LEVELS OF CONCENTRATION OF RADIONUCLIDES AND RADIOLOGICAL DETRIMENTS IN SOIL, MOSSES AND LICHEN SAMPLES FROM EKAKPAMRE, NIGERIA

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Abstract: The concentration of radionuclides ^{238}U, ^{232}Th and ^{40}K in soil, moss and lichen samples in Ekakpamre-Uvwiamughe was studied using gamma ray spectrometer with NaI(Tl) detector. The mean activity concentration of ^{238}U, ^{232}Th and ^{40}K in soil samples are 35.09±3.86, 54.70±10.12 and 787.72±4.87 $BqKg^{-1}$ respectively, Moss samples: 35.09±2.60, 53.15±10.94 and 100.93±5.18 $BqKg^{-1}$ respectively while for lichen samples are 28.47±2.31, 69.09±13.23 and 120.11±6.03 $BqKg^{-1}$. Radiological hazard indices such as absorbed dose rate, annual effective dose rate, radium equivalent and external hazard index were computed. Comparing with standard value, it was observed that the absorbed dose rate for all samples except CM, UM, CL and EL were higher than the standard value as specified by UNSCEAR. The annual outdoor effective dose calculated also revealed that all samples except CM, EM, UM, CL and EL had values higher than the standard value. In all samples the external hazard index was found to be below one, indicating that the area is safe.

Keywords: Radioactivity, concentration, dose rate, environment, oil spillage

Introduction

The environment we live in, is constantly exposed to radiation which emanates from different sources. Natural environmental radioactivity arises mainly from primordial radionuclides, such as ^{40}K, and the radionuclides from the ^{232}Th and ^{238}U series and their decay products, which occur at trace levels in all ground formations (Tzortzis *et al*., 2004; Tzortzis and Tsertos, 2004). It has been explained that the exposure of human beings to ionizing radiation from natural sources is a continuing and inescapable feature of life on earth (Tabar *et al*.,2013). Harb et al. (2010) reported that the world is naturally radioactive, and around 90% of human radiation exposure arises from natural sources such as cosmic radiations, exposure to radon gas, and terrestrial radiations. In their views, Tabar *et al.* (2013) quoting UNSCEAR (2000) stated that there are two main contributors to natural radiation exposures: high-energy cosmic ray particles incident on the earth's atmosphere and radioactive nuclides that originated in the earth's crust present in soil, air, water, food and the body.

Depending on the amount of radiation available in our environment, human beings as well as animals could be exposed to radiological hazards which in turn pose serious health risk. It is therefore of great importance that we have good knowledge of the amount of radiation we are exposed to in our environment in order for us to stay safe. This can actually be done by employing the techniques available for the detection/analysis of radioactivity in our environment. Also, pollutants arising from human activities can be found in our soil as a majority of these materials are radioactive. These radioactive materials considering their concentration, exposure time, physical and chemical properties can have a tremendous effect on life itself (Daniel *et al.,* 2015). Though a host of these materials are found to exist naturally but can also be produced artificially by bombarding proton and neutron on normal atoms of elements (Obed, 2014). The artificially produced radioactive elements which are called radioisotopes form the major components of fertilizers, herbicides and pesticides which are applied to boost crop yield and increase the soil fertility. As time progresses, the radionuclide concentration been not uniform but vary from place to place is bound to have an effect on man and its environment. Thus, radionuclide distribution knowledge is pertinent n radiation monitoring (Giwa *et al.,* 2018). Rasheed and Karmal (2013) reported that there are many methods of radioactivity analysis, and many types of detectors used for the measurement of radioactivity, they may be designed in the gaseous, liquid, or solid state which they differ not only in their physical properties but also in chemical. Also according to this same author, the radiation detector or method of radioactivity analysis requires a good understanding of the properties of nuclear radiation, the mechanisms of interaction of radiation with matter, half-life, decay schemes, decay abundances, and energies of decay. One of the techniques of analyzing radioactivity concentration in our environment is by gamma ray spectrometry (where sodium iodide is used as the detector).

