IN-SITU ASSESSMENT OF TERRESTRIAL BACKGROUND GAMMA RADIATION EXPOSURE AND DOSE LEVELS IN NKALAGU-EZILLO RICE FARM, EBONYI STATE, NIGERIA

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Abstract: *In-situ* assessment of background gamma radiation exposure rates and dose levels were carried out on Nkalagu-Ezillo rice farms during and after planting to ascertain the level of the radiological contamination of the farmland. The radiation exposure rates were measured using GQ GMC-320 Plus nuclear radiation meter at an elevation of 1.0 m above ground level with a GPS for geographical location. The results reveal that the exposure rates after planting are slightly higher than that during planting. Mean exposure rates of 0.014±0.002 mRh^{-1} and 0.015±0.002 mRh^{-1} were observed in farm 1 and farm 2, respectively. These values were found to be above the international recommended limit of 0.013 mRh^{-1} for normal environment. The evaluated mean equivalent dose and absorbed dose rates exceed their respective safe limits of 1.00 $mSvy^{-1}$ and 84.0 $nGyh^{-1}$ while the annual effective dose equivalent is in tandem with safe limit of 1.00 $mSvy^{-1}$. The study has thus revealed that the rice farms show an area of relatively high background gamma radiation exposure and dose levels. However, the contamination and the radiation levels at the present rates do not constitute any immediate health effect on the farmers and general public, but there exist the potential for long-term health hazards such as cancer due to accumulated doses.

Keywords: Background gamma radiation, dose levels, exposure rate, rice farm

Introduction

Radiation in the environment originates from both natural and man-made sources. Natural radioactivity has always been present and broadly distributed in the earth's crust and the atmosphere, either as primordial radionuclides of uranium (^{238}U) and thorium (^{232}Th) decay series and radioactive potassium (^{40}K), or as cosmic radiations that are produced constantly in the atmosphere (Samad *et al.*, 2012; Hasan *et al.*, 2013; Manjunatha *et al.*, 2013; Ferdous *et al.*, 2015; Kolo *et al.*, 2017). Radiation from primordial radionuclides is the major components of the total radiation dose to human population in the indoor and outdoor environments. The contribution of cosmic rays to environmental dose at sea level, which depends on altitude, latitude and the solar cycle, is insignificant when compared to terrestrial radiation (UNSCEAR, 2000). About 80% of the annual effective dose received by the general population comes from the natural background radiation (UNSCEAR, 2000). Anthropogenic or man-made activities have contributed to increase in background radiation exposure and doses to human population. Mechanized farming system accompanied with the use of phosphate fertilizers and other agrochemical inputs is a further source of possible exposure to the public. Elevated radiation levels and exposure to farmers can further be expected in sites used for farming.

High radiation levels and doses are detrimental to human health. Exposure to high levels of gamma radiation causes a number of harmful effects in man (Ugbede and Benson, 2018). Some of the radiation health effects are chronic lung diseases, acute leucopoenia, anemia and necrosis of the mouth (SureshGandhi *et al.*, 2014). Thorium exposure can cause lung, pancreas, hepatic, bone, kidney cancers and leukemia (Taskin *et al.*, 2009). Radon, a decay product of radium (^{226}Ra) which is part of uranium (^{238}U) decay series, is the second major cause of lung cancer. In the recent years, studies on the high background radiation areas in the world have been of prime importance for risk estimation due to long term low-level whole body exposures to the public (SureshGandhi *et al.*, 2014). The practice of radiation protection therefore, has ensured that human exposure to radiation be kept to as low as reasonably achievable, called the ALARA principle (ICRP, 1973). One of the roles of radiation protection bodies is to ensure that the exposure of the public does not exceed certain safe limits as set up from time to time by regulatory agencies (Mokobia and Oyibo, 2017).

