DOSIMETRY OF IONIZING RADIATION IN SWAMP RICE FARM IN EKOI UBOM AND EKOI IKOT NYOHO, INI LOCAL GOVERNMENT AREA

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ABSTRACT

An assessment of absorbed surface dose rate of ionization radiation in swamp rice field in Ekoi Ubom and Ekoi Ikot Nyoho Ini Local Government Area, Akwa Ibom State, Nigeria was carried out with the aid of diligert survey meter with serial number 60030. We have noted the latitude and longitude as well as the elevation of 11 locations (LT1 to LT11) in Ini using the Global Positioning System (GPS). Contour maps have been generated using Surfer 16 software for easy interpretation. The result of highest annual equivalent dose rate computed is in LT4 with ionizing radiation level of 0.52596μSv/yr. The mean of all locations annual average equivalent dose rate amount to (0.242260 ± 0.035064)μSv/yr. This value is not close to the maximum permissible dosage of 1mSv/yr and 20mSv/yr for the general public and occupational workers (farmers) in the study area respectively, meaning that the study area is not hazardous as far as nuclear radiation is concerned.

Keywords: Dose, Ionizing, Radiation, Rice-farm, Absorbed, Hazardous and Limit.

INTRODUCTION

Rice is the most rapid growing food source in Africa. It is essential for food security and improved livelihood by enhancing the economic profile status. Today, rice availability and acceptability cut across all cultural boundaries and it is one of the food items that many people count on for daily meals. In some areas, there is a long tradition of rice cultivation and certainly become part of everyday diet of many Nigerians of all ages. However, commercial production of rice is facing many constrains in many part of the world. These constrains include: level of production and processing technology, poor soil fertility, natural and human disasters [such as drought, flood and land degradation]. This accounts for high import magnitude and dependence on food aid by African countries thereby posting a huge problem on food security. Rice policy in Nigeria is characterised by inconsistency, shifting between open and protectionist trade policy and such change hinder the ability of stakeholders to develop long-term strategies for the growth of the sector. Nigeria is the world second largest importer of rice after the Philippines (CGIAR, 2008). Import of this magnitude reflects a major hindrance to the sustainable development in the rice sector in Nigeria. These may be improved by the adoption of modern rice technology and the motivation of rice farmers by providing loans, provision of subsidized farm inputs, intensify training through agricultural extension officers and assistance from women in agricultural co-operative societies. Imported rice is increasingly demanded by a large population of Africa because of its relatively high quality. This could be discouraged by training the local farmers to embark on both quality and large scale production of rice since rice production demands that the farmers acquire basic rice production, processing and storage technologies.

Ionizing radiation is radiation with sufficient energy that interacts with atoms to take away tightly bound electrons from its orbit, causing the atom to become ionized. This radiation could be in the form of a wave or particle. Alpha, beta, x ray, gamma ray and neutron ray are the most frequently types of ionizing radiation. The charged-particle radiation (alpha and beta particles) have direct ionizing consequence as they move a charge and relate directly with atomic electrons due to coulombic forces (like charges repel each other; unlike charges attract each other). Neutral radiations (neutron) have indirect ionizing influence as the first produce charged particles having the ionizing consequence. They are indirect since they do not carry an electrical charge. The charge particles are generated during collisions with atomic nuclei. X ray and gamma ray are electromagnetic radiations. They do not interact with atomic electrons via coulomb forces. The high frequency portion of the electromagnetic spectrum [x rays and gamma rays] is ionizing (Flakus, 1981; Gilmore, 2008).

Individuals are exposed to natural sources of ionizing radiation such as soil, water, vegetable and man-made sources like x-rays and medical devices. Ionizing radiation has many useful applications in medicine, industry, agriculture and investigation. Each day, humans breathe in and consume radionuclides which are unstable elements which degenerate and release ionizing radiation from air, food and water (internal exposure). External exposure may be contacted once airborne radioactive material (such as dust, liquid or aerosols) is placed on skin or clothes.

Ionizing radiation injury to tissues and organs rest on the dose of radiation taken or the absorbed dose measured in gray (Gy). The effective dose is used to account for ionizing radiation with respect to the potential causing harm; it is measured in sievert (Sv) though the smaller unit [millisieverts (mSv) or microsievert (μSv)] is preferred. The dose rate delivered is measured in microsieverts per hour (μSv/hr) or millisievert per year (mSv/yr). The likely acute effects beyond definite thresholds are skin redness, hair loss, radiation burns or acute radiation syndrome. These effects are more severe at higher doses. The dose threshold for acute radiation syndrome is about 1 Sv (1000mSv). The threat is higher for children and adolescents since they are more sensitive to radiation exposure than adults (BSS, 2012).