Ekakpamre community which is the study area for this research, due to its rich deposits of crude oil plays host to several oil companies having oil wells within the community. As a result of this, the community at some point experiences oil spillage possibly due to the activities of pipeline vandals, busted pipelines and so on. This situation affects a large portion of the soil and even water within the community by the introduction of radioactive substances into the environment which in turn poses health risks among dwellers.

The aim of this research is therefore to measure the radioactivity concentration of soil, mosses and lichen samples obtained from Ekakpamre community in Delta State of Nigeria in order to ascertain the effect crude oil spillage has on this community. In this research, the mean concentrations of^{238}U, ^{232}Th and ^{40}K in selected soil, mosses and lichen samples were measured with the aid of gamma ray spectrometry with sodium iodide as the detector.

The study area for this research is Ekakpamre community in Ughelli South Local Government Area of Delta State, Nigeria. Geographically, Ogbuagu *et al.* (2012) reports that Ekakpamre Community is located in Ughelli town, Delta State of Nigeria between Latitude 5° 52´N and Longitude 5° 58´E. This is shown in Fig. 1.

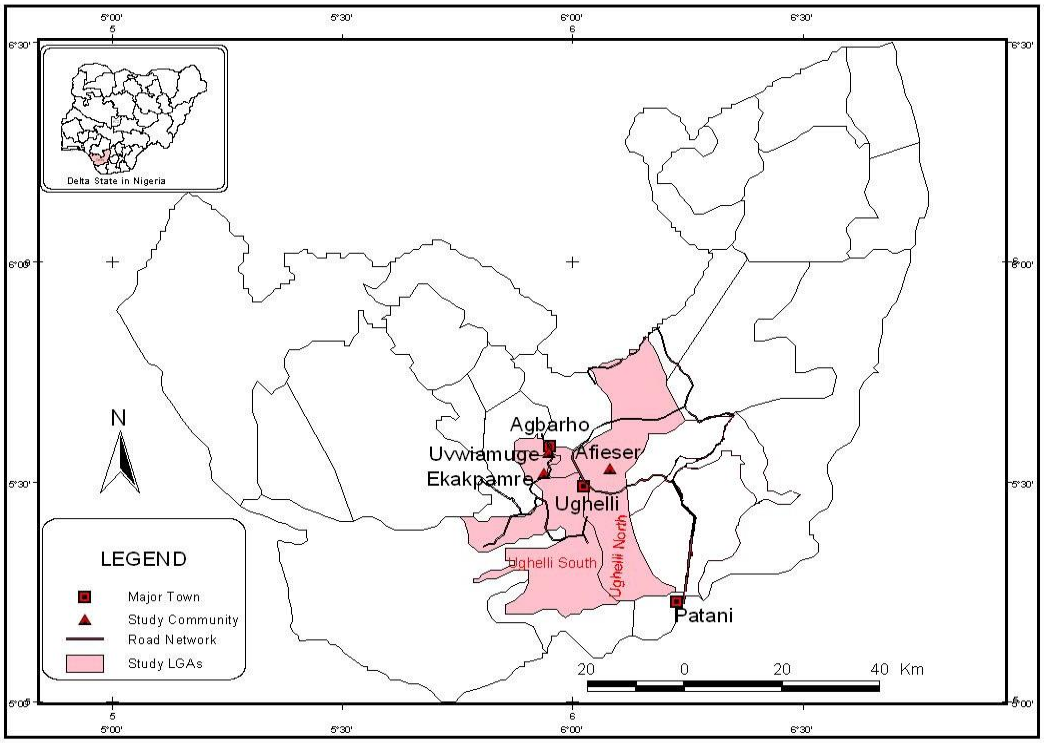

Fig. 1: Geographical Location of Ekakpamre Community (Source: Atakpo, 2009)

It is pertinent to state that Ekakpamre community is located in the Niger-Delta region of Nigeria where the predominant occupations among dwellers include fishing, trading, farming and hunting.

