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Measurement of Radiological Hazard Indices in Cereals Grown Around Ririwai Tin Mine, Kano State, North Western Nigeria

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Abstract

Mining and mineral processing in Nigeria provides economic benefits of wealth creation and employment opportunities. However the industry is associated with a number of negative challenges among which is the health impact on miners and surrounding communities arising from mining processes. The process produced large volumes of tailings and waste that may contain naturally occurring radioactive materials (NORMs). Some of the NORMs are soluble in water and have the tendency to leach into water bodies and farm lands. This work measured the radiological hazard indices in cereals grown around Ririwai Tin Mine Kano State, North Western Nigeria using Direct Gamma Spectroscopy (NaI (Tl)), The results shows that the mean activity concentration in cereals samples were 59.99±2.76, 25.95±2.55 and 46.81±1.99 Bq/kg respectively for ^{40}K, ^{226}Ra and ^{232}Th, the mean absorbed dose rate was 32.56±1.44nGyh, the mean committed effective dose for ^{40}K is0.052±0.002 mSv/year, ^{226}Ra has a mean committed effective dose of 0.980±0.100mSv/year while ^{232}Th has a mean committed effective dose of is 1.508±0.064mSv/year The total committed effective dose in cereals is 2.540±0.150mSv/year. The risk estimated were Fatality cancer risk to population per year is 1.34×10^{-4}, Lifetime fatality cancer risk to population is 9.38×10^{-3}, Severe Hereditary effect per year is 5.10×10^{-6} and Lifetime Hereditary effects is 3.40×10^{-4} . The values of all the radiological indices obtained in this study are relatively high due to high bioaccumulation of ^{40}K, ^{226}Ra and ^{232}Th by the cereals, suggesting that their consumption could pose radiological health hazards.

Keywords: Activity concentrations; Absorbed dose; Committed effective dose; Risks.

1. Introduction

Human activities such as mining, the use of ores containing natural radioactive substances and the production of energy by burning coal that contain such substances are known to have enhance the exposure from natural sources of radiation [1] Such activities generally give rise to radiation exposures that are only a small fraction of the global average level of natural exposure. However, specific individuals residing near installations releasing radioactive materials into the environment may be subjected to higher exposures. It is reported that the sites with high levels of radioactive residues be inhabited or re-inhabited, the settlers would incur radiation exposures that would be higher than the global average level of natural exposures [2]. There are several pathways by which the radioactive material can reach humans. The pathway largely depends on the processes involved and can be broadly categorised into; on-site, off-site, airborne, waterborne, food products, etc [3] The dominant exposure pathways in most situations are external gamma radiation, inhalation of radon gas and its decay products, ingestion of contaminated food and/or water [3].

Internal exposure to radiation is mainly due to ingestion and inhalation of materials containing ^{238}U and ^{232}Th decay series and ^{40}K. The committed effective doses are determined through analysis of the radionuclide contents in foods and water following an intake and in addition to bioassay data and knowledge on the metabolic behavior of the radionuclides [2]. Concentrations of NORM in foods vary widely because of differences in background levels, climate and the agricultural conditions that prevail. The body content of ^{40}K is about 0.18 % for adults and 0.2 % for children. The natural abundance is about 1.17 x 10^{-4} % and specific activity concentration of 2.6 x 10^{8} Bq/kg. The corresponding annual effective doses from ^{40}K in the body are 165 and 185 µSva^{-1} for adults and children respectively. The total annual effective dose from inhalation and ingestion of terrestrial radionuclides is 310 µSv of which 170 µSv is from ^{40}K and 140 µSv from the long-lived radionuclides in the uranium and thorium series [2]. Uranium in the body is retained primarily in the skeleton and the concentrations have been found to be approximately similar in various types of bones. Similarly, thorium is mainly deposited on bone surfaces and retained for a long period following intake by ingestion and inhalation. The annual effective dose from reference values of U/Th series radionuclides has been evaluated to be 130 µSv [4, 5] and re-evaluated in the year 2000 to be 120 µSv [2].

