Assessment of Naturally Occurring Radioactive Materials (NORMS) in Soils from Selected School Playgrounds in Zungeru

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Abstract: **Assessment of environmental radiation exposure potentials is a source of concern to nuclear scientist and policy makers as this could pose serious health threat to residence were radioactivity level exceeds the recommended value. This necessitates the need for survey of radionuclide level and exposure hazard parameters in all inhabitants to ascertain the risk to dwellers. In the present study, six soil samples were collected from playgrounds in six different schools in Zungeru township and analyzed using gamma spectroscopy for radionuclide's specific activity for Ra-226, Th-232 and K-40, from which radon equivalent, Annual Effective Dose Equivalent, Radon, External and Internal Hazard were calculated to determine the ionizing radiation exposure risk potentials. The mean measured specific activity and calculated exposure parameters were found to be 44.65±2.83 Bqkg^{-1}(Ra-226), 13.07±2.35 Bqkg^{-1} (Th-232), 227.18±13.95 Bqkg^{-1}(K-40), 73.626 nGy/h, 0.36118 mSv/y, 78.176 Bqkg^{-1}, 0.218 and 0.223 respectively. The results obtained for both the radionuclide specific activity and the exposure hazard parameters compared well with similar analysis conducted in 19 other countries and the world average. In addition the calculated exposure hazard parameters are all within safe acceptable limit for public. However, there is need to extend the conducted assessment of Naturally Occurring Radioactive materials (NORMs) to other environmental samples to attain a more general conclusion. These findings will serve a preliminary baseline data for radionuclide activity concentration in Zungeru.**

Keywords: **NORMS, Gamma spectroscopy, Specific activity, Exposure hazard parameters.**

1. BACKGROUND

The origin of Naturally Occurring Radioactive Materials (NORMs) dates back to the creation of the universe which is responsible for both terrestrial and extraterrestrial radiation. Most of the environmental NORMs results from the decay chain of K-40, Ra-226 and Th-232 which exist in varying degrees in all soils and rocks. In soil samples, the natural radioactivity measure is usually given by the representative specific activity of ^{226}Ra ^{232}Th, and ^{40}K (NCRP, 1993).

Studies and survey of natural environmental radiation which constitute main source of human exposure are of great importance and interest in health physics, it is therefore necessary to evaluate the natural radiation background in order to detect contamination among population and environment. Studies on radiation levels and radionuclide distribution in the environment provide vital radiological baseline information. Such information is essential in understanding human exposure from natural and man-made sources of radiation and necessary in establishing rules and regulations relating to radiation protection (Harb *et al.*, 2008).

Natural radioactivity arises mainly from the primordial radionuclides, such as K-40, Ra-226 and Th-232 series and their decay products, which are present at trace (Abdel-Mageed *et al.*, 2010). *Potassium-40:* Potassium is the seventh most abundant element in the crust and the sixth most abundant element in solution in the oceans. Potassium-40 is an important radionuclide in terms of the dose associated with naturally occurring radionuclides. Radioactivity from the ^{40}K in our own bodies accounts for about half of our yearly exposure to all sources of radiation. K-40 like all radionuclide elements can cause cancer via inhalation and ingestion (Peterson *et al.*, 2007).

Radium-226 All isotopes of radium have half-lives much shorter than the age of the Earth, so that any primordial radium would have decayed long ago. Radium-226 is the parent of Radon-222, a radioactive gas responsible for 60% of the total radiation dose received from natural and man-made sources. Radon-222 is the second most frequent cause of lung cancer, after cigarette smoking, causing 21,000 lung cancer deaths per year in the United States (Henshaw *et al.*, 1990). Radium is highly radioactive and its immediate daughter, radon gas, is also radioactive. When ingested, 80% of the ingested radium leaves the body through the feces, while the other 20% goes into the bloodstream, mostly accumulating in the bones (epa.gov/radiation).

*Th-232***:** Thorium is estimated to be about three to four times more abundant than uranium in the Earth's crust. When thorium is ingested, 99.98% does not remain in the body. Out of the thorium that does remain in the body, three quarters of it accumulates in the skeleton. While absorption through the skin is possible, it is not a likely means of thorium exposure.

2. STUDY OBJECTVE

The objective of the present work is investigate exposure levels to ionizing radiation from Naturally Occurring Radioactive Materials (NORMS) in Soils from selected School Playgrounds in Zungeru. The specific objectives are to:

1. Determine the levels activity concentrations of naturally occurring radio-nuclides (^{226}Ra and ^{232}Th and ^{40}K) in Soils from selected School Playgrounds in Zungeru.
2. Determine the absorbed dose rate in air in Soils from selected School Playgrounds in Zungeru
3. Measure the Annual effective dose rate to people (especially pupils) from the selected School Playgrounds.
4. Quantify the internal and external hazard indices.

