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Assessment of Radiological Hazards Indices in Vegetables Grown Around Ririwai Tin Mines, Kano State, North Western Nigeria

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Abstract

Mining industry in Nigeria provides economic benefits of wealth creation and employment opportunities. Presently there are numbers of artisanal and large scale mining activities going on across Nigeria and most of these artisanal miners currently under take only surface mining. 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 assessed the radiological hazard indices in vegetable 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 vegetable samples were 259.25±4.77, 28.05±4.97 and 54.56±2.58Bq/kg respectively for ^{40}K, ^{226}Ra and ^{232}Th, the mean absorbed dose rate was 45.043±1.98nGyh^{-1} the mean committed effective dose for ^{40}K is 0.091±0.002mSv/year, ^{226}Ra has a mean committed effective dose of 0.471±0.083mSv/year while ^{232}Th has a mean committed effective dose of 0.753±0.036mSv/year. The total committed effective dose in vegetable has a mean value of 1.320±0.125mSv/year. The risk estimated for fatality cancer, lifetime fatality cancer risk, severe hereditary effect and life time hereditary effect in vegetable were 7.26 x 10^{-5}, 5.29 x 10^{-3}, 2.60 x 10^{-6} and 1.84 x 10^{-4} respectively. The values obtained in this study are relatively high such that consumption of vegetable grown in the area could pose radiological health hazards.

Keywords: Activity Concentrations, Absorbed dose, Committed effective dose, Risks

1 INTRODUCTION

Mining activities have been identified as one of the major source of exposure to Naturally Occurring Radioactive Materials (NORMs). In recent times, there is an increased awareness of the potential problems of NORMs and this has resulted in most countries taking steps to implement regulations dedicated to radiation protection and safety. Studies have also established that, radiation exposure above certain threshold limits can damage living cells, causing death in some of them and modifying others [UNSCEAR, 2000]. If the repair of the damage or modified cells is not perfect, the resulting modification will be transmitted to other cells and this may eventually lead to cancer. The biological damage due to radiation exposure could lead to somatic or hereditary stochastic effects.

Stochastic effect is radiation effects, generally occurring without a threshold level of dose, whose probability is proportional to the dose and whose severity is independent of the dose (IAEA, 1996). Radiation exposure has also been associated with most forms of leukaemia and other types of cancers affecting various organs such as lungs, breast and thyroid glands. It is also worth noting that radiation-induced cancer may manifest itself decades after exposure Radiation exposure also has the potential to cause hereditary effects in the offspring of persons exposed to radiation (UNSCEAR, 2000).

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, in addition to bioassay data and knowledge on the metabolic behaviour of the radionuclides (UNSCEAR, 2000). 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 185μSva^{-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 (UNSCEAR, 2000). 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 (UNSCEAR, 1988, 1993) and re-evaluated in the year 2000 to be 120 μSv (UNSCEAR, 2000). In this work the radiological hazards indices in vegetables grown around Ririwai Tin Mine Kano State North Western Nigeria were assessed.

2.0 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.

