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Radiological Assessment of Soil Samples from Selected Dumpsites in Mowe, Ogun State Nigeria

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Abstract

Activity concentration of soil samples from selected dumpsites within Mowe, Ogun State, Nigeria was determined. These dumpsites are recipients of municipal waste from different sources. Two soil samples each from five selected dumpsites were collected. Gamma Spectrometry analysis was carried out to determine specific activity of radionuclides using NaI scintillation detector. The activity concentrations of radionuclides in the soil samples obtained with gamma spectroscopy ranged from 4.94±0.47Bq/kg to 28.10±2.68Bq/kg for ^{232}Th, 1.81±0.28Bq/Kg to 125.27±21.36Bq/kg for ^{238}U and 779.07±63.93Bq/Kg to 1746.61±11.82Bq/Kg for ^{40}K. Furthermore, the external hazard index (H_{ex}), and radium equivalent activity (Ra_{eq}) with mean values of 0.485 and 165.74Bq/kg are below permissible limits of 1.0 and 370 Bq/Kg respectively. However, the average values of the dose rate, and gamma representative index (I_γ) which are 82.55nGyhr^{-11} and 1.164Bq/kg when compared with the various world permissible values of 55nGyhr^{-1} and 1.0Bq/kg respectively are higher than the worldwide average. Also, external hazard index is less than unity, as well as annual effective dose rate (Outdoor) is less than the recommended limit of 1.0mSvyr^{-1}, therefore no significant radiological hazard for all soil samples in the study area.

Keywords: Dose, Pollution, Contamination, Municipal, Radioactivity, Radiation, and Radionuclide.

1. Introduction

In physics, radiation is a process in which energetic particles or energetic waves travel through a vacuum or through matter-containing media that are not required for their propagation. Man is continuously exposed to ionizing radiation from naturally occurring radioactive materials (NORM). The origin of these materials is the earth crust, but they find their way into the soil, building materials, air, water, food and the human body itself. Human activities generate different forms of wastes and when improperly managed emanate mal-odour (due to degradation of the waste), pose health burden, aesthetic nuisance and decrease the economic and social values of an area. The populace is exposed to natural background radiation from three

different sources: cosmic rays, internal radioactivity and terrestrial radioactivity. The terrestrial radioactivity which varies with geological condition of the location and altitude [1] is the major external source of radiation to human body. In addition, radiation emanates from the wastes (most especially when contaminated) coupled with the natural background radiation from the environment. disposal of waste without adequate management; particularly the radioactive contaminant can expose the populace to radiation hazards. The hazard posed by these point sources of contamination is not only in terms of odor and presence of disease causing micro-organisms, but from radiations emanating from such landfills. Our natural environment is continuously bombarded with ionizing radiations from both natural and man-made sources. The most common radionuclides in soil are the radioactive isotopes of the three natural decay series (^{238}U, and ^{232}Th and ^{40}K). The main purpose of this study to estimate the top soil of dump sites around Mowe, Obafemi Owode area of Ogun state. Mowe in Obafemi Owode (Ogun state) is a town in Nigeria about 318 miles (or 512km) south-west of Abuja, It's geographical coordinates are 6^0 48' 0" North, 3^0 26' 0" East. The city has an area of 1,410km^2 and a population of 228,851 at the 2006 census. The outcome would help the populace and government to be conscious of the hazardous effects of improper waste management and take necessary preventive measures. This will minimize exposure of the populace to high level radiation and associated detrimental effects. This research is thus of immense importance due to the need to ascertain the radiological burden posed by these wastes on the environment.

2. Conceptual Framework

2.1. Uranium

Uranium is the most important element in nature. It exists in at least three isotopic forms, with mass numbers 234, 235 and 238. Another element of importance from the nuclear energy standpoint is thorium, with atomic number 90. It occurs in nature almost entirely as a single nuclear species, with mass number 232. Thorium-232 is the parent of the thorium (4n) series. Its daughter,^{228}Th is formed through two intermediate nuclides, one of which is ^{228}Ra. Radium is far more mobile element than thorium, and the half- life of ^{228}Ra (6.7yrs) in sufficiently long to allow significant separation of ^{228}Th from the parent ^{232}Th. Its distribution is thus partially independent of the parent isotope and is more closely governed by the behaviour of ^{228}Ra.