3. SAMPLING AND SAMPLE PREPARATION

Natural occurring Radionuclides are present in various degrees is all environmental samples including soil. Perhaps the chief source where children get in contact with soil the most is the school's playground. To determine the extent of this exposure, soil samples from six different schools in Zungeru Township were analyzed for radionuclide specific activity concentration due to Th-232, Ra-226 and K-40. For each of the samples, four different portions were taken to make a composite sample. These samples were grinded to powder form to attain homogenization. The samples were oven-dried at 110 ^{o}C for 24 hrs to ensure that moisture is completely removed. The samples were sieved, packed in plastic containers, labelled, weighted and hermetically sealed with a plastic tape. The samples containers used were selected in order to match the container geometry used for efficiency calibration. The sealed samples were then stored for 30 days to enable them attain a state of secular equilibrium with their short lived progeny.

4. EXPERIMENTAL

Nuclear Spectroscopy involves the use of detectors to acquire radiation energy and convert them into photo peaks whose sizes are proportional to the gamma energy of the sample's atomic constituent. The device set-up to achieve this is called the spectrometer. Nuclear spectrometers is either a single channel instrument or a multi-channel analyzer (MCA). The single channel analyzer spectrometer consist of the detector, a linear amplifier, a pulse height selector, and a readout device, such as scalar or rate meter. The Single channel analyzer discriminate between a desired radiation and other radiation that may be considered noise making the measurement of one radioisotope in the presence of the other radioisotope possible.

The sample to be measured is placed in the coaxial high purity germanium (HPGe) semiconductor ray detector followed by the measurement of the activity of the induced radioisotopes in the standard reference materials on the same coaxial HPGe ray detector and at the same source-detector distance. The spectrum acquisition was achieved using ORTEC MAESTRO-32 spectroscopy software.

Detector Resolution:

The 137Cs source from the gamma source kit was placed in front of the HPGe detector in the 4th shelf. The coarse and fine gain controls of the 575A Amplifier was adjusted. Accumulation of the Co-60 spectrum was allowed for a time period long enough to determine the peak position.

The MCA was Readout and the result are as follows.

- Maximum count = 380
- Channel at maximum count, CMC = 399
- Right Channel = 499
- Left Channel = 375
- Full Width at Half maximum, FWHM = Cannel Difference

$$Resolution = \frac{FWHM}{CMC} = \frac{499 - 375}{399} = 0.185$$

The resolution of the HPGe detector was found to be 0.185

5. RADIONUCLIDE MEASUREMENT

In line with the methodology used by Ndontchueng *et al.,* (2013), each sample was counted for 86400 seconds for effective peak attainment. The background was also counted under the same conditions for 48 hrs and subtracted from the photo peak area for the measured samples during analysis process. The specific activity concentration in Becquerel per kilogram (Bq.kg- 1) for each radionuclide was calculated using equation 1.

$$A_{sp} = \frac{\frac{N_S}{t_S} - \frac{N_B}{t_B}}{\varepsilon(E_i) \times P_{\gamma i} \times M_S \times C} \qquad (1)$$

where: Ns is the net counts of the radionuclide in the samples; N_B is the net counts of radionuclide in the background; $P_{\gamma i}$ is the gamma emission probability (gamma yield); $\varepsilon(E_i)$ is the peak efficiency of the detector at energy Ei; t_s is the sample counting time; t_B is the background measuring time; M_s is the mass of the sample (kg) and C is the cascade summing correction coefficient.

6. RESULTS AND DISCUSSION

Details of sampling coordinates for each playground as well as specific activity concentration are summarized in Table 1.

Table 1: Sampling coordinate and radionuclide specific activity concentration

School	GPS coordinates	Ra (BqKg^{-1})	Th (BqKg^{-1})	K (BqKg^{-1})
Royal	9.802 N, 6.15 E	27.9±2.8	12.1±2.9	206.7±11.2
Madaki	9.804 N, 6.147 E	78.5±4.7	14.9±3.6	241.2±10.4
Unity	9.812 N, 6.151 E	41.6±1.5	6.1±1.2	163±5.9
Central	9.809 N, 6.155 E	36.7±2.4	13.9±1.7	228.8±17.1
Abu-hamzat	9.811 N, 6.156 E	54.1±4.4	11.9±3.2	261.7±12.4
Assul-islam	9.808 N, 6.153 E	29.1±1.46	19.5±1.5	449.2±26.7
World average		**45**	**32**	**420**

