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Radiation Mapping of Osun State, Southwestern Nigeria, Measuring the Status of Radioactivity

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Abstract

The Fukushima Daiichi nuclear disaster happened in Japan long ago in 2011, and it resulted in the emission of radioactive substances into the atmosphere. These substances were transported by air currents and were detected in several parts of the world, including Nigeria. In the aftermath of the event, it has become necessary to determine the spatial distribution of radioactivity within Osun state. This present study aims to investigate and identify areas of high gamma radiation in Osun State. This study was conducted by utilizing a Garmin GPS and a Geiger Muller counter radiation detector over the entire state. This study presents a radiation map of Osun state. It shows that the region has an elevation range of 190 m to 600 m, and the elevation chart shows that in comparison to the extreme south of the research region, the extreme north is distinguished by high heights. The average ionising radiation within the state ranges from 0.08 to 0.31 µSv/hr. Places including Ila, Boluwaduro and Obokun recorded the highest elevation, which in turn also had the highest dose of gamma radiation, while Ife North, Ife South, Isokan, and Irewole axis recorded their lowest figures of elevation and also had low doses of gamma radiation. The average annual effective dose rate was 0.33 $mSvy^{-1}$ which is greater than 0.07 $mSvy^{-1}$ for outdoor exposure. Therefore, it is important to take appropriate safety measures by wearing protection shields to avoid or minimise exposure to high levels of gamma radiation.

Keywords: Fukushima Daiichi, Gamma Radiation, Geiger Muller Counter, Radiation Map, Annual Effective Dose

Introduction

Radiation is a high-energy kind of electromagnetic wave that is emitted from an atom during radioactive decay or nuclear processes. Ambient gamma radiation refers to the continuous amount of radiation present in the environment from natural and artificial sources. Our environment contains more than sixty known radionuclides, which can be divided into three groups: primordial radionuclides, formed prior to the creation of the earth; cosmogenic radionuclides, formed as a result of cosmic ray interaction, and human-produced radionuclides formed as a result of human actions and activities (Shahbazi-Gahrouei *et al*., 2013).

As a result, the radiation exposure level fluctuates according to the area's latitude, altitude, and human activity levels (WHO, 2023).

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Modest doses of ionizing radiation can raise the risk of long-term problems like cancer. Acute health effects like skin burns or radiation sickness can happen when radiation doses exceed very high levels. As a result, level monitoring and management are crucial for guaranteeing safety.

The Fukushima Daiichi nuclear disaster happened in Japan long ago in 2011 and it resulted in the emission of radioactive substances into the atmosphere. These substances were transported by air currents and were detected in several parts of the world including Nigeria. Also, in order to meet the increasing demands of people, the environment is currently growing to accommodate new projects. These developments include homes, hospitals, higher education institutions, supermarkets, stores, markets, and network masts and antennas. Soils, cement, clay, granitic rocks, and other materials that occasionally release gamma radiation have all been utilized extensively in the construction of these modern buildings to meet the varying developmental demands. In other situations, radon gas leaks out of building materials. A modest quantity of radiation from naturally occurring radioactive elements is also exposed to humans on a daily basis (Aboud *et al*., 2019). Although building materials composed of sandstone, concrete brick, natural stone, and gypsum release low levels of radiation.

Furthermore, rapid economic progress necessitates a plethora of human activities. Mining of natural resources, extraction of petroleum products, domestic use of groundwater, and living in various types of dwellings and settings all affect exposure levels. Naturally existing radionuclides can be mobilized by transporting them from inaccessible sites to areas where humans are prevalent and by concentrating radionuclides in the environment (Mishra *et al*., 2023).

