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Assessment of Environmental Radioactivity of Surface Soils in Some Selected Local Government Area in Benue State.

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Abstract: *The activity concentrations of naturally occurring radionuclides ^{40}K , ^{238}U, and ^{232}Th in surface soil in Oju, Otukpo and Ogbadibo Local Government Area of Benue State, Nigeria were measured using NaI (TI) gamma ray spectrometric technique. The mean activity concentration of radionuclides ^{40}K, ^{238}U and ^{232}Th were 8211.358±668.544 Bq kg^{-1}, 191.812±9.046 Bq kg^{-1} and 76.478±7.478 Bq kg^{-1} in Oju, 176.792 ± 18.632 Bq kg^{-1}, 25.514 ± 5.772 Bq kg^{-1} and 42.544 ± 4.662 Bq kg^{-1} in Otukpo, 644.466±53.516 Bq kg^{-1}, 43.468±9.312 Bq kg^{-1} and 46.756 ± 4.60 Bq kg^{-1} in Ogbadibo Local Government Area respectively. The total mean absorbed dose rate in this study were 141.93304 nGyh^{-1}, 46.66065 nGyh^{-1} and 77.22535 nGyh^{-1} for Oju, Otukpo and Ogbadibo, whereas the mean annual effective dose rate are 1.25732 mSv/y, 0.40523 mSv/y and 0.62505 mSv/y. The mean activity concentrations of measured radionuclides were compared with other literature values. The ratios between the detected radioisotopes have been calculated for spatial distribution of natural radionuclides in the studied area. . Also the radiological hazard of the natural radionuclide content, radium equivalent activity (Raeq) of the soil samples was also calculated.*

Keywords: *Soils, radiological hazards, gamma ray spectrometry.*

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I. Introduction

There are many sources of background ionizing radiation level in the environment in which man lives. The environment contains ionizing radiation level that is made up of contributions from cosmic ray and terrestrial radioactivity (from natural and man-made sources). The contributions from these components vary with local geology, altitude and geomagnetic latitudes (Alaamer, 2008 & Mehade, 2014). Activities like gas and oil exploitation as well as mining of solid minerals augment the natural sources. The natural terrestrial component is due to the radioactivity of members of the decay series of ^{238}U and ^{232}Th and the non-series ^{40}K that are present in environmental materials such as different types of water, rock, soil and the building materials composed of them. Activity concentrations in soil and water give rise to radionuclide loading in food and fodder crops, which in turn gives rise to internal exposure of humans (Badran *et al*., 2003).

The radioactivity concentrations in soil give information on both natural and man-made sources which is important in radiological hazard monitoring and assessment of radiation dose for public. Studies of natural radioactivity are necessary not only for their radiological impact but also for their ability to act as excellent biochemical and geochemical traces in the environment (EPA, 2007 and Mehade, 2014).

The contribution of radiation from surface soils to human exposure can either be whole body due to external radiation originating directly from primordial radionuclides present in surface soil or internal due to inhalation of radon (Isinkaye and Emelue, 2015, Jibril and Okeyode, 2012, Ngachin *et al.*, 2007). The internal exposure to radiation, affecting the respiratory track, is due mainly to radon and its decay products which emanate from soil, sediment and building materials (Hameed *et al*., 2014). 222Rn results from radioactivity of 238U and itself decays with a half life of 3.82 days (Felix et al., 2015). Long-term exposures to radioactivity and inhalation of radionuclides have serious health effects such as chronic lung cancer and leukemia (Qureshi *et al*., 2014).

Estimated exposure to natural radiation from naturally occurring radionuclides has become environmental concern to the public and national authorities of many countries because of its deleterious effects on human health (Kitto *et al*., 2006). Therefore tremendous efforts are being made to locate and control the

sources of natural radiation where economical interest exists and on which legislation must be applied. It has been reported that natural sources contribute almost 90% of the collective radiation exposure of the world's population (UNSCEAR, 2003).