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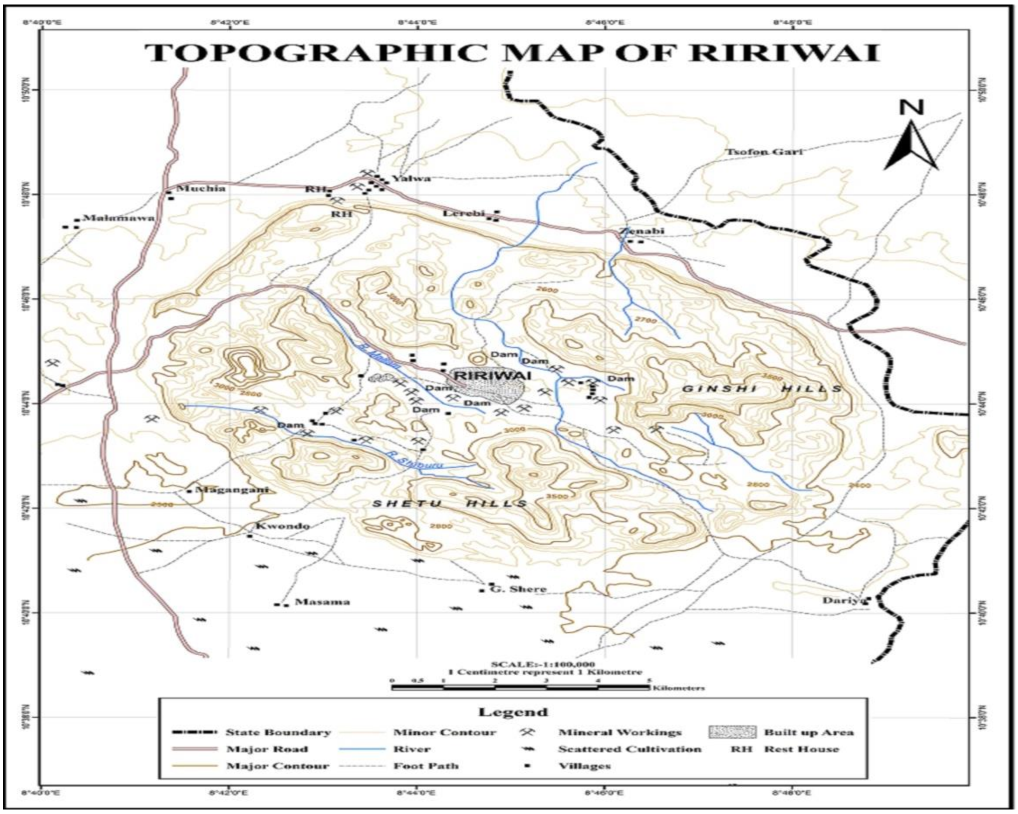
In this study radiological hazard indices in cereals grown around tin mining area located in Ririwai in Kano State North Western Nigeria was measured using NaI(Tl) gamma ray spectrometry technique.

2. Materials and Methods

The study area is Ririwai town headquarter of Doguwa Local Government Area in the extreme south of Kano State, Nigeria. It has an area of 1,473 km² and a population of 151,181 at the 2006 census. Fig; 1 shows the topographic map of the study area while the location of the farm is 10. 43 55.2 N, 008 44 38.7 E.

Fig-1. Topographic Map of the study area



Five samples of each of the following Cereals maize (*zea mais*) , guinea corn (*sorghum vulgare*) and rice (*Oriza sativa*) were collected from two farms located about 50.0m and 20.0m from the mine. Each sampling location was divided into 20m x 20m grids and samples were taken at different points and mixed together to give a sample. Each sampling point was selected independent of other location of other sampling points. By this approach all locations within the area of concern had equal chance of being selected [6]. The samples collected were oven-dried at temperature of 55^0C [7], grinded into fine powder and sieved through 32μm. The samples were then weighted and placed into plastic containers which were sealed using candle wax, vaseline and masking tape.The plastic containers were selected based on the space allocation of the detector vessel which measure 7.6cm by 7.6cm in dimension.