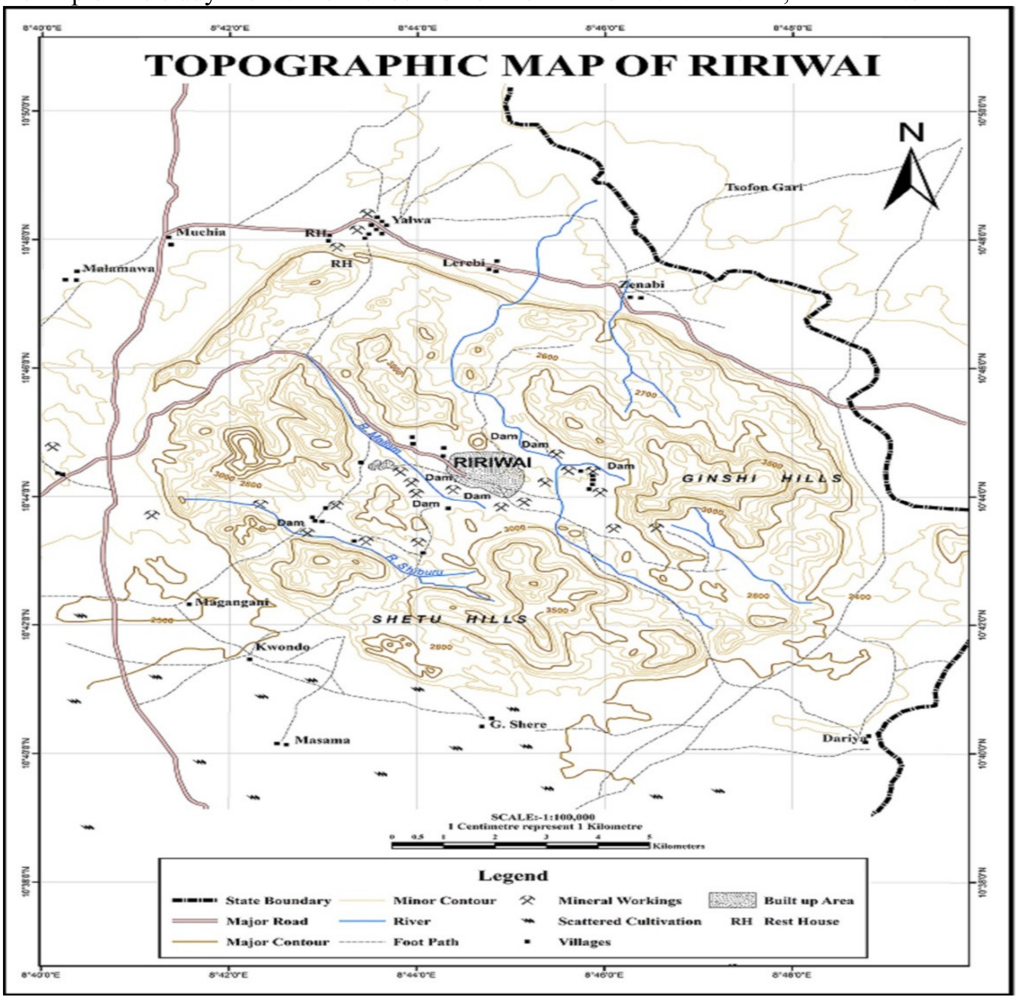

Fig. 1 Topographic Map of the study area

Six samples of *Lycopersicum esculatum* (tomatoes) and five samples of *Capsicum species* (pepper) were collected from a dry season farm within the mine area. . Each sampling location was divided into 10m x 10m 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. The samples collected were oven- dried at temperature of 55^0C (IAEA 1989). The samples were then grinded into fine powder and sieved through 32µm. The samples were then weighted and place 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 for vegetables samples 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 60kg/year for vegetable (UNSEAR, 2000) for adults and the effective dose coefficient for ^{40}K, ^{226}Ra and ^{232}Th.

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

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.

3.0 RESULTS

The activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in Bq/kg are summarized in Table;1. The absorbed dose rate calculated for vegetable samples are presented in Table 2. While committed effective dose (E_{ing}) due to ^{40}K, ^{262}Ra and ^{232}Th are presented in Table ;3

Table 1: Activity concentration of ^{40}K, ^{226}Ra and ^{222}Th for vegetables in Bq/kg

