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Radiometric Evaluation Naturally Occurring Radionuclides in Some Ongoing Drilled Boreholes across Keffi Town of Nasarawa State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author UR designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors UR, IU and AZN managed the analyses of the study. Authors UR, HAA and HOA managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study evaluate the existence radionuclides in some Ongoing dug boreholes across Keffi town of Nasarawa State, Nigeria using a hand held interceptor TM – Thermo scientific radio nuclear identiFINDER designed for in situ operation. Gamma Activity, possible radionuclide present and their trust levels, Exposure Dose Rate, Absorbed Dose Rate, Effective Dose Rates and Excess Lifetime Cancer Risk were determined. Results obtained shows that the Gamma Activity Level ranged from 0.243 to 0.589 mrem/hr with the mean of 0.441 mrem/hr. Exposure Dose Rate of the study area ranged from 2.43 to 5.89 µSv/hr with the mean of 4.41 µSv/hr. The local miners in the study area are subjected to Absorb Dose Rate ranging from 2430 to 5890 nGy/hr with the mean value of 4410 nGy/hr. Effective Dose Rate of the area under investigation were ranged from 0.42 to 0.99 mSv/yr with a mean of 0.74 mSv/yr. The Excess Lifetime Cancer Risk of the area ranged from

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1.47×10^{-3} to 3.47×10^{-3} with the mean of 2.60×10^{-3}. The result also shows that there is Palladium (^{103}Pd), Iodine (^{125}I), Samarium (^{153}Sm), Chromium (^{51}Cr) and Tallium (^{201}Tl) in significant percentage. It is concluded that natural radionuclides pollution in the drilling sites are an issue of health concern, since the radiation exposure level for workers in the study area is found to be high according to regulatory rules.

Keywords: Soil; borehole; health; radionuclide; absorbed dose; effective dose; identiFINDER.

1. INTRODUCTION

The great interest expressed worldwide for the study of naturally occurring radionuclides and environmental radioactivity has led to interest in extensive survey in many countries [1]. Natural sources still contribute almost 80% of the collective radiation exposure of the world population [2]. There are many sources of radiation and radioactivity in the environment [3]. Gamma radiation emitted from naturally occurring radionuclides also called terrestrial background radiation represents the main external source of irradiation of human body [3]. Human beings are exposed to radiation from sources outside their bodies, mainly, cosmic rays and gamma rays emitted in soil [4].

Studying the levels of radionuclide distribution in the environments provides essential radiological information. It is important to monitor the terrestrial background radiation mainly due to natural radionuclides in soil. Soil from mining sites may contain naturally occurring radionuclides in significant amounts and the resulting external radiation exposure pathway to the population has been the subject for study [1-4]. Natural radioactivity originates from extra-terrestrial sources as well as from radioactive elements in the earth crust [5]. About 340 nuclides have been found in nature, and more than 60 of these are radioactive [6]. All elements having an atomic number greater than 80 possess radioactive isotopes, and all isotopes of elements heavier than number 83 are radioactive [7].

The natural radioactivities of the earth are categorized into primordial, secondary and Cosmogenic radionuclides [1-7]. The primordial nuclides which now exist are those that have half-life at least comparable to the age of the universe. Radionuclides with half-life greater than 10^{10} years have decayed very little up to the present time [1-7].

Examples of some naturally occurring radioactive nuclides are Uranium-235 (^{235}U) with half-life 7.6×10^{8} years and Uranium-238 (^{238}U) with half-life 4.5×10^{8} years, Thorium-232 (^{232}Th) with half-life 14×10^{9} years, Radium-226 (^{226}R) with half-life 12 days and Protactinium-231 (^{231}Pa) with half-life 3.2×10^{4} years etc [8].

2. MATERIALS AND METHODS

2.1 Materials

The materials that were used in the field radiometric evaluation of naturally occurring radionuclides in mining sites across Keffi Town can be shown in Table 1.