Extreme doses of radiation to the whole body (around 10 Sv and above) received within a short time, caused more harm to interior organs and tissues of the body. This makes energetic systems stopped to function; may lead to death within days. It destroys huge number of cells. The extent of the injury rises with dose. Genes inside a cell control how a cell functions; if it is damaged may result in cancer. This means that the cell has lost the ability to control the rate at which it reproduces and may be passed on children (UNSCEAR, 2001). Measuring this radiation with an instrument will give scientists or researchers the ability to describe their environment at levels of accuracy. A statistically significant increase in cancer has not been detected in populations exposed to doses of less than 0.05Sv (ICRP, 2013). The overall average absorbed dose by food subjected to radiation processing shall be less than 10kGy (NAFDAC, 2019). The stipulated regulatory maximum permissible level is 1mSv/yr for member of the public and 20mSv/yr for rice farmers (ICRP, 1990). The deterministic effect causes harm to tissue and malfunctioning of cells due to high doses and the stochastic effect causes induction of cancer with decades after exposure (Huether and Mc Cance, 2016) should be monitored. This is because low doses of ionizing radiation may increase the risk of longer term effects like cancer (BSS, 2012).

LOCATION AND GEOLOGY OF THE STUDY

Ini Local Government is located about latitude $5^0 20^1$ and 5^0 31^1 N and longitude 7^0 38^1 and 7^0 53^1 E (Figure 1) (Ogundele, et al., 2012). The area is underlain by two main rock types which are Clay/shale and sandstone (Olugbenga and Christopher, 2015). The clay-shale arrangement is over five metres thick, becoming silty clay in some localities (Udo and Agabi, 2019). Carbonized streaks of plant remains are present in the dark gray portion of the shale predominantly in the area towards the boundary between Akwa-Ibom State and Abia State. The sandstone is about six to eight metres in some exposures particularly around Ebo, Okpoto and Iwere (Olugbenga and Christopher, 2015). Texturally, it is medium to coarse grained and fining upwards (Esu et al., 1999). The people are mainly farmers, producing food items such as rice, palm produce, cocoa and banana. Hunting is also practiced by the people who are mainly of lbibio stock. Ini Local Government Area has a tropical climate with a maximum annual rainfall of 2000mm; monthly temperatures range between 26º C and 28º C. The area is characteristics by deep sandy loam soils with a pH of 4.5 – 5.2. The soil is well drained with an undulating relief. The vegetation of the area is that of a typical tropical rain forest though a greater portion of it has been modified by humans into secondary forest (Olugbenga and Christopher, 2015). Ini Local Government Area was carved out of the former Ikono Local Government Area in 1991. It is bounded by Ikono, Obot Akara, and Abia State. It has a land mass of 320,451 Sq. Km. It natural resources include limestone, clay, gravel, fine sand, crude oil and Iron Ore. The forest region provides timber and fire wood.