Radiological studies on sediments and water in Nigeria especially in the Niger Delta region has been carried out because of the activities of oil exploration and exploitation industries. The result showed an increase in background radiation of some areas which include Akoko, Southwestern Nigeria (Ajayi 2008), Aluu, Rivers State Nigeria (Avwiri *et al*, 2014), Imo state, Oguta lake (Isinkaye and Emelue, 2015), Guma, Benue State (Sombo, Ayaaka & Utah, 2016). Sombo *et al.,* (2016) reported that the specific activity concentration of the background ionization radiation of the surface soils sample measured from Guma Local Government of Benue State, ranged from 38.12–58.10Bq/kg for 40K, 3.53–4.41Bq/kg for ^{238}U and 3.35–7.11Bq/kg for ^{232}Th in the urban areas with mean values of 46.23, 413 and 4.92Bq/kg respectively. The values obtained are lower than the world average value of 420, 33, and 45Bq/kg reported by Avwiri and Ononugbo (2012). The objective of this study is to assess the environmental radioactivity of surface soils and evaluate their radiological health risk to the populace associated with the use of the surface soils from Oju, Otukpo and Ogbadibo Local Government Areas. The result obtained from this study will serve as radioactivity database for the area and will also be relevant in the radiological mapping of the area.

II. Materials and Methods

2.1 Sampling Sites

Table 1. Sampling Locations and their coordinates.

S/N	Location	Latitude	Longitude	POPULATION
1	Oju	60 51'0" N	8025'0" E	195,750
2	Otukpo	70 11' 35" N	808'47 "E	309, 530
3	Ogbadibo	70 19'30" N	80 14'63" E	152, 190

Population: (Census, 2011)

2.2 Sample Collection and Preparation

Fifteen surface soil samples were collected randomly from various locations along the river bank. Surface soils were collected at about 500 meters away from the river bank. 4kg of Surface soil samples collected were placed in black polythene bags and properly labeled at the point of collection. The collected samples were transported to the National Institute of Radiation Protection and Research, University of Ibadan.

In the soil samples large stones and other objects were removed, then were sun dried for 24 hours to a constant mass, then sieved through mesh 500 μm. All soil samples were weighed and sealed in marinelli containers (Mohsen *et al*., 2008). The samples were sealed hermitically and externally using cellophane tape and kept for about four weeks to reach secular equilibrium where the rate of decay of ^{226}Ra becomes equal to that of their daughters before it is taken for gamma ray spectrometric analysis (Ononugbo, Avwiri, & Ogan, 2016).

2.3 Measurement Set-up

The detection and measurement of radionuclides in the samples were carried out by gamma spectrometry system using a 8.5cm x 6.5cm NaI (Ti) detector model 802 and the detector was shielded in a 10cm thick and cylindrical in shape Canberra leads to reduce gamma ray background. The concentration of the various radionuclide of interest were determined in Bq kg-1 for soil samples for the identification of the various radionuclide that may be present in the samples through gamma energies they emit, the system have to be efficiency collaborated using a set of International Atomic Energy Agency standard source of known radionuclide with well defined energies within the range of interest (0.511 – 2.615 Mev) (Ajibode et al., 2013, Ravisankar et al.,2014).

The samples were analyzed at National Institute of Radiation Protection and Research centre (NIRPR), University of Ibadan. Gamma Ray Spectrometry using a thallium activated 3"x3" Sodium iodide NaI (TI) detector connected to ORTEC 456 amplifier. The detector, enclosed in a 100mm thick lead shield, was connected to a computer program SAMPO 90 window that matched gamma energies to a library of possible isotopes. Since the accuracy of the quantitative measurements is depended on the calibration of the spectrometry system and adequate energy. Background measurement and efficiency calibration of the system was made possible using Cs-137 and Co-60 standard sources from IAEA, Vienna.

The activity concentration (A) of each radionuclide in the samples was determined by using the net count *(cps)* (found by subtracting the background counts from the gross counts with same counting time under the selected photo peaks), weight of the sample, the photo-peak efficiency and the gamma intensity at a specific energy

$$A = \frac{cps}{E\ x\ I\ x\ W} \qquad 1$$

Where, A = activity concentration of the sample in $Bqkg^{-1}$ *or* BqL^{-1}
cps = the net count per second
E = the counting efficiency of the gamma energy
I = Absolute intensity of the gamma ray and
W = net weight of the sample (in kilogram, kg or litre, L).
The errors in the measurement were expressed in term of standard deviation ($\pm 2\sigma$) where σ is expressed as (UNSCEAR, 2000).

$$\sigma = [\frac{N_s}{T_s^2} + \frac{N_b}{T_b^s}]^{1/2} \quad 2$$

Where, N_s is the sample counts measured in time T_S and N_b is the background counts measured in time T_b. The standard deviation $\pm 2\sigma$ in *cps* was converted into activity in Bqkg^{-1}.