S/N	Samples ID	^{40}K	^{226}Ra	^{232}Th
1	T1	314.42±3.49	16.4±1.19	35.66±2.32
2	T2	191.13±0.96	7.75±0.78	25.40±0.39
3	T3	228.72±2.30	36.56±9.19	37.98±1.14
4	T4	216.12±1.34	23.06±7.67	42.74±1.14
5	T5	127.26±4.02	18.78±5.75	35.15±3.22
6	T6	323.05±1.56	28.93±8.83	38.38±1.41
7	P1	459.16±15.44	19.35±8.23	81.21±11.32
8	P2	193.49±0.48	31.84±3.52	39.24±1.14
9	P3	137.39±4.07	32.13±4.99	56.10±2.67
10	P4	208.02±4.34	25.65±1.12	55.99±1.14
11	P5	453.03±13.51	68.12±3.43	152.28±2.50
Mean		**259.25±4.77**	**28.05±4.97**	**54.56±2.58**

Table 2: Activity concentration of ^{40}K, ^{226}Ra and ^{222}Th for vegetables in Bq/kg and absorbed dose rate in nGyh^{-1}

S/N	Samples ID	^{40}K in Bq/kg	^{226}Ra in Bq/kg	^{232}Th in Bq/kg	Absorbed dose rate nGyh^{-1}
1	T1	314.42±3.49	16.4±1.19	35.66±2.32	35.41±1.60
2	T2	191.13±0.96	7.75±0.78	25.40±0.39	23.67±0.32
3	T3	228.72±2.30	36.56±9.19	37.98±1.14	34.17±1.20
4	T4	216.12±1.34	23.06±7.67	42.74±1.14	35.89±1.10
5	T5	127.26±4.02	18.78±5.75	35.15±3.22	27.40±2.39
6	T6	323.05±1.56	28.93±8.83	38.38±1.41	37.99±1.33
7	P1	459.16±15.44	19.35±8.23	81.21±11.32	69.08±7.86
8	P2	193.49±0.48	31.84±3.52	39.24±1.14	32.78±0.87
9	P3	137.39±4.07	32.13±4.99	56.10±2.67	41.09±2.01
10	P4	208.02±4.34	25.65±1.12	55.99±1.14	43.67±0.97
11	P5	453.03±13.51	68.12±3.43	152.28±2.50	114.32±2.23
	Mean	**259.84±4.77**	**28.05±4.97**	**54.56±2.58**	**45.04±1.98**

Table 3: Committed annual effective dose from ingestion of ^{40}K, ^{226}Ra and ^{232}Th series radionuclide in vegetables 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	T1	0.117±0.0012	0.275±0.0200	0.492±0.0320	0.884±0.0532
2	T2	0.017±0.0003	0.130±0.0131	0.351±0.0054	0.552±0.0188
3	T3	0.085±0.0008	0.614±0.1540	0.524±0.0157	1.223±0.1705
4	T4	0.080±0.0005	0.387±0.1280	0.590±0.0157	1.057±0.1442
5	T5	0.047±0.0015	0.315±0.0966	0.485±0.0444	0.847±0.1425
6	T6	0.120±0.0006	0.486±0.1483	0529±0.0195	1.135±0.1684
7	P1	0.171±0.0057	0.325±0.1382	1.120±0.1562	1.616±0.3451
8	P2	0.072±0.0002	0.535±0.0591	0.542±0.0157	1.149±0.0750
9	P3	0.050±0.0015	0.539±0.0838	0.774±0.0368	1.364±0.1221
10	P4	0.077±0.0016	0.430±0.0188	0.772±0.0157	1.279±0.0361
11	P5	0.169±0.0050	1.144±0.0576	2.101±0.0345	3.414±0.0971
	Mean	**0.091±0.002**	**0.471±0.083**	**0.779±0.023**	**1.320±0.107**

The activity concentration of ^{40}K, ^{226}Ra and ^{232}Th in vegetable samples are presented in Table 1.The mean activity concentration of ^{40}K is 259.254±4.683Bq/kg in a range of 127.26– 459.160Bq/kg with a standard deviation of 114.578±5.041. The mean activity concentration for ^{226}Ra obtained was 28.052±4.973 in a range of 7.750 - 68.120Bq/kg with standard deviation of 15.652±3.200 while the mean activity concentration of ^{232}Th is 54.557±2.588Bq/kg in a range of 25.400-152.280Bq/kg with standard deviation of 35.720±3.022. Fig. 2 shows the percentage distributions of ^{40}K ,^{226}Ra and ^{232}Th in vegetables as 76%, 8% and 16% respectively.

