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Assessment of Radioactivity Concentration Level in Soil Samples of some Gold Mining Areas of Shiroro, Niger State, Nigeria

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Abstract: The radiological effects of Gold mining in Shiroro, Niger state was estimated. A total of 30 soil samples were collected from various mining spots. The radio nuclides concentrations in the soil sample were measured using gamma spectroscopy method. The average values of ^{238}U, ^{232}Th *and* ^{40}K obtained were 34.56 Bqkg^{-1}, 28.79 Bqkg^{-1} and 230.44 Bqkg^{-1} respectively. These radioactivity concentration values obtained are lower than the world average value of 35 Bqkg^{-1} for ^{238}U, 30 Bqkg^{-1} for ^{232}Th, and 400 Bqkg^{-1} for ^{40}K by UNSCEAR. The hazard indices and excess lifetime cancer risk were estimated using standard analytical methods. The mean values obtained for absorbed dose rate, internal hazard index, external hazard index, gamma indices, , radium equivalent, annual effective dose equivalent (indoor), annual effective dose (outdoor) and excess lifetime cancer risk respectively were 43.04 nGyh^{-1}, 0.35, 0.25, 0.34, 93.47, 0.21 mSvyr^{-1}, 0.05 mSvyr^{-1} and 0.184 respectively. The values when compared with the corresponding world recommended levels were found to be lower than the standard limit and as such, radiation exposure to the miners, those that process it and those that live very close to the study area may not pose significant health hazard to them.
Keywords: Gold mining, Radiological hazard indices, Excess lifetime cancer risk and Radionuclides.

1 Introduction

Mining has been identified as a major source with significant contributions to the increase of naturally occurring radioactive material (NORM) into the environment [1]. The improper disposal, re-use, and recycling of NORM has led to circumstances resulting in contamination events and unnecessary public exposures. Mining activities lead to pre-concentration and accumulation of NORM in stockpiles, waste piles (tailings), pipes, water bodies and finally leading to exposure of humans through the food chain, as a result it is important to investigate and provide sound scientific data for the assessment of exposure of individual workers and the general public [2, 3]. The rate of leaching of pollutants from solid materials will change with time and be dependent on several factors that will regulate the rate of pollutants release from these sources [4].

All living organisms are generally exposed to ionizing radiation from natural sources. These natural sources include high energy cosmic ray particles and radionuclides that originate from the earth's crust and are present everywhere. Radioactive materials (NORMS) occur naturally in the environment (e.g. uranium, thorium and potassium). Some of these radioactive materials arise from human activities such as medical or industrial uses of radioactivity [1, 5]. In essence, natural sources of radiation are concentrated by mining and other industrial activities. Human beings are exposed to these natural sources through inhalation and ingestion causing internal exposure and irradiation from external gamma rays causing external exposure. The main sources for internal exposures are the alpha and beta radiation. Naturally occurring radioactive materials (NORMs) are found everywhere on earth [5, 6].

Materials may contain the primordial radionuclides such as potassium, radium, thorium uranium and the radioactive daughter nuclei may cause harm to human beings. The decay products of either the thorium or uranium decay series are alpha or beta emitters which can cause internal exposure to delicate organs of the body [7, 8]. However, the concentration of NORMs is generally low but it can be increased by human activities which among them includes mining. When undisturbed, the radionuclides in the decay series are more or less in radiological equilibrium. The human operations like mining and mineral processes cause disequilibrium. As a result of different properties in the

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decay series and geochemical migration and differences in their half-lives, radionuclides can potentially cause harm to biological life [4,9]. Gamma radiation emitted from primordial radionuclide and their progeny is one of the main external sources of radiation exposure to the humans. Gamma radiation from radionuclides with half- lives comparable to the age of the earth such as ^{40}K and radionuclides from the progeny of ^{238}U and ^{232}Th series are the main contributors of external sources of radiation to human body. Of this natural radionuclide potassium is the most abundant and his found in the earth's crust on average of 2.6%, while uranium and thorium are present in levels of parts per million (PPM) [7]. This study aimed at assessing the radioactivity concentration level of ^{238}U, ^{232}Th and ^{40}K in soil sample of Gold mining areas of Shiroro, Niger state.

2Method

2.1 Study Area

The study area of this study is Shiroro Local Government Area, Niger State in North-central, Nigeria as shown in Figure 1. The area lies within, longitude 10°4'60" N and latitude 6°52'60" E. It covers an area under 5,015 square kilometers and population below 100,000. The study area experiences distinct dry and wet seasons with annual rain fall varying from 1,100 mm in the northern parts to 1,600 mm. The maximum temperature (usually not more than 45^{o}C) is recorded between March and June, while the minimum is usually between December and January. The rainy seasons last between 120 days to 150 days.