Radium equivalent activity

The measured values of Ra_{eq} were obtained by making use of the following equation (Huy, 2005 & Alharbi, 2011).

Ra_{eq} (Bqkg^{-1}) = $A_U + 1.43A_{Th} + 0.077A_k$ 3

Here A_U, A_{Th}, and A_K are the average activity concentrations of ^{238}U, ^{232}Th, and ^{40}K, respectively.

Absorbed dose rate in air

The values of D_r in air and 1 m above the ground level are calculated from the measured activity concentrations of ^{238}U, ^{232}Th, and ^{40}K radionuclides using the following semiempirical formula (El-Shershaby, 2016 & Fatima, 2008).

D_r (nGyh^{-1}) = $0.427A_U + 0.662A_{Th} + 0.043A_K$ 4

Eq. (3.4) was modified to include the contributions of artificial radionuclides of cesium, ^{137}Cs, as well as cosmic radiation via the following equation (El-Shershaby, 2006).

D_y(nGyh^{-1}) = $0.427A_U + 0.662A_{Th} + 0.043A_K + 0.03A_{Cs} + 34$ 5

Here 0.427, 0.662, and 0.043 are the dose rate conversion factors to convert the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K and ^{137}Cs radionuclides into absorbed dose rates as proposed by UNSCEAR, (2003). Basically, these factors are representative of the absorbed dose rates in air per unit activity per unit of soil mass, in units of nGy h^{-1} per Bq kg^{-1}.

Annual effective dose equivalent

The annual effective dose equivalent (AEDE*)* received by individuals was calculated from the calculated values of D_r by applying the dose rate conversion factor of 0.7 Sv Gy^{-1} and the occupancy factors of 0.2 (5/24) and 0.8 (19/24) for outdoors and indoors, respectively (UNSCEAR, 2003). The annual effective outdoor doses, D_{out}; the annual effective indoor doses, D_{in}; and total annual effective doses, D_{tot}, were calculated according to the following equations (Veiga, 2006).

D_{out} (mSvy^{-1}) = D_r(nGyh^{-1}) x 24h x 365.25d x 0.2 x 0.7SvGy^{-1} x 10^{-6} 6

D_{in} (mSvy^{-1}) = D_r (nGyh^{-1}) x 24h x 365.25d x 1.4 x 0.8 x 0.7SvGy^{-1} x 10^{-6} 7

Dtot (m S v y^{-1}) = $D_{out} + D_{in}$ *8*

Radiological Hazard Indices

External and internal radiation hazard indices

The external radiation hazard index, H_{ex} , corresponding to ^{238}U, ^{232}Th, and ^{40}K *natural* radionuclides, was calculated using the following equation (Shams, 2013 *and* Beretka, 1985).

$$\mathbf{H_{ex}} = \frac{\mathbf{A_U}}{\mathbf{370Bqkg^{-1}}} + \frac{\mathbf{A_{Th}}}{\mathbf{259Bqkg^{-1}}} + \frac{\mathbf{A_K}}{\mathbf{4810Bqkg^{-1}}} \quad 9$$

$$\mathbf{H_{in}} = \frac{\mathbf{A_U}}{\mathbf{185Bqkg^{-1}}} + \frac{\mathbf{A_{Th}}}{\mathbf{259Bqkg^{-1}}} + \frac{\mathbf{A_K}}{\mathbf{4810Bqkg^{-1}}} \quad 10$$

The measured values of H_{ex} and H_{in} should also be less than or equal to unity, i.e. H_{ex} and $H_{in} < 1$.

III. Results and Discussion

The result of activity concentration of ^{40}K, ^{238}U and ^{232}Th with their radium equivalent values in the soil are presented in Table 2 - 4 & Figure 1. The associated radiation hazard parameters calculated are shown in Table 5-7.

