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Determination of Activity Levels 226ra, 232th and 40k in some Soil Samples of Federal Polytechnic Kaltungo Main Campus Using Gamma Ray Spectrometry

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Authors' contributions

This work was carried out in collaboration among all authors. Author SHS designed the study, the objective, methodology and wrote the first draft of the manuscript, Author LDAJ conducted the sample collection and preparation. Author DHI conducted research in the literature review. Author AAK managed the analysis of the soil samples collected from the study area. Author DDH conducted the background radiation reading of the study area. All authors read and approved the final manuscript.

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ABSTRACT

This paper presents an investigation on radioactivity level of radioactive elements within Federal Polytechnic Kaltungo Main Campus. A total of forty (40) soil samples were analyzed using Gamma-Ray Spectrometry of 76×76mmNaI (TI) detector crystal with radioactivity activity concentration of potassium (40K), Radium (226Ra) and Thorium (232Th) were determined within the study area. Results obtained showed the highest activity concentration of 40K, 226Ra, and 232Th from locations AB3 (898.7365 Bq/kg), AB3 (107.7457 Bq/kg) and AB2 (243.1510 Bq/kg) respectively. The mean activity of 206.7681 Bq/kg obtained for 40K was seen to be lower than the world average of 420 Bq/kg while the mean activity concentrations of 232Th (95.393 Bq/kg) was above the world average of 50 Bq/kg. These upshots could be attributed to the presence of mountains which surround the polytechnic and the quarry activity taking place close to the polytechnic. Equally, Thorium. 226 Ra also had a lowest mean activity concentration of 43.8600 Bq/kg, which is also lower than the world average of 370 Bq/kg. In-situ dose rate measurement of the study area was also carried out using a Radiation Alert Inspector meter and the background radiation reading obtained was seen to fall within a range of 0.11μsv/hr - 0.21μsv/hr, which did not exceed the 1mSv/yr as recommended by National Council on Radiation Protection (NCRP).

Keywords: Background radiation; activity concentration; gamma ray spectrometry.

1. INTRODUCTION

Ionizing radiation exposure comes from two main sources, both of which are widely known to exist as naturally occurring radionuclides (NORs) on Earth. These include both natural and artificial sources. On the crust of the planet, there is naturally occurring radioactivity that may be further divided into two different sources, such as virgin and modified natural sources. Virgin sources of radiation are those that have existed on the earth from the beginning of time and are either cosmogenic or of primordial (terrestrial) origin. Mining, the use of non-renewable energy, the manufacturing of fertilizers, or the use of natural materials in building construction are the primary sources of modified natural sources, sometimes referred to as technologically enhanced natural radiation (TENR). Inhalation of radon and its offspring which is dangerous to human from natural radiation in locations with a high background radiation level. The primary external source of irradiation to the human body is gamma radiation from radionuclides like the 226Ra, 40K, and 232Th family, as well as their decay products. At sea level, the absorbed dose rate from cosmic radiation in the air is around 30 $nGyh^{-1}$ [1].

Exposures to gamma radiation result from the traces of terrestrial radionuclides present in all rock formations. Similarly, to this, the key factors affecting natural environmental radiation are the location's geology and climate [2]. These directly affect the level of absorbed dose received in a location by altering the soil composition and natural radioactivity concentration levels. Lower levels of radiation are connected with sedimentary rocks and greater levels with igneous rocks like granite. There are certain exceptions; for example, some shale and phosphate rocks contain a significant number of radionuclides [3].

Studies have shown that the wide distribution of radionuclides in rocks and soils contributes significantly to the background radiation dose received by humans [4]. High levels of radionuclides and the radiation they emit can potentially cause health complications and system malfunction [4]. Therefore, it is important to evaluate the level of naturally occurring radioactive materials (NORM) in environmental samples for public health purposes [4].

Ionizing radiation is a natural environmental hazard whose potential physiological (somatic) and genetic damage have been released greatly. With the discovery of atomic and nuclei energy amidst advancements in technology, the beneficial uses of technological enhanced radiation, especially in the production of power are being continuously increased and these expose man to harmful radiations. The long half-life of some radioisotopes and the lack of knowledge of the effect of high chronic doses make adequate environmental radiation protection a reason for caution in balancing benefits and risks (Sathish et al., 2010).