2.2. Thorium

Thorium-232 is the parent of the thorium (4n) series. Its daughter, ^{228}Th is formed through two intermediate nuclides, one of which is ^{228}Ra. Radium is a far more mobile element than thorium, and the half- life of ^{228}Ra (6.7yrs) in sufficiently long to allow significant separation of ^{228}Th from the parent ^{232}Th. Its distribution is thus partially independent of the parent isotope and is more closely governed by the behaviour of ^{228}Ra. Thorium-230 and Thorium-234 are each daughter products of uranium isotopes, although with widely differing half- lives of 7.5×10^4 years and 24 days, respectively. They have a quite uniform source in sea water.

2.3 Potassium

Potassium, soft, silver white metal is an important constituent of soil; it is also widely distributed in nature and is present in all plant and animal tissues. Potassium-40 is a naturally occurring radioactive isotope of potassium. Two stable (non-radioactive) isotope of Potassium

exist, Potassium-39 and Potassium-41. Potassium-39 comprises most (about 93%) of naturally occurring Potassium-40 and Potassium-41 accounts for essentially the rest. Radioactive Potassium-40 comprises a very small fraction of about 0.012% of naturally occurring Potassium, Several radioactive isotopes of Potassium exist in addition to Potassium -40.These isotopes all have half-lives of less than one day. The half-life of Potassium-40 is 1.3 billion years, and decays to Calcium- 40 by emitting a beta particle with no attendant gamma radiation (89% of the time) and to the gas argon-40 by election capture (EC) with emission of an energetic gamma ray (11%of the time). Potassium-40 is an important radionuclide in terms of the dose associated with naturally occurring radionuclides. It is present in mineral waters and brines, and in various minerals such as carnalities, feldspar, saltpetre, greensand, and sylvite. Potassium is an important constituent of a fertile soil and is essential nutrient for plant growth and in the human diet [2, 3].

3.0 Methodology

3.1 Sample Collection and Preparation

A total of ten samples were collected from the study location around Mowe metropolis, Ogun state. The top layers of the soil which contained wastes that are yet to decompose were removed. Soil samples were collected to a depth of about 0-10cm using a coring tool that was thoroughly cleaned and dried before each sample was collected. Ultimate care was taken in the extraction of soil sections to avoid mixing or cross contamination of soil samples. About six to eight hundred grams of each sample were collected in a plastic bag at the sampling points [4]. Soil samples were well mixed after removing foreign materials such as pieces of stones and gravel. The samples were weighted and then dried at room temperature. After shaking thoroughly the samples were sieved with a 1mm mesh screen. Three hundred grams of soil samples were then sealed in a container and kept for 30days to allow for a radon and its progenies to reach secular equilibrium prior to gamma counting [5].

The activity concentration of soil samples were calculated using the formulae;

$$A_i = \frac{NC_i}{\varepsilon \times y_i \times M \times T} \quad (1)$$

A_i is the activity concentration of the i^{th} radionuclide in Bq/kg
NC_i=net counts of the i^{th} radionuclide (background subtracted) in the corresponding photopeak
y_i= the emission probability of the i^{th} radionuclide
ε =efficiency of the NaI at the energy of the i^{th} radionuclide
M=Mass of the soil sample in kg
T= counting time (18000 seconds) [6].

3.2. Study Area

Table 1: Shows soil sample location and number of samples

Sample code	Location	Longitude	Latitude	No.of samples
PR	Pakuro Road	3.42473	6.80023	2
OI	Oke-Ipa	3.42424	6.80342	2
MW	Mowe Market	3.43505	6.80745	2
AR	Adesan Road	3.42913	6.82528	2
LS	Lagos Street	3.43020	6.82333	2