Farming which is a major part of agriculture involves activities which alter the natural characteristics of the top soil. Activities such as applications of high yielding fertilizers, whether organic or inorganic, used to replenish micro and macro elements lost by soil and other agrochemical inputs for controlling weeds and pests can greatly enhance natural radioactivity and radiation levels of farm soil and the farm environment as a whole. Phosphorus is the chief constituent of fertilizers. The phosphorus content of chemical fertilizers originates from phosphate rocks/ores which contain varying levels of natural radionuclides Uranium (^{238}U), Thorium (^{232}Th) and Potassium (^{40}K) that emit alpha particles, beta particles, and gamma radiations (Hassan et al., 2016; Nwaka and Jibiri, 2018). Paschoa and Godoy (2002) noted that phosphate ores typically contain about 1500 Bq/kg of uranium and radium. Studies regarding the radioactive contents and radiation doses in fertilizers of different matrices have been reported by different researchers in different parts of the world including Nigeria. Continuous and persistent usage of fertilizers can redistribute, restructure and raise the level of radioactivity in the soil profile as well as the background gamma radiation levels of the farming environment. Also, the radionuclides contents in crops grown on fertilizer enhanced soils may also increase, through various uptake mechanisms of soil to plant and they successively find their way into the human body through the ingestion pathway.

The perceived implication of increase background radiation levels of farmlands due to inputs of fertilizers and other agrochemicals with high radioactivity contents suggests the need for accurate assessment and monitoring of natural radioactivity and background gamma radiation levels of farming environments. Such study will serve as bases for radiation health physicist and radiation protection agencies to mark out programs for adequate handling of fertilizers and protection of farmers against high radiation levels and doses. It will provide bases for assessing and monitoring any additions following any anthropogenic activities. It will also serve as a guide in assessing the performance of epidemiological studies of diseases traceable to radiation. The present study thus aimed at assessing the background radiation exposures and dose rates to farmers in rice farm located between the boundaries of Nkalagu and Ezillo communities of Ishielu LGA of Ebonyi State. This pioneering study in the area aims at providing baseline data of background radiation in the rice farming environments which will serve as reference database for any addition to the radiation levels of the environment in future farming seasons.

Materials and Methods

Study area

The study area Nkalagu-Ezillo rice farm is located between the boundaries of Nkalagu and Ezillo on both sides of Abakaliki-Enugu expressway in Ishielu local government area of Ebonyi State, Nigeria. The rice farm is divided into two each located on both sides of the Abakaliki-Enugu expressway. The farms were initially owned and managed by the government but have been leased out to individuals on agreed terms for effective management. For the purpose of this study, the farms are labeled as farm 1 and farm 2. Farm 1 was initially owned by the federal government under the supervision of the National Youth Service Corps (NYSC) while Farm 2 was initially owned and managed by Ebonyi State government. Fig. 1 and 2 show respectively the map of the study area and sections of the rice farm 1 and 2.

