

## Original Research Article

# Determination of Radioactivity Levels $^{226}\text{Ra}$ , $^{232}\text{Th}$ and $^{40}\text{K}$ in some Soil Samples within Federal Polytechnic Kaltungo Main Campus using Gamma Ray Spectrometry

**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  $76 \times 76 \text{ mm NaI (TI)}$  detector crystal with radioactivity activity concentration of potassium ( $^{40}\text{K}$ ), Radium ( $^{226}\text{Ra}$ ) and Thorium ( $^{232}\text{Th}$ ) were determined within the study area. Results obtained showed the highest activity concentration of  $^{40}\text{K}$ ,  $^{226}\text{Ra}$ , and  $^{232}\text{Th}$  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  $^{40}\text{K}$  was seen to be lower than the world average of 420 Bq/kg while the mean activity concentrations of  $^{232}\text{Th}$  (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.  $^{226}\text{Ra}$  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  $0.11 \mu\text{sv/hr}$  -  $0.21 \mu\text{sv/hr}$ , which did not exceed the  $1 \text{ mSv/yr}$  as recommended by National Council on Radiation Protection (NCRP).

**Keywords:** Background Radiation, Activity concentration and Gamma Ray spectrometry

## 1.0 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 is the primary cause of dosage from natural radiation in locations with a normal background radiation level.

The primary external source of irradiation to the human body is gamma radiation from radionuclides like the  $^{226}\text{Ra}$ ,  $^{40}\text{K}$ , and  $^{232}\text{Th}$  family, as well as their decay products. At sea level, the absorbed dose rate from cosmic radiation in the air is around  $30 \text{ nGy}^{-1}$ [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].

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 man-produced 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).

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[4]. Therefore, it is crucial to critically review and evaluate the existing literature on high background radiation areas to ensure the reliability of the findings.

One area of research related to background radiation is its impact on reproductive health. Spermatogenesis, the process of sperm production, is sensitive to ionizing radiation [5]. Laboratory studies have found negative effects of radiation on sperm quantity and quality. However, the chronic effects of low-level background radiation exposure on spermatogenesis are poorly understood [5]. Studies have been conducted to investigate the correlation between chronic background radiation and sperm swimming endurance in bank voles from Chernobyl [5]. The findings suggest a relatively weak correlation between background radiation and sperm quality [5].

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.

One study conducted by [6], 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, Kauna south and Kaduna north, to ascertain the radioactivity level of  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ . 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 [7]. In Igabi the background radiation readings is low and the activity level of the  $^{226}\text{Ra}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$  is average [8]. 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 [9].

### 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 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.



Figure 1 Google map of the study area

## 2.0 MATERIALS AND METHODS

## I. Materials

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

## II. Methods

### a. Soil sample collection

Soil samples were collected in 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.

### b. 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 76mm. 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. [10].



**Fig 2** prepared samples being weighed.

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

### **c. Soil sample radioactivity evaluation**

The study was performed using a 76mm x 76mm NaI (TI) 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 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).

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

### **d. Calibration and efficiency determination**

Two calibration point sources, Cs-137 and Co-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-137[7].

## **3.0 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. Figures 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 Figure 4 and 5 depicts the bar chats of the result obtained from the Gama ray spectrometry of the activity level of  $^{40}\text{K}$ ,  $^{226}\text{Ra}$  and  $^{232}\text{Th}$ . Figure 4 illustrates

the result in count per second (cps) while Figure 5 is in Becquerel per kilogram (Bg/kg) respectively. Figure 3 shows the bar chart for natural back ground radiation readings in  $\mu\text{sv/hr}$ . The highest activity concentration of  $^{226}\text{Ra}$ ,  $^{40}\text{K}$  and  $^{232}\text{Th}$  were found in soil collected from locations AB3 (107.7457 BqKg<sup>-1</sup>), AB3 (898.7365 BqKg<sup>-1</sup>), and AB4 (243.1510 BqKg<sup>-1</sup>), respectively, where the mean value activity of  $^{40}\text{K}$  (206.7681 BqKg<sup>-1</sup>) is lower than the world average of 420 BqKg<sup>-1</sup> and hence makes the environment safe from concentration of  $^{40}\text{K}$  and the mean value activity concentrations of  $^{232}\text{Th}$  (95.393 BqKg<sup>-1</sup>) is above the world average of 50 BqKg<sup>-1</sup> 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.  $^{226}\text{Ra}$  which has the lowest mean activity concentration level of 43.8600 BqKg<sup>-1</sup>, is lower than the world average of 370 BqKg<sup>-1</sup>. This means the study area is safe from the activity of  $^{226}\text{Ra}$ .