Materials and Methods

The soil, moss and lichen used in this research were collected randomly from different locations within the community. A total of fifteen (15) samples were collected for the purpose of this research. These include three samples of lichen, six samples each of soil and moss respectively. The obtained samples were stored in polythene bags and labelled accordingly. All the samples were later taken to the laboratory and dried at 90^{o}C for two hours with a temperature-controlled oven. Thereafter, the samples were removed from the oven, sieved with a 2 mm mesh and ground into powder form using mortar and pestle. The soil samples were weighed using a digital electronic weighing balance (METLAR MT-5000D) and 240 g of the samples were poured into polythene bag and sealed with cello-tape to prevent them from further exposure to air and other unwanted particles. All the samples were taken to the Centre for Energy Research and Development (CERD) laboratory located at the Obafemi Awolowo University, Ile-Ife, Nigeria for further analysis. The samples were analyzed using a gamma ray spectrometer with NaI(Tl) as the detector.

Result and Discussion

Activity concentration values of soil, moss and lichen samples

The measured activity concentration of ^{238}U, ^{232}Th and ^{40}K of all the samples used in this research are presented in Table 1. The mean values of the activity concentration of all the samples are also presented in Table 2 and Fig. 2, respectively.

Table 1: Mean concentrations of the activity of soil, moss and lichen samples

Samples	^{238}U (BqKg^{-1})	^{232}Th (BqKg^{-1})	^{40}K (BqKg^{-1})
CS1	27.56±2.25	10.66±4.95	199.27±2.73
CS2	20.73±1.95	91.36±16.44	986.44±5.40
ES1	32.53±2.50	125.66±20.84	1111.94±5.81
ES2	50.94±10.84	40.39±2.89	742.03±5.60
US1	58.28±3.64	52.59±10.94	1051.39±5.50
US2	20.52±1.95	7.56±4.64	635.24±4.20
Mean Value	35.09±3.86	54.70±10.12	787.72±4.87
CL2	12.45±1.63	32.17±8.26	111.94±5.80
EL1	37.19±2.71	44.48±9.97	151.68±7.04
UL1	35.78±2.60	130.61±21.47	96.72±5.25
Mean Value	28.47±2.31	69.09±13.23	120.11±6.03
CM1	43.02±2.91	50.73±10.58	101.26±5.28
CM2	39.02±2.81	51.63±9.88	102.43±4.28
EM1	23.49±2.10	96.72±17.10	86.03±4.79
EM2	29.68±2.36	48.11±10.32	96.01±5.25
UM1	34.91±2.66	57.06±11.57	132.22±6.51
UM2	40.42±2.75	14.64±6.19	87.64±4.98
Mean Value	35.09±2.60	53.15±10.94	100.93±5.18

Table 2: Mean activity concentration values of soil, moss and lichen samples

Samples	^{238}U (BqKg^{-1})	^{232}Th (BqKg^{-1})	^{40}K (BqKg^{-1})
CS	24.15±2.10	51.01±10.70	592.86±4.07
ES	41.74±6.67	83.03±11.87	926.99±5.71
US	39.40±2.80	30.08±7.79	843.32±4.85
CL	12.45±1.63	32.17±8.26	111.94±5.80
EL	37.19±2.71	44.48±9.97	151.68±7.04
UL	35.78±2.60	130.61±21.47	96.72±5.25
CM	41.02±2.86	51.18±10.23	101.85±4.78
EM	26.59±2.23	72.42±13.71	91.02±5.02
UM	37.67±2.71	35.85±8.88	109.93±5.75

