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Background Ionising Radiation and Estimated Health Risk in Cereal Farmland in Uyo, Akwa Ibom State, Nigeria

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Abstract
Radionuclides are found in soils, plants, vegetables, fruits and in farmlands. These radionuclides contaminate the farmland, environment, the cereal, food products and could cause deleterious effect on both animals and human beings when ingested or inhaled. The farmland is owned by a government research institute with a mandate to develop improved varieties of some cereal plants. In situ measurement of the background ionising radiation was conducted with a radiation survey meter which measured the exposures in micro Seviert per hour and the expected health indicators risk on the workers evaluated.The mean BIR measured was obtained as 0.097µSv/hr. The annual equivalent dose rate of radiation obtained in the farm was range between 0.1033 to 0.3328 mSv/yr with a mean value of 0.1699 mSv/yr. The mean annual effective dose rate of 0.1190 mSv/yr was obtained while the mean calculated ECLR is 0.416 X 10^{-3}. The AEDR obtained in this study is lower than the international commission on radiation protection recommended safety limit for the public but higher than values from many works in dumpsites. The ECLR value for this work is higher than the recommended safe value, an indication of potential health risk for the workers and inhabitant of the farmland. Therefore regulatory controls are necessary which include workers spending fewer periods in the farmland and decontamination of the farm.
Keywords: Gamma radiation, occupational risk, Annual effective dose rate, National Cereal Institute, Uyo

1. INTRODUCTION

Our environment is bombarded with ionising radiation from primordial, cosmogenic and artificial sources, with its attendant effect on human beings and environment as it continuously interact with it. The terrestrial sources are rocks, soils, plants, water and air and vegetations (UNSCEAR, 2000). The naturally occurring radioactive material (NORM) found in soils and rocks are mostly ^{40}K, ^{235}Th, ^{238}U and ^{228}Ra and their associated decayed radionuclides. These NORM are brought to the surface through human activities and it is obvious that when these rocks disintegrate naturally, the radionuclides so formed are transferred to the soil through rain infiltration process (Taskin, *et al,* 2009) and transferred to plants which act as one of the paths through which radioactivity and radiation get to man (NCRP ,1987).

It is also established from various studies that these NORM are also present in building materials such as, stones, sand, gravel, cement, concrete, brick, tiles, wood, gypsum, granites etc (Alharbi *et al.*, 2011, Akhar, 2005), clay soils and river sediments (Ramasammy, et al 2009), quarry sites, waste dumpsites (Essien and Akpan 2016, Essien and Essiet 2016. Akinloye and Olomo, (2005) established that vegetation in an environmental field contains traces of radionuclides and Inyang *et al.*,(2009) measured radiation emission from timbers from the forest in Northern Cross River State sold in the timber markets in Calabar, Nigeria. In some parts of Nigeria, a number of authors have reported measurements of gamma radiation exposure levels from soils, building materials, dumpsites etc as seen in the literatures but a few are been obtained for farmlands hence the need to conduct this study. The radioactive elements being the source of these ionising radiations are concentrated mostly in the surface layers of soil and could migrate downwards changing the chemical and physical conditions of the soil system contaminating the soil. In the soils the plants absorbed the NORMs and hold them in their root zone and consequently transferred it to all other parts of the plants. The plants therefore act as a source that these dangerous isotopes may get into animal tissues and human beings which could lead to the destruction of the tissues and a consequent biological effect.

It is known that the presence of these NORMs and heavy metals in the soils contaminates the plants on these soils as the plants on these soils uptake the radionuclides and the heavy metals (Chibowski, 2000, Poursharif et al., 2016) and the farmlands are contaminated by these NORMs (Hamzah *et al.*, 2011). A survey of farmlands show a transfer of ^{137}Cs and ^{90}Sr from soils to cereal grains (Kostiainen and Rantavaara, 2002), the transfer of the radionuclide into tea leaves and other edible plants have been established by different authors (Keser *et al* 2011, Chakraborty, *et al.*, 2013, Gorur *et al.,* 2011). Natural radioactivity concentration have been determined in some vegetables and fruits (Harb, 2015) and in medicinal plants and its associated committed effective dose due the ingestion of the plants determined by (Chandrashekara and Samasshekarappa, 2016).