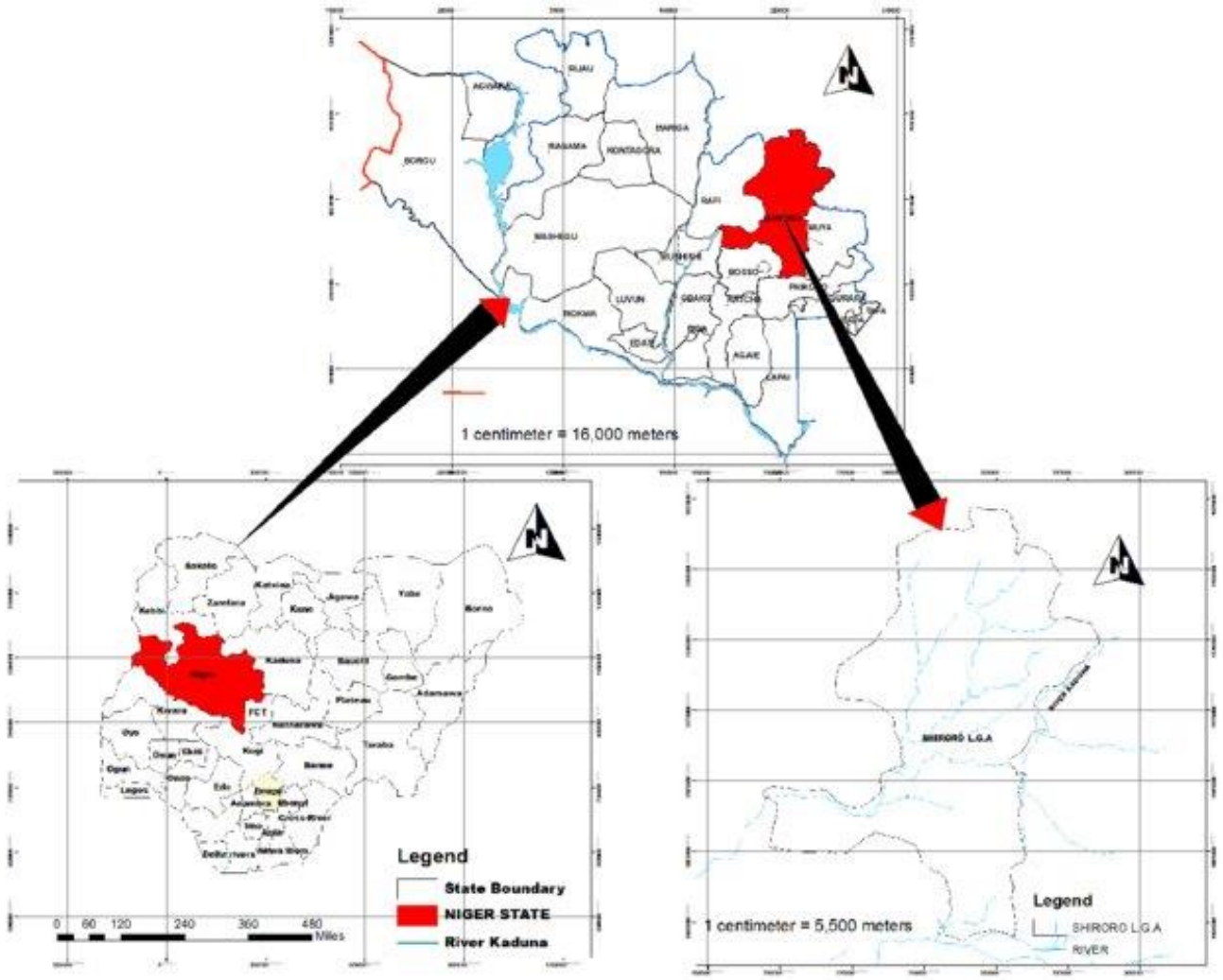

Fig. 1: Map of Study Area.

2.2 Sampling Techniques

The Sampling technique that was used for sample collection is the systemic random sampling. This is a probability sampling method in which sample members from a larger population are selected according to a random starting point but with a fixed, periodic interval. This interval, called the sampling interval, is calculated by dividing the population size by the desired sample size.