Moreover, radiation is now an essential tool in medicine, food processing, research, and industry. It is used in medicine to identify disorders and, in high doses, to cure diseases like cancer (Jain, 2021). High doses of radiation are employed to destroy hazardous germs in food and lengthen fresh crops' half-life (Alfarobbi & Anggraini, 2018). Natural radiation generates heat, which is then converted into electricity in nuclear power reactors (Horvath & Rachlew, 2016). Radioactive materials are employed in various consumer items, including americium-241 in smoke detectors and tritium gas in exit signs, as well as for various scientific and industrial applications (Jaksic *et al*., 2023). Everyone is exposed to ionizing radiation on a regular basis because there is no region on Earth that does not have natural radioactivity (Shahbazi-Gahrouei *et al*., 2013). If the accumulation of all these radiation doses exceeds the standard recommended limit of 1 mSv/y for the public and occupational 20 mSv/y average over a period of 5 years (ICRP, 2000), this may have severe consequences over time.

Understanding radiation in our surroundings is, therefore, essential for creating and maintaining a safe radiation environment. If external dose rates and radioactive concentrations are evaluated, estimations of the extent of a hypothetical radionuclide leak may be more accurate. Estimates of the radiation dosage to persons in an area will also be more accurate if ambient ionizing dose levels are known. Continuous monitoring of background data will also allow for the detection of early patterns in the release and deposition. Monitoring will also help with well-established sample and measurement methodologies. Since it is thought that mining activities and mineral exploration are now taking place in various parts of the state, this study intends to examine and identify hot spots and areas of high gamma radiation in Osun State.

Gamma radiation research and the concept are not brand-new in Nigeria. A lot of research has been done to evaluate the ambient gamma radiation levels in Osun state. At Obafemi Awolowo University in Ile-Ife, Nigeria, Esan *et al*. (2022) measured the distribution of cosmic and natural radioactivity levels of ^{238}U, ^{232}Th, and ^{40}K in soil overlying the lithologic units. According to the study, there is a 1.15 per 1000 population average cancer risk. In general, no major health risks are associated with the radiation threat from the research area's soils. However, this study is regarded as the first to map all of the local government areas in the state of Osun.

Material and Methods

Study Area

The entire Osun state in southwest Nigeria is the research area. Kwara in the north, Ekiti and Ondo in the east, Oyo in the west, and Ogun in the south are the four states that border it. The research region, which encompasses every local government area in Nigeria, is situated between latitudes 7° and 8° N and longitudes 3° 50′ and 5°10′ E (Fig. 1).