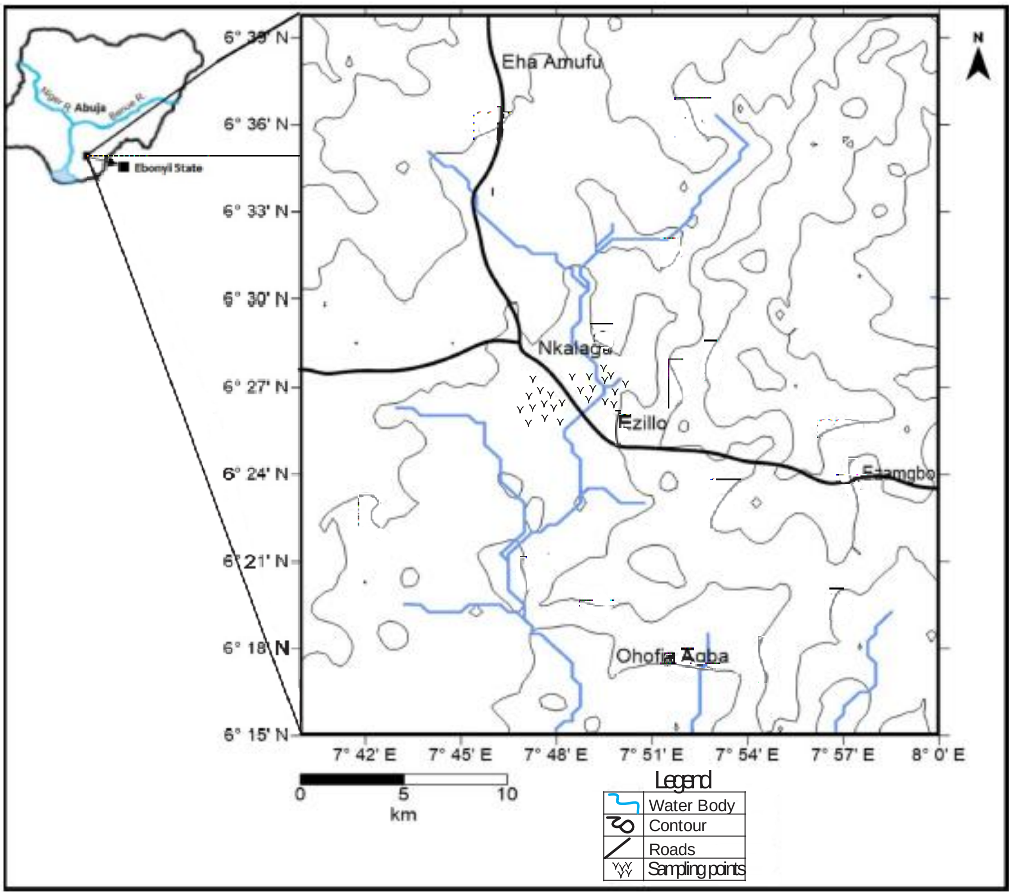

Fig. 1: Map of Ebonyi State showing the study area

Fig. 2: Cross section of Nkalagu-Ezillo rice farms

Sampling and measurement

Twelve (12) sampling points which evenly cover the four cardinal directions for each farm were carefully marked out for the study. Measurements of terrestrial outdoor background gamma radiation dose rates in the farms were done using a portable GQ GMC-320 Plus nuclear radiation survey meter (GQ Electronics LLC, USA). The detector contains a Geiger Muller tube capable of detecting α, β, γ and x-rays. When radiation passes through the Geiger tube, it triggers an electrical pulse which the CPU registers as counts. In-situ measurements of gamma radiation exposure levels, which enable sample points maintain their original environmental characteristics (Agbalagba *et al.*, 2016; Ugbede and Echeweozo, 2017) were conducted at twelve different sampling points for each farm during rice planting and 90 days after planting. The precise locations of the sampling points were determined using a geographical positioning system (GPS). The exposure rates at the respective sample point were measured with the standard practice of keeping the detector tube at a height of 1.0 m from the ground level. Due to the fluctuating nature of radiation and other environmental parameters, five repeated measurements at intervals of 300 seconds were taken from each sampling point and the average of the five measurements was considered and recorded as the gamma exposure rate for that particular point. Following the guidelines of National Council on Radiation Protection and Measurements (NCRP, 1993) on the use of radiation survey meters and measurements, the study was conducted between the hours of 1300 and 1600 since the radiation meter has a maximum response to radiation within these hours. The average exposure rate during planting was denoted as A1 while that after planting was denoted as A2. The mean gamma radiation exposure rates were determined from the two averages (A1 and A2). The mean exposure rates obtained were quantitatively used to evaluate the radiation doses and its health impact to farmers in the farming environments using well established radiological relations.