2.2 Methods

2.2.1 The study area

Twelve sample points were chosen in Keffi Town. The sample points are. These points as well as their respective coordinates are listed in Table 2.

Table 1. Material and their specifications

Materials	Specifications
Thermo scientific interceptor	This is a spectroscopic Personal Radiation Detector Design for in situ operation combining the qualities of personal radiation detection with radioisotope identiFINDER capabilities.
Map of Keffi Town	This will provide names and directions of all the localities in the area.
Measuring tape	This is for measuring grid size and depth of the pit.
Geographical Positioning System (GPS)	Was used in finding the coordinates at each sample point.

Table 2. Coordinates of all sample points

Point Codes	Coordinate (North)	Coordinate (East)
Ganuwa	$8^0 50' 17.5"$	$7^0 52' 31.7"$
Yalwa	$8^0 50' 22.9"$	$7^0 52' 0.03"$
Ungwan Nepa	$8^0 50' 28.0"$	$7^0 53' 10.7"$
Ungwan Dad'i	$8^0 50' 24.9"$	$7^0 53' 11.7"$
GRA	$8^0 51' 19.8"$	$7^0 53' 40.4"$
High Court	$8^0 50' 57.9"$	$7^0 54' 10.0"$
Area Command	$8^0 50' 55.1"$	$7^0 51' 58.8"$
Ungwan Tanko	$8^0 51' 40.7"$	$7^0 51' 53.8"$
Ungwan Lambu	$8^0 50' 37.8"$	$7^0 54' 44.9"$
Ungwan Kwara	$8^0 51' 25.8"$	$7^0 52' 37.0"$
K'ofar Kokona	$8^0 50' 32.4"$	$7^0 52' 51.8"$
Main Park	$8^0 52' 57.3"$	$7^0 50' 55.3"$