**Table 1.** Result of Background Radiation Reading of Federal polytechnic Kaltungo.

S/NO	Example	Background Reading ( $\mu\text{sv/hr}$ )			Mean (SD) Exposure Rate ( $\mu\text{sv/hr}$ )
		1	2	3	
	Code				
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	0.11	0.12	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	0.15	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
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

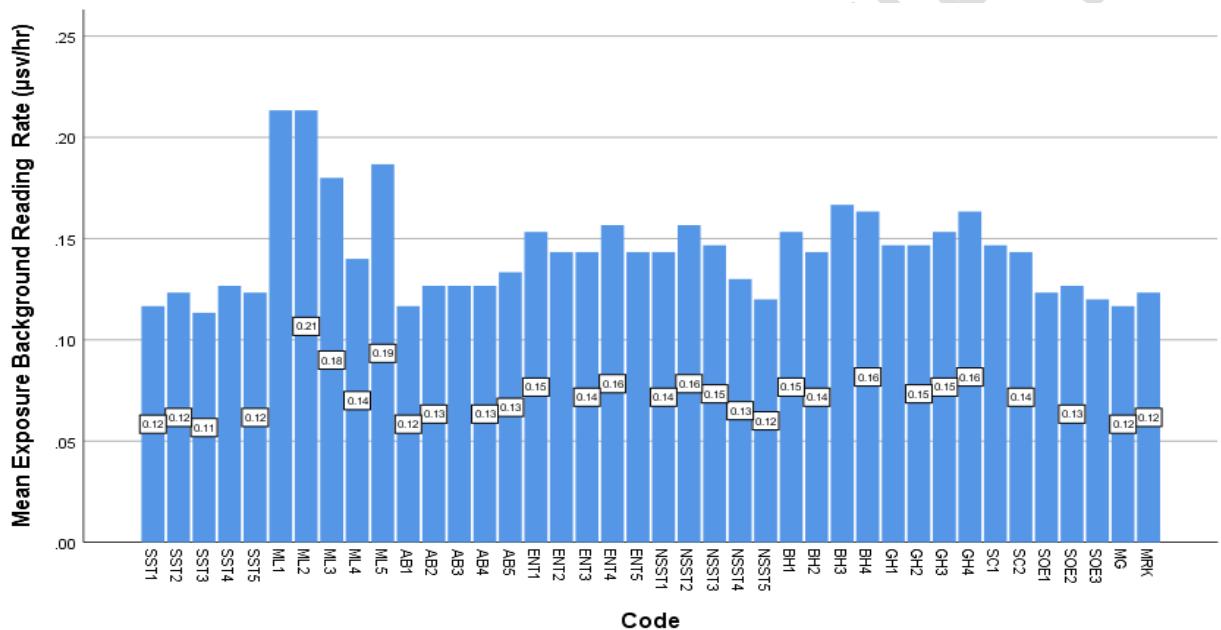


Figure. 3 Bar chat of the background Radiation Reading in  $\mu\text{sv/hr}$

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

S/N	Sample ID	Th-232				Ra-226				K-40			
		Mean (CP S)	Error (CP S)	Mean (Bg/K g)	Error (Bg/Kg)	Mean (CP S)	Error (CP S)	Mean (Bg/K g)	Error (Bg/Kg)	Mean (CP S)	Error (CP S)	Mean (Bg/K g)	Error (Bg/Kg)
1	SST 1	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	SST 2	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	SST	0.19	0.00	146.8	0.24	0.07	0.00	88.54	7.46	0.06	0.00	123.2	8.16