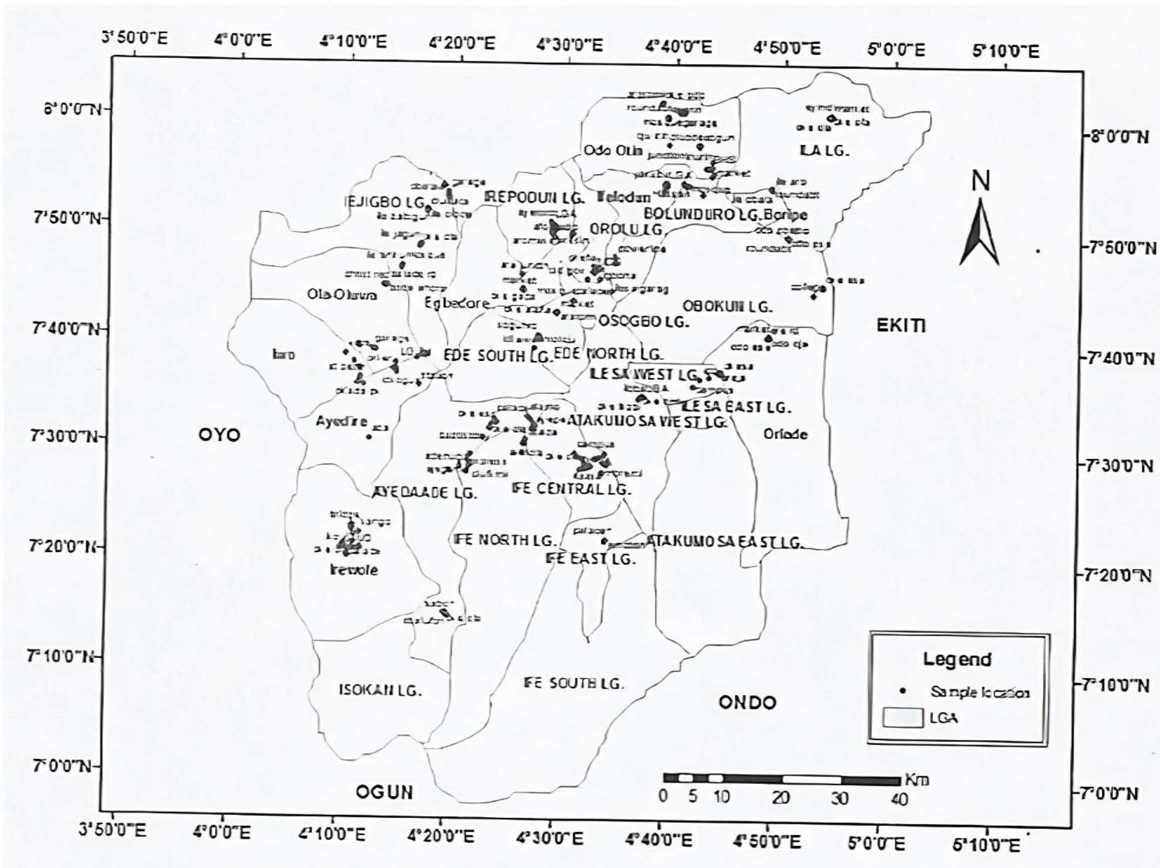

Fig. 1. Map of Osun State Showing Measurement Location Areas

Local Geology

The geology of Osun State comprises three main rock formations: the Precambrian Basement Rock, the Crustaceous Sedimentary rocks and the Tertiary volcanic rocks. A large portion of the state is covered in metamorphic rocks from the basement complex. Schists, which are connected to quartzite ridges, are prominent in the Ilesa region (Rahman, 1988). Although the metamorphic rocks have little differentiation, two distinct rock groups can nevertheless be distinguished. The first category includes migmatite complexes with outcrops in the Ilesa and Ile-Ife regions, including banded magmatic and auguen gneisses. The second set of metasediments are found in the Ikire region and include schists, quartzites, calsilicates, metaconglomerates, amphibiolites, and metamorphic iron beds. A clear perspective of the study area's geological map is shown in Fig. 2.

Results and Discussion

Measurement of Background Ionizing Radiation

A Geiger Muller counter and the Germain model of the geographical positioning system (GPS) were used to take the inventory. The Geiger Muller counter was used to detect and measure the ambient ionizing dose rate of radiation in the research region. The GPS was used to record the coordinates (longitude, latitude, and elevation) of each site where the ionizing dose rate is being measured simultaneously.

