Original Research Article

ASSESSMENT OF OUTDOOR GAMMA EXPOSURE LEVEL OF SOME SWAMPY AGRICULTURAL SOILS OF NASARAWA WEST, NIGERIA

ABSTRACT

In this study, assessment of outdoor background exposure levels in some selected swampy agricultural soil in Nasarawa West, Nigeria has been conducted. An in-situ measurement of outdoor background exposure rate (in $mRhr^{-1}$) for a total of fifty farms (ten each from Keffi (KF), Kokona (KK), Karu (KR), Toto (TT), and Nasarawa (NS)) were done using a well calibrated portable halogen-quenched Geiger Muller (GM) detector (Inspector alert Nuclear radiation monitor SN:3544). A geographical positioning system (GPS) was used at an elevation of 1.0 m above ground level to obtain the geographical location. The radiological hazard parameters were evaluated using the measured outdoor background exposure rates. The values obtained were compared with recommended permissible limits to ascertain the radiological hazard status of the swampy agricultural farms. The mean values of the outdoor background exposure levels (0.23, 0.038, 0.028, 0.022, and 0.039 mRh^{-1}), absorbed dose rates (458.49, 334.95, 188.79, 194.01, and 343.65 $nGyh^{-1}$) and excess lifetime cancer risk (1.968, 1438, 0.810, 0.832, and 1.475) each for KF, KK, KR, TT, and NS respectively, are higher than the recommended safe limits of 0.013 mRh^{-1}, 84.0 $nGyh^{-1}$, 0.00029 respectively as recommended by UNSCEAR and ICRP. On the other hand, the mean annual effective dose equivalent (AEDE) values (0.563, 0.410, 0.232, 0.238, and 0.421 $mSvy^{-1}$ for KF, KK, KR, TT, and NS respectively) are below the recommended permissible limits of 1.00 $mSvy^{-1}$ for general public exposure. Generally, the study revealed that swampy agricultural soils in Nasarawa west are radiologically safe with little contamination which could be attributed to the geological formation and partly due to human activity in the area.

INTRODUCTION

Human activities such as commerce, agriculture, industry, among others on the earth's surface have become a major source of concern to the ecosystem and man, in terms of their effects on the environment and human health [1, 2]. The negative health impact of the human industrial activities in the environment has been a subject of discussion in contemporary times [3]. Presently the human environment is faced with so many problems, prominent among which is exposure to background gamma radiation emitted from the natural radioactivity sources that are all over the earth due to substantial primordial radionuclides [4, 5]. The fluctuation of the background ionizing gamma radiation level depends on the percent age radionuclei concentration in the soil, the altitude, and the variation in the geographical conditions of different region [6]. The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has reviewed and evaluated global and regional exposures to ionizing radiation sources and the report provides data on individual annual average doses and the ranges of background ionizing gamma radiation from various sources [7]. The background ionizing gamma radiation exposures may be of little or no radiological concern in most parts of the world [7, 8]. In such places the significance of assessing levels of radiation exposure from various natural components could therefore be to establish the relative importance of each component [9], or/and to provide baselines against which the radiological impacts of the practices that generate artificial ionizing radiation exposures could be measured [10]. Although the studies of atomic bomb survivors provide strong evidence of health effects such as cancer and non-cancer diseases associated with single acute exposure to moderate and high doses of ionizing radiation, the effect of low dose-rates on health and cancer risks after exposure to ionizing radiation is, as yet, unclear [7, 11]. However, it is encouraged that investigations are made to some of these regions where a high level of background ionizing gamma radiation is observed to evaluate its hazard and long term effect as a result of exposure to both high and low-level exposures to this occurring natural radiation [12]. Based on these circumstances, it is necessary to carry out an environmental assessment of the existing exposure situation to background ionizing gamma radiation in the study area to get a scientific evidence of health effects due to chronic low-dose-rate radiation exposure.

MATERIALS AND METHODS

Study Area

Nasarawa west agricultural zone as the study area consisting of Keffi (KF), Kokona (KK), Karu (KR), Nasarawa (NS), and Toto (TT) Local Government Areas is bordered by Federal Capital Territory, Abuja, Kogi State and Kaduna state respectively. The study area dominated by guinea savannah vegetation has agriculture as the mainstay of its economy with the production of varieties of cash crops such as rice, groundnut, cassava, pepper, cowpea, sesame, sorghum, yam throughout the year by the populace that engage in subsistence farming. It also contains various minerals such as cassiterite, columbit, mica, granite, quartz, iron ore, and bauxite which are mostly mined by artisanal miners. The study area extends over the equatorial climatic zone. Mean Temperature of the zone varies from 25 to 28 ℃ with two rainy and two dry seasons. The Figure below shows the maps of Nasarawa West as the study area.