[5] examined the impact of environmental radiation on the incidence of cancer and birth

defects in regions with high natural radioactivity. They observed that natural radioactive elements released from crystalline rock can enter trophic chains, including soil, plants, animals, and humans, leading to increased radiation exposure and potential health effects.

Several studies have been carried out on assessing radioactivity level of radioactive element both within and outside Nigeria to understand the sources, effects, and risks of ionizing radiation These studies have highlighted the importance of accurate information about the health effects of exposure to high levels of background radiation. However, many published papers suffer from methodological and other common types of errors [6]. Therefore, it is crucial to critically review and evaluate the existing literature on high background radiation areas to ensure the reliability of the findings.

Modeling background radiation in urban environments can be challenging due to spatial-temporal fluctuations caused by variations in soil composition, building materials, and weather patterns [7]. Mobile sensor networks have been developed to continuously monitor background radiation and estimate its spatial distribution and temporal fluctuation [7].

Another important aspect of background radiation research is its assessment and risk evaluation. Studies have been conducted to assess the radiation risk from background radiation exposures in hospitals. These studies provide valuable information on the levels of natural background radiation and the associated risks in healthcare settings.

[8] assessed the natural radioactivity of surface soil in Poovar village, Kerala, India. Their findings contribute to radiological mapping and impact assessments in the region.

One study conducted by [9], assessed the excess lifetime cancer risk from gamma radiation levels in Effurun and Warri cities of Delta state, Nigeria. The study highlighted the health consequences of increased background ionizing radiation from various sources.

Similarly, research was conducted in Kaduna metropolis which consist of four local government areas which Chikun, Igabi, Kaduna south and Kaduna north, to ascertain the radioactivity level of 226Ra, 232Th and 40K. In Chikun LGA it has been discovered that the background radiation is mostly low however in Kaduna Refining and Petrochemical Company (KRPC) the background radiation is above the average and this is caused as a result of waste dumps from the refinery site [10]. In Igabi the background radiation readings is low and the activity level of the 226Ra, 232Th and 40K is average [11]. In Kaduna south is an industrial area that comprise of different companies, the activity of the radioactive element is average and hence not hazardous for the members of the public [12].

1.1 Study Area

Federal Polytechnic Kaltungo main campus which has a total land area of one hundred and two hectares (102) is surrounded by

Fig. 1. Google map of the study area

mountainous areas and located south of Kaltungo town, Kaltungo Local Government Area of Gombe State is on latitude 9.8205 and longitude 11.3409 respectively. The land area is undulating and composed of gravel, sandy and loamy soil covered with few trees.

2. MATERIALS AND METHODS

2.1 Materials

Materials used for this research include Radiation Alert Inspector, photomultiplier tube (PMT), NaI (Tl) detectors, plastic container for packaging the soil samples, High Purity Germanium (HPGe) detector, hole, liquid nitrogen coolers, masking tape and soil samples.

2.2 Methods

2.2.1 Soil sample collection

Soil samples were collected in a radon impermeable cylindrical plastic container, within the polytechnic in the following areas: admin block, Entrepreneur block, School of science and technology complex, school of engineering complex, Library, School Clinic, Department of Mass Communication, and both boys' and girls' hostel. For the collection of the soil samples, the topmost soil was cleared and the soil beneath was taken. In each sample area, three background radiation readings were taken and the average was determined before the soil samples were collected and labelled for easy identification and taken to the laboratory for preparation and analysis.

2.2.2 Soil sample preparation

Each of the obtained soil samples was dried off before being pulverized into a fine powder. It was also done to package the samples inside radon-impermeable cylindrical plastic containers that were chosen based on the area allotted for the detector vessel, which has dimensions of 76mm by 76 mm. The packaging of each sample was triple-sealed to keep radon-222 from escaping. The lid assembly gap is filled with candle wax to close any gaps between the lid and container, and the lid and container are then tightly sealed together using masking adhesive tape. The inside rim of each container's lids was coated with Vaseline jelly during the sealing process [13].