Equivalent dose rate (EDR): To estimate the whole body equivalent dose rate over a period of 1 year, the recommendation of the National Council on Radiation Protection and Measurement was adopted (NCRP, 1993; Avwiri *et al.*, 2013; Mokobia *et al.*, 2016)

$$1mRh^{-1} = \frac{0.96\times 24\times 365}{100} mSvy^{-1} \qquad (1)$$

Radiation absorbed dose rate (ADR): the absorbed dose was estimated using equation 2 (Rafique *et al*, 2014; Agbalagba *et al*, 2016; Agbalagba, 2017; Benson and Ugbede, 2018)

$$1\mu Rh^{-1} = 8.7\eta Gyh^{-1} = \frac{8.7\times 10^{-3}}{\left(1/8760y\right)}\mu Gyy^{-1} \qquad (2)$$

This implies that (Ugbede and Benson, 2018);

$$1mRh^{-1} = 8.7\eta Gyh^{-1}\times 10^{3} = 8700\eta Gyh^{-1} \quad (3)$$

Annual effective dose equivalent (AEDE): The computed absorbed dose rates were used to calculate the AEDE using equation 4 (Rafique *et al*, 2014; Agbalagba *et al.*, 2016; Agbalagba, 2017; Benson and Ugbede, 2018)

$$AEDE\left(mSvy^{-1}\right) = ADR\left(\eta Gyh^{-1}\right)\times 8760h\times 0.7Sv/Gy\times 0.2 \quad (4)$$

Where ADR is the absorbed dose rate in ηGyh^{-1}, 8760 is the total hours in a year, 0.7Sv/Gy is the dose conversion factor from absorbed dose in air to the effective dose and 0.2 is the occupancy factor for outdoor exposure as recommended by UNSCEAR (2008).

Results and Discussion

The results for the background terrestrial gamma exposure levels and radiation dose rates for farm 1 and farm 2 are shown in Tables 1 and 2, respectively. Radiation exposure rates defined the amount of exposure one received per unit of time in the vicinity of radiation sources. In farm 1, the exposure rates ranged from 0.011 to 0.016 mRh^{-1} during planting and 0.009 to 0.020 mRh^{-1} after planting with mean value of 0.014±0.002 mRh^{-1}. Similarly, in farm 2, the exposure rates ranged from 0.010 to 0.017 mRh^{-1} during planting and 0.010 to 0.021 mRh^{-1} after planting with mean value of 0.015±0.002 mRh^{-1}.

The variation in BIR exposure values can be attributed to the different natural occurring radioactive materials (NORMs) presents and their concentration in the farm soil and also to the geological and geophysical setting of the environments. The BIR exposure rates for each sampling point during planting are all almost lower than those after planting for both farms. It is observed that for both farms, 75% of the sample points after planting have exposure rates greater than those during planting. This observation clearly shows the effect of fertilizer and other agrochemical inputs after plantation. The mean exposure rates recorded in both farms exceeded the 0.013 mRh^{-1} international recommended BIR value for normal environment (ICRP, 2007; Osimobi *et al*, 2015; Agbalagba *et al* 2016) as depicted in Fig. 3. It is expected that farming activities through mechanized system will continuously bring out the NORMs accumulated in the soils. Also the addition of fertilizers and other agrochemical additives to the soils are expected to contaminate the soils and could raise the background ionizing radiation level of the environment (Diab *et al*, 2008). The fact that the mean exposure rates at these rice farms exceeded ICRP stipulated limit is an indication that the provision of the farming environment is not radiologically healthy. The mean BIR values recorded in the rice farmlands are higher than 0.008 – 0.014 mRh^{-1} values reported by Mokobia and Oyibo (2017) in some farmlands located within the 25 local government areas of Delta State, Nigeria, but are far lower than mean values of 0.022±0.002 and 0.025±0.002 measured by Avwiri *et al* (2016) in salt lake areas of Okposi Okwu and Uburu respectively located in Ebonyi State.