The absorbed dose rate for vegetable samples as indicated in Table 2, shows that the mean absorbed dose rate is 45.043±1.989nGyh^{-1} in a range of 23.670-114.320nGyh^{-1} with a standard deviation of 25.803±2.044. Fig 3 shows that ^{40}K, ^{226}Ra and ^{232}Th contributed 24%, 3% and 73% respectively to the absorbed dose rate.

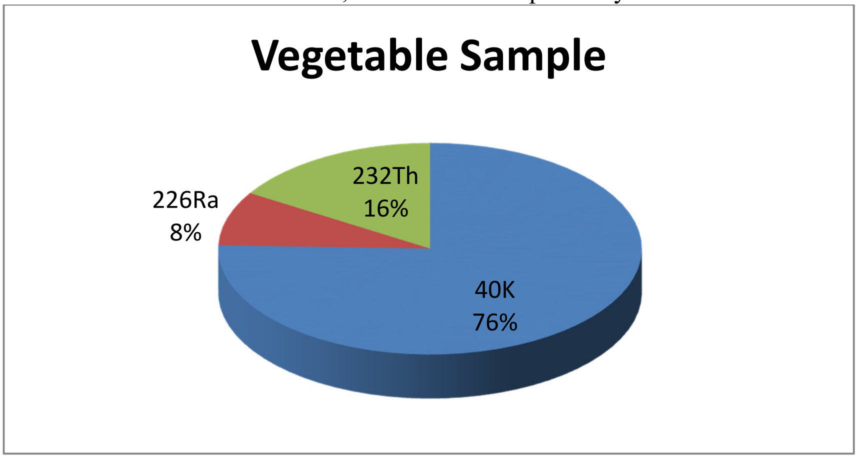

Figure 2 : Percentage Distribution of ^{40}K, ^{226}Ra & ^{232}Th Activity conc. in Vegetable

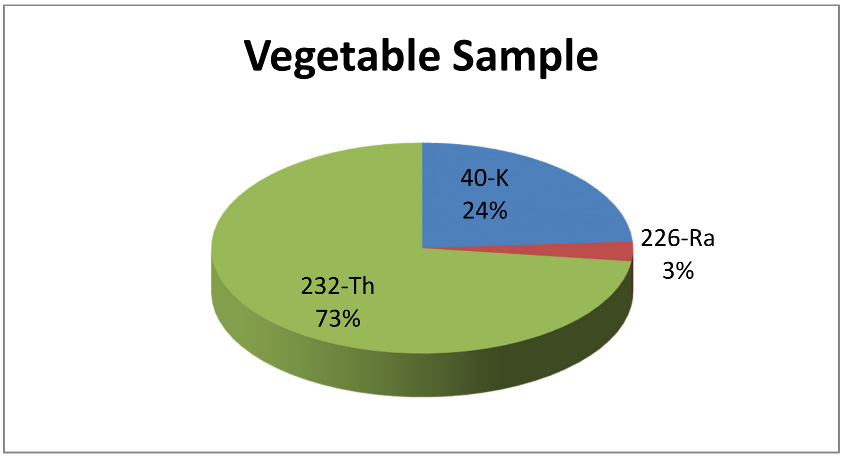

Figure 3: Percentage Contribution of ^{40}K, ^{226}Ra & ^{232}Th in absorbe Dose Rate for Vegetable