	3	42	34	58	04	63	65	45	76	87	58	5	57
4	SST 4	0.09 32	0.00 42	105.1 13	4.50 67	0.04 27	0.00 26	49.81 41	2.68 95	0.01 88	0.00 26	28.39 36	3.78 81
5	SST 5	0.03 23	0.00 23	37.63 85	3.66 37	0.02 58	0.00 14	33.43 02	0.35 46	0.08 91	0.00 54	153.6 56	9.54 32
6	ML1	0.01 49	0.00 16	32.09 12	1.44 82	0.03 21	0.00 63	35.30 15	4.15 17	0.32 12	0.00 24	387.0 62	5.63 19
7	ML2	0.02 32	0.00 12	24.33 17	2.45 39	0.03 16	0.00 27	73.70 11	3.54 41	0.06 72	0.00 61	117.6 07	6.92 17
8	ML3	0.07 34	0.00 15	84.06 72	0.01 57	0.05 91	0.00 17	60.90 13	2.05 87	0.11 21	0.00 17	157.9 82	1.80 86
9	ML4	0.09 54	0.00 32	107.3 71	3.48 53	0.02 51	0.00 15	17.30 61	1.30 85	0.08 23	0.00 12	143.9 55	3.62 95
10	ML5	0.02 31	0.00 08	25.55 08	1.62 06	0.04 93	0.00 43	40.03 44	3.79 37	0.05 04	0.00 11	63.89 6	0.15 65
11	AB1	0.11 37	0.00 36	133.1 48	4.49 1	0.03 18	0.00 12	15.07 99	1.46 27	0.05 26	0.00 13	98.20 16	0.45 66
12	AB2	0.01 35	0.00 18	243.1 51	2.56 61	0.04 03	0.00 29	36.60 22	3.54 23	0.14 56	0.00 23	212.0 24	4.79 76
13	AB3	0.23 51	0.00 13	287.5 08	1.38 63	0.08 36	0.00 04	107.7 46	0.37 46	0.47 41	0.00 34	898.7 37	6.86 47
14	AB4	0.12 37	0.00 41	131.1 58	4.37 1	0.08 95	0.00 27	102.8 07	3.27 04	0.48 21	0.00 32	756.3 29	4.83 21
15	AB5	0.08 62	0.00 29	94.47 18	3.48 53	0.03 62	0.00 26	29.50 02	3.27 01	0.07 54	0.00 16	74.78 52	0.94 31
16	ENT 1	0.11 18	0.00 39	127.4 16	4.30 33	0.00 87	0.00 41	9.820 3	4.76 68	0.06 23	0.00 13	95.84 89	1.78 63
17	ENT 2	0.09 24	0.00 23	107.6 41	2.06 85	0.00 95	0.00 15	10.64 45	5.37 97	0.03 12	0.00 17	65.74 34	1.06 68
18	ENT 3	0.08 35	0.00 32	97.34 26	3.48 53	0.05 72	0.00 29	54.77 51	3.86 21	0.12 31	0.00 19	33.18 71	2.87 73
19	ENT 4	0.10 21	0.00 31	115.9 43	3.08 42	0.02 35	0.00 38	38.82 21	3.08 36	0.15 34	0.00 36	221.4 89	7.25 41
20	ENT 5	0.09 32	0.00 07	105.0 22	0.82 79	0.02 34	0.00 29	38.82 22	3.04 36	0.14 52	0.00 15	238.7 66	3.78 4
21	NSS T1	0.05 83	0.00 26	66.86 24	3.87 07	0.02 7	0.00 13	33.89 15	1.38 95	0.42 14	0.00 16	217.5 32	1.68 8
22	NSS T2	0.07 56	0.00 75	87.92 32	8.95 66	0.02 35	0.00 51	26.30 88	6.55 02	0.31 88	0.00 14	208.7 11	8.37 55
23	NSS T3	0.11 07	0.00 43	126.3 85	4.31 9	0.06 34	0.00 35	74.75 5	4.15 17	0.31 21	0.00 27	323.5 24	4.46 53
24	NSS T4	0.09 23	0.00 31	105.1 13	3.48 54	0.06 71	0.00 13	83.58 54	0.76 43	0.23 21	0.00 58	502.3 88	9.32 64
25	NSS T5	0.04 78	0.00 3	55.02 53	3.08 43	0.04 17	0.00 28	55.17 75	3.04 65	0.21 85	0.00 36	199.4 46	5.09 56
26	BH1	0.02 03	0.00 12	23.33 01	1.83 36	0.00 85	0.00 11	9.72 15	1.87 15	0.03 51	0.00 14	66.41 31	0.61 22
27	BH2	0.11 35	0.00 07	128.8 63	0.82 79	0.04 36	0.00 45	40.27 09	5.61 44	0.03 61	0.00 29	98.71 32	5.38 99
28	BH3	0.08 51	0.00 23	95.51 81	2.45 39	0.02 36	0.00 37	32.03 17	4.56 6	0.04 52	0.00 31	83.05 28	4.49 23
29	BH4	0.08 24	0.00 33	93.86 72	3.48 53	0.02 43	0.00 34	25.01 84	4.91 51	0.08 92	0.00 13	140.4 53	0.66 46