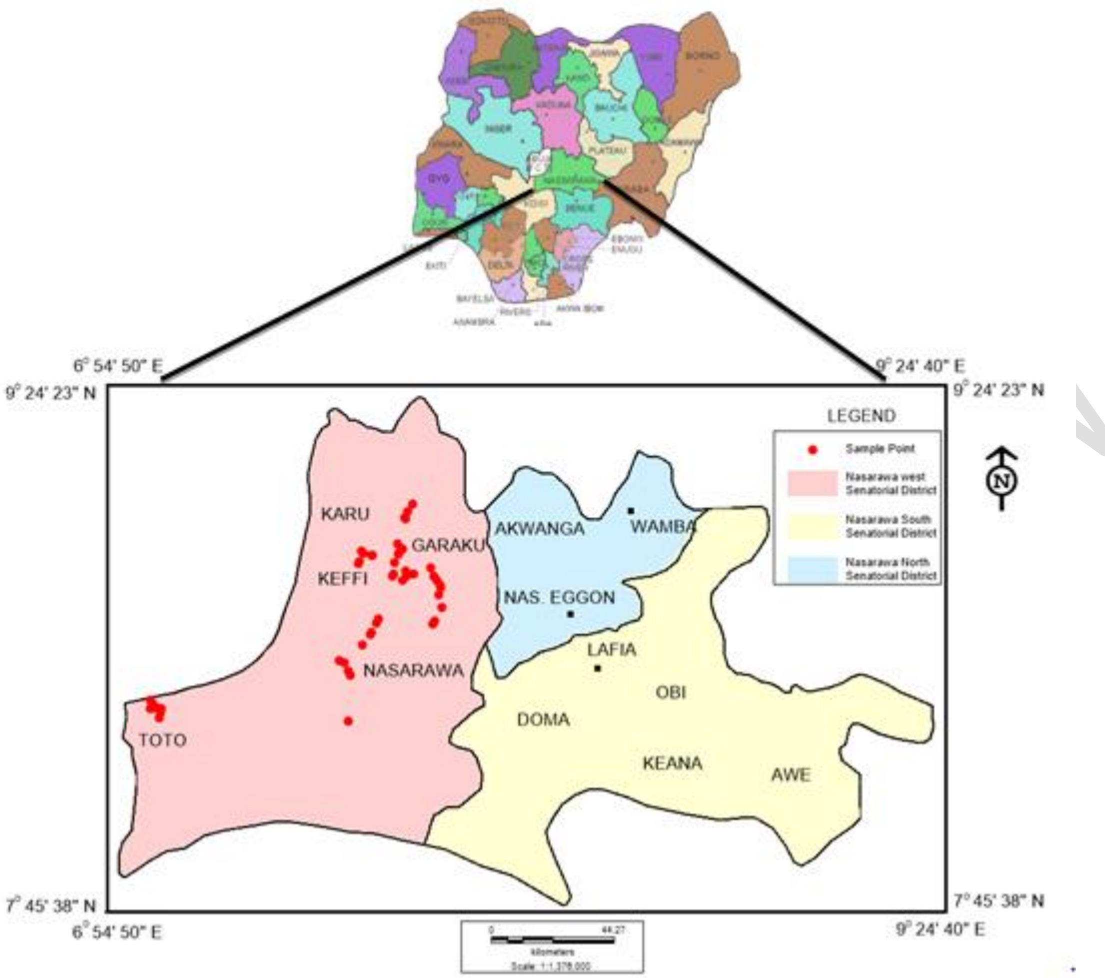

Figure 1: Map of the sampled locations in Nasarawa west

Measurements and Sampling

In-situ measurements of the background gamma exposure level were taken over some selected locations in Nasarawa West, Nigeria. The latitude and longitude of sampled locations were measured using the global positioning system (GPS) (model: German 301). The instrument used for the measurement of background ionizing radiation is a hand-held factory calibrated Inspector Alert Nuclear radiation survey meter with the serial number 35440, manufactured by SE international, Inc. USA. The meter's sensitivity is 3500 CPM/ (mRh^{-1}) referenced to Cs-137 and its maximum alpha and beta efficiencies are 18% and 33% respectively. It has a halogen-quenched Geiger-Muller detector tube with effective diameter of 45 mm and a mica window density of 1.5 – 2.0 $mg.cm^{-2}$ (As stated in the operational manual) capable of detecting α- particles β-particles, γ- rays and x-rays within the temperature range of -10 ℃ to 50 ℃ was used to carry out the measurement. The Inspector Alert Nuclear radiation survey monitor was characterized for environmental measurement. The equipment's accuracy is high, with an error value of 5 percent. Its reliability and sensitivity are very high. Although it is portable but provides an outlined details of detection, weather-protection, and can be easily used.