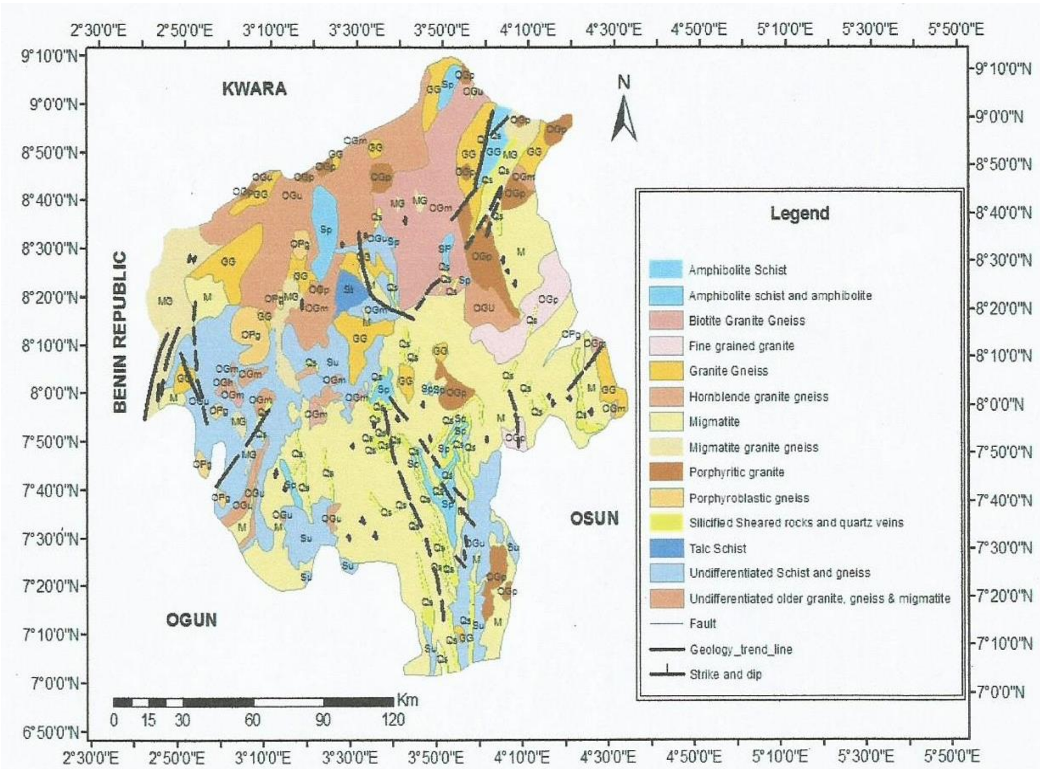

Fig. 2. Geology Map of the Study Area

The procedure and method used by Anekwe & Onoja (2020) were strictly adhered to. Locating two to three towns and villages, based on size, allowed for radial mapping from the state's capital centre to the four cardinal points. Geiger Muller counters were used to measure exposure rates one meter above the ground in order to take an inventory of the location's absorbed dose. Until the reading were stable at each point, three to five readings were taken at intervals of two minutes. Following that, ten measurements of the local ambient gamma radiation were made for each town. Throughout the course of this investigation, 60 towns and villages spread evenly across the state were visited.

Calculation of Annual Effective Dose Rate (AEDR)

To determine the health risks in terms of annual effective dose rate (AEDR), the values of the mean background radiation were utilized as a sample absorbed dose. For the calculation of the AEDR, we used an occupancy factor of 0.2 for outdoor exposure and the dose conversion factor of 0.7 $SvGy^{-1}$ recommended by the United Nations Sources and Effects of Atomic Radiation (UNSCEAR) as a conversion coefficient from the absorbed dose in air to the effective dose received by adults. In order to calculate the annual effective dose rate, Agbalagba & Anekwe (2020) formula was used.

$$\text{AEDR} = \text{Absorbed Dose} \times 1.2264 \times 10^{-1} \quad (1)$$

The activity concentration, the annual effective dose coming from the same region were averaged and presented (Table I), together with the reference level for mean of the measured natural radionuclidesin Osun state

Elevation Map

The coordinate readings (longitude, latitude, and elevation) collected during fieldwork in the research region to determine areas of high elevation and low height were used to create the elevation map (Fig. 3). Because there is a strong association between altitude and exposure rate, making it evident that persons who live or work at high