Various studies also show that fertilizer also contributes to soil contamination as it adds to radioactivity concentration in the soil as the study indicates radioactivity level due to the presence of the Norms in the soil from cultivated area where fertilizer was used (Diab et al 2008, Hamzah et al 2011). Therefore it is certain that the raw materials used in the production of fertilizer contain some quantity of radioactive materials such as Uranium, thorium and radioactive potassium.

The background ionising radiation (BIR) interacting with human beings could have deleterious effect as the radiation interacts with the deoxyribonuclide acid (DNA) thus producing free radicals. The resulting free radical causes changes in the chemical bonds of the body thus causing biological effect. In view of the effect of (BIR) on humans it is necessary to estimate the health risk of BIR on the workers and the public in the study area

In this study, the risk indicators evaluated are BIR, annual effective dose rate (AEDR) and excess lifetime cancer risk (ECLR)

2. MATERIALS AND METHOD

2.1 Study Site

The cereal farmland considered for the investigation was the National Cereal Research Institute (NCRI) out station at Owut Uta, Uyo. It is located along Aka Nnung Udoe Road in Ibesikpo Asutan local government area, Akwa Ibom State (Lat.4^0 30' and 5^0 30' N, Long. 7^0 5' and 8^0 20'E, 100m altitude (Uwah *et al.,* 2011). The NCRI of Nigeria was established by decree 13 of 1975 with the mandate to conduct research into genetic improvement and production of major stable grains like rice, maize, cowpea, Cassava and sugarcane but in 1987 the mandate was extended to include more crops like beniseed, soybeans and overall farming system and resource management. The station besides saving as government research agency also saves researchers from the universities on special research (Uwah *et al.,* 2011, Ekwere *et al.,* 2013). The farmland was divided into plots according to the type of crop planted. Rice occupies 4 plots, cassava 2 plots, a plot of pumpkin and 3 plots of maize

2.2 Exposure Measurement

In situ measurement of the background ionising radiation (BIR) level was carried out using Radex (RD 1212) radiation meter which measured ionising radiation level rate in micro Sievert per hour (μSv/h). The meter is a handheld digital radiation detector which detects gamma radiation, X radiation and beta radiations with a dose power range of 0.05 to 999 $\mu Sv/h$ and a linear energy response to gamma radiation between 0.1 to 1.25 MeV. For effective monitoring, the radiation meter was placed at the gonad level of 1m above ground level with the window of the meter directed toward each site and 10 readings taken in different directions in each site and the mean recorded. Again background radiation was also measured in five different locations at 10 m away from the farm. Measurements of exposure levels in this investigation were taken in the afternoon between 1000 hours and 1700 hours for effective response of the meter to environmental radiation exposures within Calabar (Inyang *et al.,* 2009).

2.3 Estimation of occupational risk indicators.

2.3.1 Annual effective Dose

The background ionising radiation (σ) measured in μSv/h is converted to annual effective dose in AEDR (mSv/yr) according to (UNSCEAR 2000, Gupta and Chauhan, 2011)

$$AEDR(mSv/yr) = \sigma(\mu Sv/hr) \times 24hrs \times 365.25days \times 0.2 \times 0.7 \times 10^{-3} \quad 1$$

The annual effective dose rate per year received by the workers is obtained from equation 1 where 0.2 is the outdoor occupancy factor and 0.7 the conversion factor from annual equivalent dose rate (Etuk *et al*., 2015) to annual effective dose rate (AEDR).

2.3.2 Excess cancer lifetime risk

The risk on the worker in the environment if occupied for 70 years known as excess cancer lifetime risk (ECLR) is obtained from the effective rate by multiplying the effective dose rate by the risk factor R_F of 0.05 per Sv and the expected lifetime age (D_L) of 70 years (Essien and Emmanuel, 2016) .

$$ELCR = AEDR \times D_L \times R_F \quad 2$$

3.0 Results

The farmland was divided into ten plots according to crops planted on the farmland and coded PT 01to PT10 and presented in Table 1. The measured and calculated risk indicators are presented in Table 2.

Table 1 Crop plots and their code

S/N	Plot Code	Crop
1	PT 1a	Rice
2	PT 1b	Rice
3	PT 1c	Rice
4	PT 1d	Rice
5	PT 2a	Cassava
6	PT 2b	Cassava
7	PT 3	Pumpkin
8	PT 4a	Maize
9	PT 4b	Maize
10	PT 4c	Maize

Table 1 shows the farmland and the plots accommodating the different crops. Plots 1 (a-d) are for rice, plots 2 (a and b) are for cassava, plot 3 is for pumpkin while maize accommodate plots 4(a-c) while PT05 was outside the main entrance of the cereal farm.