The tube of the radiation meter was raised to the standard height of 1.0 m above the ground so as to enable sample points maintain their original environmental characteristics [13,14,15] with its window facing the site to be measured and then vertically downward [16] . The GM tube generates a pulse of electrical current each time radiation passes through the tube and causes ionization and each pulse is electronically detected and registered as a count. Readings were obtained between the hours of 1200 and 1600 since the radiation meter is assumed to have a maximum detection response to radiation within these hours as recommended by the National Council on Radiation Protection and Measurements [17]. The measurement was taken four times spanning over some few minutes in each sampled locations and the mean was found.

$$Count\ rate\ per\ minute\ (CMP) = 10^{-3}\ Roentgen\ x\ F \qquad 1$$

where F is the quality factor, which is equal to 1 for external environments.

Radiological Hazard Indices

i. Absorbed dose rate (ADR) in air

The absorbed dose is used to assess the potential for any biochemical changes in specific tissues. It quantifies the radiation energy that might be absorbed by a potentially exposed individual. The measured outdoor background exposure levels were converted to radiation absorbed dose rate in air using Equation 3 according to idris et al. [15].

$$1\ \mu Rh^{-1} = 8.7\ \eta Gyh^{-1} = \frac{8.7x10^{-3}}{(1/8760y)}\ nGyy^{-1} \qquad 2$$

This implies that:

$$1mRh^{-1} = 8.7\ \eta Gyh^{-1}\ x\ 10^{3} = 8700\ nGyh^{-1} \qquad 3$$

ii. Annual effective dose equivalent (AEDE)

The AEDE is used in radiation assessment and protection to quantify the whole body absorbed dose per year. It is used to assess the potential for long-term effects that might occur in the future. The annual effective dose equivalent (AEDE) per year received by workers and the population is obtained from equation 4 [14, 15, 16].

$$AEDE(mSv.y^{-1})_{outdoor} = D(nGy.h^{-1})x\ 8760h\ x\ CF\ x\ OFx10^{-3} \qquad 4$$

where D is the absorbed dose rate in $nGyh^{-1}$, 8760h is the total hours in a year, CF is the dose conversion factor from absorbed dose in air to the effective dose in Sv/Gy (CF = 0.7 Sv/Gy), OF is the occupancy factor, the expected period the members of the population would spend within the study area. OF = 0.2 for outdoor as it is expected that human beings would spend 20 % of their time outdoors as recommended by UNSCEAR [7, 15].

iii. Excess lifetime cancer risk (ELCR)

The ELCR was evaluated using the AEDE values as shown in Equation 6 according to Idris et al. [15].

$$ELCR = AEDE\ (mSvy^{-1})\ x\ DL\ x\ RF \qquad 6$$

where DL is average duration of life (70 years) and RF is the fatal cancer risk factor per sievert (Sv^{-1}). For lowdose background radiation, which is considered to produce stochastic effects, ICRP 103 uses a fatal cancer risk factor value of 0.05 for public exposure [14, 15, 16]

Results and Discussion

The result of exposure rate was measured from swampy agricultural soils in Nasarawa west (Keffi, Kokona, Karu, Toto and Nasarawa). Inspector Alert Nuclear Radiation Meter (SN: 35440, by SE international, Inc. USA) was used to measure the background radiation level in mR/hr. Table 1-5 and Figure 2 presents result of exposure rate.

Table 1: Measured Exposure Rate and their Geopoints and Elevation for swampy agricultural soils in Keffi, Nasarawa State.

S/N	**Sampling code**	**Geopoints**		**Elevation (m)**	**Exposure Rate (mR/hr)**
		Longitude	Latitude		
1	KF1	$8^0$52’33.48’’ N	$7^0$52’30.52’’ E	308	0.230
2	KF2	$8^0$52’42.21’’ N	$7^0$52’37.35’’ E	322	0.020
3	KF3	$8^0$54’35.29’’ N	$7^0$52’19.49’’ E	315	0.017
4	KF4	$8^0$53’28.86’’ N	$7^0$53’17.74’’ E	294	0.016
5	KF5	$8^0$50’53.57’’ N	$7^0$51’40.68’’ E	330	0.015
6	KF6	$8^0$48’50.72’’ N	$7^0$51’35.90’’ E	317	0.160
7	KF7	$8^0$48’27.46’’ N	$7^0$52’26.15’’ E	298	0.019
8	KF8	$8^0$47’44.42’’ N	$7^0$53’18.24’’ E	274	0.021
9	KF9	$8^0$49’03.18’’ N	$7^0$53’49.55’’ E	280	0.013
10	KF10	$8^0$49’23.48’’ N	$7^0$53’52.69’’ E	295	0.016

Table 2: Measured Exposure Rate and their Geopoints and Elevation for swampy agricultural soils in Kokona, Nasarawa State.

