ($mSvy^{-1}$) due to the natural radionuclides in the soil samples, the following factors were considered (i) the conversion factor of 0.7 $SvGy^{-1}$ (UNSCEAR, 2000) which converts the absorbed dose in air to effective dose. (ii) The indoor and outdoor occupancy factors of 0.8 and 0.2 were used respectively (Masok *et al* 2015; UNSCEAR 1988), these occupancy factors are the proportion of the total time during which an individual is exposed to a radiation field. (iii) Eight thousand seven hundred and sixty hours per year (iv) the factor converting nano to milli (10^{-6}). The effective dose rate was calculated using the equation given by (Kessaratikoon *et al*. 2008; Masok *et al*.2015).

$$IAEDR = D \times 0.7 \times 8760 \times 0.8 \times 10^{-6} \quad (3)$$

$$OAEDR = D \times 0.7 \times 8760 \times 0.2 \times 10^{-6} \quad (4)$$

Where (IAEDR) is the indoor annual effective dose rate and (OAEDR) is the outdoor annual effective dose rate.

3.0 RESULTS

The results of activity concentration of radionuclides obtained from gamma ray analysis of soil samples collected from Ogbete coal mine dumpsite area are presented in table 1. The gamma absorbed dose rate ($nGyh^{-1}$) at 1m above the ground due to ^{238}U, ^{232}Th and ^{40}K in the soil samples was calculated using (2) and presented in table 2. The indoor annual effective dose rate ($mSvy^{-1}$) was calculated using (3) while the outdoor annual effective dose rate was calculated from (4) and presented in columns 3 and columns 4 respectively in table 2

Table1. Activity Concentration of Radionuclide in the Soil Sample.

Sample Identity	^{226}Ra (^{238}U) ($BqKg^{-1}$)	^{228}Ra (^{232}Th) ($BqKg^{-1}$)	^{40}K ($BqKg^{-1}$)
ES-01	21.2 ± 2.4	27.6 ± 1.5	155.5 ± 15.6
ES-02	22.8 ± 2.6	28.8 ± 2.9	150.7 ± 16.0
ES-03	27.4 ± 3.0	29.7 ± 0.8	156.5 ± 13.5
ES-04	15.3 ± 2.9	19.2 ± 0.8	115.2 ± 20.1
ES-05	19.9 ± 3.7	23.3 ± 1.8	143.5 ± 18.8
ES-06	17.9 ± 2.9	22.4 ± 1.6	136.0 ± 20.3
ES-07	18.2 ± 2.4	27.9 ± 0.5	140.9 ± 19.5
ES-08	17.7 ± 2.3	25.1 ± 1.8	142.4 ± 16.6
ES-09	11.5 ± 3.1	19.7 ± 0.7	268.4 ± 32.0
ES-10	14.7 ± 3.0	20.1 ± 1.7	234.9 ± 22.5
Min	**11.5 ± 3.1**	**19.2 ± 0.8**	**115.2 ± 20.1**
Max	**27.4 ± 3.0**	**29.7 ± 0.8**	**268.4 ± 32.0**
Average	**18.7 ± 2.9**	**24.4 ± 2.2**	**164.4 ± 17.3**
World Average	**33**	**45**	**420**

Table 2. Calculated Values of Absorbed Dose Rate, Indoor and Outdoor Annual Effective Dose Rates.

Sample Identity	Total Absorbed Dose Rate ($nGyh^{-1}$)	Annual Effective Dose Rate ($mSvy^{-1}$)	
		Indoor	Outdoor
ES-01	34.0	0.17	0.04
ES-02	35.3	0.17	0.04
ES-03	38.1	0.19	0.05
ES-04	24.2	0.12	0.03
ES-05	30.8	0.15	0.04
ES-06	28.3	0.14	0.03
ES-07	32.0	0.16	0.04
ES-08	29.9	0.15	0.04
ES-09	29.3	0.14	0.04
ES-10	29.6	0.15	0.04
Min	**24.2**	**0.12**	**0.03**
Max	**38.1**	**0.19**	**0.05**
Average	**31.2**	**0.15**	**0.04**
World Average	**59**	**0.50**	**0.07**