The coordinates listed in Table 2 are mentioned in the map as shown in Fig. 1

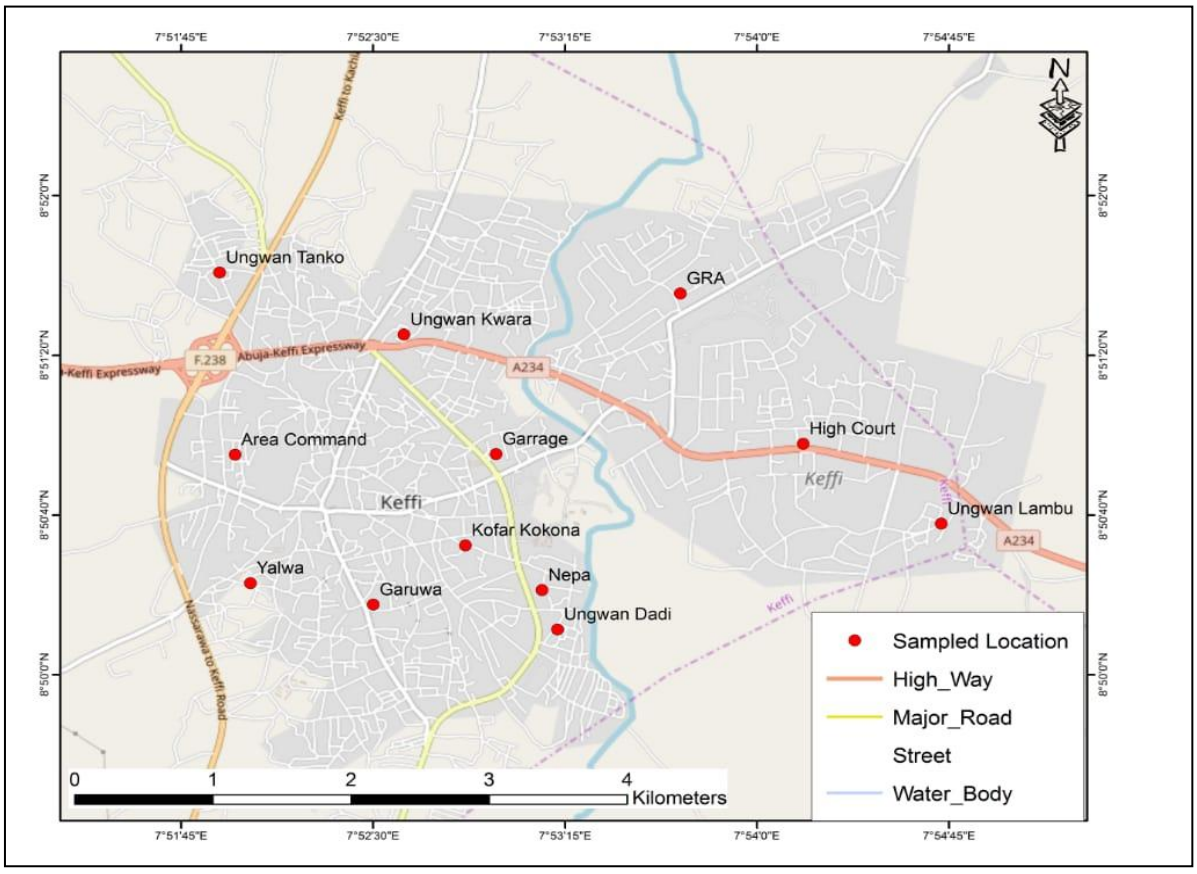

Fig. 1. Map showing sample location in Nasarawa West

2.2.2 Data collection

The data are collected manually from the spectrometer and recorded on a book for further analysis. After the drilling of the soil, the radiation measurement was done with the device touching the soil surface. The procedure was done in sequence, covering all the data points in the study area.

2.2.3 Sampling method

To assess a radiometric evaluation of the study area, the stratified random sampling technique was adapted where a grid sampling (data) was defined for the region. The grid of the study area was defined in a range of 50×25 meters grid. Since the net was defined, in each data point the gamma radiation rate (mrem), the dose rate (μSv

per hour), the trust level and the type of radionuclides are obtained.

2.2.4 Population sample

When the grid of the study area was defined in the Keffi town, twelve (12) locations were chosen. Four data were taken randomly in each location making 48 and the coordinate of each location is taken for further analysis.

2.2.5 Data analysis

In other to compute the experimental result for Exposure Dose Rate (μSvhr^{-1}), Absorbed Dose Rate (nGyhr^{-1}), the Effective Dose Rate (mSvhr^{1}) and Excess Lifetime Cancer Risk, the following methods and formulas were used according to UNSCEAR [9].

1. Gamma Activity Level, GAL(mremhr^{-1}), $= \frac{\sum N}{N}$ (1)

2. Exposure Does Rate (μSvhr^{-1}), is gotten from the relation 1 mremhr^{-1} = 10 μSvhr^{-1} (2)

3. Absorbed Does Rate, D(nGyhr^{-1}) is gotten from the relation 1 μSvhr^{-1} = 10^3 nGyhr^{-1} (3)

4. Effective Dose Rate (mSvhr^{-1}), $ED = D \times T \times OF \times CCF \times 10^{-6}$ (4)

5. Excess Life-Time Cancer Risk ELCR = EDR × DL × RF (5)

Where

$\sum N$=Sum of all the readings taken at each position of the site

N = The frequency of the values

D =Absorbed does rate (nGyhr^{-1})

T = Time spend in a year = 24 hrs × 7 days × 4 weeks × 12 months = 8064 hrsy^{-1} for the public 5 hrs × 5 days × 4 weeks × 12months = 1200 hrsy^{-1} for workers

OF= Occupancy factor = 0.2

CCF = Conversion Coefficient factor = 0.7SvGy^{-1}.

Also, to interpret the compute the experimental result for all the hazard indices mentioned above, Microsoft Excel software was used.