After the samples were prepared, the empty container was weighed to determine its weight, and then the samples were sealed in the container and weighed again to determine the weight of the container plus the soil sample. The weight of the soil sample alone was then determined by deducting the weight of the empty container, as shown in Fig. 2. By keeping the samples for 30 days before using gamma-ray spectrometry, radon, and its short-lived progeny were given the chance to attain secular radioactive equilibrium

2.2.3 Soil sample radioactivity evaluation

The study was performed using a 76mm x 76mm NaI (Tl) detector crystal that is optically attached to a photomultiplier tube (PMT). A preamble and a 1-kilovolt external source are included in the assembly. A 6 cm lead shield constructed of

Fig. 2. Prepared samples being weighed

copper and cadmium sheets shields the detector from damage. This system's goal is to cut back on ambient and dispersed radiation.

Maestro, a program for data collecting, is produced by Canberra Nuclear Products. The components of each sample were measured for a total of 29000 seconds. The peak areas of each energy level in the spectrum were utilized to compute the activity concentrations in each sample by the use of the following equation;

$$C = \frac{C_n}{C_{fk}} \quad (1)$$

Where C is the radionuclide sample's activity concentration (expressed in $Bqkg^{-1}$), C_{fk} is the detecting system's calibration factor and C_n refers to the count rate (counts/second).

$$Counts\ per\ second\ (cps) = \frac{net\ count}{live\ time} \quad (2)$$

2.2.4 Calibration and efficiency determination

Two calibration point sources, Cs-137 and C0-60, were used to calibrate the system for energy and efficiency. These were counted for 30 minutes using an amplifier gain that provides a 72% energy resolution for the 66.16 keV of Cs-1s37 [10].

3. RESULTS AND DISCUSSION

Tables 1 and 2, shows the result for background radiation reading and the result from the laboratory analysis of Gamma Ray spectrometry respectively. Figs. 3, 4 and 5 are the statistical analysis of the result obtained for both the background radiation readings and analysis of the Gama ray spectrometry, while Figs. 4 and 5 depicts the bar chats of the result obtained from the Gama ray spectrometry of the activity level of ^{40}K, ^{226}Ra and ^{232}Th. Fig. 4 illustrates the result in count per second (cps) while Fig. 5 is in Becquerel per kilogram (Bg/kg) respectively. Fig. 3 shows the bar chat for natural back ground radiation readings in *μ*sv/hr.

The highest activity concentration of 226R, 40K and 232Th were found in soil collected from locations AB3 (107.7457 BqKg^{-1}), AB3 (898.7365 BqKg^{-1}), and AB4 (243.1510 BqKg^{-1}), respectively, where the mean value activity of ^{40}K (206.7681 BqKg^{-1}) is lower than the world average of 420 BqKg^{-1} and hence makes the environment safe from concentration of ^{40}K and the mean value activity concentrations of ^{232}Th (95.393 BqKg^{-1}) is above the world average of 50 BqKg^{-1} this is because of the presence of mountains which surround the polytechnic and more so the quarry activities occurring close to the institution can also be the contributing factor to the rise in the activity of thorium in the area. This means the environment is not conducive for the humans due to the quarry activity which if it continues is dangerous to the student and staff of the polytechnic. ^{226}Ra which has the lowest mean activity concentration level of 43.8600 BqKg^{-1}, is lower than the world average of 370 BqKg^{-1}. This means the study area is safe from the activity of ^{226}Ra.