2.3 Sample Collection

Thirty samples of soil were collected from some selected

Gold mining sites in Shiroro LGA, Niger state, Nigeria. The samples were collected by coring tool to a depth of 5 cm or to the depth of the plough line. The collected samples each were measured using a beam balance and were approximately 4 kg in wet mass were immediately transferred into a high-density polyethylene zip lock plastic bag to prevent cross contamination. Each sample was marked with a unique identification number (sample ID) for traceability and its position coordinates were recorded for reference purposes using GPS.

2.4 Sample Preparation

A total of thirty soil samples were collected from the study area. All samples were dried for 4 to 6 days to ensure that moisture is completely removed. All samples were crushed, homogenized and sieved through a 200 µm, which was the optimum size enriched in heavy minerals. Samples were placed in polyethylene beaker of 250 cm^3 volume each and weighed. The beakers were completely sealed for 4 weeks to reach secular equilibrium of radium and thorium and their progenies.

In the laboratory, soil samples were each transferred into a separate metal drying pan and dried at a temperature of 105 ^{0}C for 24 h in an oven (Labotech; model number MT 202) to remove all residual moisture and to obtain samples with constant weight. The dried samples were pulverized into fine power for homogeneity [10]. Pulverized homogenized samples were each transferred into a separate 500 ml wide mouth plastic containers for gamma spectroscopy analysis.

Table 1: Raw Result of Activity Concentration of Soil samples.

Sample code	Longitude	Latitude	Activity concentration in soil (Bq/kg)		
			238U	232Th	40K
SM1	6.75108	9.0230	26.7±3.1	18.0±4.2	198.4±2.8
SM2	6.75222	9.0033	37.3±2.5	11.2±4.1	98.3±6.1
SM3	6.75336	9.0105	28.2±1.9	21.2±1.8	344.8±2.6
SM4	6.7545	9.0221	39.8±4.1	23.0±3.5	198.3±5.3
SM5	6.75564	9.0703	20.4±2.8	22.2±4.8	176.6±7.1
SM6	6.75678	9.0675	28.1±3.0	19.9±2.6	98.4±4.8
SM7	6.75792	9.0193	37.2±2.4	28.9±4.6	228.3±5.9
SM8	6.75906	9.0325	51.4±5.1	37.2±3.4	208.4±3.8
SM9	6.76020	9.0203	23.3±3.4	35.0±2.9	398.3±2.7
SM10	6.76134	9.0063	22.3±2.8	30.8±3.7	91.4±8.1
SM11	6.76248	9.0013	34.8±4.2	22.0±5.1	298.7±6.2
SM12	6.76362	9.0401	17.3±6.1	35.2±3.3	168.3±5.3
SM13	6.76476	9.0023	38.2±3.7	21.7±4.7	244.8±4.5
SM14	6.76590	9.0034	49.4±1.8	33.0±6.1	268.3±3.6
SM15	6.76704	9.0653	34.4±3.9	22.2±3.3	176.6±6.8
SM16	6.76818	9.0133	28.1±4.2	14.9±5.2	98.4±4.9
SM17	6.76932	9.0603	47.2±1.3	29.9±3.2	190.3±5.2
SM18	6.77046	9.0507	21.4±4.2	37.2±1.6	268.4±2.8
SM19	6.77160	9.0613	46.3±5.0	45.0±1.3	188.3±6.9
SM20	6.77274	9.0563	32.3±3.7	30.8±4.8	261.4±4.8
SM21	6.77388	9.0088	30.8±4.3	38.0±3.9	298.4±6.1
SM22	6.77502	9.0043	27.3±5.7	36.2±2.7	308.3±5.5
SM23	6.77616	9.0397	48.2±2.9	26.2±3.7	114.8±3.5
SM24	6.77730	9.0079	49.8±5.2	29.0±4.8	128.3±3.8
SM25	6.77844	9.0057	50.4±1.7	32.2±2.8	206.1±3.6
SM26	6.77958	9.0129	28.1±3.6	24.9±6.1	498.4±7.2
SM27	6.78072	9.0260	47.2±3.1	28.9±3.3	248.3±3.8
SM28	6.78186	9.0067	21.4±6.2	37.2±3.7	278.4±7.6
SM29	6.78300	9.0045	43.3±2.6	37.0±4.7	318.3±8.3
SM30	6.78414	9.0456	26.3±4.2	34.8±2.8	309.3±5.7