S/N	**Sampling code**	**Geopoints**		**Elevation (m)**	**Exposure Rate (mR/hr)**
		Longitude	Latitude		
1	KK1	$8^0$49’56.20’’ N	$7^0$58’48.68’’ E	269	0.015
2	KK2	$8^0$48’55.56’’ N	$7^0$55’27.71’’ E	297	0.031
3	KK3	$8^0$48’25.36’’ N	$7^0$59’34.18’’ E	289	0.017
4	KK4	$8^0$47’43.16’’ N	$8^0$00’04.71’’ E	318	0.023
5	KK5	$8^0$41’50.18’’ N	$8^0$00’34.69’’ E	311	0.026
6	KK6	$8^0$46’10.77’’ N	$8^0$00’49.22’’ E	332	0.023
7	KK7	$8^0$44’56.90’’ N	$8^0$00’29.85’’ E	305	0.044
8	KK8	$8^0$42’37.53’’ N	$8^0$00’26.69’’ E	273	0.040
9	KK9	$8^0$39’57.16’’ N	$7^0$59’44.29’’ E	283	0.140
10	KK10	$8^0$39’28.44’’ N	$7^0$59’16.68’’ E	287	0.026

Table 3: Measured Exposure Rate and their Geopoints and Elevation for swampy agricultural soils in Karu, Nasarawa State.

S/N	**Sampling code**	**Geopoints**		**Elevation (m)**	**Exposure Rate (mR/hr)**
		Longitude	Latitude		
21	KR1	$8^0$59’11.18’’ N	$7^0$53’51.09’’ E	349	0.032
22	KR2	$8^0$59’28.76’’ N	$7^0$53’48.25’’ E	342	0.016
23	KR3	$9^0$02’05.06’’ N	$7^0$55’13.16’’ E	372	0.026
24	KR4	$9^0$00’37.62’’ N	$7^0$54’23.22’’ E	366	0.022
25	KR5	$8^0$53’08.61’’ N	$7^0$45’13.13’’ E	335	0.025
26	KR6	$8^0$52’50.88’’ N	$7^0$45’31.94’’ E	356	0.019
27	KR7	$8^0$51’13.85’’ N	$7^0$44’46.65’’ E	377	0.023
28	KR8	$8^0$50’51.09’’ N	$7^0$44’35.88’’ E	380	0.022
29	KR9	$8^0$52’17.59’’ N	$7^0$47’12.21’’ E	351	0.015
30	KR10	$8^0$52’21.85’’ N	$7^0$47’16.58’’ E	351	0.017

Table 4: Measured Exposure Rate and their Geopoints and Elevation for swampy agricultural soils in Toto, Nasarawa State.

S/N	**Sampling code**	**Geopoints**		**Elevation (m)**	**Exposure Rate (mR/hr)**
		Longitude	Latitude		
31	TT1	$8^0$24’58.32’’ N	$7^0$03’30.08’’ E	177	0.023
32	TT2	$8^0$24’11.10’’ N	$7^0$04’05.15’’ E	116	0.025
33	TT3	$8^0$24’11.73’’ N	$7^0$04’06.07’’ E	118	0.024
34	TT4	$8^0$23’28.96’’ N	$7^0$03’42.14’’ E	114	0.026
35	TT5	$8^0$23’25.45’’ N	$7^0$03’33.73’’ E	116	0.023
36	TT6	$8^0$21’48.80’’ N	$7^0$05’18.78’’ E	156	0.025
37	TT7	$8^0$22’43.70’’ N	$7^0$05’23.98’’ E	162	0.017
38	TT8	$8^0$23’34.70’’ N	$7^0$05’45.30’’ E	193	0.019
39	TT9	$8^0$23’32.71’’ N	$7^0$05’09.74’’ E	176	0.020
40	TT10	$8^0$23’22.50’’ N	$7^0$05’17.47’’ E	175	0.021

Table 5: Measured Exposure Rate and their Geopoints and Elevation for swampy agricultural soils in Nasarawa, Nasarawa State.