The samples were stored for 30 days to allow for secular equilibrium between the long-lived parent radionuclide and their short-lived daughter radionuclides in the ^{238}U and ^{232}Th decay series before the counting commenced. The analysis was carried out using direct gamma spectrometry with a 76x76mm NaI(Tl) detector.

The absorbed dose rate were calculated from the activity concentrations of the relevant radionuclides using equation (1).

$$D\ (nGyh^{-1}) = 0.0417A_K + 0.0462\ A_U + 0.604A_{Th} \qquad (1)$$

where;

A_K, A_U and A_{Th} are the activity concentrations of ^{40}K, ^{238}U and ^{232}Th respectively, E quation (2) was used to calculate the committed effective dose (E_{ing}) due to ^{40}K, ^{262}Ra and ^{232}Th based on the annual consumption rate of 120kg/year for cereal for adults and the effective dose coefficient for ^{40}K, ^{226}Ra and ^{232}Th [2].

$$E_{ing} = A_{sp}.I_n.\sum_{j=1}^{3} DCF_{ing}\ (K, Ra, Th) \qquad (2)$$

where, A_{sp} is the activity concentration of the radionuclides, I_n annual consumption rate and DCF_{ing} is the ingestion dose coefficient in Sv/Bq.

The cancer and hereditary risks due to low doses without threshold dose known as stochastic effect were estimated using the ICRP cancer risk assessment methodology [8, 9]

3. Results

The activity concentration for ^{40}K ^{226}Ra and ^{232}Th in Bq/kg for Maize, Rice and Guinea Corn are tabulated in Table 1.

Table-1. Activity Concentration for ^{40}K, ^{226}Ra and ^{232}Th, for Cereals in Bq/kg

S/N	Samples ID	^{40}K in Bq/kg	^{226}Ra in Bq/kg	^{232}Th in Bq/kg
1	RR1	39.81±2.17	55.85±4.75	78.90±2.16
2	RR2	32.19±3.42	13.22±0.46	55.87±2.28
3	RR3	32.92±2.35	11.82±0.43	23.43±2.59
4	RR4	29.23±1.56	40.99±3.48	54.96±1.65
5	RR5	44.67±1.60	18.26±0.71	7.79±0.31
6	RM1	69.46±4.58	9.74±0.78	27.59±3.46
7	RM2	14.59±1.13	12.47±4.99	41.09±1.97
8	RM3	76.52±1.55	36.84±2.71	29.02±1.65
9	RM4	50.79±1.82	20.78±0.16	51.42±1.48
10	RM5	76.31±0.16	29.05±1.48	51.43±3.19
11	RGC1	108.39±2.79	30.59±3.13	51.99±1.82
12	RGC2	32.50±1.61	18.54±3.94	53.51±1.62
13	RGC3	30.02±1.39	17.15±3.59	49.37±1.48
14	RGC4	131.39±2.57	37.04±3.88	63.07±2.16
15	RGC5	131.26±2.64	36.96±3.82	62.94±2.08
Mean		**59.99±2.76**	**25.95±2.55**	**46.81±1.99**

The results shows that the mean activity concentration for ^{40}K in the cereals is 59.99±2.76Bq/kg in range of 44.590 – 131.39Bq/kg with a standard and deviation of 37.84±2.2 ,for ^{226}Ra the mean activity concentration is 25.95±2.55Bq/kg in a range of 9.74 – 55.85Bq/kg with standard deviation of 13.46±1.70 while ^{232}Th has a mean value of 46.81±1.99Bq/kg in a range of 7.79 – 79.90Bq/kg and standard deviation 18.15±0.749. The values obtained in this study are very high when compared with the reference values of 80mBq/kg and 3.0mBq/kg for ^{226}Ra and ^{232}Th respectively this could be attributed to geochemical nature of the soil in the study area where the cereals were grown. Also the cereals have high bio-accumulation tendency for thorium and uranium; they are often used as phytoremediators in an uranium contaminated soils [10]. Fig 2 shows the percentage distributions of ^{40}K ,^{226}Ra and ^{232}Th.