7. DETERMINATION OF EXPOSURE HAZARD PARAMETERS

The measured Radionuclide's Specific Activity of ^{226}Ra ^{232}Th, and ^{40}K (Bqkg-1) in the soil samples are used to calculate the absorbed dose rate (D) Annual Effective Dose Equivalent (AEDE), Radium Equivalent Activity (Raeq), External Hazard Index (H_{ex}) and Internal Hazard Index (H_{in}) using equations 2 to 7 respectively.

$$D(nGy.h^{-1}) = 0.92A_{Ra} + 1.1A_{Th} + 0.08A_K$$ (2) (UNSCEAR, 2000).

$$AEDE(\mu Sv.y^{-1}) = D(nGy.h^{-1}) \times 8760h \times 0.8 \times 0.7Sv.Gy^{-1} \times 10^{-6}$$ (3) (UNSCEAR, 2000).

$$R_{eq}(Bq.Kg^{-1}) = A_{Ra} + 1.43A_{Th} + 0.077A_K$$ (4) (Beretka and Mathew, 1985)

$$H_{ex} = \frac{A_{Ra}}{370} + \frac{A_{Th}}{259} + \frac{A_K}{4810} \leq 1 \quad (5)$$ (Kpeglo *et al.*, 2011; UNSCEAR, 2000; Ndontchueng *et al.*, 2013)

$$I_\gamma = \frac{A_{Ra}}{200(\frac{Bq}{kg})} + \frac{A_{Th}}{300(\frac{Bq}{kg})} + \frac{A_K}{3000(\frac{Bq}{kg})} \quad (6)$$ (EC, 1999)

$$I_\alpha = \frac{A_{Ra}}{200(\frac{Bq}{kg})} \quad (7)$$ (Ndontchueng *et al.*, (2013)

where: A_{Ra}, A_{Th} and A_K are the activity concentration of ^{226}Ra (238U), ^{232}Th and ^{40}K, respectively.
Summary of the results obtained on evaluating data on Table 1 using equations 2 to 7 are presented in Table 2.

Table 2: Radiation Hazard Parameters

School	D (nGy/h)	AEDE (mSv/y)	Raeq (Bqkg-1)	H_{ex}	I_α
Royal	55.514	0.272329	63.7754	0.165097	0.1395
Madaki	107.906	0.529344	112.358	0.319837	0.3925
Unity	58.022	0.284633	67.9406	0.169872	0.208
Central	67.358	0.330431	76.7279	0.200425	0.1835
Abu hamzat	83.798	0.411079	91.2679	0.24657	0.2705
Assul islam	69.158	0.339261	56.985	0.208346	0.1455
World average	**60**	**0.410**	**370**	**<1**	**≤ 0.5**

Worldwide averages of all the measured activity concentration and calculated exposure hazard parameters are compared with those measured in the present studies for validation. Data for mean values of a wide range of samples analyzed for NORMS were evaluated for percentage composition of Ra-226, Th-232 and K-40 radionuclides. The reviewed literature are based on analysis of over 1000 environmental samples investigated for activity concentration. The sampling geology covered some 18 countries at random as presented in Table 3.

Table 3: Review of NORMs' Specific Activity.

Country	Ra 226	%Ra	Th232	%Th	K-40	%K	Refence
Australia	51.8	24.13793103	48.1	22.4137931	114.7	53.44827586	Beretka and Mathew (1985)
Austria	26.7	10.64168992	14.2	5.659625349	210	83.69868473	Sorantin and Steger(1984)
Bangladesh	61	4.788069074	80	6.279434851	1133	88.93249608	Roy *et al.* (2005)
Brazil	61.7	9.017831044	58.5	8.55013154	564	82.43203742	Malanca *et al.*, (1993)
China	51.7	17.74193548	32	10.98146877	207.7	71.27659574	Lu et al. (2012)
Egypt	35	23.80952381	19	12.92517007	93	63.26530612	Elbahi, (2004)
Finland	40.2	12.92189007	19.9	6.396657023	251	80.68145291	Mustonen (1984)
Greece	92	21.24711316	31	7.159353349	310	71.59353349	Stoulos *et al.*, (2003)
Italy	46	11.38613861	42	10.3960396	316	78.21782178	Sciocchetti *et al.*, (1984)
Japan	36	18.36734694	21	10.71428571	139	70.91836735	Suzuki *et al.*, (2000)
Malaysia	81.4	23.65591398	59.2	17.20430108	203.5	59.13978495	Chong and Ahmed (1982)
Netherlands	27	9.782608696	19	6.884057971	230	83.33333333	Ackers *et al.*, (1985)
Norway	29.6	9.638554217	18.5	6.024096386	259	84.3373494	Stranden and Bertiez, (1980)
Pakistan	26.1	7.96460177	28.7	8.758010375	272.9	83.27738785	Khan and Khan (2001)
Turkey	41	12.2754491	26	7.784431138	267	79.94011976	Turhan, (2008)
Nigeria	43.8	31.97080292	21.5	15.69343066	71.7	52.33576642	Ademola, (2008)
Ghana Present	35.94	11.505218	25.44	8.143927268	251	80.35085473	Kpeglo *et al.*, (2011)
Work	44.65	15.67217	13.06667	4.586405	227.1833	79.74143	Present Work
Algeria	41	8.367346939	27	5.510204082	422	86.12244898	Amrani and Tahtat, (2001)
World Average	32	6.438632	45	9.054326	420	84.50704	Ndontchueng *et al.*, (2013)