4.0 DISCUSION OF RESULTS.

4.1 Activity Concentration of Radionuclide.

Table1 summarizes the results of measurement of natural radionuclides (^{238}U, ^{232}Th and ^{40}K) concentration in the collected soil samples. World

average concentrations are 33 Bqkq^{-1}, 45 Bqkg^{-1} and 420 Bqkg^{-1} for^{238}U, ^{232}Th and ^{40}K respectively (UNSCEAR 2000). From table 1, the activity concentration of ^{238}U ranges from 11.5 ± 3.1Bqkg^{-1} to 27.4 ± 3.0 Bqkg^{-1} with an average of 18.7 ± 2.9 Bqkg^{-1} while that of ^{232}Th ranges from 19.2 ± 0.8 Bqkg^{-1} to 29.7 ± 0.8 Bqkg^{-1} with an average of 24.4 ± 2.2 Bqkg^{-1} and that of ^{40}K ranges from 115.2 ± 20.1Bqkg^{-1} to 268.4 ± 32.0 Bqkg^{-1} with an average of 164.4 ± 17.3Bqkg^{-1}. The ranges and averages of activity concentration of ^{238}U, ^{232}Th and ^{40}K in the study area are lower than the world figures of 33 Bqkg^{-1}, 45 Bqkg^{-1} and 420 Bqkg^{-1} respectively.

4.2 Radiological Implication.

Radiation dose depend on the intensity and energy of radiation, type of radiation, exposure time, the area exposed and the depth of the energy deposition. In order to assess the health effects of people living in the study area, the 'Absorbed Dose Rate' (D), 'Indoor Annual Effective Dose Rate' (IAEDR) and the 'Outdoor Annual Effective Dose Rate' (OAEDR) have been calculated from the activity concentration of ^{238}U, ^{232}Th and ^{40}K using equations (2), (3) and (4) respectively and the values are presented in Table 2.

Table 2 shows that, the absorbed dose rates due to the terrestrial gamma rays at 1m above the ground in the study area are in the range of 24.2 nGyh^{-1} to 38.1 nGyh^{-1} with an average of 31.2 nGyh^{-1} which is lower than the world average value of 59 nGyh^{-1} given by (UNSCEAR, 2000). The indoor annual effective doses are in the range of 0.12 mSvy^{-1} to 0.19 mSvy^{-1} with an average of 0.15 mSvy^{-1} while the outdoor annual effective doses are in the range of 0.03 mSvy^{-1} to 0.05 mSvy^{-1} with an average value of 0.04 mSvy^{-1} both of which are lower compared with the world average value of 0.5 mSvy^{-1} and 0.07 mSvy^{-1} respectively (UNSCEAR, 2000).

5. Conclusion

The international commission on radiological protection has recommended the annual effective dose equivalent limit of 1mSvy^{-1} for the individual members of the public and 20 mSvy^{-1} for the radiation workers. The ranges and averages of activity concentration of ^{238}U, ^{232}Th and ^{40}K in the study area are lower than the world figures of 33 Bqkg^{-1}, 45 Bqkg^{-1} and 420 Bqkg^{-1} respectively as reported by (UNSCEAR, 2000). The Slight variation observed in the activity concentration of the soil samples may be attributed to the soil type, formation, geological location and transport process involve in the study area. The Average value of the absorbed dose rate (31.2 nGyh^{-1}) was much lower than the world average value of 59 nGyh^{-1} (OECD, 1979). The results show that the indoor annual effective dose from natural radioactivity has an average value lower than the natural world recommended value. The values of hazards indices confirm that the study area is radiologically safe for agricultural activities and residential purposes. This assertion could be verified because no significant radiological impact has been observed on the surrounding environment and the living population of the present study area.

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