3. RESULTS AND DISCUSSION

3.1 Results

The data collected from different drilling sites such as radionuclides with their respective trust level and gamma activity level (mrem/yr), the evaluations made for the radiological hazard parameters such as exposure dose rates (μSv/hr), absorbed dose rate (nGy/hr), effective dose rate (mSv/yr) and excess lifetime cancer risk are presented in Table 2 to Table 3.

Radionuclides, Trust Levels and Other Parameters:

The radionuclides with their respective trust levels obtained from the field using radiation identiFINDER are presented in Table 3.

3.2 Analysis of Results

In this study, the results were obtained by the use of mathematical formulae (see Equation 1 to 5). The average values presented in Table 3 are used to plot charts presented in Figs. 2 to 6 in order to compare the results with previous works.

3.3 Discussion

The results of the radiometric evaluation of naturally occurring radionuclides in boreholes drilling sites across Keffi Town of Nasarawa State, Nigeria using thermo scientific radiation identiFINDER device have been presented. The trust level of the various radionuclide found in the drilling sites are presented in Table 2. Five radionuclides (^{103}Pd, ^{125}I, ^{153}Sm, ^{51}Cr, ^{201}Tl) were found in the soil from drilling site.

From Table 3, it is possible to see that ^{103}Pd was found in 66.7% of the points where the values were measured the trust level of the device reaches 53-89% indicating that the radionuclides are likely found in the area. It is also possible to see that ^{125}I was found in 60% of the points where the values were measured. The trust level of the device for ^{125}I reaches 45-75% indicating that the radionuclides is likely found in the area. It is also possible to see that ^{153}Sm, ^{51}Cr and ^{201}Tl were found in 1% of the points where the values were measured. The trust level of the device for ^{153}Sm, ^{51}Cr and ^{201}Tl reaches 51%, 43% and 41% respectively, indicating that the radionuclide is likely found in the area with the exception of ^{51}Cr and ^{201}Tl. However, the trust

level of the device indicate that the radionuclides used for both medical and industrial purpose found in the study area with the exception of four (4) areas are most likely present.