S/N	**Sampling code**	**Geopoints**		**Elevation (m)**	**Exposure Rate (mR/hr)**
		Longitude	Latitude		
41	NS1	$8^0$40’24.30’’ N	$7^0$48’37.48’’ E	264 m	0.027
42	NS2	$8^0$39’31.78’’ N	$7^0$48’10.29’’ E	267	0.025
43	NS3	$8^0$37’53.68’’ N	$7^0$47’13.22’’ E	223	0.021
44	NS4	$8^0$37’27.56’’ N	$7^0$47’02.27’’ E	231	0.017
45	NS5	$8^0$35’27.88’’ N	$7^0$45’26.97’’ E	212	0.013
46	NS6	$8^0$21’13.04’’ N	$7^0$42’30.61’’ E	185	0.210
47	NS7	$8^0$30’35.67’’ N	$7^0$42’35.21’’ E	201	0.025
48	NS8	$8^0$29’51.41’’ N	$7^0$42’55.04’’ E	212	0.019
49	NS9	$8^0$32’09.53’’ N	$7^0$41’47.37’’ E	192	0.015
50	NS10	$8^0$32’29.05’’ N	$7^0$40’49.81’’ E	199	0.023

Outdoor Background Exposure Rate

The outdoor background exposure rate measured ranged from 0.013to 0.23 mRh^{-1}, 0.015 to 0.140 mRh^{-1}, 0.015 to 0.036 mRh^{-1}, 0.017 to 0.026 mRh^{-1}, and 0.013 to 0.21 mRh^{-1} with mean values of 0.0527, 0.0385, 0.0217, 0.0223, and 0.0395 mRh^{-1} for KF, KK, KR, TT, and NS respectively (Table 1-5, Figure 2). The mean outdoor background exposure rate for the swampy agricultural soils in Nasarawa west exceeded the permissible recommended limit of 0.013 mRh^{-1} [14, 15, 16]. The high exposure rate level in the swampy agricultural soil is attributed to the geological formation, geophysical characterization and man made activities that cotributes to the overal exposure level. The high outdoor background levels indicates that the environment is radiologically unhealthy and contaminated for the general public. The mean exposure level reported here is higher than 0.021 mRh^{-1} value observed by Idris *et al*. [15] in Lafia Metropolis, Nasarawa State, Nigeria.

Absorbed Dose Rate

The calculated absorbed dose rate values are in the range (mean) 113.1 - 2001 $nGyh^{-1}$ (458.49 $nGyh^{-1}$), 130.5 - 1218 $nGyh^{-1}$ (334.95 $nGyh^{-1}$), 130.5 - 226.2 $nGyh^{-1}$ (188.79 $nGyh^{-1}$), 147.9 - 226.2 $nGyh^{-1}$ (194.01 $nGyh^{-1}$), and 113.1 - 1827 $nGyh^{-1}$ (343.65 $nGyh^{-1}$) for KF, KK, KR, TT, and NS respectively (Table 1-5, Figure 3). The mean absorbed dose rate is higher than the world weighted average of 59.00 $nGyh^{-1}$ [14, 15, 16] and recommended safe limit of 84.0 $nGyh^{-1}$ [15, 16] for outdoor exposure. The result indicates that the swampy agricultural soil is contaminated with gamma emitting radionuclides. However, the induced health effect to the farmers may not be immediate, but however there is a potential for long-term health hazards in the future due to the doses accumulated. The mean dose rate from this investigation is higher than those earlier reported by Idris et al. [15], Ugbede & Benson [13] in Lafia Metropolis, Nasarawa State, Nigeria and Emene Industrial Layout of Enugu State, Nigeria but was below result reported in Ughelli metropolis in Delta State Nigeria by Agbalagba, et al. [14].

Annual effective dose equivalent (AEDE)

The calculated values of AEDE range (mean) are 0.138 to 2.454 $mSvy^{-1}$ (0.562 $mSvyr^{-1}$), 0.160 to 1.494 $mSvyr^{-1}$ (0.411 $mSvyr^{-1}$), 0.160 to 0.277 $mSvyr^{-1}$ (0.232 $mSvyr^{-1}$), 0.181 to 0.277 $mSvyr^{-1}$ (0.238 $mSvyr^{-1}$), and 0.138 to 2.241 $mSvyr^{-1}$ (0.421 $mSvyr^{-1}$) for KF, KK, KR, TT, and NS respectively (Table 1-5, Figure 4). The mean values are higher than world average value of 0.07 $mSvy^{-1}$ [14, 15, 16] but within UNSCEAR and ICRP recommended permissible limits of 1.00 $mSvy^{-1}$ for the general public [15, 16]. This indicates that the studied location is radiologically contaminated but still within the ICRP and UNSCEAR permissible limit. However, there is no immediate radiological health effect on members of the public. The AEDE from the present study are similar to those reported by Idris et al. [15] in Lafia Metropolis, Nasarawa State Nigeria and Ononugbo et al. [16] in Residential Buildings in Emelogu Village in Rivers State.