Table I: Background gamma dose rate in Osun State

S/N	Location	Longitude (E)	Latitude (N)	Elevation (m)	Mean Gamma Dose (μSv/hr)	Annual Effective Dose ($mSvy^{-1}$)
1	Atakunmosa East	4^0 81’	7^0 55’	349	17 ± 0.01	0.29
2	Atakunmosa West	4^0 64’	7^0 48’	399	18 ± 0.02	0.30
3	Ayedaade	4^0 34’	7^0 29’	252	13 ± 0.01	0.23
4	Ayedire	4^0 18’	7^0 52’	247	22 ± 0.01	0.38
5	Boluwaduro	4^0 45’	7^0 53’	512	22 ± 0.01	0.38
6	Boripe	4^0 66’	7^0 88’	437	22 ± 0.01	0.38
7	Ede North	4^0 30’	7^0 74’	317	22 ± 0.01	0.38
8	Ede South	4^0 37’	7^0 42’	309	19 ± 0.01	0.33
9	Egbedore	4^0 47’	7^0 70’	335	18 ± 0.01	0.31
10	Ejigbo	4^0 33’	7^0 61’	339	16 ± 0.01	0.28
11	Ife Central	4^0 32’	7^0 30’	274	25 ± 0.01	0.44
12	Ifedayo	4^0 62’	7^0 59’	231	18 ± 0.03	0.30
13	Ife East	4^0 36’	7^0 21’	285	18 ± 0.01	0.31
14	Ife North	4^0 28’	7^0 18’	258	17 ± 0.01	0.29
15	Ife South	4^0 45’	7^0 15’	273	17 ± 0.01	0.29
16	Ifelodun	4^0 40’	7^0 59’	395	20 ± 0.01	0.35
17	Ila	4^0 55’	8^0 01’	529	23 ± 0.01	0.40
18	Ilesha East	4^0 45’	7^0 42’	388	22 ± 0.03	0.31
19	Ilesha West	4^0 43’	7^0 39’	396	20 ± 0.01	0.35
20	Irepodun	4^0 50’	7^0 48’	331	16 ± 0.01	0.28
21	Irewole	4^0 11’	7^0 21’	206	22 ± 0.01	0.38
22	Isokan	4^0 13’	7^0 33’	215	20 ± 0.01	0.35
23	Iwo	4^0 11’	7^0 38’	267	18 ± 0.01	0.31
24	Obokun	4^0 45’	7^0 49’	479	21 ± 0.01	0.37
25	Odo-Otin	4^0 42’	8^0 01’	396	19 ± 0.01	0.33
26	Ola Oluwa	4^0 13’	7^0 47’	304	21 ± 0.01	0.37
27	Olorunda	4^0 35’	7^0 52’	337	18 ± 0.01	0.31
28	Oriade	4^0 52’	7^0 35’	371	20 ± 0.02	0.30
29	Orolu	4^0 28’	7^0 51’	341	17 ± 0.01	0.29
30	Osogbo	4^0 39’	7^0 49’	397	17 ± 0.01	0.29
	Mean Annual Effective Dose for Osun State					0.33

altitudes are exposed to more cosmic radiation than those who do so at low altitudes. The research region has an elevation range of 190 meters to 600 meters, and the elevation chart shows us exactly where there are high heights. In comparison to the extreme south of the research region, the extreme north is distinguished by high heights and is consistently much cooler.

Isodose Map

Figure 4 depicts places that receive similar amounts of background ionizing radiation. The average ionizing radiation ranges from 0.08 to 0.3l μSv/hr. The isodose map also demonstrates that persons who live or work at high altitudes are exposed to more cosmic radiation than those who live or workat low altitudes. As a result, the higher the height, the greater the radiation in such places .