Table-2. Activity Concentration for ^{40}K, ^{226}Ra and ^{232}Th, for Cereals in Bq/kg and Absorbed dose Rate in $nGyh^{-1}$

S/N	Samples ID	^{40}K	^{226}Ra	^{232}Th	Absorbed dose rate $nGyh^{-1}$
1	RR1	39.81±2.17	55.85±4.75	78.90±2.16	59.90±1.61
2	RR2	32.19±3.42	13.22±0.46	55.87±2.28	35.70±1.54
3	RR3	32.92±2.35	11.82±0.43	23.43±2.59	16.42±1.68
4	RR4	29.23±1.56	40.99±3.48	54.96±1.65	36.31±1.22
5	RR5	44.67±1.60	18.26±0.71	7.79±0.31	7.41±0.89
6	RM1	69.46±4.58	9.74±0.78	27.59±3.46	20.01±2.32
7	RM2	14.59±1.13	12.47±4.99	41.09±1.97	26.50±1.48
8	RM3	76.52±1.55	36.84±2.71	29.02±1.65	22.42±1.18
9	RM4	50.79±1.82	20.78±0.16	51.42±1.48	34.14±0.98
10	RM5	76.31±0.16	29.05±1.48	51.43±3.19	35.58±2.01
11	RGC1	108.39±2.79	30.59±3.13	51.99±1.82	37.33±1.35
12	RGC2	32.50±1.61	18.54±3.94	53.51±1.62	34.45±1.22
13	RGC3	30.02±1.39	17.15±3.59	49.37±1.48	31.86±1.12
14	RGC4	131.39±2.57	37.04±3.88	63.07±2.16	45.28±1.60
15	RGC5	131.26±2.64	36.96±3.82	62.94±2.08	45.20±1.55
	Mean	59.99±2.76	25.95±2.55	46.81±1.99	32.56±1.45

Table-3. Committed Annual Effective dose From Ingestion of ^{40}K, ^{226}Ra and ^{232}Th Series raDionuclide in Cereals in mSv/Year

S/N	Samples ID	^{40}K H_{ing} mSv/year	^{226}Ra H_{ing} mSv/year	^{232}Th H_{ing} mSv/year	Total H_{ing} mSv/year
1	RR1	0.034±0.002	2.190±0.190	2.541±0.069	4.765±0.0261
2	RR2	0.028±0.003	0.520±0.018	1.799±0.073	2.347±0.094
3	RR3	0.029±0.002	0.463±0.017	0.754±0.083	1.246±0.102
4	RR4	0.025±0.001	1.046±0.136	1.770±0.053	2.841±0.190
5	RR5	0.038±0.001	0.715±0.028	0.250±0.009	1.003±0.038
6	RM1	0.060±0.004	0.380±0.030	0.888±0.111	1.328±0.145
7	RM2	0.013±0.001	0.488±0.195	1.323±0.063	1.824±0.259
8	RM3	0.066±0.001	1.444±0.106	0.934±0.053	2.444±0.160
9	RM4	0.044±0.002	0.814±0.006	1.656±0.047	2.517±0.055
10	RM5	0.066±0.001	1.138±0.058	1.656±0.103	2.860±0.162
11	RGC1	0.094±0.002	1.199±0.123	1.674±0.059	2.967±0.184
12	RGC2	0.028±0.001	0.727±0.154	1.723±0.052	2.478±0.207
13	RGC3	0.026±0.001	0.672±0.141	1.589±0.047	2.287±0.189
14	RGC4	0.114±0.002	1.452±0.152	2.031±0.069	3.597±0.223
15	RGC5	0.113±0.002	1.449±0.149	2.027±0.067	3.589±0.218
	Mean	0.052±0.002	0.980±0.100	1.508±0.064	2.540±1.500