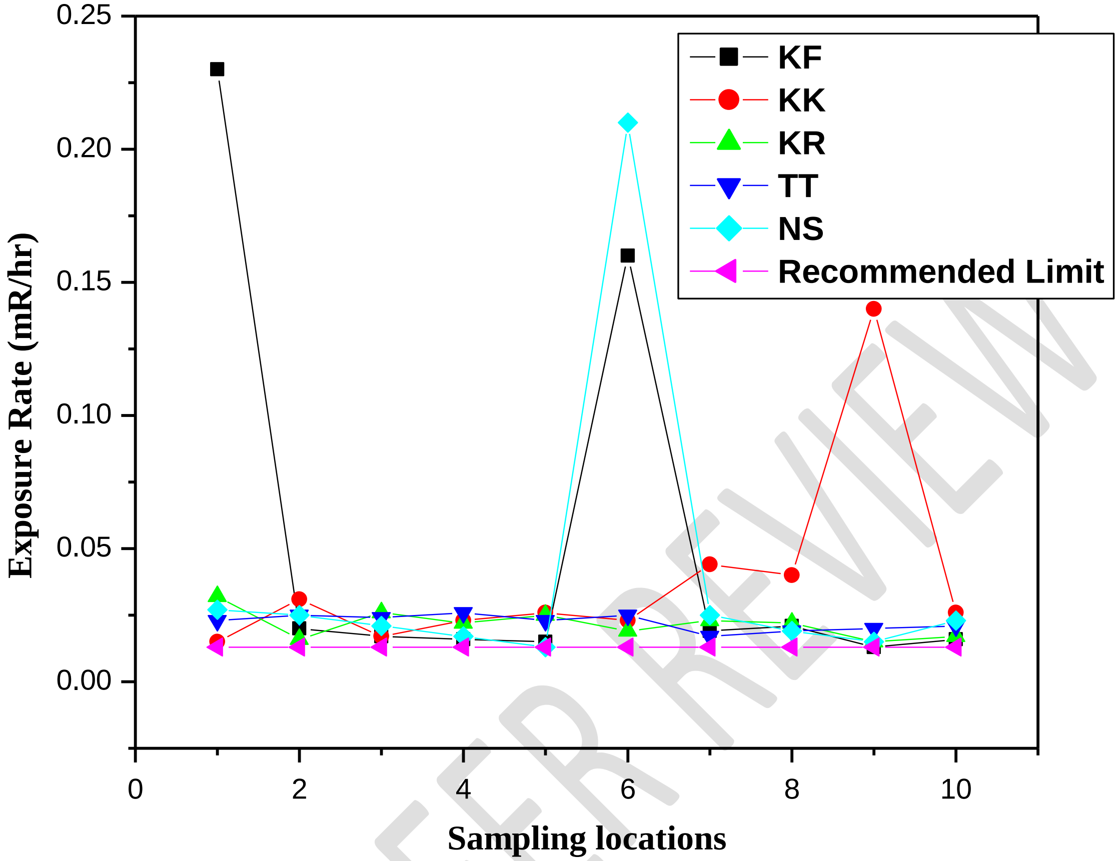

Figure 2: Comparison of measured outdoor background exposure rates and the recommended limit.