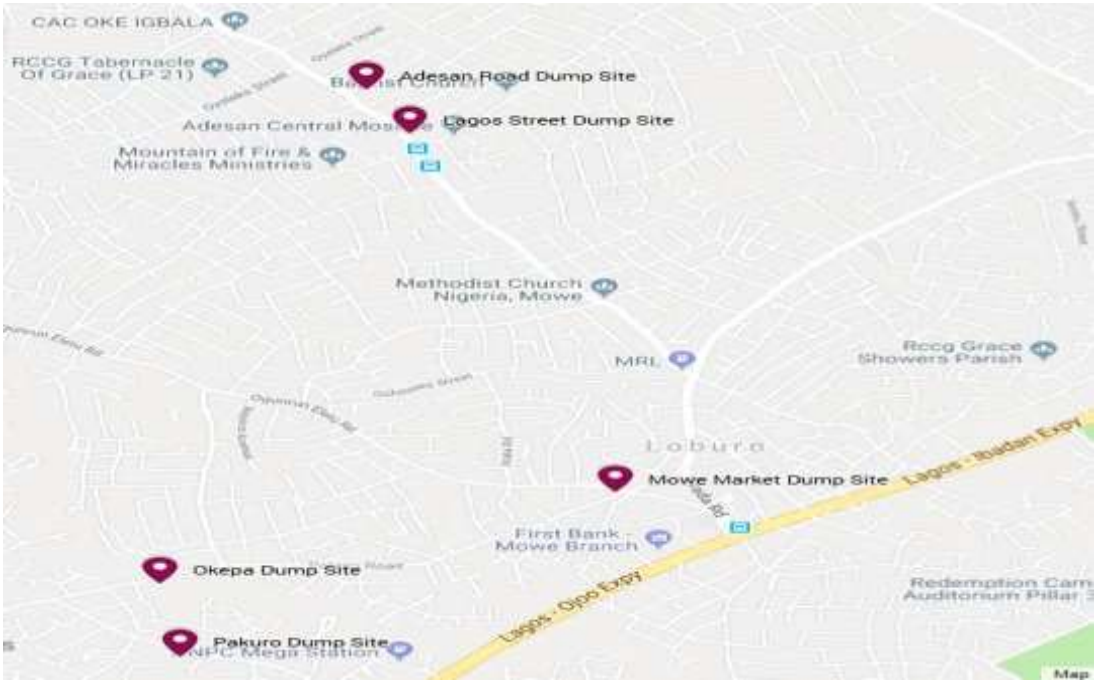

Figure 1: Shows location Map of the study area.

4.0 Theoretical Consideration and Calculations

4.1 Radium Equivalent Activity (Ra_{eq})

Due to non-uniform distribution of ^{238}U, ^{232}Th and ^{40}K in soils, a single parameter is defined with respect to radiation exposure which compares the activity of materials containing different elements of these primordial radionuclides. This single entity, called the Radium equivalent activity (Ra_{eq}) is measured in Bq/kg. It is quantitatively expressed as follows (UNSCEAR, 2000).

The Ra_{eq} was calculated by the equation described by bereka *et al* (1985) and Yang *et al* (2005) as indicated by the equation below;

$$Ra_{eq} = \frac{10}{130}Ck + \frac{10}{7}CTh + CRa \qquad \text{(2)}$$

where, Ra_{eq} is the radium equivalent activity measured in becquerel per kilogram, and C_{Ra}, C_{Th}, and C_K are the respective specific activities in $Bqkg^{-1}$ of ^{226}Ra, ^{232}Th, and ^{40}K respectively.[7,8]

4.2. External Radiation Hazard (H_{ex})

The external hazard index (H_{ex}) commonly used to evaluate the indoor radiation dose rate due to external exposure to gamma radiation from natural radionuclides in building materials as reported by Hamzah *et al* (2008) was presented in the equation below;

$$H_{ex}= \frac{Ck}{4810} + \frac{CTh}{259} + \frac{CRa}{370} \leq 1 \qquad \text{_____(3)}$$

4.3. Absorbed Gamma Dose Rates (D_R)

The absorbed gamma dose rates DR (nGh−1) in air at 1m above the ground surface for the uniform distribution of radionuclides were calculated based on guidelines provided by UNSCEAR (1993), EC (1999) and Papastefanou *et al* (2005) from the natural radionuclides as:

$$DR\ (nG\ h^{-1}) = 0.0417C_k + 0.604C_{Th} + 0.462C_{Ra} \qquad \text{_____(4)}$$

where C_{Ra}, C_{Th} and C_K are the activity concentrations (Bq kg−1) of ^{226}Ra, ^{232}Th and ^{40}K, respectively, in the samples[9]. The absorbed dose rate expresses the received dose in the open air from the radiation emitted from radionuclides concentration in environmental materials. Also, it is the first major step for evaluating the health risk and is expressed in gray (Gy).