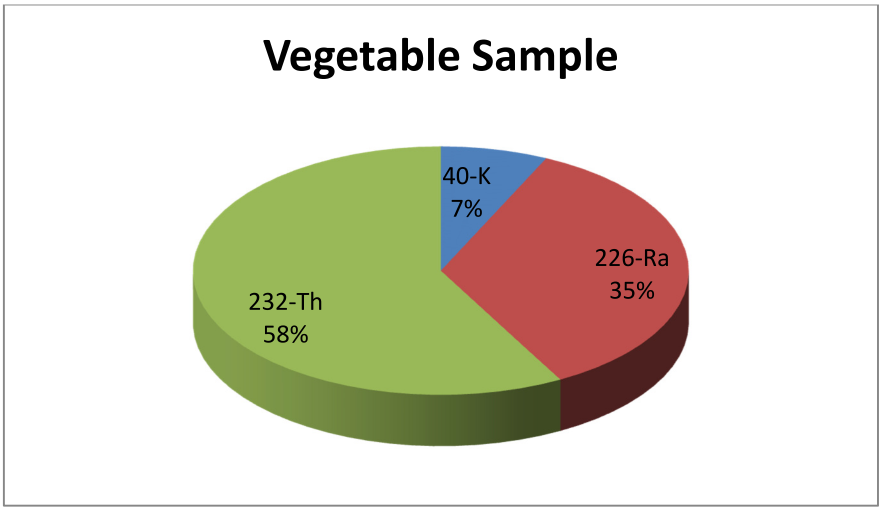

Figure 4: Percentage Contribution of ^{40}K, ^{226}Ra & ^{232}Th in Total Committed Dose Rate for Vegetable Sample

The committed effective dose due to ^{40}K, ^{226}Ra and ^{232}Th in vegetable are presented in Table 3. The results shows that the mean committed effective dose for ^{40}K is 0.091±0.002mSv/year in a range of 0.017– 0.171mSv/year with a standard deviation of 0.049±0.002. ^{226}Ra has a mean committed effective dose of 0.471±0.083mSv/year ranges between 0.130-1.144mSv/year with a standard deviation of 0.263±0.054. ^{232}Th has a mean committed effective dose of 0.753±0.036mSv/year in a range between 0.351-2.101mSv/year with standard deviation of 0.493±0.042. The total committed effective dose in vegetable has a mean value of 1.320±0.125mSv/year in a range of 0.552 - 3.414mSv/year with standard deviation of 0.750±0.090. Fig. 4 shows the % contribution of ^{40}K, ^{226}Ra and ^{232}Th the total annual committed effective in vegetable ^{40}K has 6.90% ^{226}Ra has 35.90 and ^{232}Th has 57.40 %. The high value obtained in vegetables samples can be attributed to the fact that some of the vegetables grown in the study area are also used as phytoremediators in a uranium contaminated soil because of their high bioaccumulation of uranium (Ivan, 2011).

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 (ICRP, 2007) 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 7.26×10^{-5} , Lifetime fatality cancer risk to population is 5.29×10^{-3}, Severe Hereditary effect per year is 2.60×10^{-6} and Lifetime Hereditary effects is 1.82×10^{-4}

4.0 Conclusion

In this study assessment was made on the radiological hazard indices resulting from artisanal mining mineral processing and other anthropogenic activities around Ririwai Tin mine. The study was motivated by the fact that the study area is known to have other industrial and energy minerals. . Beside tin other industrial and energy minerals such as uranium, thorium, lead, e.t.c were reported to be in commercial quantities in the area (Kinnaird et,al 1985, Echophonic 2008, Kamilliyus et, al 2014, Abiye,2005).

The values of activity concentration, absorbed dose rate and committed annual effective in vegetables are relatively high because of the bioaccumulation of the radionuclides by the vegetable. The risk estimated for fatality cancer, lifetime fatality cancer risk, severe hereditary effect and life time hereditary effect in vegetable were 7.26×10^{-5}, 5.29×10^{-3}, 2.60×10^{-6} and 1.84×10^{-4} respectively, these value are also within the negligible values of ($1 \times 10^{-6} – 1 \times 10^{-4}$) recommended by USEPA (1993). The values obtained in this study are relatively high such that consumption of vegetable grown in the area could pose radiological health hazards.

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