Table 2 Mean BIR and estimated health risk indicators

S/N	Plot code	BIR $\sigma(\mu Sv/hr)$	HT (mSv/yr)	AEDR (mSv/yr)	ECLR $\times 10^{-3}$
1	PT01a	0.084	0.1471	0.1029	0.360
2	PT01b	0.089	0.1559	0.1091	0.382
3	PT01c	0.078	0.1366	0.0956	0.335
4	PT01d	0.082	0.1436	0.1005	0.352
5	PT02a	0.076	0.1331	0.0931	0.326
6	PT02b	0.088	0.1541	0.1078	0.378
7	PT03	0.190	0.3328	0.2329	0.816
8	PT04a	0.069	0.1208	0.0845	0.296
9	PT04b	0.059	0.1033	0.0723	0.253
10	PT04c	0.062	0.1086	0.0760	0.266
11	PT05	0.092	0.1612	0.1128	0.395
	Mean	0.097	0.1699	0.1190	0.416

The background ionising radiation recorded in Table 2 shows a mean exposure range of 0.078 to 0.089 μSv/h with a mean value of 0.083 μSv/h for rice plots, BIR contribution from cassava plot range from 0.078 to 0.088 μSv/h with a mean value of 0.082 μSv/h, pumpkin contributed the highest exposure of 0.190 μSv/h while maize plots exposure range between 0.059 to 0.069 μSv/h with a mean value of 0.063 μSv/h. The BIR measured 5 meters away from the main entrance into the farm coded PT05 recorded 0.092 μSv/h. The annual equivalent dose rate of radiation obtained in the farm was range between 0.1033 to 0.3328 mSv/yr with a mean value of 0.1699 mSv/yr. The mean annual effective dose rate of 0.1190 mSv/yr was obtained by using an outdoor occupancy factor of 0.2 for 24 hours and a conversion factor of 0.7 while the mean calculated ECLR is 0.416 X 10^{-3}

4. DISCUSSION

The National Research Institute farm, Uyo has been in continuous operation for over 20 years undertaking the research into the improvement of the crops within their mandate. The use of mechanized system of farming, tilling the soils, scrapping the top soils etc continuously bring out the NORMs accumulated in the soils. Again addition of fertilizers and other additives to the soils are known to contaminate the soils and could raise the background ionising radiation level of the environment. The knowledge of background ionising radiation level of an environment is necessary to provide information on the health risk due to the exposures to the occupants of the environment, workers and the public with the consequent guidance of the radiation regulators on possible remediation controls.