30	GH1	0.17 13	0.00 09	195.6 91	1.62 26	0.05 38	0.00 15	61.78 29	5.35 79	0.21 05	0.00 21	186.8 36	2.38 82
31	GH2	0.08 25	0.00 37	94.89 86	3.09 9	0.04 33	0.00 28	47.63 85	3.04 36	0.31 21	0.00 09	328.5 33	0.54 67
32	GH3	0.00 93	0.00 11	10.43 6	1.43 25	0.04 75	0.00 38	52.48 95	4.32 04	0.21 05	0.00 17	378.2 86	4.46 35
33	GH4	0.08 63	0.00 23	95.50 32	2.62 24	0.00 27	0.00 06	2.698 9	0.81 01	0.06 77	0.00 21	119.7 83	1.66 83
34	SC1	0.05 61	0.00 44	62.87 28	4.31 09	0.03 84	0.00 17	40.44 32	2.01 26	0.04 31	0.00 11	54.78 58	0.51 22
35	SC2	0.08 37	0.00 21	94.48 05	2.05 28	0.02 78	0.00 26	33.20 37	2.69 89	0.14 23	0.00 12	213.0 35	0.52 12
36	SOE 1	0.05 49	0.00 48	67.09 73	7.37 75	0.05 62	0.00 43	60.02 95	4.67 86	0.03 64	0.00 19	67.72 08	2.99 47
37	SOE 2	0.04 49	0.00 6	51.73 19	6.15 84	0.04 28	0.00 36	55.17 85	4.06 55	0.01 27	0.00 28	110.0 97	4.99 11
38	SOE 3	0.08 27	0.00 24	93.85 13	2.06 85	0.00 35	0.00 63	30.80 7	7.42 18	0.11 43	0.00 31	176.0 84	4.76 97
39	MG	0.09 84	0.00 28	111.2 7	3.37 19	0.05 13	0.00 18	61.95 21	2.57 08	0.03 16	0.00 34	96.73 31	5.88 91
40	MRK	0.02 26	0.00 13	25.65 16	1.23 48	0.03 12	0.00 27	36.71 03	3.23 45	0.06 34	0.00 26	82.82 04	0.46 46