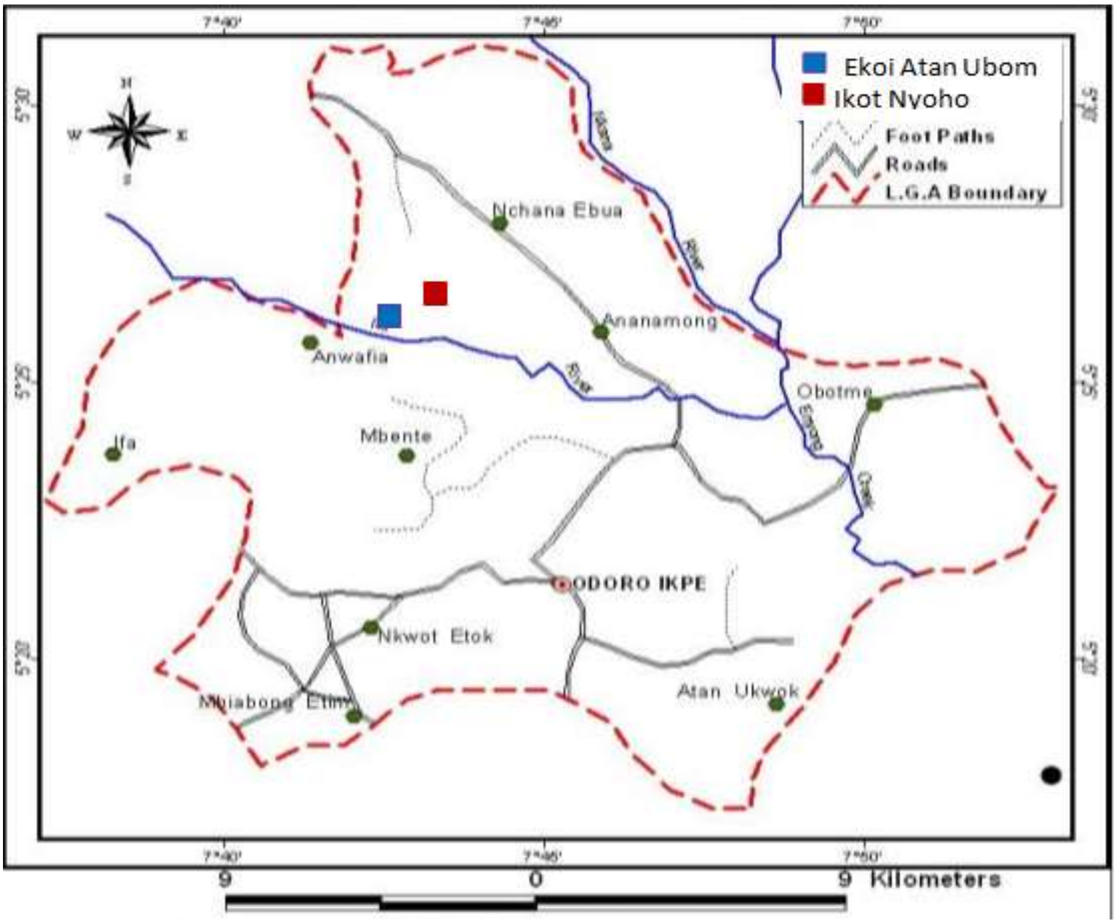

Figure 1: The map of Ini Local Government Area showing study locations
Source: Ogundele et al. (2012)

THEORETICAL BASIS

Radiation

Radiation is the energy that comes from a source and travels through some material or space. They can also occur when an unstable nuclei of atoms decay and release particles. It is the energy unit mass that can be deposited in the body system. Radiation is measured in rads (Ademola, 2008). The ionizing radiation sources naturally occurring in the earth's surface can be classified as alpha particle, beta particle, gamma ray and x-ray.

Alpha Particles (α)

Alpha radiation is the weakest form of radiation and can be stopped by a piece of paper. Atomic particles contain two neutrons and two protons. When alpha particles are released it causes the parent atom to lose four mass numbers and two atomic numbers (Equation 1). They quickly lose their kinetic energy in the atmosphere due to their strong interaction with other molecules which is caused by their abundant mass and electrical charge. An alpha emitter is may be very harmful to the body. They are mostly produced in radioactive breakdown.

$$^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He \quad (1)$$

Uranium Thorium Alpha particle

Beta Particles (β)

They are streams of high energy electrons; their penetration is better than those of alpha and can serious damage to the human body. They can be stopped by a wood or a thin sheet of metal. The decay process is given in Equation 2.

$$^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}e \quad (2)$$

Strontium Yttrium Beta particle

Gamma Radiation (γ)

This is an electromagnetic radiation which could be seen as a wave or a photon; they cause serious damage to the nucleus of cells (Gilmore, 2008). They are used in sterilization of medical equipment and food. Gamma rays easily pass through the skin and other organic substances. X-rays are included in this group though have lower penetration abilities than gamma rays.

Concept of Radioactivity

The phenomenon of radioactivity was discovered in 1896 by a French Physicist, Henri Becquerel. He noticed while performing some experiment that uranium gave out some kind of rays that would penetrate through thin black paper and affect the photographic plate placed on the other side. This phenomenon is called radioactive substances of elements (Anyakaho, 2000). There are two types of radioactivity, natural and artificial radioactivity. Radioactivity is the spontaneous decay or disintegration of the nucleus of the atom of an element during which it emits, alpha, beta particles or x-ray or a combination of any or all the three energy (or heat). Some of these elements that spontaneously emit radiation from their nucleus are Radium, Thorium, Radon, Ionium and Polonium.