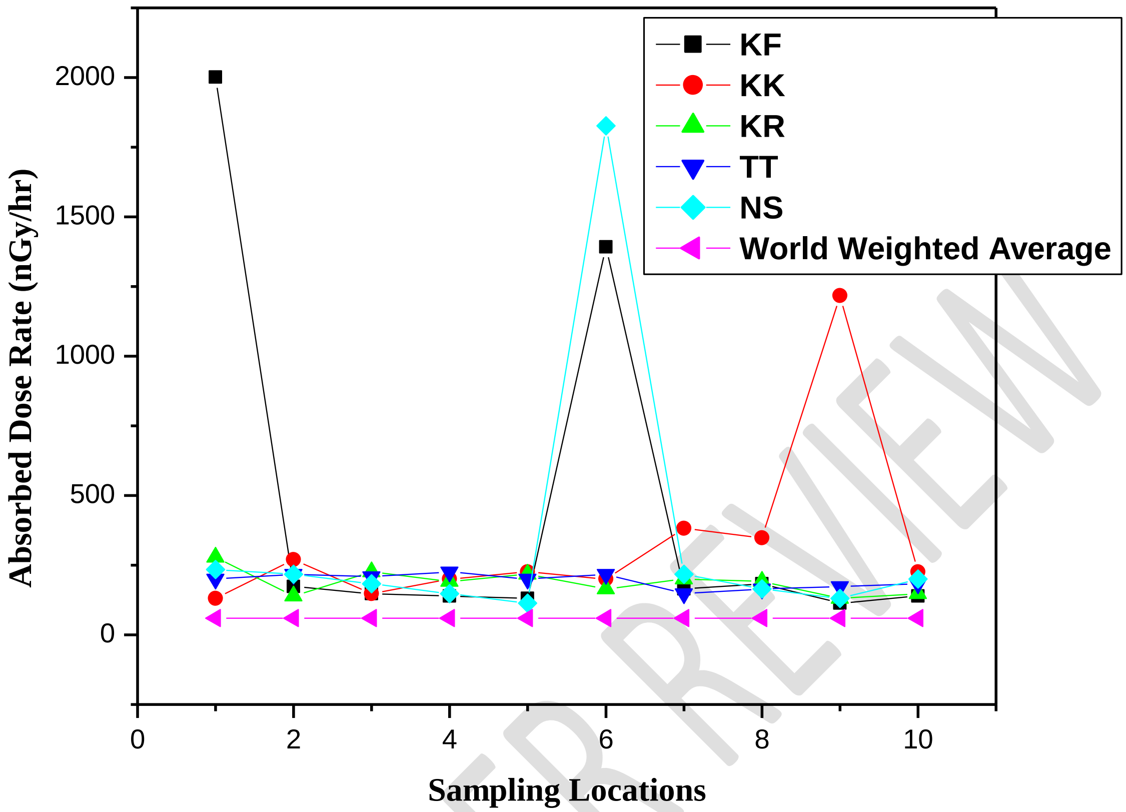

Figure 3: Comparison of absorbed dose rates and the world weighted average.

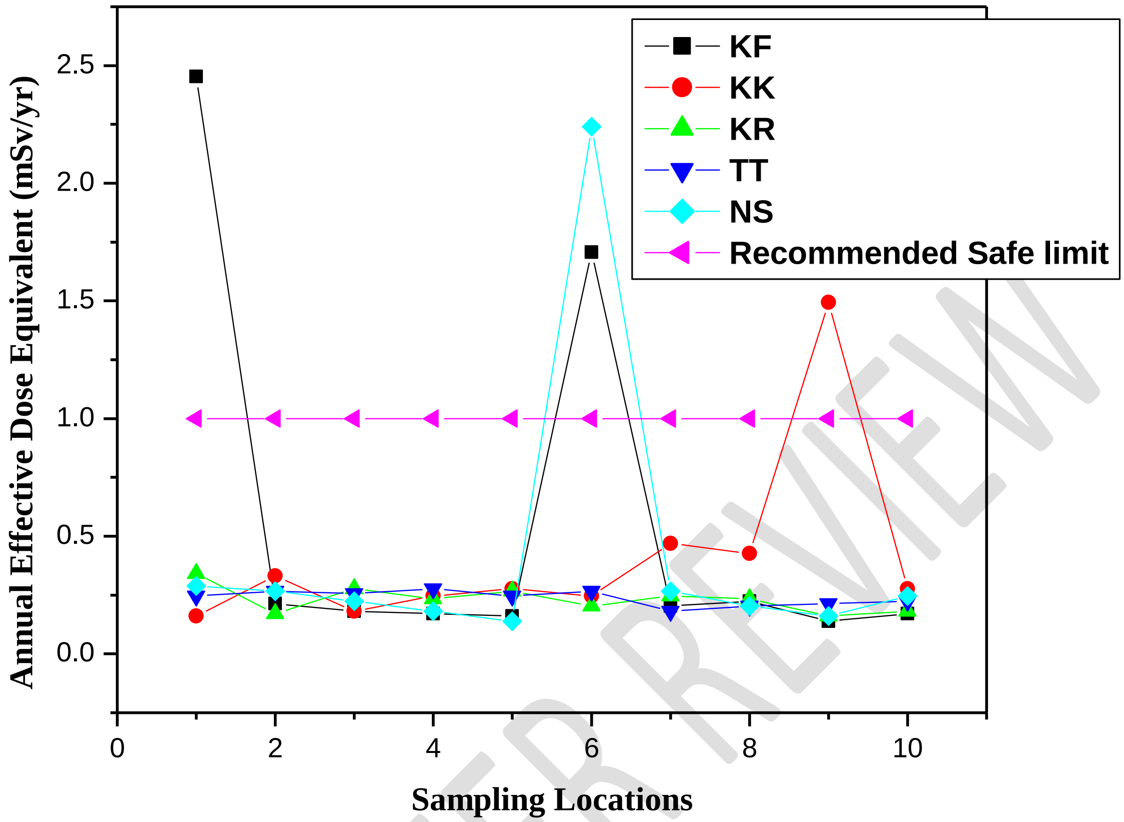

Figure 4: Comparison of annual effective dose equivalent and the recommended safe limit.