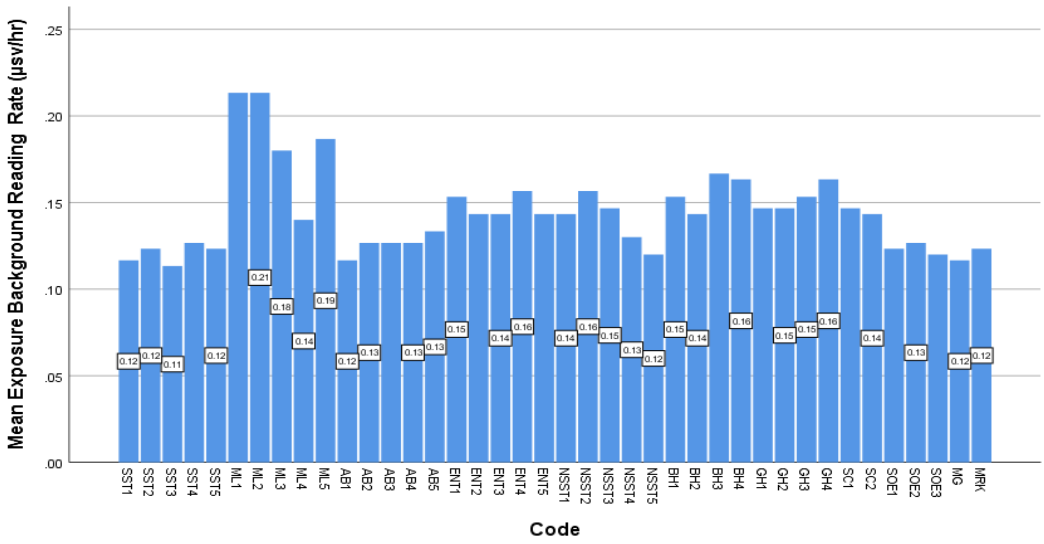

Fig. 3. Bar chat of the background Radiation Reading in *μ*sv/hr

Table 1. Result of background radiation reading of Federal polytechnic Kaltungo

S/NO	Example	Background Reading (μsv/hr)			Mean (SD) Exposure Rate (μsv/hr)
	Code	*1*	*2*	*3*	
1	SST1	0.12	0.12	0.11	0.11 ±0.006
2	SST2	0.12	0.13	0.12	0.12±0.003
3	SST3	0.11	O.11	O.12	0.11±0.003
3	SST4	0.13	0.12	0.13	0.12±0.006
5	SST5	0.12	0.12	0.13	0.12±0.003
6	ML1	0.23	0.20	0.21	0.21±0.003
7	ML2	0.21	0.22	0.21	0.21±0.003
8	ML3	0.18	0.17	0.19	0.18±0.000
9	ML4	0.13	0.15	0.14	0.14±0.000
10	ML5	0.20	0.18	0.18	0.18±0.006
11	AB1	0.10	0.13	0.12	0.11±0.006
12	AB2	0.12	0.14	0.12	0.12±0.006
13	AB3	0.13	0.12	0.13	0.12±0.006
14	AB4	0.14	0.12	0.12	0.12±0.006
15	AB5	0.13	0.14	0.13	0.13±0.003
16	ENT1	0.15	O.15	0.16	0.15±0.003
17	ENT2	0.14	0.14	0.15	0.14±0.003
18	ENT3	0.15	0.14	0.14	0.14±0.003
19	ENT4	0.16	0.15	0.16	0.15±0.006
20	ENT5	0.14	0.15	0.14	0.14±0.003
21	NSST1	0.14	0.14	0.15	0.14±0.003
22	NSST2	0.16	0.15	0.16	0.15±0.006
23	NSST3	0.13	0.16	0.15	0.14±0.006
24	NSST4	0.13	0.12	0.14	0.13±0.000
25	NSST5	0.11	0.13	0.12	0.12±0.000
26	BH1	0.15	0.16	0.15	0.15±0.003
27	BH2	0.14	0.16	0.13	0.14±0.003
28	BH3	0.16	0.18	0.16	0.16±0.006
29	BH4	0.15	0.17	0.17	0.16±0.003
30	GH1	0.16	0.14	0.14	0.14±0.006
31	GH2	0.14	0.15	0.15	0.14±0.006

S/NO	Example	Background Reading (μsv/hr)			Mean (SD) Exposure Rate (μsv/hr)
	Code	*1*	*2*	*3*	
32	GH3	0.15	0.15	0.16	0.15±0.003
33	GH4	0.16	0.16	0.17	0.16±0.003
34	SC1	0.14	0.15	0.15	0.14±0.006
35	SC2	0.15	0.14	0.14	0.14±0.003
36	SOE1	0.12	0.13	0.12	0.12±0.003
37	SOE2	0.13	0.12	0.13	0.12±0.006
38	SOE3	0.11	0.12	0.13	0.12±0.000
39	MG	0.11	0.12	0.12	0.11±0.006
40	MRK	0.13	0.11	0.13	0.12±0.003