Theory of Radioactivity

All the radionuclides decay according to the radioactive decay law (Equation 3).

$$\frac{dN}{dt} = -\lambda N \quad (3)$$

$$\frac{dN}{N} = -\lambda dt \qquad (4)$$

$$\int_{N_0}^{N} \frac{dN}{N} = -\lambda \int_0^t dt$$

$$\ln N - \ln N_0 = -\lambda t$$

$$e^{ln\frac{N}{N_0}} = e^{-\lambda t}$$

$$\frac{N}{N_0} = e^{-\lambda t} \qquad (5)$$

$$N(t) = N_0 e^{-\lambda t} \qquad (6)$$

Considering the time taken for half of the radioactive material to decay, $t = t_{\frac{1}{2}}; N = \frac{N_0}{2}$

$$\frac{N_0}{2} = N_0 e^{-\lambda t_1/_2} \qquad (7)$$

$$\ln \frac{1}{2} = \ln e^{-\lambda t_1/_2}$$

$$-0.693 = -\lambda t 1/_2$$

$$t1/_2 = \frac{0693}{\lambda} \qquad (8)$$

where λ is the decay constant, N_0 is the amount of original nuclei. Equations (6) and (8) indicate the amount of radioactive nuclei present and the time taken for half of the sample to decay respectively.

In industries, they are used for the detection of leak or blockages in underground pipes and tracking the disposal of waste.
There are three kinds of dose in radiological protection: Absorbed dose [also called total ionizing dose (TID) which is a measure of the energy deposited in a medium by ionizing radiation; the S. I Unit is Gray (Gy)], Equivalent dose [is a measure of radiation present but not biologically significant; it is expressed in Equation 9] and Effective dose is the sum of the weighted equivalent dose in all tissue or organs of the body (Equation 10); it is measured in Sievert (Sv)].

$$H_T = \sum W_R D_{T,R} \qquad (9)$$

$$E = \sum W_T H_T = \sum W_T W_R D_{T,R} \qquad (10)$$

(Mc Collough and Schueler, 2000).
Where H_T is the average equivalent dose over the tissue or organ (T) due to the incident radiation (R).
W_R is the radiation weighting factor.
$D_{T,R}$ is the average absorbed dose over the tissue or organ (T) due to the incident radiation (R).
W_T is the tissue weighting factor.

The annual equivalent dose rate and standard deviation may be computed using Equations 11 (Marilyn and Maguire, 1995) and 12 respectively.

$$H_{AEDR} = \frac{24 \times 365.25 \ \mu \ H_E}{1000} \qquad (11)$$

$$\sigma = \frac{H_{ED} - L_{ED}}{N} \qquad (12)$$

The equivalent absorbed dose may be obtained from absorbed dose using a multiplication factor of 0.1.

where H_{AEDR} is the Annual equivalent dose rate

σ is the standard deviation

H_E is the average equivalent dose

μ is the outdoor occupancy factor equal to 0.2

H_{ED} is the highest equivalent dose

L_{ED} is the lowest equivalent dose

N is the number of sample space

(Marilyn and Maguire, 1995)

MATERIALS AND METHOD

The materials required to conduct this research include: Diligert 200 survey meter with serial number 60030 [used to assess absorbed surface dose rate in rice field], the Global Positioning System (GPS) [used in measuring the coordinate of the surveyed locations] and Surfer 16 software [a contouring and 3D surface mapping software program that runs on Microsoft window].

The survey was conducted after inspection of the equipment; battery check (3.5V) was performed and source/operational check tested. 11 rice farm locations (LT1 to LT11) in Ini Local Government Area, Akwa Ibom State were considered for assessment of absorbed surface dose and other measurements. Measurements were taken at a height of about one meter above the farm soil (Agbalagba and Meindinyo, 2013; Meindinyo et al., 2017a; Meindinyo et al., 2017b). Readings were noted twice with the monitor before considering the average absorbed surface dose rates. Corresponding latitudes and longitudes as well as elevation thicknesses were noted with the aid of GPS. The contour Map was produced using the coordinates obtained from the field data.