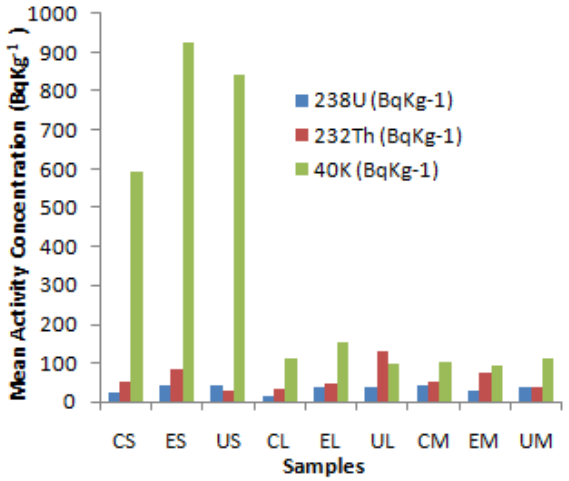

Fig. 2: Mean activity concentration values of soil, moss and lichen samples

From Table 1, the activity concentration of ^{238}U was in the range of 12.45±1.63 to 58.28±3.64 BqKg^{-1} for all the samples with sample code CL2 having the least activity concentration while sample with code US1 recorded the highest activity concentration. For ^{232}Th, the activity concentration of all the samples varied between 7.56±4.64 and 130.61±21.47 BqKg^{-1} with UL1 having the highest activity concentration while US2 had the least activity concentration. For ^{40}K, the range of activity concentration was between 1111.94±5.81 and 86.03±4.79 BqKg^{-1}, respectively. Also, it was observed that the activity concentration of radionuclides in moss and lichen are lower than that of soil which suggests that the soil is the primary source of primordial radionuclide. This result seems to be in agreement when compared with some existing literatures (.Ljiljana *et al.*, 2020; Grdović *et al.*, 2010; Dragović *et al.*, 2010; Čučulović *et al.*, 2012; Mitrović *et al.*, 2016; Krmar *et al.*, 2018).

Calculation of absorbed dose (AD) rate

In this research, as reported by Faweya *et al.* (2014), the absorbed dose rate for all the samples were calculated using the direct relationship between terrestrial gamma radiation and radionuclide concentrations at 1 m above ground as proposed by Beck *et al*. (1972) and UNSCEAR (1988).

$$D = 0.427A_U + 0.662A_{Th} + 0.043A_K \quad (1)$$

In equation (1), D is referred to as the dose rate measured in nGyh^{-1}. A_U, A_{Th} and A_K represent the concentrations of the activities of ^{238}U, ^{232}Th and ^{40}K radionuclides, respectively. Fig. 3 shows the comparison of absorbed dose rates of the different samples.

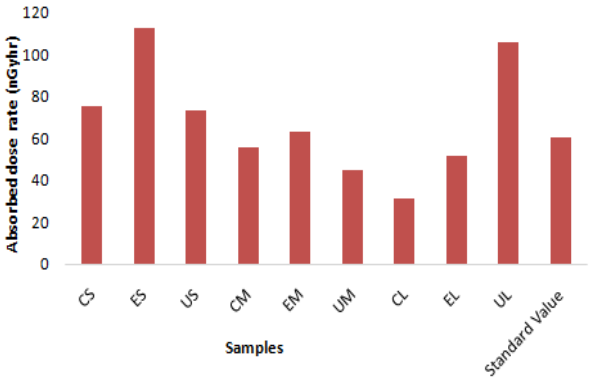

Fig. 3: Comparison of absorbed dose rates of the different samples with standard

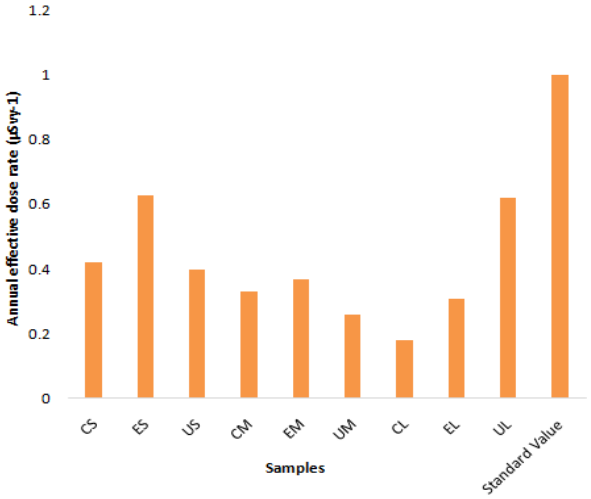

Fig. 4: Comparison of annual effective dose rates of the different samples with standard

Calculation of annual effective dose (AED) rate

The Annual Effective Dose rate in air helps in assessing the effectiveness of the gamma dose in causing damage to human tissue (Bello *et al*., 2015).