Table 2. Result of Thorium (^{232}Th), Radon (^{226}Ra) and potassium (^{40}K) obtained from soil samples analysis

		Th-232				Ra-226				K-40			
S/N	Sample ID	Mean (CPS)	Error (CPS)	Mean (Bg/Kg)	Error (Bg/Kg)	Mean (CPS)	Error (CPS)	Mean (Bg/Kg)	Error (Bg/Kg)	Mean (CPS)	Error (CPS)	Mean (Bg/Kg)	Error (Bg/Kg)
1	SST1	0.0235	0.0006	27.8384	0.0157	0.0234	0.0006	27.7615	0.8121	0.1468	0.0009	228.305	1.3897
2	SST2	0.0454	0.0025	50.7152	2.4796	0.0196	0.0035	19.2958	0.1424	0.3228	0.0015	516.564	2.3883
3	SST3	0.1942	0.0034	146.858	0.2404	0.0763	0.0065	88.5445	7.4676	0.0687	0.0058	123.25	8.1657
4	SST4	0.0932	0.0042	105.113	4.5067	0.0427	0.0026	49.8141	2.6895	0.0188	0.0026	28.3936	3.7881
5	SST5	0.0323	0.0023	37.6385	3.6637	0.0258	0.0014	33.4302	0.3546	0.0891	0.0054	153.656	9.5432
6	ML1	0.0149	0.0016	32.0912	1.4482	0.0321	0.0063	35.3015	4.1517	0.3212	0.0024	387.062	5.6319
7	ML2	0.0232	0.0012	24.3317	2.4539	0.0316	0.0027	73.7011	3.5441	0.0672	0.0061	117.607	6.9217
8	ML3	0.0734	0.0015	84.0672	0.0157	0.0591	0.0017	60.9013	2.0587	0.1121	0.0017	157.982	1.8086
9	ML4	0.0954	0.0032	107.371	3.4853	0.0251	0.0015	17.3061	1.3085	0.0823	0.0012	143.955	3.6295
10	ML5	0.0231	0.0008	25.5508	1.6206	0.0493	0.0043	40.0344	3.7937	0.0504	0.0011	63.896	0.1565
11	AB1	0.1137	0.0036	133.148	4.491	0.0318	0.0012	15.0799	1.4627	0.0526	0.0013	98.2016	0.4566
12	AB2	0.0135	0.0018	243.151	2.5661	0.0403	0.0029	36.6022	3.5423	0.1456	0.0023	212.024	4.7976
13	AB3	0.2351	0.0013	287.508	1.3863	0.0836	0.0004	107.746	0.3746	0.4741	0.0034	898.737	6.8647
14	AB4	0.1237	0.0041	131.158	4.371	0.0895	0.0027	102.807	3.2704	0.4821	0.0032	756.329	4.8321
15	AB5	0.0862	0.0029	94.4718	3.4853	0.0362	0.0026	29.5002	3.2701	0.0754	0.0016	74.7852	0.9431
16	ENT1	0.1118	0.0039	127.416	4.3033	0.0087	0.0041	9.8203	4.7668	0.0623	0.0013	95.8489	1.7863
17	ENT2	0.0924	0.0023	107.641	2.0685	0.0095	0.0015	10.6445	5.3797	0.0312	0.0017	65.7434	1.0668
18	ENT3	0.0835	0.0032	97.3426	3.4853	0.0572	0.0029	54.7751	3.8621	0.1231	0.0019	33.1871	2.8773