The mean absorbed dose rate in the cereals is 32.56±1.44nGyh^{-1} .It ranges between 7.41±0.89 and 59.90±2.32nGy/h with a standard deviation of 12.88±0.38 as shown in Table 2. ^{232}Th contributed 88.42% to the total absorbed dose rate in cereals while ^{40}K and ^{226}Ra contributed 7.82% and 3.44% respectively as shown in Fig. 3. The committed annual effective dose for cereals was calculated using effective dose coefficient for ^{40}K, ^{226}Ra and ^{232}Th Table 3 shows that the mean committed annual effective dose due ^{40}K is 0.052±0.002 mSv/year in a range of 0.013 – 0.114mSv/year with standard deviation of 0.033±0.001. ^{226}Ra mean committed effective dose is 0.980±0.100mSv/year in a range of 0.380 – 2.190mSv/year with standard deviation of 0.503±0.067. The mean committed effective dose for ^{232}Th in cereals is 1.508±0.064mSv/year in a range of 0.254 – 2.541mSv/year with standard deviation of 0.585±0.024. The men total committed effective dose in the cereals is 2.540±0.150mSv/year in a range of 1.003 – 4.765mSv/year with standard deviation of 0.988±0.072. The percentage contribution to the total committed effective dose for ^{40}K, ^{226}Ra and ^{232}Th are 2.047%, 38.582% and 59.370% respectively as shown in Fig. 4

Figure-2. Percentage Distribution of ^{40}K, ^{226}Ra & ^{232}Th Activity conc. in Cereals

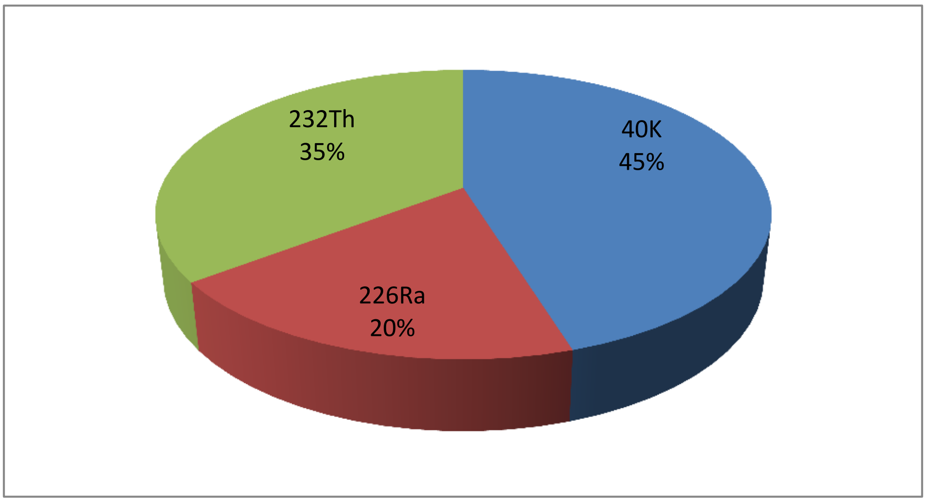


Figure-3. Percentage Contribution of ^{40}K, ^{226}Ra & ^{232}Th in Absorbed dose Rate for Cereals