3.1 Results

Table 2: Activity Concentration (Bqkg^{-1}) of Soil Samples in Oju LGA

SAMPLE CODE	K-40	U-238	Th-232
AINU	2615.90±197.02	44.86±10.25	57.39±4.87
IKACHI UKPA	2154.0±200.21	32.26 ± 2.53	144.66±16.91
IMOHO IBILLA-IGEDE	2550.96±195.87	35.85±7.74	73.64±6.37
OGENGENG	858.98±72.62	69.41±15.22	73.00±6.26
OMUDA	157.59±14.12	47.16±9.49	33.70±2.98
Average	**8211.358±668.544**	**191.812±9.046**	**76.478±7.478**

Table 3: Activity

SAMPLE CODE	K-40	U-238	Th-232
ALLAN AKPA	262.37±23.76	27.55±6.64	41.87±3.63
ASA OTTO	288.33±34.45	31.97±7.18	95.35±11.37
OGBUOJU ICHO	73.71±8.39	21.24±4.87	32.06±3.68
OKPOKU	145.25±16.30	21.02±4.61	15.62±2.02
OTOBI-AKPA	114.30±10.26	25.79±5.56	27.82±2.61
Average	**176.792±18.632**	**25.514±5.772**	**42.544±4.662**

Concentration (Bqkg^{-1}) of Soil Samples in Otukpo LGA

Table 4: Activity Concentration in (Bqkg^{-1}) of Soil Samples in Ogbadibo LGA

SAMPLE CODE	K-40	U-238	Th-232
ODOBA	122.01 ±3.23	30.88±6.58	35.34±4.32
OLAICHAGBAHA	432.09±39.32	35.85±7.99	57.67±4.80
OLAIGBENA	504.82±44.43	49.45±10.20	36.00±3.07
OROKAM 1	1894.60±150.75	79.48±16.58	53.81±4.74
UGBOKPO	268.81±29.85	21.68±5.21	50.96±6.07
Average	**644.466±53.516**	**43.468±9.312**	**46.756±4.60**

Table 5: The absorbed dose Rate (D), annual effective dose rate (AEDR) (indoor and outdoor) index (external, Hex and internal, Hin) and radium equivalent activity (Raeq) for Soil Sample in Oju LGA

Sample Code	Absorbed dose ($nGyh^{-1}$)	Annual Effective dose indoor (mSvy^{-1})	Annual Effective dose outdoor (mSvy^{-1})	Annual Effective dose total (mSvy^{-1})	External hazard Index (H_{ex})	Internal hazard Index (H_{in})	Radium Equivalent Activity (RAeq)
AINU	169.6311	0.20804	1.16410	1.37214	0.88667	1.00792	328.30
IKACHI-UKPA	202.16194	0.24793	1.38842	1.63635	1.09354	1.18073	404.84
IMOHO IBILLA-IGEDE	173.74891	0.21309	1.19328	1.40637	0.91156	1.00845	337.51
OGENGENG	114.90014	0.14091	0.78912	0.93003	0.64803	0.83562	239.9
OMUDA	49.22309	0.06037	0.33806	0.94173	0.29034	0.41780	107.5
AVERAGE	**141.93304**	**0.17507**	**0.97460**	**1.25732**	**0.76603**	**0.08901**	**283.61**

Table 6: The absorbed dose Rate (D), annual effective dose rate (AEDR) (indoor and outdoor) index (external, Hex and internal, Hin) and radium equivalent activity (Raeq) for Soil Sample in Otukpo LGA

Sample Code	Absorbed dose ($nGyh^{-1}$)	Annual Effective dose indoor (mSvy^{-1})	Annual Effective dose outdoor (mSvy^{-1})	Annual Effective dose total (mSvy^{-1})	External hazard Index (H_{in})	Internal hazard Index (H_{in})	Radium Equivalent Activity (RAeq)
ALLAN AKPA	50.76365	0.06226	0.34864	0.54866	0.29067	0.36513	107.6
ASA-OTTO	89.17108	0.10935	0.61241	0.72176	0.51451	0.60090	190.4
OGBUOJU-ICHO	33.46273	0.04104	0.22982	0.27086	0.19651	0.25392	72.7
OKPOKU	25.56173	0.03135	0.17555	0.20690	0.14732	0.20413	54.5
OTOBI-AKPA	34.34407	0.04211	0.23587	0.27798	0.20080	0.27058	74.5
AVERAGE	**46.66065**	**0.05722**	**0.32045**	**0.40523**	**0.26996**	**0.33893**	**99.9**