In this research, the annual effective dose rate pertaining to the radionuclides in the moss and soil samples were calculated. This was actually achieved by applying the conversion factor of 0.7 SvGy^{-1}, which convert absorbed dose in air to human effective dose and using an outdoor occupancy factor of 0.2(Faweya *et al.*, 2014).The formula employed for the calculation of the AED is that given by as shown in Equation 3.

$$E = TFQ\varepsilon \quad (3)$$

Where E is the effective dose rate (Svy^{-1}), T is the time in seconds in a year (8760), F is the occupancy factor which is the average time spent outdoor in the area (0.2), Q is the quotient of effective dose rate in air (0.7 SvGy^{-1}), ε is the factor converting nano (10^{-9}) to micro (10^{-6}) and D is the absorbed dose rate in air (nGyh^{-1}) (Jibiri and Adewuyi, 2008).

The comparison of annual effective dose rates of the different samples with the standard value is displayed in Fig. 4.

Calculation of the radium equivalent dose (Ra_{eq})

In order to determine if there are any radiological hazards associated with humans through the use of soil within the study area for the construction of buildings, the radium equivalent activity of the soil samples were determined. In their opinion, El-Kamel (2012) reported that the radium equivalent activity can be calculated from the relation suggested by Beretka and Mathew (1985) as shown in Equation 4.

$$Ra_{eq} = (A_{Th} \times 1.43) + A_{Ra} + (A_k \times 0.077) \quad (4)$$

Where A_{Th} is the activity concentration of ^{232}Th in Bqkg^{-1}, A_{Ra} is the activity concentration of ^{226}Ra in Bqkg^{-1}, A_K is the activity concentration of ^{40}K in Bqkg^{-1} (UNSCEAR, 2000; Avwiri and Agbalagba, 2013; Akpolile and Ugbede, 2019; El-Kamel, 2012).

Figure 5 displays the comparison of radium equivalent for the different samples with the standard value.