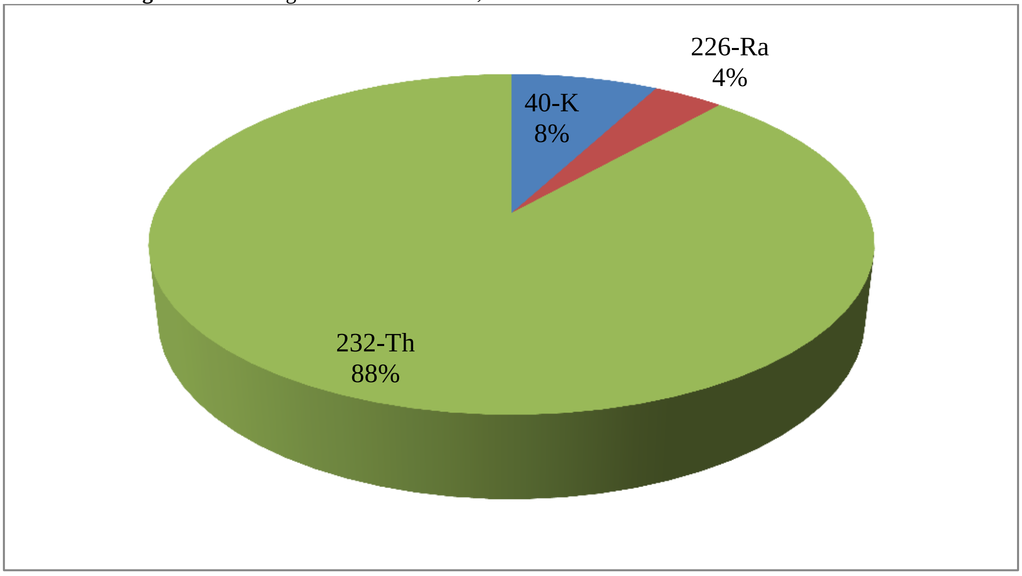
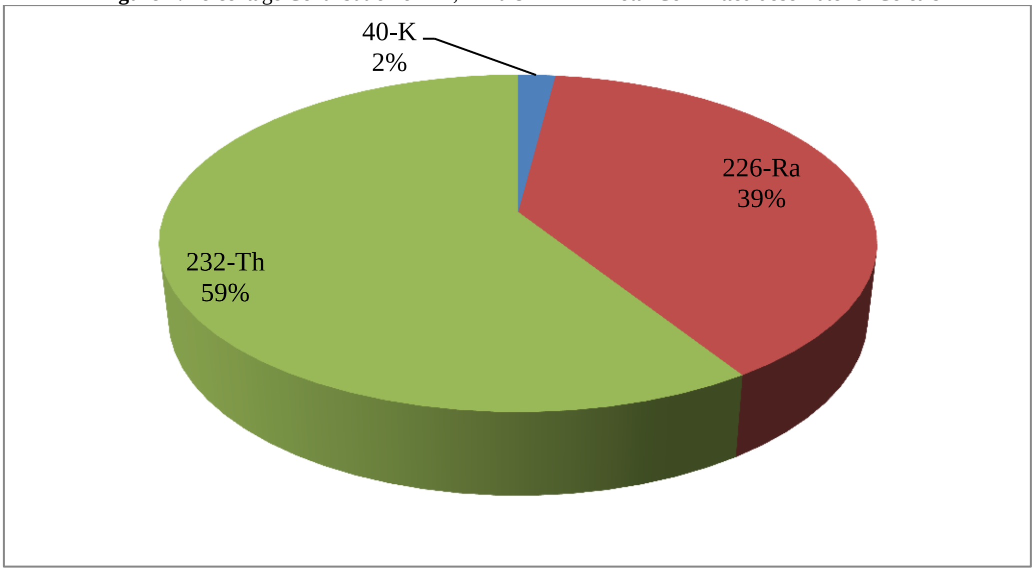


Figure-4. Percentage Contribution of ^{40}K, ^{226}Ra & ^{232}Th in Total Committed dose Rate for Cereals



The risk of exposure due to low doses and dose rates of radiation to members of the public were estimated based on the ICRP risks assessment methodology using the 2007 recommended risk coefficients [9] and an assumed 70 years lifetime. The risk evaluated were fatality cancer risk, life time cancer risk, severe hereditary effect and life time hereditary effect. The results shows that the fatality cancer risk to population per year is 1.34×10^{-4} , lifetime fatality cancer risk to population is 9.38×10^{-3} , Severe hereditary effect per year is 5.10×10^{-6} and lifetime hereditary effects is 3.40×10^{-4}

4. Conclusions

The values of activity concentration absorbed dose rate and committed annual effective dose obtained in cereals are very high .This could be attributed to the fact that the cereals have capacity to bioaccumulate high amount of radioelements present in the soil. The risk estimated for cereals were slightly above the negligible cancer fatality risk recommended by USEPA ($1 \times 10^{-6} – 1 \times 10^{-4}$) [11]. Based on the findings from this study consumption of cereals grown around the area could pose radiological health challenges.

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