The review is done in order to assess the risk to exposure of Ra-226, Th-232 and K-40 among the individuals coming in contact with the studied soil. The observed result are further evaluated to ascertain the present work's measured specific activity in comparism with other existing literature from 17 countries.

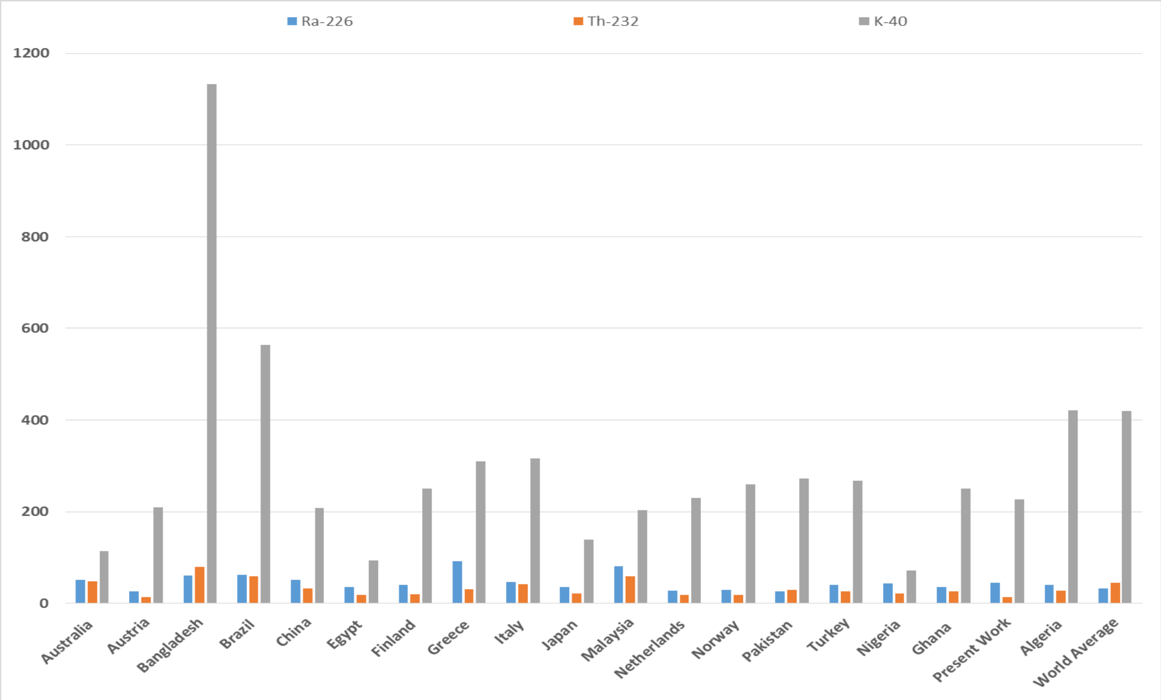

Figure 1: Comparism of Specific Activity in Literature and the present work

8. CONCLUSION

The computed results for both the external and internal hazard indices are less than unity and 0.5 respectively, which are the limits acceptable by ICRP 2000. The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were all found to be above the world's average as can be seen from Table 1. Thorium and potassium contributed the lowest and highest values respectively to the measured specific activities in all the playgrounds. The annual effective dose rate in all the samples analyzed was less than 1 mSvy^{-1}, which is the acceptable limit for public. Since the annual effective dose rate obtained is less than the limit set for the public, coming in contact with soils in the considered playgrounds then the evaluated samples did not pose any threat to the pupil's and public in these schools.

9. RECOMMENDATIONS

- Additional soil and other environmental samples should be collected from these and more schools for analysis to get more confirmatory results.
- Research should be done to determine the presence of heavy metals in schools playgrounds.
- Pupils should be encouraged to maintain personal hygiene practices such as washing hands thoroughly at meal times because there is a possibility of high levels of toxic elements.
- Large scale surveys to ascertain the distribution and concentration of these NORMS in the country should be initiated to enable policy makers design suitable measures to minimize the risk of exposure among dwellers.

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