2.5 Method of Data Analysis

The activity concentration of soil samples from Gold mining area in Shiroro Niger state obtained using NaI(Ti) detector at National Institute of Radiation protection and Research Ibadan were analyzed. Evaluation of radiological hazard effects depending upon the activity concentration of primordial radioactive elements, various radiological hazards delivered to the surrounding living biota are

calculated as follows;

i. Absorbed Dose Rate (D): The total absorbed dose rate (D) in nGy/h is calculated using the following formula:

$$D\ (nGy/h) = 0.462\ A_U + 0.604\ A_{Th} + 0.0417\ A_K \quad 1$$

where, A_U, A_{Th} and A_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in $Bqkg^{-1}$.

ii. Gamma index: The gamma index (Iγ) has been introduced to account for the combined impact of ^{238}U, ^{232}Th and ^{40}K as radiological hazard associated with soil, vegetation and water.

$$\text{Gamma index} = \frac{A_U}{300} + \frac{A_{Th}}{200} + \frac{A_K}{3000} \quad 2$$

where, A_U, A_{Th} and A_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in $Bqkg^{-1}$.

Table 2: Calculated Radiological Hazard Parameter of Soil Samples from Shiroro Gold Mined, Niger State.

Sample Code	D($nGyh^{-1}$)	H_{in}	H_{ex}	$I\gamma$	Ra_{eq}	$AEDE_{indoor}$	$AEDE_{outdoor}$	ELCR
SM1	31.54	0.26	0.18	0.25	67.71	0.15	0.04	0.135
SM2	28.13	0.27	0.16	0.21	60.88	0.14	0.03	0.120
SM3	40.31	0.31	0.23	0.31	85.06	0.20	0.05	0.173
SM4	40.61	0.35	0.24	0.31	87.95	0.20	0.05	0.174
SM5	30.25	0.23	0.18	0.24	65.74	0.15	0.04	0.129
SM6	29.13	0.25	0.17	0.23	64.13	0.14	0.04	0.125
SM7	44.23	0.36	0.26	0.34	96.10	0.22	0.05	0.189
SM8	54.97	0.46	0.33	0.43	120.64	0.27	0.07	0.235
SM9	48.63	0.34	0.28	0.39	104.01	0.24	0.06	0.208
SM10	32.74	0.26	0.2	0.26	73.38	0.16	0.04	0.140
SM11	41.91	0.34	0.24	0.33	89.25	0.21	0.05	0.179
SM12	36.32	0.26	0.22	0.29	80.59	0.18	0.04	0.155
SM13	41.04	0.34	0.24	0.32	88.08	0.20	0.05	0.176
SM14	54.02	0.45	0.32	0.42	117.24	0.27	0.07	0.231
SM15	36.72	0.31	0.22	0.28	79.74	0.18	0.05	0.157
SM16	26.11	0.23	0.15	0.2	56.98	0.13	0.03	0.112
SM17	47.86	0.41	0.28	0.37	104.61	0.23	0.06	0.205
SM18	43.63	0.32	0.26	0.35	95.26	0.21	0.05	0.187
SM19	56.48	0.46	0.34	0.44	125.14	0.28	0.07	0.242
SM20	44.5	0.35	0.26	0.35	96.47	0.22	0.05	0.191
SM21	49.71	0.38	0.29	0.39	108.11	0.24	0.06	0.213
SM22	47.43	0.35	0.28	0.37	102.80	0.23	0.06	0.203
SM23	42.91	0.39	0.26	0.33	94.50	0.21	0.05	0.184
SM24	45.91	0.41	0.27	0.35	101.14	0.23	0.06	0.197
SM25	51.39	0.44	0.30	0.40	112.31	0.25	0.06	0.220
SM26	48.95	0.35	0.28	0.38	102.08	0.24	0.06	0.210
SM27	49.69	0.42	0.29	0.38	107.64	0.24	0.06	0.213
SM28	44.05	0.32	0.26	0.35	96.03	0.22	0.05	0.189
SM29	55.72	0.44	0.33	0.44	120.71	0.27	0.07	0.239
SM30	46.16	0.34	0.27	0.36	99.88	0.23	0.06	0.198
MEAN	43.04	0.35	0.25	0.34	93.47	0.21	0.05	0.184

iii. Radium Equivalent Activity (Ra_{eq}) : The Radium Equivalent Activity (Ra_{eq}) was calculated using;

$$Ra_{eq}\ (Bq/kg) = A_U + 1.43A_{Th} + 0.077A_K \quad 3$$

where A_{Ra}, A_{Th} and A_K are the specific activities of ^{238}U, ^{232}Th and ^{40}K (in $Bqkg^{-1}$).