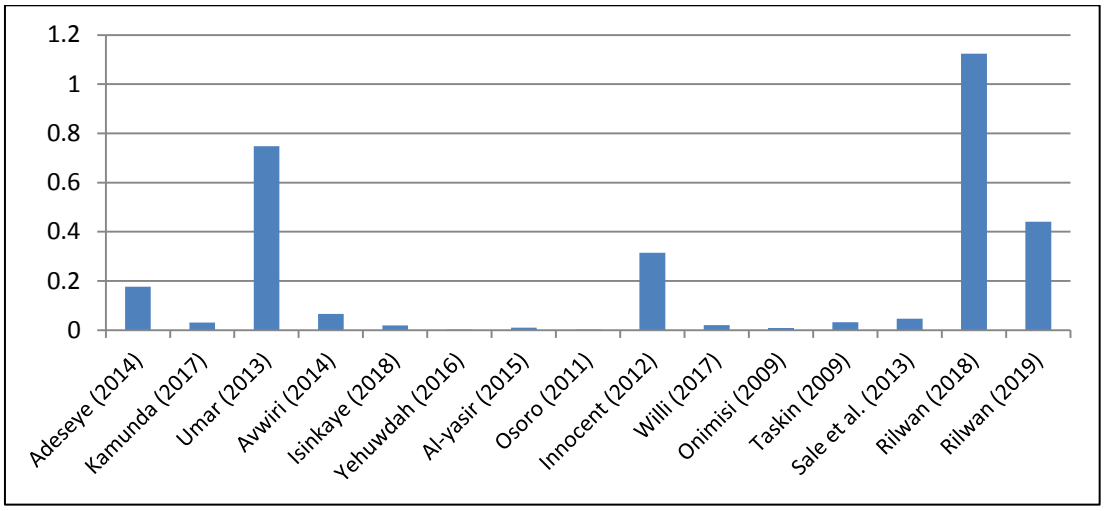

Fig. 2. Comparison of gamma activity (mren/hr) with other authors

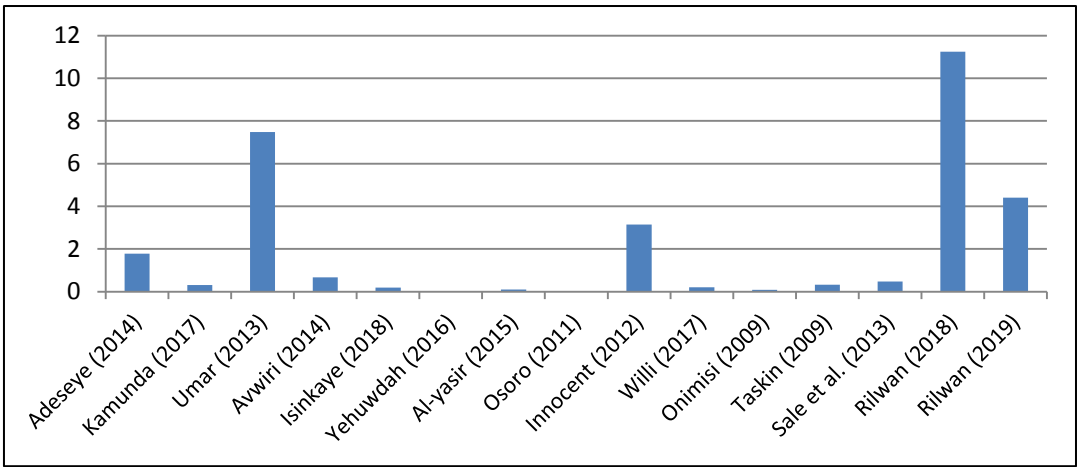

Fig. 3. Comparison of exposure dose rate (μSv/hr) with other authors

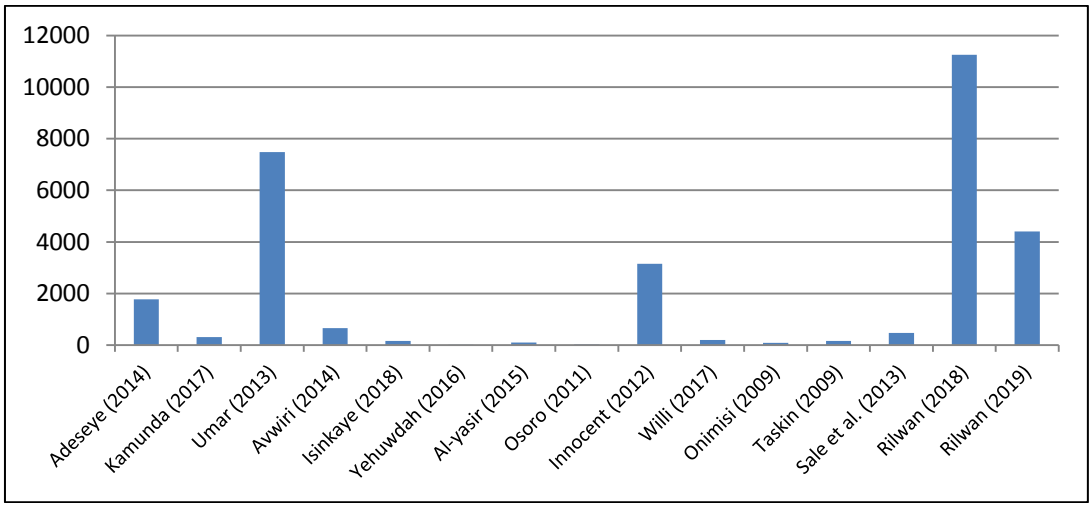

Fig. 4. Comparison of absorbed dose rate (nGy/hr) with other authors

Table 3. Radionuclides, trust levels and other parameters

Sample points	Radionuclide I	TL (%)	Radionuclide II	TL (%)	GAL (mrem/hr)	ExDR (μSv/hr)	ADR (nGy/hr)	EDR (mSv/yr)	ELCR x 10^{-3}
Ganuwa	Med-Pd-103	67	Med-I-125	59	0.564	5.64	5640	0.95	3.32
Yalwa	Med-Pd-103	72	Med-I-125	60	0.268	2.68	2680	0.45	1.58
Ungwan Nepa	Med-Pd-103	89	Med-I-125	53	0.283	2.83	2830	0.48	1.68
Ungwan Dad'i	Med-Pd-103	67	Med-I-125	51	0.243	2.43	2430	0.42	1.47
G.R.A	Med-Pd-103	62	Med-I-125	52	0.543	5.43	5430	0.91	3.19
High Court	Med-Pd-103	61	Med-Sm-153	51	0.503	5.03	5030	0.85	2.98
Area Command	Med-Pd-103	64	Med-I-125	45	0.399	3.99	3990	0.67	2.35
Ungwan Tanko	Med-Pd-103	64	Med-I-125	47	0.396	3.96	3960	0.67	2.35
Ungwan Lambu	Med-Pd-103	63	Ind-Cr-51	43	0.589	5.89	5890	0.99	3.47
Ungwan Kwara	Med-I-125	66	Med-Pd-103	62	0.525	5.25	5250	0.88	3.08
K'ofar Kokona	Med-Pd-103	53	Med-Tl-201	41	0.500	5.00	5000	0.84	2.94
Main Park	Med-I-125	75	Med-Pd-103	54	0.476	4.76	4760	0.80	2.80
Mean					**0.441**	**4.41**	**4410**	**0.74**	**2.60**

Where TL = Trust Level of the Device, GAL = Gamma Activity Level, ExDR = Expsure Dose Rate, ADR = Absorbed Dose Rate, EDR = Effective Dose Rate and ELCR = Excess Lifetime Cancer Risk