RESULTS

The primary data obtained from measurements of absorbed dose of ionizing radiation including calculated parameters are presented in Table 1, Figures 2 and 3. The major software used to create contour map was Surfer 16 (a contouring and 3 D surface mapping software program that runs on Microsoft window which generate the contour lines). The contour maps of the absorbed surface dose rate levels and elevation in LT1 to LT11 are captured in Figures 3 and 4 respectively.

Table 1: The Summary of Result of Dose rate Computed

S/N	Locations		Elevation (m)	Average Absorbed Surface Dose Rate (mR/hr)	Equivalent absorbed Surface Dose Rate (µSv/hr)	Annual Equivalent Absorbed Surface Dose Rate (µSv/yr)
	Latitude (^{0}N)	Longitude (^{0}E)				
LT1	5.0590	7.8826	78.2	0.0110	0.11	0.192852
LT2	5.0588	7.8809	77.8	0.0150	0.150	0.26298
LT3	5.0587	7.8792	77.0	0.0145	0.145	0.254214

LT4	5.3887	7.7042	40.8	0.0080	0.080	0.140256
LT5	5.2930	7.7359	128.5	0.0300	0.300	0.52596
LT6	5.2928	7.7372	129.9	0.0190	0.190	0.333108
LT7	5.2927	7.7378	131.0	0.0115	0.115	0.201618
LT8	5.2926	7.7394	128.2	0.0110	0.110	0.192852
LT9	5.2926	7.7402	117.5	0.0135	0.135	0.236682
LT10	5.2930	7.7412	99.9	0.0095	0.095	0.166554
LT11	5.1015	7.8618	36.8	0.0090	0.090	0.157788
				0.0138 ± 0.002	0.138182 ± 0.02	0.242260 ± 0.035064

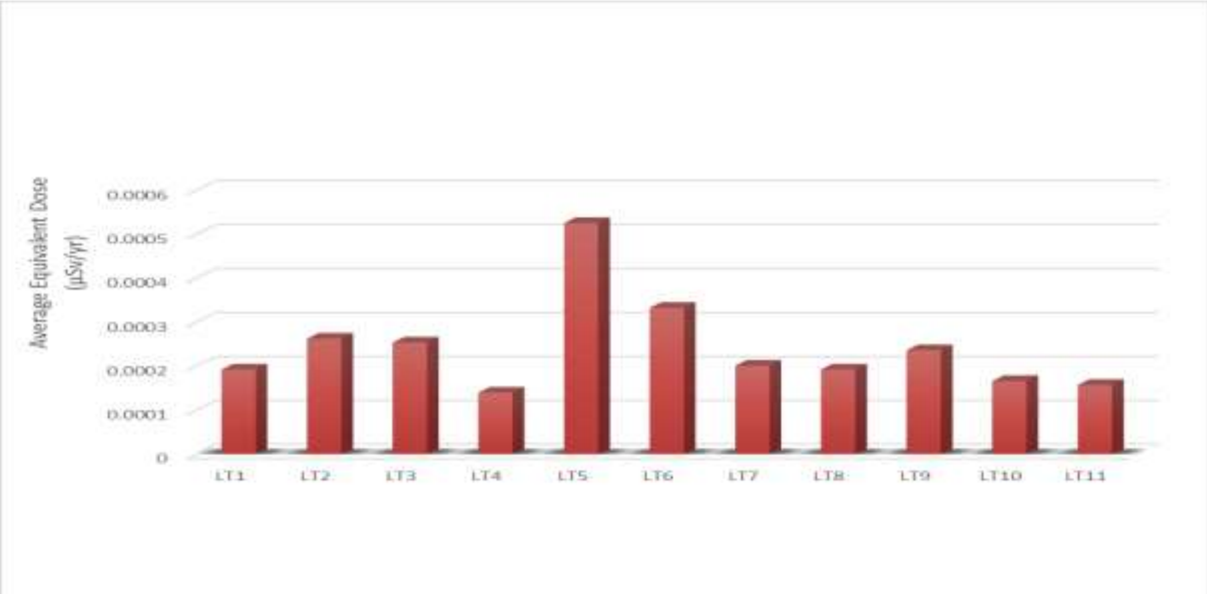

Figure 2: The Bar Chat plot of Annual Equivalent Dose rate measured at Locations LT1 to LT11