Table 7: The absorbed dose Rate (D), annual effective dose rate (AEDR) (indoor and outdoor) index (external, H_{ex} and internal, H_{in}) and radium equivalent activity (Raeq) for Soil Sample in Ogbadibo LGA

Sample Code	Absorbed dose ($nGyh^{-1}$)	Annual Effective dose indoor ($mSvy^{-1}$)	Annual Effective dose outdoor ($mSvy^{-1}$)	Annual Effective dose total ($mSvy^{-1}$)	External hazard Index (H_{ex})	Internal hazard Index (H_{in})	Radium Equivalent Activity (RAeq)
ODOBA	41.82727	0.05121	0.28726	0.33847	0.24523	0.32873	90.8
OLAICHAGBAHA	72.06536	0.08838	0.49493	0.58331	0.40939	0.50628	151.5
OLAIGBENA	66.65441	0.08174	0.45778	0.53951	0.37760	0.51125	139.8
OROKAM I	151.02798	0.18521	1.03723	1.22240	0.81646	1.03127	302.3
UGBOKPO	54.55171	0.06690	0.37465	0.44155	0.31124	0.36983	115.2
MINIMUM	**41.82727**	**0.05121**	**0.28726**	**0.33847**	**0.24523**	**0.32873**	**90.8**
MAXIMUM	**151.02798**	**0.18521**	**1.03723**	**1.22240**	**0.816459**	**1.03127**	**302.3**
AVERAGE	**77.22535**	**0.09469**	**0.53037**	**0.62505**	**0.43198**	**0.54947**	**159.92**

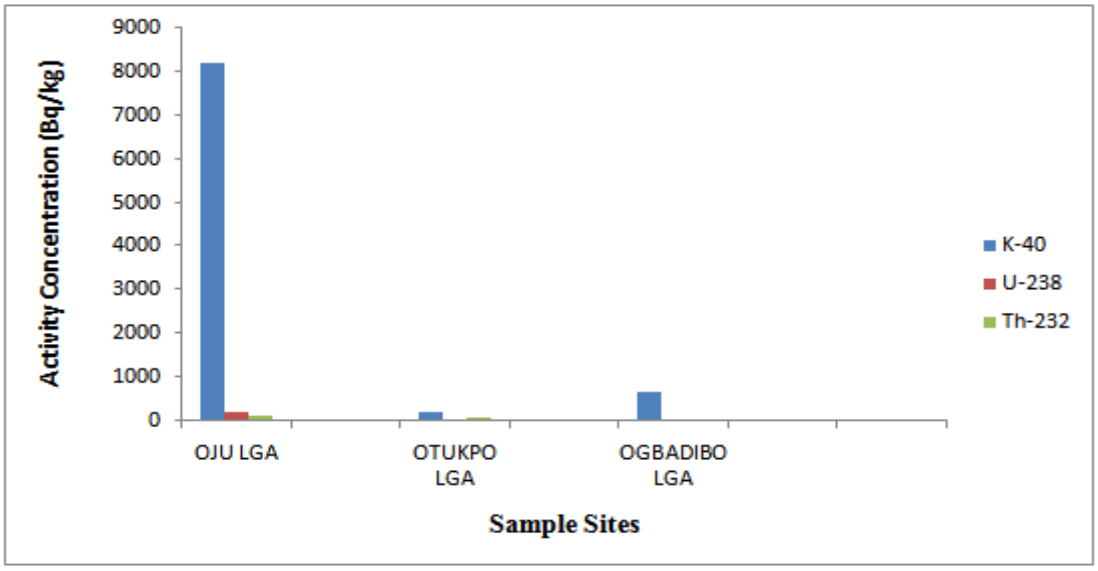

Fig. 1: Mean Concentrations of ^{40}K, ^{238}U and ^{232}Th in Surface Soils of the Study Areas.