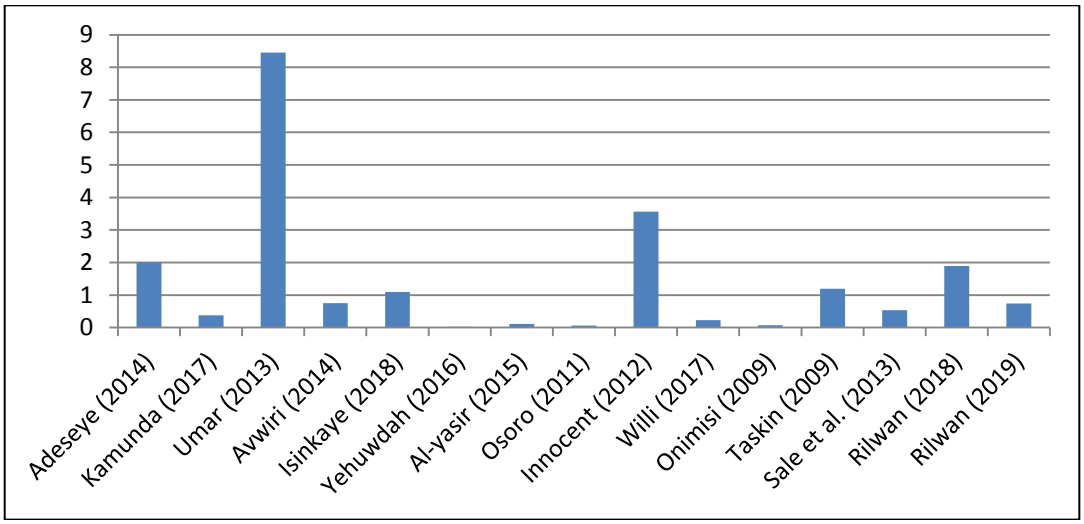

Fig. 5. Comparison of effective dose rate (mSv/yr) with other authors

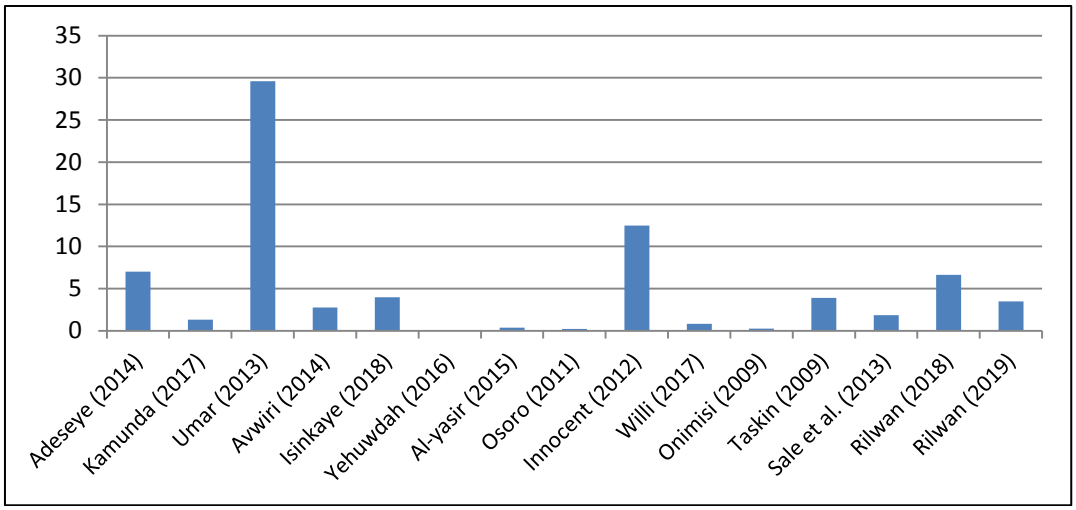

Fig. 6. Comparison of excess lifetime cancer risk with other authors

Finding of this study have revealed that the mean Gamma Activity Level for Keffi boreholes drilling sites is 0.441 mrem/hr. Which implies that the level of radiation in those areas is extremely lower than 1mrem/hr as agreed by regulatory bodies and may not cause radiological hazard to the workers if not accumulated over time. This finding is in line with the finding of several authors [10,11,12], but not in line with the finding of Kamunda et al. [13] who's mean gamma activity level was 0.03 mrem/hr, [14] who's mean gamma activity level was 0.07 mrem/hr, [15] who's mean gamma activity level was 0.02 mrem/hr, [16] who's mean gamma activity level was 0.002 mrem/hr, [17] who's mean gamma activity level was 0.01 mrem/hr, [18] who's mean gamma activity level was 0.003 mrem/hr, [19] who's mean gamma activity level was 0.02 mrem/hr, [20] who's mean gamma activity level was 0.009 mrem/hr, [21] who's mean gamma activity level was 0.032 mrem/hr and [22] who's mean gamma activity level was 0.05 mrem/hr.

On Exposure Dose Rate, Finding of this study has revealed that the mean Exposure Dose Rate for Keffi boreholes drilling sites is 4.41 µSv/hr. Which implies that the level of radiation in those areas is extremely lower than 10 µSv/hr as agreed by regulatory bodies and may not cause radiological hazard to the workers if not accumulated over time. This finding is in line with the finding of several authors [10,11,12], but not in line with the finding of Kamunda et al. [13] who's mean Exposure Dose Rate was 0.312 µSv/hr, [14] who's mean Exposure Dose Rate was 0.664 µSv/hr, [15] who's mean Exposure Dose Rate was 0.2 µSv/hr, [16] who's mean Exposure Dose Rate was 0.02 µSv/hr, [17] who's

mean Exposure Dose Rate was 0.1 µSv/hr, [18] who's mean Exposure Dose Rate was 0.03 µSv/hr, [19] who's mean Exposure Dose Rate was 0.2 µSv/hr, [20] who's mean Exposure Dose Rate was 0.09 µSv/hr, [21] who's mean Exposure Dose Rate was 0.32 µSv/hr and [22] who's mean Exposure Dose Rate was 0.5 µSv/hr.