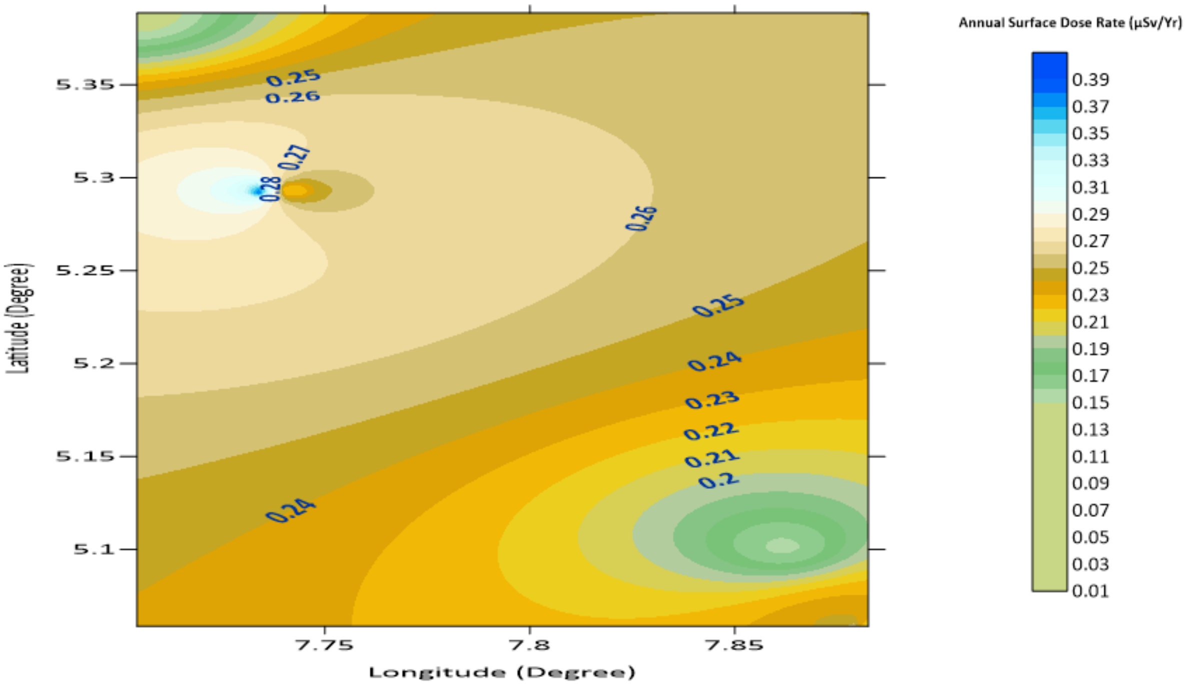

Figure 3: Contour Map of Annual Surface Dose Rate measured with Latitude

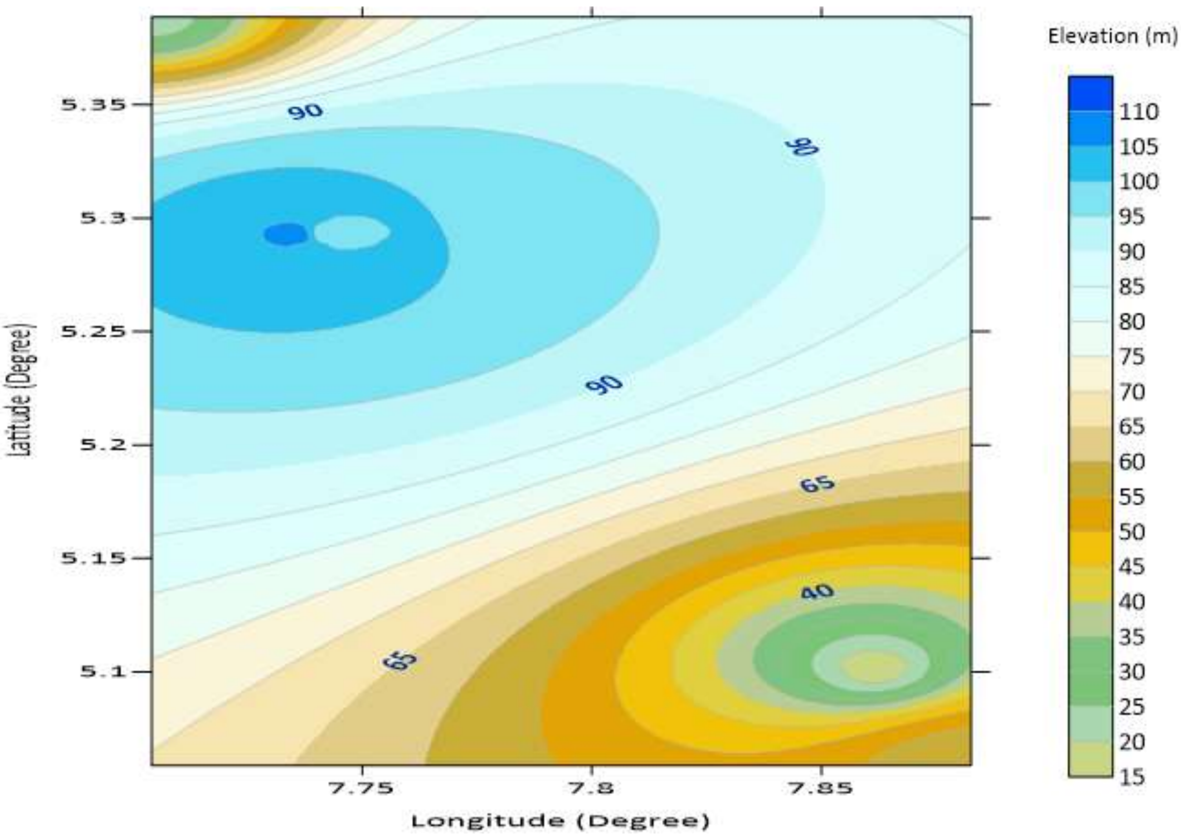

Figure 4: Contour Map of locations with Elevation

DISCUSSION

11 locations (LT1 to LT11) were investigated for average surface dose rate, equivalent absorbed surface dose rate and annual equivalent absorbed surface dose rate. Table 1 and Figure 2 present the values obtained from each location. LT4 has the lowest level value of ionizing radiation (equivalent dose rate and annual equivalent dose rate as 0.08000µSv/hr and 0.140256µSv/yr respectively); LT5 has the lowest level value of ionizing radiation (equivalent dose rate and annual equivalent dose rate as 0.3000µSv/hr and 0.52596µSv/yr respectively). Equivalent absorbed dose rate was computed using a multiplication factor 0.1 in µSv/hr; Annual equivalent absorbed dose rate was obtained using equation 11 in µSv/yr. The outdoor occupancy factor was considered as 0.2 and 365.25 for days in a year. Figure 3 shows the contouring of measured parameter information; it increases with latitude.
The standard deviation was achieved using equation 12. The mean values of average absorbed dose rate, equivalent absorbed dose rate and annual equivalent absorbed dose rate are (0.014 ± 0.002) mR/hr, (0.138 ± 0.020) µSv/hr and (0.242 ± 0.035) µSv/yr respectively to three places of decimal. The stipulated regulatory maximum permissible level is 1 mSv/yr for members of the public and 20 mSv/yr for rice farmers (ICRP, 1990). These result levels in the study locations are below the standard.