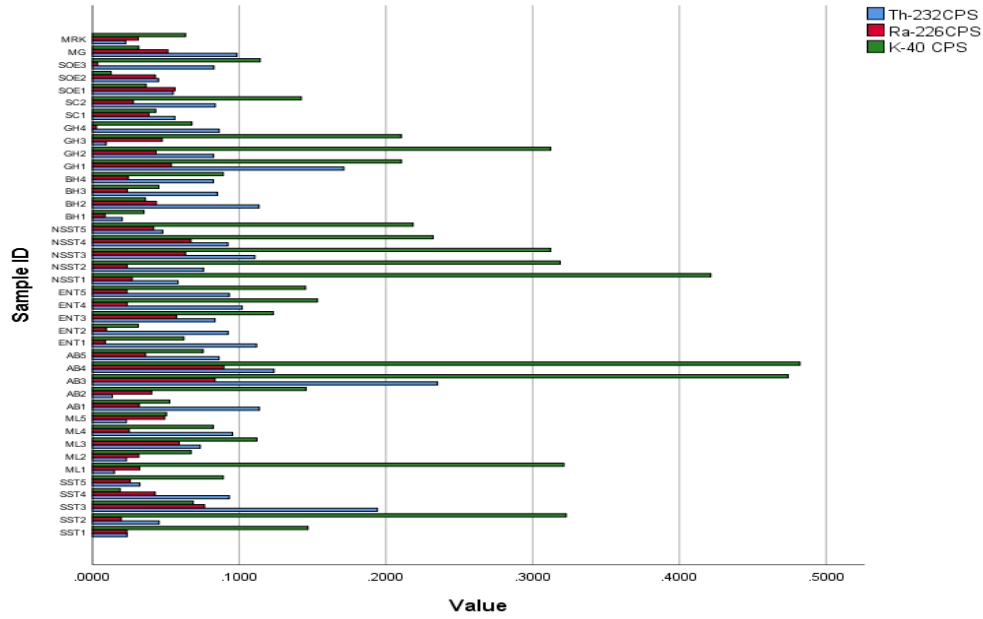


Figure 4. Bar chat of  $^{232}\text{Th}$ ,  $^{226}\text{Ra}$  and  $^{40}\text{K}$  in CPS

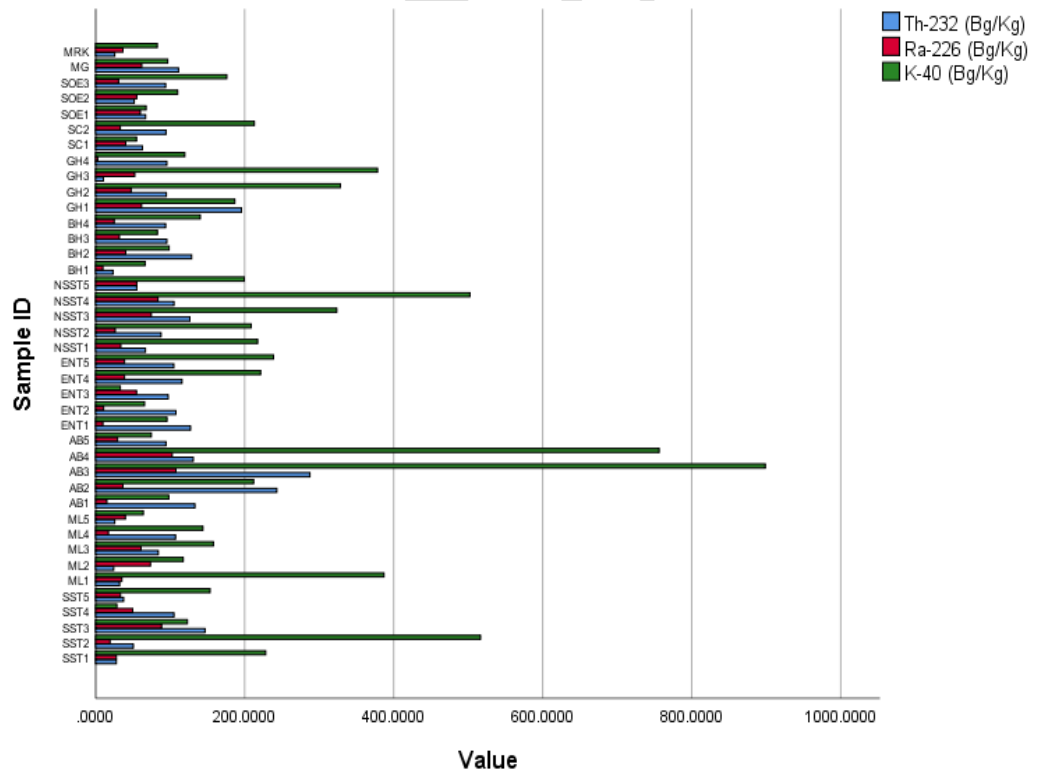


Figure 5. Bar chat of  $^{232}\text{Th}$ ,  $^{226}\text{Ra}$  and  $^{40}\text{K}$  in Bg/Kg

#### 4.0 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 effect 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  $^{232}\text{Th}$  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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