4.4. Annual Effective Dose Rate (A_e)

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 mille (10^{-6}).

The effective dose rate was calculated using the equation given by (Kessaratikoon *et al.*, 2008; Masok *et al.*, 2015).

$$IAEDR\ (mSvy^{-1}) = D(nGyh^{-1})\times 8760(h) \times 0.7\times 0.8\times 10^{-6} \qquad \text{____(5)}$$

$$OAEDR\ (mSvy^{-1}) = D(nGyh^{-1})\times 8760(h) \times 0.7\times 0.2\times 10^{-6} \qquad \text{____(6)}$$

Where (IAEDR) is the indoor annual effective dose rate and (OAEDR) is the outdoor annual effective dose rate.[10]

4.5. Representative Gamma Index (I_γ)

The gamma radiation hazard due to the respective concentrations of the investigated natural radionuclides in the soil samples is assessed by the representative gamma index ($I_{\gamma r}$).This index, according to Jibiri and Okeyode (2012), is a screening parameter for materials of possible radiation health challenge. It is calculated using the following equation (El-Gamal *et al.*, 2007; Ravisankar *et al.*, 2014):

$$I_\gamma = \frac{1}{150}CRa + \frac{1}{100}CTh + \frac{1}{1500}Ck \leq 1 \quad \text{_____(7)}$$

Where C_{Ra}, C_{Th} and C_k are the specific activites of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg respectively.

Table 2: Activity Concentration of Soil Samples.

S/N	LOCATIONS	SAMPLES CODES	K-40 (Bq/Kg)	U-238 (Bq/Kg)	TH-232(Bq/kg)
1	ADESAN ROAD 1	S_1	BDL	1.81±0.28	BDL
2	ADESAN ROAD 2	S_2	1727.12±108.52	10.29±1.61	11.24±1.06
3	LAGOS STREET 1	S_3	1018.64±63.93	63.48±9.91	13.66±1.29
4	LAGOS STREET 2	S_4	779.07±50.02	99.92±17.56	12.59±1.20
5	MOWE MARKET 1	S_5	1746.61±11.82	37.55±7.21	14.92±1.42
6	MOWE MARKET 2	S_6	1240.70±79.55	89.04±15.76	13.25±1.26
7	OKE- IPA 1	S_7	1128.01±72.61	66.22±12.26	BDL
8	OKE- IPA 2	S_8	928.30±56.63	58.65±11.12	13.42±1.28
9	PAKURO 1	S_9	836.81±53.75	120.49±20.60	28.10±2.68
10	PAKURO 2	S_{10}	1313.23±84.20	125.27±21.36	4.94±0.47
		Average Values	1071.85±58.10	67.28±11.77	11.21±1.07

BDL: Below Detection Limit
(Bq/Kg): Becquerel Per Kilogram

Table 3: Shows The Radiological Parameters Of All The Dumpsite Soil Samples Calculated From Mowe.

SAMPLE CODES	**Ra_{eq} ($Bq.kg^{-1}$)**	**H_{ex}**	**RGI (I_γ)**	**DR($nGy.h^{-1}$)**	**IAEDR ($mSvy^{-1}$)**	**OAEDR ($mSvy^{-1}$)**
S_1	1.81	0.010	0.012	0.84	0.041	0.001
S_2	159.21	0.430	1.332	83.56	0.409	0.103
S_3	161.35	0.437	1.059	80.06	0.393	0.098
S_4	177.83	0.481	1.311	86.25	0.423	0.106
S_5	193.21	0.523	1.564	99.19	0.487	0.122
S_6	203.41	0.549	1.550	100.88	0.495	0.124
S_7	152.99	0.772	1.193	77.63	0.381	0.095
S_8	149.23	0.404	1.144	73.91	0.363	0.091
S_9	225.00	0.608	1.642	107.53	0.528	0.132
S_{10}	233.34	0.631	0.836	115.61	567.14	0.142
MEAN	165.74	0.485	1.164	82.55	0.405	0.101