		Th-232				Ra-226				K-40			
S/N	Sample ID	Mean (CPS)	Error (CPS)	Mean (Bg/Kg)	Error (Bg/Kg)	Mean (CPS)	Error (CPS)	Mean (Bg/Kg)	Error (Bg/Kg)	Mean (CPS)	Error (CPS)	Mean (Bg/Kg)	Error (Bg/Kg)
19	ENT4	0.1021	0.0031	115.943	3.0842	0.0235	0.0038	38.8221	3.0836	0.1534	0.0036	221.489	7.2541
20	ENT5	0.0932	0.0007	105.022	0.8279	0.0234	0.0029	38.8222	3.0436	0.1452	0.0015	238.766	3.784
21	NSST1	0.0583	0.0026	66.8624	3.8707	0.027	0.0013	33.8915	1.3895	0.4214	0.0016	217.532	1.688
22	NSST2	0.0756	0.0075	87.9232	8.9566	0.0235	0.0051	26.3088	6.5502	0.3188	0.0014	208.711	8.3755
23	NSST3	0.1107	0.0043	126.385	4.319	0.0634	0.0035	74.755	4.1517	0.3121	0.0027	323.524	4.4653
24	NSST4	0.0923	0.0031	105.113	3.4854	0.0671	0.0013	83.5854	0.7643	0.2321	0.0058	502.388	9.3264
25	NSST5	0.0478	0.003	55.0253	3.0843	0.0417	0.0028	55.1775	3.0465	0.2185	0.0036	199.446	5.0956
26	BH1	0.0203	0.0012	23.3301	1.8336	0.0085	0.0011	9.72	1.8715	0.0351	0.0014	66.4131	0.6122
27	BH2	0.1135	0.0007	128.863	0.8279	0.0436	0.0045	40.2709	5.6144	0.0361	0.0029	98.7132	5.3899
28	BH3	0.0851	0.0023	95.5181	2.4539	0.0236	0.0037	32.0317	4.566	0.0452	0.0031	83.0528	4.4923
29	BH4	0.0824	0.0033	93.8672	3.4853	0.0243	0.0034	25.0184	4.9151	0.0892	0.0013	140.453	0.6646
30	GH1	0.1713	0.0009	195.691	1.6226	0.0538	0.0015	61.7829	5.3579	0.2105	0.0021	186.836	2.3882
31	GH2	0.0825	0.0037	94.8986	3.099	0.0433	0.0028	47.6385	3.0436	0.3121	0.0009	328.533	0.5467
32	GH3	0.0093	0.0011	10.436	1.4325	0.0475	0.0038	52.4895	4.3204	0.2105	0.0017	378.286	4.4635
33	GH4	0.0863	0.0023	95.5032	2.6224	0.0027	0.0006	2.6989	0.8101	0.0677	0.0021	119.783	1.6683
34	SC1	0.0561	0.0044	62.8728	4.3109	0.0384	0.0017	40.4432	2.0126	0.0431	0.0011	54.7858	0.5122
35	SC2	0.0837	0.0021	94.4805	2.0528	0.0278	0.0026	33.2037	2.6989	0.1423	0.0012	213.035	0.5212
36	SOE1	0.0549	0.0048	67.0973	7.3775	0.0562	0.0043	60.0295	4.6786	0.0364	0.0019	67.7208	2.9947
37	SOE2	0.0449	0.006	51.7319	6.1584	0.0428	0.0036	55.1785	4.0655	0.0127	0.0028	110.097	4.9911
38	SOE3	0.0827	0.0024	93.8513	2.0685	0.0035	0.0063	30.807	7.4218	0.1143	0.0031	176.084	4.7697
39	MG	0.0984	0.0028	111.27	3.3719	0.0513	0.0018	61.9521	2.5708	0.0316	0.0034	96.7331	5.8891
40	MRK	0.0226	0.0013	25.6516	1.2348	0.0312	0.0027	36.7103	3.2345	0.0634	0.0026	82.8204	0.4646