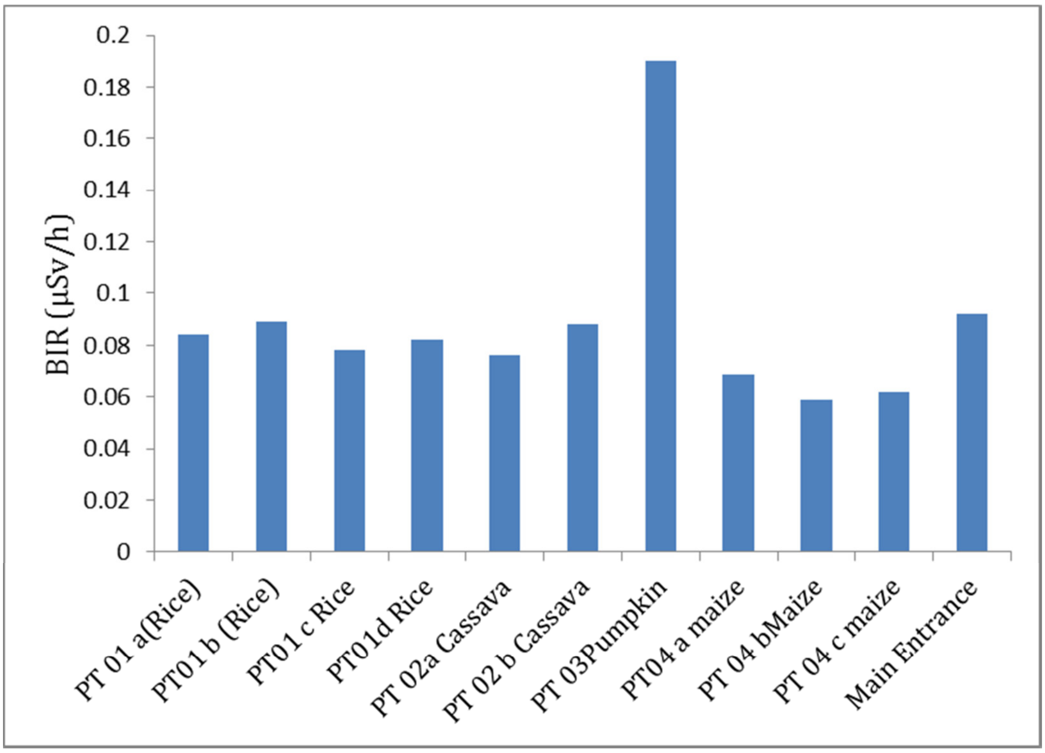

FIG.1. The measured mean background ionising radiation per plot

The measured mean BIR per plot (fig. 1) shows that pumpkin plot has the highest radiation level which could come from the type of fertilizer applied to the plot which could be different from those applied to other plots while the high BIR measured at the main entrance of the research farmland compared to the BIR measured inside the farmland shows that the BIR at the entrance could be from other sources as the location is close to the main road where vehicular movement and other sources of radionuclides abound. Figure 2 shows that pumpkin contributed 45% , cassava 20 % , rice 20 % and maize 15 % of BIR to the total BIR in the farmland. The mean annual BIR obtained for the cereal farmland is 0.850 mSv/yr which is lower than the world wide annual BIR of 2.4 mSv/yr (Avwiri and Olatubosun, 2014)

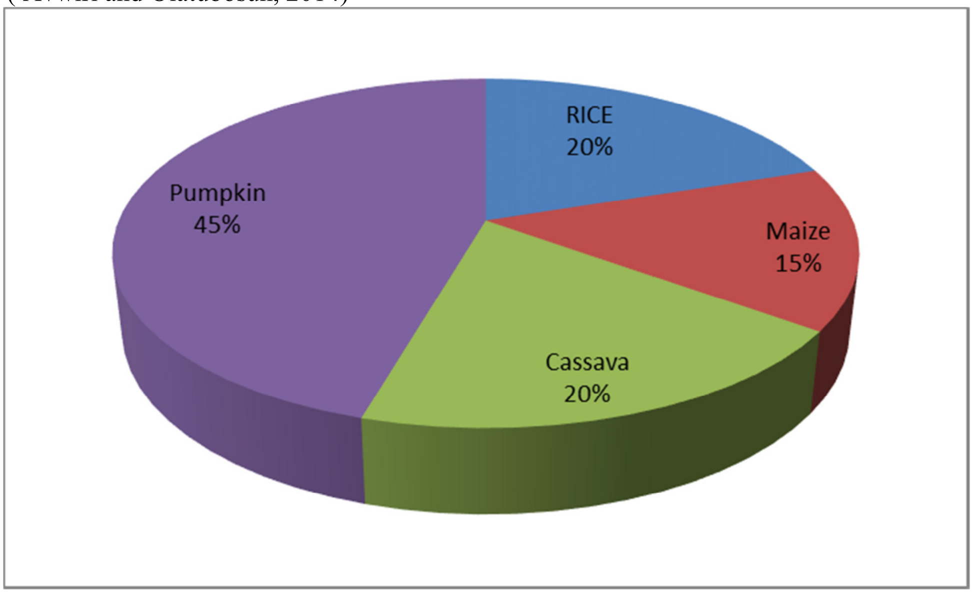

FIG. 2 Percentage contribution of crops to the total BIR in the farmland

The annual effective dose rate (AEDR) which indicates the occupational risk on the workers and occupants of the farm was calculated and compared with the international commission on radiation protection (ICRP) standard and presented in figure 3. The results show that none of the plots presents AEDR above the 1 mSv/yr safety limit as prescribed by ICRP (2000). The mean AEDR obtained for the research farm is 0.1128 mSv/yr which is lower than the ICRP recommended value of 1 mSv/yr for the public and lower than the mean AEDR of 0.17 mSv/yr obtained for the central dumpsites in Uyo, Akwa Ibom State (Essien and Essiet, 2016) but higher than the mean AEDR of 0. 095 mSv/yr obtained for the central mechanic village in Uyo Akwa Ibom State (Essien and Umoh, 2016). The comparison of the mean AEDR obtained for this study with studies in different dumpsite in Nigeria show that the AEDR in this study area is higher, typically the AEDR of 0.026mSv/yr was obtained from a dumpsite in Port Harcourt, Nigeria (Farai *et al.,* 2008), 0.038 mSv/yr obtained from a dumpsite in Osogbo, Osun State, Nigeria (Bamidele and Olatunji, 2014) showing an increased radiation level from the organic fertilizer and other additives such as pesticides applied on the farmland.