Table 1: Terrestrial gamma radiation exposure rates and dose levels in farm 1

Farm 1 sample point	Geographical position	Gamma radiation exposure rates (mRh^{-1})			Radiation dose levels		
		A1	A2	Mean exposure rate	Equivalent dose rate $mSvy^{-1}$	Radiation absorbed dose (ηGyh^{-1})	Annual effective dose equivalent ($mSvy^{-1}$)
N1	N6º27′0.28" E7º48′2.11"	0.011	0.009	0.010	0.84	87.00	0.11
N2	N6º27′0.07" E7º47′59.22"	0.012	0.015	0.014	1.17	121.80	0.15
N3	N6º26′55.94" E7º47′56.73"	0.014	0.016	0.015	1.26	130.50	0.16
N4	N6º26′51.63" E7º47′49.80"	0.016	0.020	0.018	1.51	156.60	0.19
N5	N6º26′44.28" E7º47′54.7"	0.011	0.013	0.012	1.01	104.40	0.13
N6	N6º26′49.67" E7º48′0.34"	0.011	0.014	0.013	1.09	113.10	0.14
N7	N6º26′52.36" E7º48′3.98"	0.013	0.015	0.014	1.18	121.80	0.15
N8	N6º26′58.96" E7º48′7.48"	0.012	0.019	0.016	1.35	139.20	0.17
N9	N6º26′49.66" E7º48′6.04"	0.012	0.015	0.014	1.18	121.80	0.15
N10	N6º26′45.17" E7º48′7.26"	0.014	0.017	0.016	1.35	139.20	0.17
N11	N6º26′48.78" E7º48′10.42"	0.014	0.011	0.013	1.09	113.10	0.14
N12	N6º26′54.16" E7º48′9.38"	0.016	0.015	0.016	1.35	139.20	0.17
	Mean±SD			**0.014±0.002**	**1.20±0.18**	**123.98±18.59**	**0.15±0.02**

Table 2: Terrestrial gamma radiation exposure rates and dose levels in farm 2

Farm 1 sample point	Geographical position	Gamma radiation exposure rates (mRh^{-1})			Radiation dose levels		
		A1	A2	Mean exposure rate	Equivalent dose rate $mSvy^{-1}$	Radiation absorbed dose (ηGyh^{-1})	Annual effective dose equivalent ($mSvy^{-1}$)
S1	N6º27′5.36" E7º48′6.50"	0.010	0.012	0.011	0.93	95.70	0.12
S2	N6º27′7.20" E7º48′10.20"	0.013	0.014	0.014	1.18	121.80	0.15
S3	N6º27′8.84" E7º48′14.55"	0.017	0.019	0.018	1.51	156.60	0.19
S4	N6º27′13.85" E7º48′14.75"	0.016	0.015	0.016	1.35	139.20	0.17
S5	N6º27′19.09" E7º48′18.14"	0.012	0.015	0.014	1.18	121.80	0.15
S6	N6º27′24.17" E7º48′25.15"	0.014	0.021	0.018	1.51	156.60	0.19
S7	N6º27′30.26" E7º48′22.33"	0.015	0.019	0.017	1.43	147.9	0.18
S8	N6º27′39.61" E7º48′13.75"	0.012	0.010	0.011	0.93	95.70	0.12
S9	N6º27′29.11" E7º48′4.70"	0.014	0.015	0.015	1.26	130.50	0.16
S10	N6º27′20.91" E7º47′54.80"	0.012	0.016	0.014	1.18	121.80	0.15
S11	N6º27′17.31" E7º47′55.25"	0.014	0.012	0.013	1.09	131.10	0.16
S12	N6º27′12.31" E7º47′59.49"	0.014	0.017	0.016	1.35	139.20	0.17
	Mean±SD			**0.015±0.002**	**1.24±0.20**	**129.83±20.14**	**0.16±0.02**

The radiological dose parameters for farm 1 ranged from 0.84 to 1.51 $mSvy^{-1}$ with mean value 1.20±0.18 $mSvy^{-1}$ for equivalent dose rate, 87.00 to 156.60 ηGyh^{-1} with mean value 123.98±18.59 ηGyh^{-1} for absorbed dose and 0.11 to 0.19