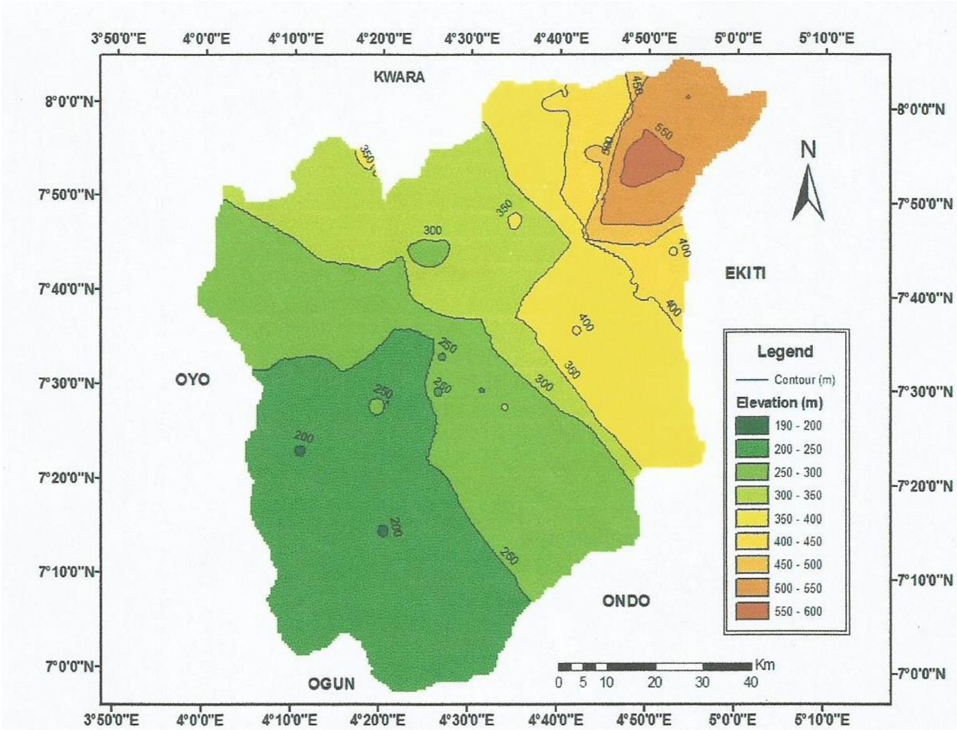

Fig. 3: Spatial Distribution of Elevation (Elevation Map of Osun State)

Ila, Boripe, Osogbo, and sections of Irewole, Aiyedire, and Olorunda would be at high danger from ambient ionizing radiation. Oriade, Iwo, Aiyedire, Obokun, Ilesa, Ede, Olaoluwa, Ife Central, Ife East, Ayedaade, Isokan, and Ejigbo are some of the communities with moderate or intermediate doses. It is characterized by modest doses in the remainder of the state. Ife Central, on the other hand, received a significant dose of gamma radiation while falling within a low elevation range. This is due to local geology and human activities such as fossil fuel combustion, a high rate of fertilizer application, and mining in that area.

Annual Effective Dose Rate

The result of the estimated annual effective dose equivalent is as shown in Fig. 5; it shows mean value of 0.33 $mSvy^{-1}$. Therefore, the state is described to be in the safe limit for members of the public. Specifically, Ife Central had the highest value of the annual effective dose of 0.44 $mSvy^{-1}$ this can be as a result of artisan mining activities in the area. There is tendency that radioactive materials which poses risk to the miners and those living nearby are present in those communities. Moreover, there is an industrial activity going on in the city, particularly those involved in the usage of nuclear medicine facilities. They can also contribute to the high level of doses recorded in Ile-Ife. The ambient worldwide average annual effective dose is 0.41 $mSvy^{-1}$ with 0.07 $mSvy^{-1}$ for outdoor exposure (Al Mugren, 2015; Agbalagba, 2017). The values obtained in this study are all well above the recommended worldwide mean annual effective dose level for outdoor environment, which is a pointer to radiation contamination of Osun state. The causes of the general high rate of annual effective dose in Osun could be as a result of its local geology, which is prone to high level of radon gas. It is a naturally occurring radioactive gas that is produced from the decay of uranium in the soil. It has the ability to seep into the environment and buildings especially the poorly ventilated ones. There are also tertiary health care centers across the state, which perform medical procedures such as x-ray, CT scans and nuclear medicine procedures. All these contribute to the calculated high annual effective dose in the state.