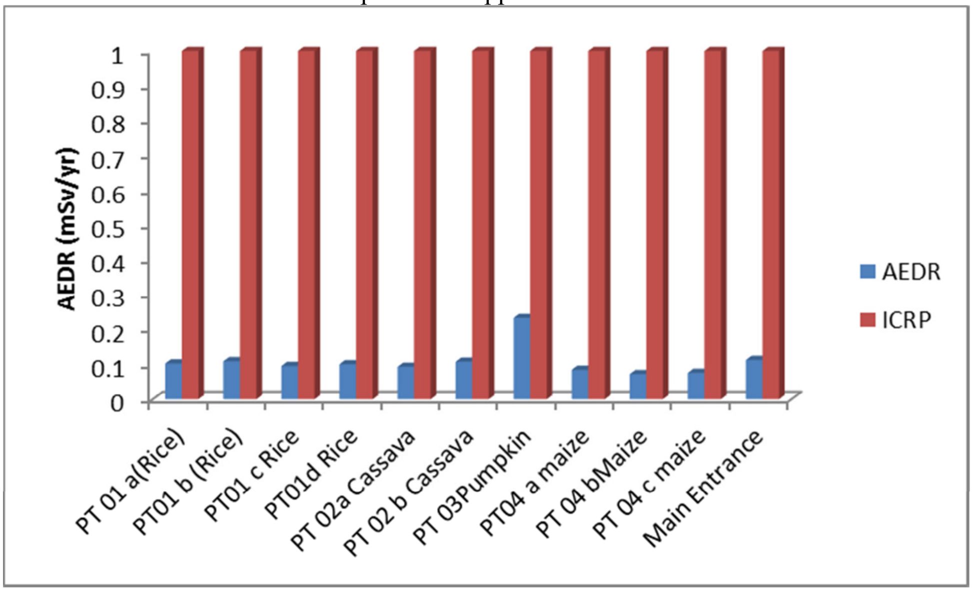

FIG 3. The comparison of the annual equivalent dose rate (AEDR) with the ICRP standard

Table 2 show that the mean excess cancer lifetime risk which defines the probability of the people living in the study area to develop cancer if they are there for 70 years is obtained for this work as 0.416 x 10^{-3}. This value is higher than the world average ECLR safe limit of 0.344 x 10^{-3} (Garsel, 2010) and indication of a potential health risk due to the exposures in this farm as there is no low level radiation without health risk when interacted with for a long time. Therefore, there is need for regulatory control to be set for the workers and staff of the farm. The probable control measure is that workers should spend less period in the farm, probably 60 hours a week throughout 50 weeks in a year in order to limit the exposure level (Jibiri and Obarhua 2013) and the workers should not be allowed to spend their 70 years in the farm. Again, there is need for the treatment of the farmland to decontaminate the land. The treatment is aimed at preventing the radioactive material from spreading to the other areas, reduce the radiation hazards to the public, and avoid the transfer of much of the radioisotope into the cereal and food products. The suggested decontaminating method could include, irrigation and leaching, application of dilute solutions of acids and salts or application of lime, gypsum or the contaminated soil could be isolated for a while for the radionuclides to decay (USDA).

5 CONCLUSIONS

The National Cereal Research Institute of Nigeria farm saves both as government research centre for the improvement of cereal crop and research centre for postgraduate students. The measurement of background ionising radiation is necessary to estimate the potential health risk due to the exposures. The results for this study show that the mean background ionising radiation obtained from this work was below the mean worldwide value while the estimated annual effective dose rate was lower than the ICRP recommended acceptable safe limits of 1mSv/yr for the public while the estimated excess cancer lifetime risk was higher than the worldwide value. This indicates that there is a potential health risk for workers who work there for a longer period of years. Therefore it recommended that workers should be encouraged to work for a fewer period in a week and less number of years. Secondly the farmland should be decontaminated.

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