iv. Annual Effective Dose Equivalent (AEDE): The annual effective dose equivalent (AEDE) for indoor and outdoor air is determined following UNSCEAR (2000) as:

$$AEDE_{indoor} = D(nGyh^{-1})xCF \times 8760 \times 0.8x10^{-6}\left(\frac{mSv}{yr}\right) \quad 4$$

$$AEDE_{outdoor} = D(nGyh^{-1})xCF \times 8760 \times 0.2x10^{-6}\left(\frac{mSv}{yr}\right) \quad 5$$

where D (nGy/h) is the total absorbed dose, 0.7Sv/Gy is the conversion coefficient (CF) from absorbed dose to effective dose received by adults; 10^{-6} is the conversion factor from nano to equal measurements [5].

v. External Hazard Indices (HI_{ex}): The gamma ray radiation hazards due to the specified radioactive elements in soil samples are assessed by calculating the following two hazard indices using the relationship given as:

$$HI_{ex} = \frac{A_U}{370} + \frac{A_{Th}}{259} + \frac{A_k}{4810} \quad 6$$

where, A_U, A_{Th} and A_K are the activity concentrations of ^{238}U, ^{232}Th, and ^{40}K in Bq kg^{-1}. The recommended value by UNSCEAR (2000) report for the hazard indices is less than unity.

vi. Excess Lifetime Cancer Risk (ELCR): Excess lifetime cancer risk (ELCR) is calculated using the formula explained by [11-15] as:

$$ELCR = AEDE \times DL \times RF \quad 7$$

where, AEDE, DL, and RF are annual effective dose equivalent, duration of life (70 years) and risk factor (0.05 Sv^{-1}), respectively [1].

3 Results and Discussion

The measured activity concentration level of ^{238}U, ^{232}Th and ^{40}K of soil samples collected from some selected Gold Mining Site in Shiroro area of Niger State, Nigeria are presented in Table 1. Sodium Iodide (NaI) detector was used to determine the activity concentration of the soil sample collected. The radiological parameters analysed in this research includes the absorbed dose, annual effective dose, internal and external hazard, excess life cancer risk, and gamma index and radium equivalent.

The mean activities concentration level of ^{238}U, ^{232}Th, and ^{40}K in the samples collected are 34.56 $Bqkg^{-1}$, 28.79 $Bqkg^{-1}$ and 230.44 $Bqkg^{-1}$ respectively. These radioactivity concentration values obtained are below the world average value of 35 $Bqkg^{-1}$for ^{238}U, 30 $Bqkg^{-1}$ for ^{232}Th and 400

The mean activities concentration level of ^{238}U, ^{232}Th, and

The absorbed dose ranged from 26.11 to 56.48 $nGyhr^{-1}$ with an average value of 43.04 $nGyhr^{-1}$for all soil samples. These indicates that the people living within mining site are less expose to gamma dose radiation. The result does not exceed the permissible limit as recommended by UNSCEAR (2000).

The radium equivalent ranged from 56.98 Bq/kg to 125.15 Bq/kg. The mean value of 93.8 Bq/Kg is lower than the recommended limit set by UNSCEAR [12].

The internal hazard index (H_{in}) varied from 0.23 to 0.46), with the mean value of (0.35), while the external hazard indices (H_{ex}) for the soil samples of the study ranged from 0.15 to 0.43. This value is far less than unity. This implies that the soil is safe for agricultural practice.

The indoor and outdoor annual effective dose equivalent ranged from 0.13 to 0.28 mSv/y and 0.03mSv to 0.07mSv with a mean value of 0.21 mSv/y and 0.05mSv respectively. These values for indoor and outdoor annual effective dose equivalent are lower than the world average values of 0.450 mSv/yr and 0.070 mSv/yr respectively.

The mean excess lifetime cancer risk (ELCR) for all samples is 0.184 and is lower than the world average value of 0.29 [1]. This implies that the risk of developing cancer by the miners, workers and the people living near this environment in general is low. This imply that the soil does not pose much or any threat to the public, though no radiation is said to be safe.

4 Conclusions

Radioactivity levels of ^{238}U, ^{232}Th and ^{40}K has been measured in the soil samples collected in soil samples of some Gold mining area of shiroro in Niger state, Nigeria. The activities concentration of ^{238}U, ^{232}Th, and ^{40}K were measured and an average of 34.56 $Bqkg^{-1}$, 28.79 $Bqkg^{-1}$ and 230.44 $Bqkg^{-1}$ respectively were obtained. These values are slightly lower than the world average. All radiation parameter estimate from the soil samples of Gold mining area of Shiroro in Niger state are within the safe limit. Finally, we conclude that the radiation emitted from the radionuclides present in the soil of the study area do not pose any radiological health hazard to the public of the area and the activity carried out on soil such as agriculture.

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