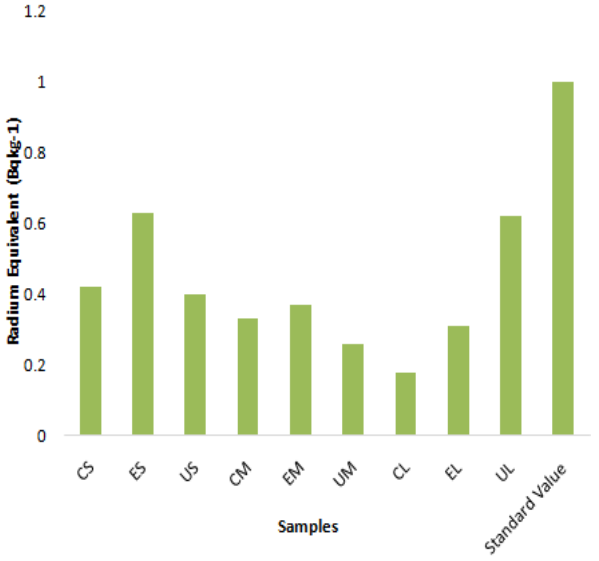

Fig. 5: Comparison of Radium equivalent for the different samples

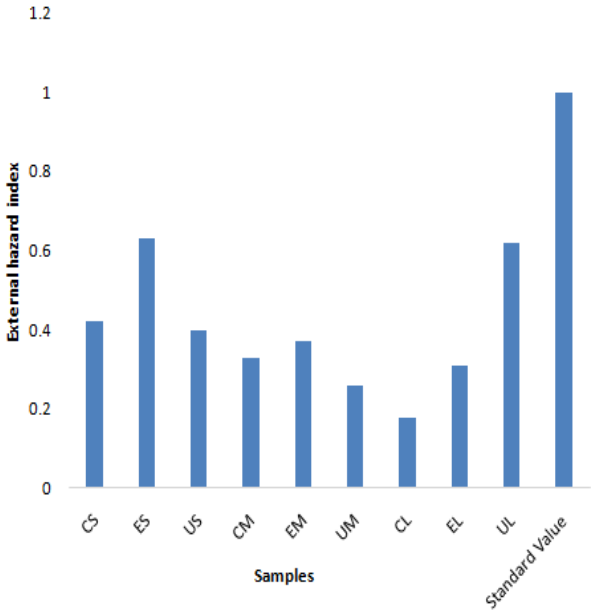

Fig. 6: Comparison of external hazard index for the different samples

Table 3: Calculated values of absorbed dose rate, annual effective dose, radium equivalent dose and external index of soil and moss samples

Samples	D(nGyhr^{-1})	E(μSvy^{-1})	Ra_{eq}(Bqkg^{-1})	H_{ex}
CS	75.46	92.54	156.52	0.42
ES	112.65	138.15	231.85	0.63
US	73.00	89.53	147.35	0.40
CM	55.78	68.40	122.05	0.33
EM	63.21	77.52	137.16	0.37
UM	44.55	54.63	97.40	0.26
CL	31.43	38.54	67.07	0.18
EL	51.85	63.59	112.48	0.31
UL	105.90	129.88	230.00	0.62
Standard Value by UNSCEAR (2000)	60	80	370	1

Calculation of the external hazard index (H_{ex})

External hazard index (H_{ex}) is defined as the radiation dose rate arising from external exposures to gamma radiation and is calculated as given by Alamgir *et al.* (2012) as:

$$H_{ex}=\frac{C_{Ra}}{370}+\frac{C_{Th}}{259}+\frac{C_K}{4810} \quad (5)$$

A comparison of the external hazard index for the different samples with the world average is shown in Fig. 6.

Table 3 shows the values of absorbed dose rate, annual effective dose and radium equivalent dose of selected soil and moss samples.

From Table 3, the absorbed dose rate (D) for soil samples ranges between 75.46 and 112.65 nGyh^{-1}, that for moss sample was between 44.55 and 63.21 nGyh^{-1} while for lichen sample is between 31.43 21 to 105.90 21 nGyh^{-1}. The annual effective dose (E) for the soil samples was between 89.53 and 138.15 μSvy^{-1}, moss sample were in the range of 54.63 to 77.52 μSvy^{-1} while that for lichen is 38.54 μSvy^{-1} to 129.88 μSvy^{-1}. The radium equivalent (Ra_{eq}) for the soil samples was in the range of 147.35 BqKg^{-1} and 231.85 BqKg^{-1}, for the moss samples was in the range of 97.40 to 137.16 BqKg^{-1} while that for lichen is 67.07 to 230.00 BqKg^{-1}. From Fig. 1 above, it is obvious that in all the samples, ^{40}K has the highest activity concentration. Comparing the values of absorbed dose rate, radium equivalent, external hazard index and annual effective dose with world average, it was observed that the absorbed dose rate for all samples except CM, UM, CL and EL were higher than the world average, the annual outdoor effective dose calculated also revealed that all samples except CM, EM, UM, CL and EL had values higher than the standard value as shown in Table 3. The external hazard index in all samples is less than 1 indicating that the area under study is safe.

Conclusion

The activity concentration of soil, moss and lichen samples obtained from various locations in Ekakpamre community in Delta State, Nigeria was studied and the result showed that the activity concentration of ^{232}Th and ^{40}K was above the world average possibly tending to their occupation and the presence of oil activity in the area while ^{238}U was found to be within the limit. The values of the mean absorbed dose rate, annual effective dose rate and radium equivalent were higher than the world average value for some samples indicating that some measures and precaution has to be taken to avoid the risk of cancer as time progresses while the external hazard index value was lower than one indicating that the area under study is safe.

Conflict of Interest

The author has declared that there is no conflict of interest related to this work.

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