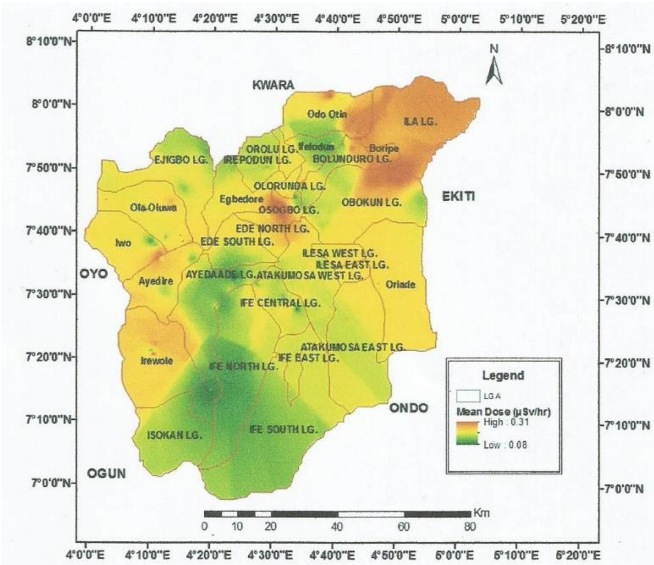

Fig. 4: Isodose Map of Osun State

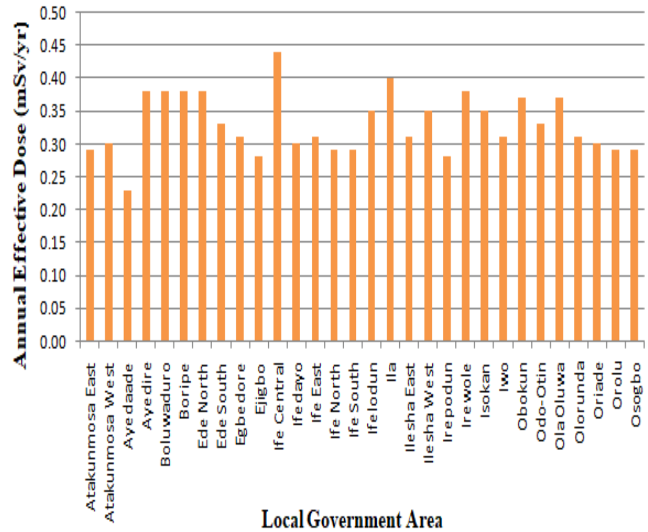

Fig. 5. Annual Effeive Dose Rate per Local Government

Conclusion

A study of the terrestrial background ionizing radiation levels of Osun to map the radiological contamination of the state has been carried out. In the sixty (60) towns and villages visited, the elevation map gives a clear view of areas with high altitudes and mean dose map also gives the area with low, medium or high ionizing mean dose of the study area. Places including Ila and Boluwaduro, Obokun recorded the highest elevation which in turn also have the highest dose of gamma radiation while Ife North, Ife South, Isokan, Irewole axis recorded their lowest figures of elevation and also had low doses of gamma radiation.

However, Ife Central had the highest dose of gamma radiation but falls within the lowest range of elevation which is as a result of local geology and human activities (burning of fossil fuel, fertilizer application) in that area. Also, the average effective dose due to background radiation of Osun State is estimated to be 0.33mSvy^{-1} which is much higher than 0.07 mSvy^{-1} for outdoor exposure. It is then deduced that the level of ionizing radiation in Osun State is at a high range of exposure for outdoor exposure as at the time this research was carried out.

Geo-spatial techniques have also provided us the basis for understanding the mapping of ambient gamma radiation in Osun State in order to identify high activity areas that will be useful to environmental radiation planners and nuclear regulatory authority in order to set appropriate exposure limits for the populace.

This state absorbed dose rate map is going to have multifaceted uses and benefit the residents of the state and international scientific community and decision makers. Also, it comes at an opportune moment, when researchers are focusing on local governments radiation level at a higher pace in order to address the climate change crisis as a result of radiation from the warm upper atmosphere combined with small amount of radiation from the earth's surface radiating to space. Also, radioactive contamination has a great potential to cause damage to bimolecules, especially those connected with photosynthesis in plants and phytoplanktons. Similar research should be carry out to assess the indoor background ionizing radiation of Osun state especially those areas where activities of mining and excess fertilizer applications as well as those houses whose roofs are high and whose materials of windows inside the building are made of rocks.

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Conflict of Interests

Authors declare that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. The order of authors has been approved by all of us.

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