The numbers of on the contour lines represent the absorbed surface dose rate involved and the intervening spaces are marked with colours to highlight the values of the surface dose rate. The higher the number on the contour lines, the higher the value of the absorbed dose rate involved. This could be used to predict the value of absorbed dose in the area outside the study area.

CONCLUSION

We have carried out research on the assessment of ionizing radiation level from 11 locations in Ini, Akwa Ibom State using diligert survey monitor. The lowest effect of ionizing radiation obtained is experienced in LT4 with annual equivalent dose rate of 0.140 µSv/yr; the highest effect of ionizing radiation obtained is in LT5 with annual equivalent dose rate of 0.526 µSv/yr. The mean of all average annual equivalent dose rate computed amount to (0.242 ± 0.035) µSv/yr. Our environment (Ini) is safe due to this fact. The people are convinced that the ionizing radiation rice farmers are experiencing is below ICRP maximum permissible standard. This survey should be conducted yearly to ensure the level of ionizing radiation is still within safety limit since radiation may increase due to continuous human activities. Though deterministic effect that causes harm to tissue and malfunctioning of cells due to high doses is not supported by this result, the stochastic effect that causes induction of cancer with decades after exposure should be monitored. This is because low doses of ionizing radiation may increase the risk of longer term effects like cancer.

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