3.2 Discussion

3.2.1 Specific Activity concentration of ^{40}K, ^{238}U and ^{232}Th in the Soils.

The activity concentration of ^{40}K, ^{238}U and ^{232}Th in the soil samples are determined and shown in Table 2-4 and Figure 1. The mean activity concentration for ^{40}K are 8211.358 ±6 68.544 $Bqkg^{-1}$, 176.792 ± 18.632$Bqkg^{-1}$, and 644.466 ± 53.516 Bq kg^{-1} for Oju, Otukpo and Ogbadibo respectively. The mean activity concentration for ^{238}U are 191.812 ± 9.046 $Bqkg^{-1}$, 25.514 ± 5.772 $Bqkg^{-1}$ and 43.468 ± 9.312 $Bqkg^{-1}$ for Oju, Otukpo and Ogbadibo. The mean activities concentration for ^{232}Th are 76.478 ± 7.478 $Bqkg^{-1}$, 42.544 ± 4.662 $Bqkg^{-1}$, and 46.756 ± 4.60 Bq kg^{-1} for Oju, Otukpo and Ogbadibo respectively.

The activity concentration of ^{40}K, ^{238}U and ^{232}Th in the surface soils vary from area to area because surface of a soil can exhibit large variation in geochemical and mineralogical properties (Krmar *et al*., 2009). In all the sampling points, mean activity concentration of the natural radionuclide is of the order $^{232}Th < ^{238}U < ^{40}K$. in Oju, $^{238}U < ^{232}Th < ^{40}K$ in Otukpo and $^{238}U < ^{232}Th < ^{40}K$ in Ogbadibo Local Government Area. The activity concentration of ^{232}Th is high which may be due to the presence of monazite deposit. The increasing trend of ^{40}K is due to the presence of sandy and clay soil. The activity concentration of ^{40}K and ^{232}Th for all measured samples is higher than the world average value of 450.0 and 33.0 Bqkg-1 in Oju and Ogbadibo while the mean activity concentration of ^{40}K in Otukpo is within the world value 0f 450.0 Bq/kg and the mean values of $^{238}U$are within their world values of 45.0 $Bqkg^{-1}$ in Otukpo and Ogbadibo but higher than the world value of 45.0 in Oju LGA respectively. Fig. 1 compares the mean activity concentration of ^{40}K, ^{238}U and ^{232}Th in surface soils of the study areas.

3.2.2Radiological Indices

In order to assess the health effects, the quantities such as radium equivalent activity (Raeq), absorbed dose rate (D), annual effective dose (E) and external hazard index (Hex) have been calculated from the activity

concentrations of ^{238}U, ^{232}Th and ^{40}K using equations (3), (4), (6 & 7), (9) and (10), respectively and the values are shown in Table 5-7.

The results shown in Table 5-7 depict that the mean value for absorbed dose rates due to the terrestrial gamma rays at 1m above the ground is 88.60663 nGyh-1 for soil samples in the study areas. The mean value is higher than the world average value of 55 nGyh-1 (UNSCEAR, 2000). While the mean value of the radium equivalent activity calculated is less than the world mean value of 390 Bq/kg. The little values of the background ionizations radiation and absorbed dose rate obtained in the sample areas may be as a result of metamorphic rock underlying the territory, lead mining, use of phosphate fertilizer by farmers in the areas, brown earth volcanic formation of material (salt spring) and other hazardous materials in the areas. Therefore, continuous absorption of the radiation dose may result to health problems such as cancer of the lungs, mutation, heart disease, chronic kidney disease, hypokalemia and antibiotics, erythema, low and high blood pressure etc. This calls for medical investigation of the radiological level of the surface soils in the study areas.

IV. Conclusions

The radionuclide contents, activity concentrations and radiological impact of the soil samples collected from Oju, Otukpo and Ogbadibo Local Government of Benue State were investigated in the present study. The results indicated that only the natural radionuclides were present in the samples. The natural radioactivity concentrations of ^{40}K, ^{238}U and ^{232}Th were relatively higher than the world average values except ^{238}U in Otukpo soil samples. The values of mean absorbed dose rate is higher than the world mean value while annual effective dose and the radium equivalent activity were lower than the global mean values except in Oju where the mean value of annual effective dose rate is higher than the global mean value; whereas the external hazard indices were found less than unity which indicated that there may be no immediate health implication to the general populace especially in Oju LGA but prolonged exposure could lead to radiation related health hazard, therefore Government should monitor the activities of farmers, fishermen and other industrial activities on the surface soils in the study area and its environment. This result serves as a radiological baseline data of the study area.

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