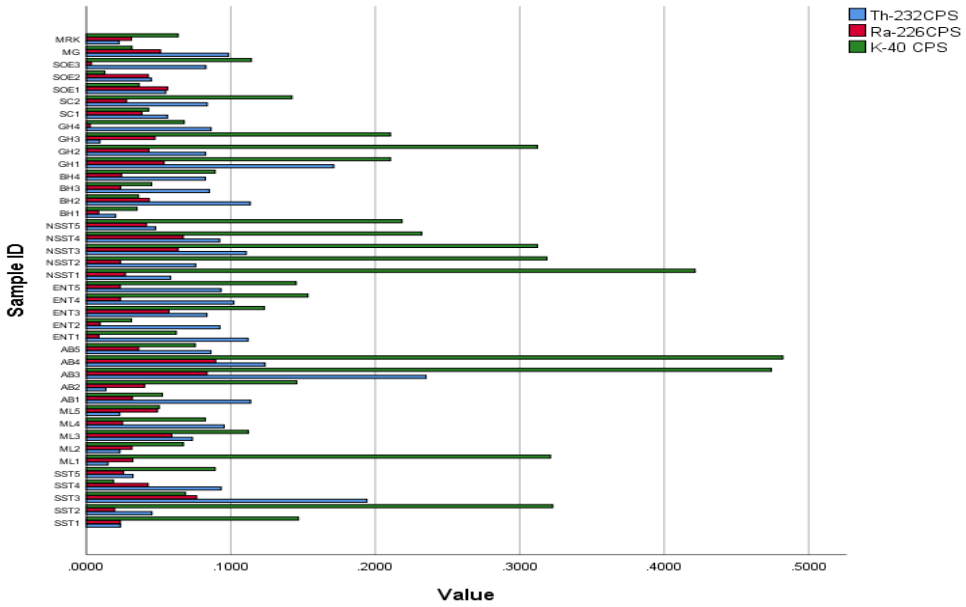

Fig. 4. Bar chat of 232Th, 226Ra and 40K in CPS

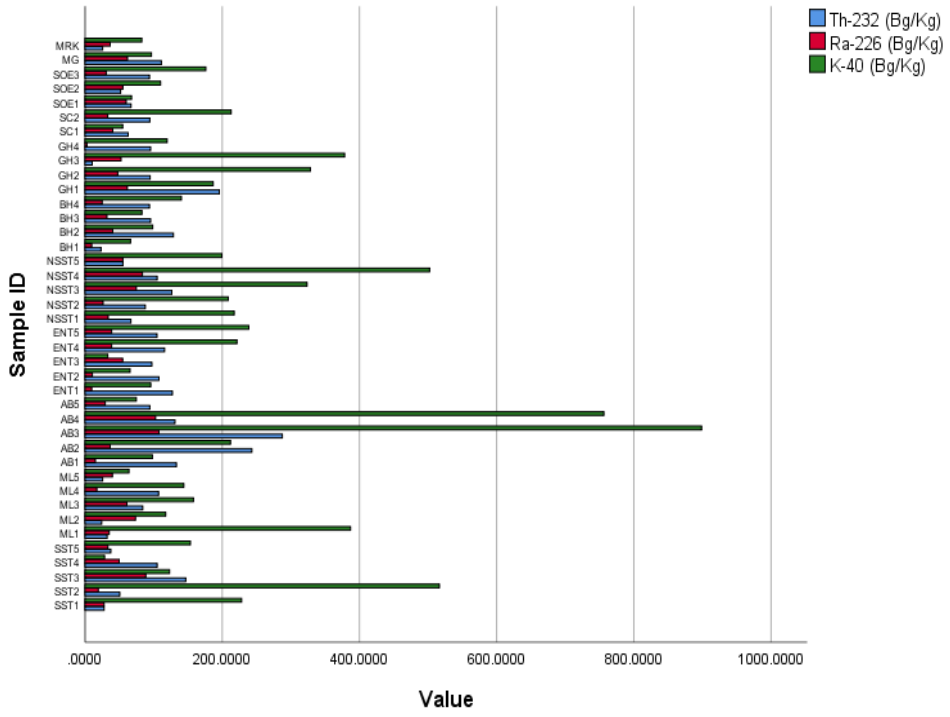

Fig. 5. Bar chat of 232Th, 226Ra and 40K in Bg/Kg

4. CONCLUSION

The obtained results are seen to be in agreement with Effen Huber et al. (1998) who based their argument on the recommendations of the German Commission of radiological protection (1991) of annual effective dose of 1msv/yr., which is equally the ICRP (1990) recommended dose rate for members of the public. However, areas like AB3, AB4 and SST2 that have an annual effect dose more than the recommended value were observed to contain some rocky stones which have been brought from the quarry operating close to the school. This shows that the high level of 232Th observed within the school premises is as a result of the quarry

activities. Hence there is a need for further investigation on radioactivity level of the quarry site.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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