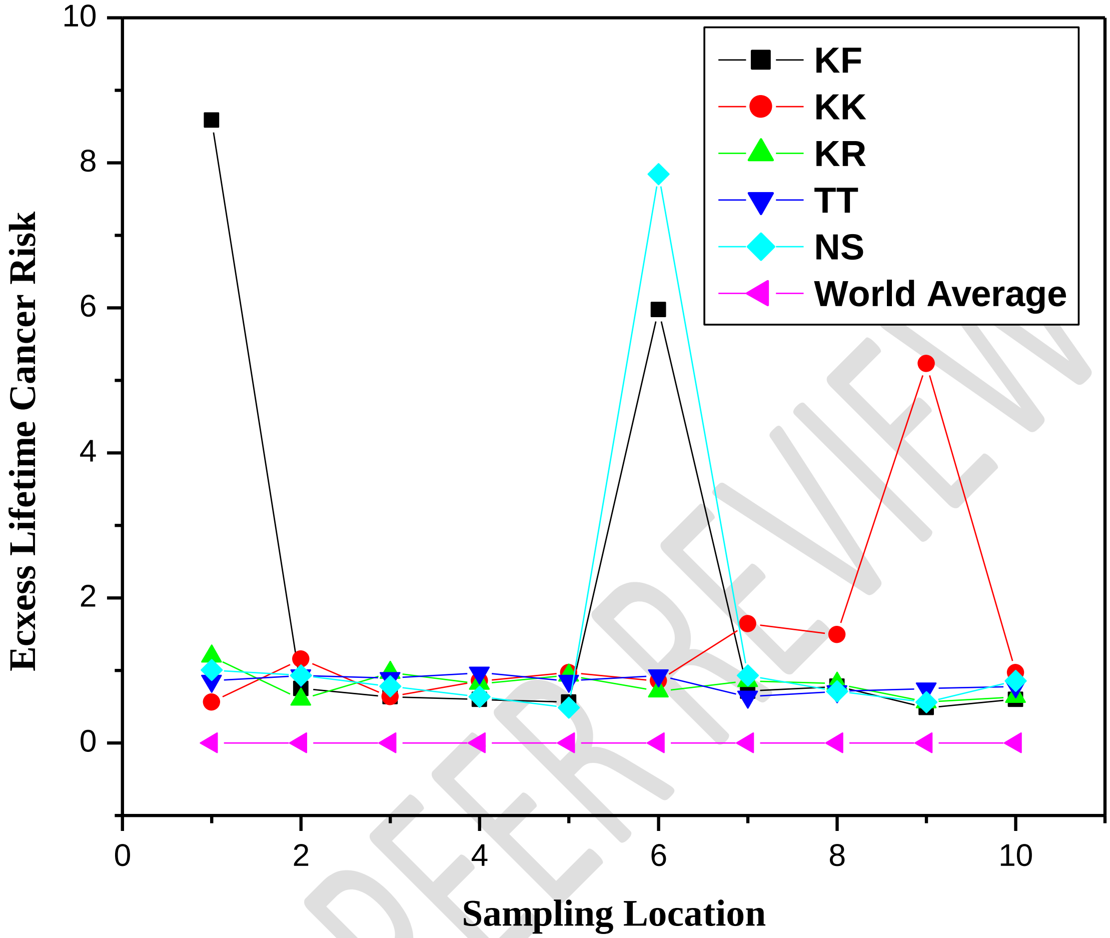

Figure 5: Comparison of excess lie time cancer risk and world average.

Excess lifetime cancer risk ELCR

The calculated ELCR values are in the range (mean) of 0.485 to 8.589 (1.968), 0.560 to 5.228 (1.438), 0.560 to 0.970 (0.810), 0.635 to 0.970 (0.833), and 0.485 to 7.842 (1.475) for KF, KK, KR, TT, and NS respectively (Table 1-5, Figure 4. The mean values are higher than the world average value of 0.00029. These are quite high and the possibilities of cancer development by residents who wish to spend all their life time in the area is imminent. The ELCR values reported in this study is lower than those reported by Uburu Salt Lake environments of Ebonyi State, Nigeria reported by Idris et al. [15] in Lafia Metropolis, Nasarawa State, Nigeria and Agbalagba, et al. [14] in industrial areas of Warri Nigeria.

Conclusion

This study was carried out to examine the outdoor background exposure levels in some selected swampy Agricultural Soils in Nasarawa west, Nigeria. The results obtained are well within the recommended dose limits reported by ICRP and are within the world average value reported by UNSCEAR. Generally, the study shows that the swampy Agricultural soils in Nasarawa State are relatively safe radiologically with little contamination which could be attributed to the geology of the area and partly due to application of fertilizer, herbicides, pesticides and others in the farm lands. However, the contamination will not pose any immediate radiological health effect on farmers but there is tendency for long -term health hazards in the future such as cancer due to accumulation of dose over time.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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