5. Discussion

The activity concentration being the result measured in the laboratory with NaI detector was used in calculating other radiology risk parameters. The results for the ten soil sample are shown in Table 2 and 3. Table 2 shows the activity concentration of naturally and artificially occurring radioactive elements, ^{40}K, ^{238}U and ^{232}Th. The activity concentration of ^{40}K, ^{238}U and ^{232}Th in the dumpsites range from 779.07±63.93 to 1746.61±11.82, 1.81±0.28 to 125.27±21.36

and 4.94±0.47 to 28.10±2.68 respectively. However, the average specific activities of ^{238}U, ^{232}Th and ^{40}K for the world average is 35Bq/kg, 30Bq/kg and 400Bq/kg, respectively. The overall results of the study showed that specific activity of ^{40}K and ^{238}U are higher than the world's average while ^{232}Th is found to be within limit. In table 3 the calculate value of Ra_{eq} ranged from 1.81 to 233.34Bq/kg^{-1} with a mean value of 165.74Bq/kg^{-1}.Therefore, the values of radium equivalent from all the sampling sites are below the maximum permissible level of 370Bq/kg^{-1}. In my findings, the values of absorbed dose rate (D_R) ranged from 0.84 to 115.61nGyhr^{-1} with a mean value of 82.55nGyhr^{-1}.The highest absorbed dose rate is found to be 115.61 for Pakuro 2 region. However, this clearly revealed that the calculated mean absorbed dose rate is higher than the recommended limit of 55nGyhr^{-1}. $AEDE_{out}$ values ranged from 0.001 to 0.142 with a mean value of 0.101mSvyr^{-1}, this is very much less than the world average value of 1mSvy^{-1} by (ICRP).

The average values of the gamma representative index (I_γ) of soil samples ranged from 0.012 to 1.642 Bq/kg with mean value of 1.164Bq/kg. The highest value of I_γ is 1.642 Bq/kg, which is more than the permissible limit 1.0 Bq/kg. For radon and its short-lived progeny to produce negligible hazardous effect to the respiratory organs from materials (soils) to be used in construction,the external hazard index should be less than unity. After calculating the external hazard index (H_{ex}), the value obtained is less than unity, which is under the criterion level. Their values ranged from 0.01 to 0.772 with mean value of 0.485.Therefore, it does not exceed the upper limit, which is 1.