$mSvy^{-1}$ with mean value 0.15±0.02 $mSvy^{-1}$ for AEDE. For farm 2, the dose level ranged from 0.93 to 1.51 $mSvy^{-1}$ with mean value 1.24±0.20 $mSvy^{-1}$ for equivalent dose rate, 95.70 to 156.60 ηGyh^{-1} with mean value 129.83±20.14 ηGyh^{-1} for absorbed dose and 0.12 to 0.19 $mSvy^{-1}$ with mean value 0.16±0.02 $mSvy^{-1}$ for AEDE. Maximum dose level of 1.51 $mSvy^{-1}$ for equivalent dose, 156.60 ηGyh^{-1} for absorbed dose and 0.19 $mSvy^{-1}$ for AEDE were observed at location N4 in farm 1 (coordinate N6º26′51.63"; E7º47′49.80") and at locations S3 and S6 in farm 2 (N6º27′8.84"; E7º48′14.55" and N6º27′24.17"; E7º48′25.15", respectively). Radiation absorbed dose is a measure of the amount of energy absorbed per unit mass. It quantifies the radiation energy that might be absorbed by a potentially exposed individual as a result of a specific exposure (Benson and Ugbede, 2018). The absorbed doses in the rice farmlands are far higher than the recommended safe limit of 84.0 $nGyh^{-1}$ (Fig. 4) (UNSCEAR, 2008; Ononugbo and Mgbemere, 2016) and world recorded average value of 59.00 nGy/h (Monica *et al.*, 2016; Agbalagba, 2017). The implication of this is that more radiation energy are deposited and absorbed by body tissues of rice farmers. Since the human body tissues are sensitive to radiation energy at different rates the implication is that the farmers are at risk of high radiation doses. High radiation levels and doses in the environment are detrimental to human health. Ionizing radiations are highly energetic particles with characteristic high penetrating power. When such radiation passes through biological cells, it causes both excitation and ionization which alters the cells structure (Emelue *et al.*, 2014). Exposure to high levels of gamma radiation can cause a number of harmful effects such as mutation, cancer of various degrees and different kinds of diseases.

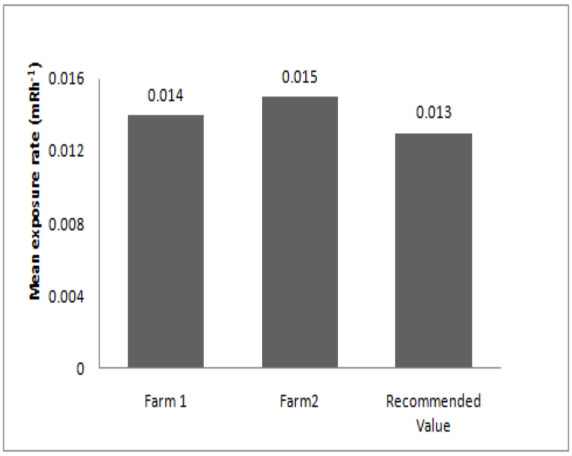

Fig. 3: Comparison of the mean exposure rate with recommended limit

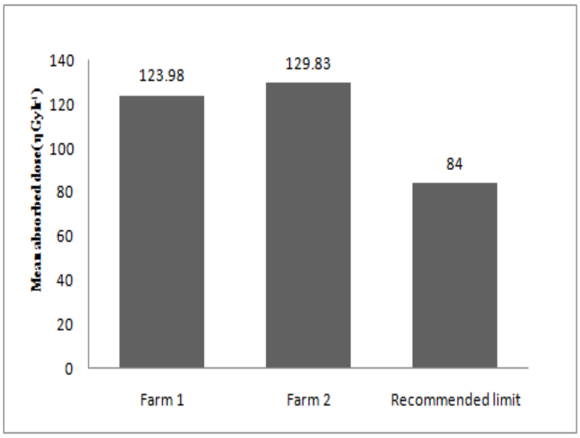

Fig. 4: Comparison of the mean absorbed dose rate with recommended limit

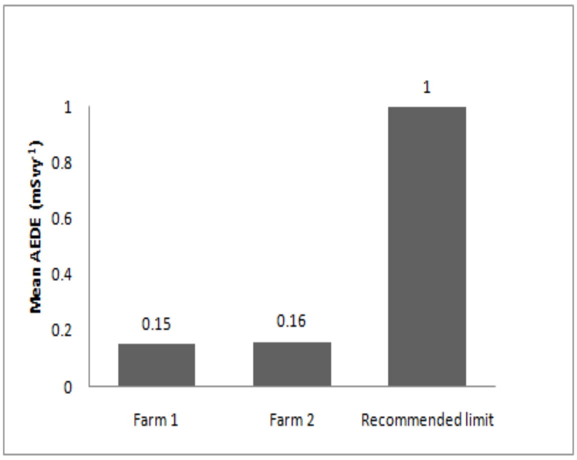

Fig. 5: Comparison of the mean annual effective dose equivalent with recommended limit