On Absorbed Dose Rate, Finding of this study has revealed that the mean Absorbed Dose Rate for Keffi boreholes drilling sites is 4410 nGy/hr. Which implies that the level of radiation in those areas is extremely lower than 10000 nGy/hr as agreed by regulatory bodies and may not cause radiological hazard to the workers if not accumulated over time. This finding is in line with the finding of several authors [10,11,12], but not in line with the finding of Kamunda et al. [13] who's mean Absorbed Dose Rate was 312 nGy/hr, [14] who's mean Absorbed Dose Rate was 664 nGy/hr, [15] who's mean Absorbed Dose Rate was 163.28 nGy/hr, [16] who's mean Absorbed Dose Rate was 20 nGy/hr, [17] who's mean Absorbed Dose Rate was 98 nGy/hr, [18] who's mean Absorbed Dose Rate was 25.2 nGy/hr, [19] who's mean Absorbed Dose Rate was 204 nGy/hr, [20] who's mean Absorbed Dose Rate was 89 nGy/hr, [21] who's mean Absorbed Dose Rate was 164.53 nGy/hr and [22] who's mean Absorbed Dose Rate was 469 nGy/hr.

On Effective Dose Rate, Finding of this study has revealed that the mean Effective Dose Rate for Keffi boreholes drilling sites is 0.74mSv/yr. Which implies that the level of radiation in those areas is extremely lower than 20mSv/yr as agreed by regulatory bodies and may not cause radiological hazard to the workers if not accumulated over time. This finding is in line with the finding of several authors [13,14,15,17, 19,20,21,22]. But not in line with the finding of [16] who's mean Effective Dose Rate was 0.023 mSv/yr, [18] who's mean Effective Dose Rate was 0.062mSv/yr, [10] who's mean Effective Dose Rate was 3.56mSv/yr, [12] who's mean Effective Dose Rate was 8.45mSv/yr and [11] who's mean Effective Dose Rate was 2.0mSv/yr.

On Excess Lifetime Cancer Risk, Finding of this study has revealed that the mean Excess Lifetime Cancer Risk for Keffi boreholes drilling sites is 2.60×10^{-3}. Which implies that the level of radiation in those areas is significantly higher than 0.29×10^{-3} as agreed by regulatory bodies and may cause cancer to the workers when they work there for ages of 70. This finding is in line with the finding of several authors [13,14,15,17,19,20,21,22]. But not in line with the finding of Yehuwda [16] who's mean Excess Lifetime Cancer Risk was 0.081×10^{-3}, [18] who's mean Excess Lifetime Cancer Risk was 0.22×10^{-3}, [10] who's mean Excess Lifetime Cancer Risk was 12.46×10^{-3}, [12] who's mean Excess Lifetime Cancer Risk was 29.58×10^{-3} and [11] who's mean Excess Lifetime Cancer Risk was 7.0×10^{-3}.

4. CONCLUSION AND RECOMMENDATION

4.1 Conclusion

From the findings presented, it can be concluded that natural radionuclides pollution in the mining area are an issue of health concern.

4.2 Recommendation

It is therefore recommend that proper radiation monitoring exercises should be conducted on the borehole sites from time to time in order to safeguard the workers as well as the public of the area from high radiation exposure due to direct inhalation of the above mentioned radionuclide excavated from the soil in the process of drilling. With a strict regulatory control, the local miners can be restricted on the time they should spend in the drilling sites, for long exposure time might be the major factor that led to the high cancer risk.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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