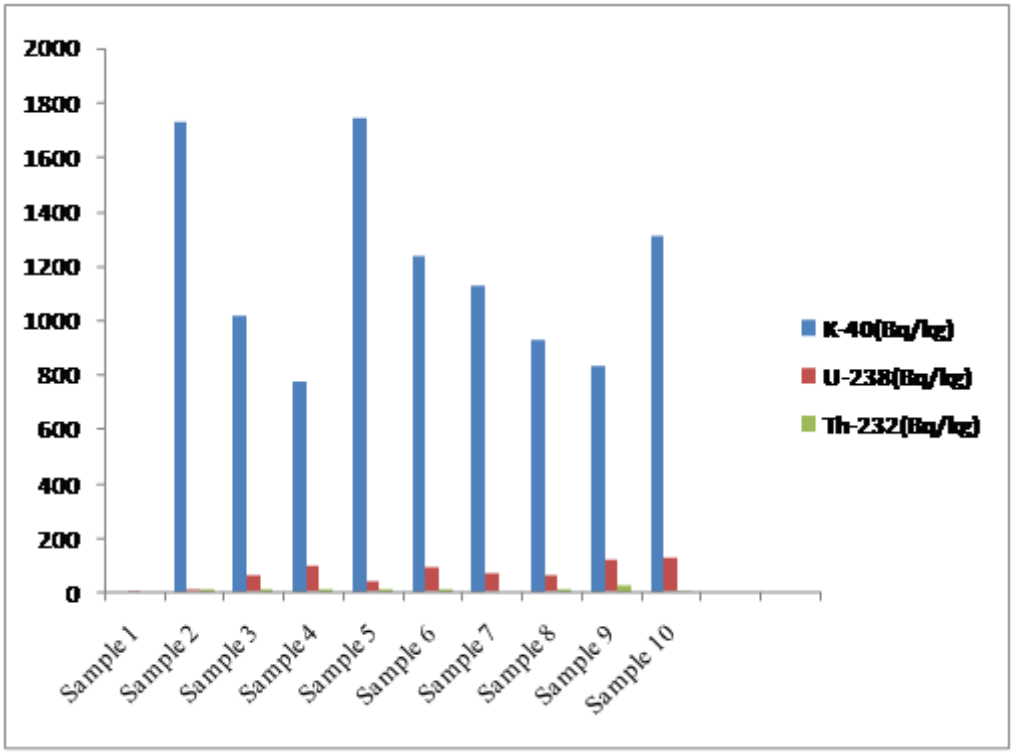

Figure 2: Shows The Activity Concentration Of Soil Samples From Mowe.

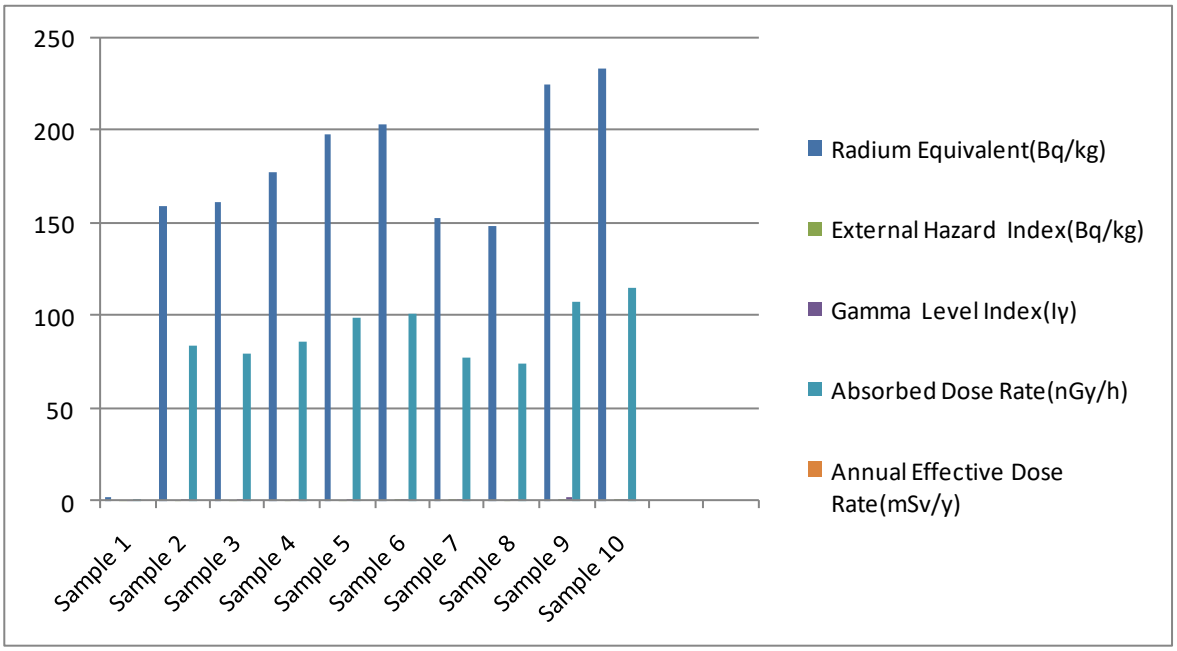

Table 3: Shows The Calculated Parameters In The Soil Samples From Mowe.

6. Conclusion

The absorbed dose level of the emitted radiation on the populace of the study is high when compared with Nigeria and world, mean values which is 54nGyh^{-1} by UNSCEAR 2000. But the calculated external (H_{ex}) hazard index for the soil samples were below permissible limit of unity, hence there is no immediate negative health implications on the inhabitants and the environment, but caution should be taken against long term cumulative effects. The average values of the dose rate, gamma representative index (I_γ) which are 82.55nGyhr^{-1} and 1.164Bq/kg when compared with the various world permissible values of 55nGyhr^{-1} and 1.0Bq/kg respectively are higher than the worldwide average. Therefore, Caution should taken in the areas with higher values against hazard. Since the mean value obtained for annual effective dose rate (Outdoor) is less than limit of 1mSvyr^{-1} by (ICRP), and external hazard index is also less than unity, therefore no significant radiological hazard for all soil samples in the study area.

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