The equivalent dose and annual effective dose are radiation protection indices which quantify, respectively the radiation dose to a particular organ of the body and whole body radiation dose per year. The values for the equivalent dose for both farms ranged from 0.84 to 1.51 $mSvy^{-1}$ with mean values 1.20±0.18 $mSvy^{-1}$ and 1.24±0.20 $mSvy^{-1}$ respectively, for farm 1 and 2. These mean values exceeded the 1.00 $mSvy^{-1}$ recommendations of the International Commission on Radiological Protection (ICRP, 2007; Mokobia *et al*, 2016). These values further indicate and stress the radiological unhealthiness of the rice farms. The mean annual effective dose equivalents for both farms are 0.15±0.02 $mSvy^{-1}$ and 0.16±0.02 $mSvy^{-1}$ respectively. As indicated in Fig. 5, these values are lower than the ICRP permissible limits of 1.00 $mSvy^{-1}$ for the general public and 20.00 $mSvy^{-1}$ for occupational workers dealing with radiation sources within a year (ICRP, 2007). This is an indication that the radiation contamination of the study rice farms does not pose any immediate radiological health challenges to an exposed individual within the area. Similar range of values of AEDE has also been recorded by Essien *et al.* (2017) in cocoa plantation in Uyo, Akwa Ibom State and also by Ugbede and Echeweozo (2017) around quarry environment in Okpoto community of Ebonyi State. But are far lower than values of 0.41 $mSvy^{-1}$, 0.53 $mSvy^{-1}$, 0.47 $mSvy^{-1}$ and 0.50 $mSvy^{-1}$ for outdoor environments of some beaches in Delta State as observed by Mokobia *et al.* (2016) and also those of 0.288±0.045 $mSvy^{-1}$ and 0.335±0.084 $mSvy^{-1}$ in salt lake areas of Okposi Okwu and Uburu respectively located in Ebonyi State as noted by Avwiri *et al.* (2016). This variation in doses per the study areas is due to the different geological features of these areas and the natural and man-made activities associated with them which might have negative impact on the radiation levels.

The radiological compliance of any environment is quantified based on its dose levels as compared with international recommendations for normal environment. The rice farms show areas of relatively high background gamma radiation exposure and dose levels, which indicate areas of radiological contamination. However, the contamination and the radiation levels at these rates do not constitute any immediate health effect on the farmers and general public, but there exist the potential for long-term health hazards in future such as cancer due to accumulated doses. This suggests the need for regular monitoring and regulatory actions by relevant radiation protection bodies and government agencies concerned with environmental health in ensuring that the radiation levels in the farming environment and the immediate community is maintained to as low as reasonably achievable.

Conclusion

Background ionizing radiation is part of the natural environment and as such humans and other living organisms are continuously exposed. Anthropogenic or man-made activities have contributed to increase in background radiation exposure and doses to human population. The perceived implication of increase background radiation levels in farmlands due to inputs of fertilizers and other agrochemicals with high radioactivity contents has suggested the need for accurate assessment and monitoring of background gamma radiation exposure and dose levels of Nkalagu-Ezillo rice farms. The study has shown that the background gamma radiation exposure and dose levels in the rice farmlands are relatively higher than stipulated limit for normal environment, thus the area is radioactively contaminated. The radiation levels at these present rates, however, do not constitute any immediate radiation induced health effect on the farmers and general public, but there exist the potential for long-term health hazards such as cancer due to accumulated doses.

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