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Evaluation of Radon-222 Concentration Levels in Drinking Water Sources at Mararraba-Udege Quarrying and Mining Site in Nasarawa Lga, Nasarawa State, Nigeria

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Abstract: In this study, Evaluation of Radon-222 Concentration Levels in Drinking Water Sources at Mararraba-Udege Quarrying and Mining Site in Nasarawa LGA, Nasarawa State, Nigeria was assessed Three (3) reading is taken at each point and the average was taken and each point were sampled, a total of fifteen samples were selected and the concentration rate were measured using a Liquid Scintillation Counter (manufactured by Packard Tri-carb LSA 1000TR)), the Liquid Scintillation Counter was held at an elevation of 1.0m above ground level, the absorbed dose rate, annual effective dose rate, were calculated, using the radiological hazard indices, the result obtained are in the range of 0.8719-0.9048 Bq/L,0.831-0.859 mSv/y, 11.040-11.413 mSv/y for CRn, Eing, and Einh respectively, the obtained values of Eing and Einh this value is higher than the permissible limit of 1.3mSv/y for inhalation and 0.1-0.2mSv/y for ingestion set by WHO (WHO, 2004). This indicates that the inhabitants around Mararraba-Udege Quarrying and Mining Site and its workers are not safe from radiation hazards, so there is a need to educate, create awareness among Mararraba-Udege Quarrying and Mining Site workers and members of the public around the mining site on the risks associated with Rodon-222 and precautions to take.

Keyword: Randon-222 Concentration, Annual Effective Dose by Ingestion, Annual Effective Dose by Inhalation.

1 Introduction

Water management is a pressing concern with significant implications for our daily lives [1- 5]. Recognized as the most crucial natural resource [2, 6- 8], the accessibility of dependable water sources is vital for development, as regions without water, like deserts, are uninhabitable [1, 3, 9- 11]. Ensuring the availability of high-quality freshwater is essential for environmental sustainability [12- 14]. Regular monitoring of groundwater quality is particularly important in areas where geological factors pose health risks [7, 9, 15].

The presence of radioactive elements in the earth, such as uranium and radon, underscores the importance of understanding their impact. Radon, emanating primarily from the ground, poses significant health risks, particularly through inhalation, leading to DNA damage and potential lung cancer [5, 16- 19]. Long-term exposure to radon, especially in conjunction with smoking, increases the risk of lung cancer [20, 21]. Effective risk communication strategies are necessary to raise public awareness and encourage mitigation efforts [22].

Recent years have seen increased attention on natural radioactivity's effects, with the UNSCEAR estimating an average annual radiation dose equivalent to 2.4 mSv/yr per person [13, 23- 25]. This research will employ the Liquid Scintillation Counter technique to measure radon concentrations and assess their impact on human health, contributing to global scientific understanding on this issue.

The research aimed at evaluating radon-222 concentration levels in drinking water sources of Mararraba-Udege Quarrying and Mining site in Nasarawa LGA of Nasarawa State, Nigeria.

2 Experimental Section

2.1 Materials

The materials that were used in carrying out this study are presented in Table 1.

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Table 1: Materials and their Specifications.

S/N	Materials		Specifications
1.	Plastic sample collection bottles		50ml
2.	Liquid Scintillation Counter(manufactured by Packard Tri-carb LSA 1000TR)	1	
3.	Disposable hypodermic syringe (20ml, 10ml, and 2 ml) capacity with 38mm hypodermic needle	8	
4.	Indelible ink and masking tape	1	

2.2 Sample and Sampling Technique

To obtain representative samples and ensure equal chances of selection, a simple random sampling technique was employed to choose two areas of the Mararraba-Udege Quarrying and Mining site in Nasarawa LGA of Nasarawa State, Nigeria. This technique was also used to select (15) samples of boreholes and wells' water from these areas for sampling.

2.3 Study Area

The study area is Maraban-Udege, which is located in the Nasarawa Eggon Local Government Area of Nasarawa State, with a population of 149,129 (2006 census) and a Land Area of 1,208km^2

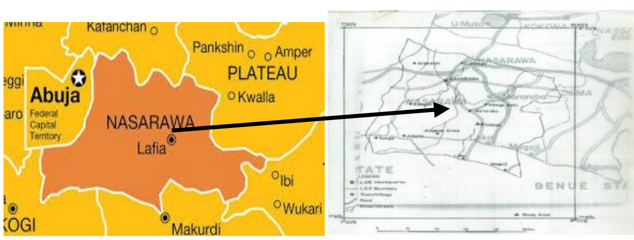

Fig. 1: Map of study area.

2.4 Method of Sample Collection

Each sample was assigned a unique number for easy identification, along with recording the GPS location of each sample. A total of fifteen groundwater samples from the well were collected from the two areas under study using plastic containers with lids. To prevent contamination, the containers were thoroughly washed and rinsed with distilled water before use. Each water sample was preserved with 20 ml of concentrated HNO_3 per liter to minimize the absorption of dissolved radon onto the container walls.

The water samples were collected after operating the boreholes for at least four minutes to ensure fresh samples. At each location, the containers were filled to the brim without any headspace to prevent CO_2 from dissolving in the water, which could affect its chemistry, such as pH. The containers were immediately sealed to avoid radon loss through degassing during transport to the laboratory.

The samples were sent for analysis immediately after collection, with a maximum delay of three days, to minimize the effects of radioactive decay and ensure maximum accuracy in the results.

2.5 Method of Sample Preparation

Each water sample (10 ml) was transferred into a 20 ml glass scintillation vial, and 10 ml of Insta-Gel scintillation cocktail was added. The vials were tightly sealed and shaken for more than two minutes to extract radon-222 from the water phase into the organic scintillate. The samples were then counted for 60 minutes in a liquid scintillation counter, using energy discrimination for alpha particles.

2.6 Method of Sample Analysis

The samples were analyzed using a Liquid Scintillation Counter (Tri-Carb LSA 1000TR) model located at the Centre for Energy Research and Training (CERT), Ahmadu Bello University, Zaria-Nigeria.

2.7 Method of Data Analysis

The analysis for this study was in four (4) parts, which included calculation of concentration in Bq/l, Annual effective dose to stomach and lungs, and Comparison of findings with standard and other researchers.

2.8 Radon-222 Concentration in Bq/l Estimation Method

The Radon-222 concentration in Bq/l was calculated using equation (3.1) as follows:

$$Rn(BqL^{-1}) = \frac{1000ml(CS-CB)}{10ml\ X\ 1.0L(CF\ X\ D)} \quad (3.1)$$

Where: Rn = Radon level in Bql^{-1}, CS = Sample Count/Second, CB = Background Count/Second, CF = Conversion factor, and D = Decay Constant

2.9. Annual Effective Dose by Ingestion Estimation Method

The annual effective dose of Radon-222 by ingestion was estimated using the equation:

E_{ing} = K x G x C x T x 1000 (3.2)

E_{ing} = Annual effective dose by ingestion (mSv^{-1}), K = Conversion coefficient concentration of ^{222}Rn ($SvBq^{-1}$), G = Daily Consumed Water (L/d), C = Concentration of ^{222}Rn (BqL^{-1}), T = time span of water consumption (365 days), 1000 = conversion coefficient of Sv to mSv [26, 27].

2.10 Dose Contribution to the Stomach due to Ingestion

It is a product of the stomach tissue weighted factor (0.1196) with the corresponding ingestion dose using the Equation below [28]:

$Dose\ to\ the\ Stomach\ (D_{stomach}) = E_{ing} \times 0.1196$ (3.3)

Annual Effective Dose by Inhalation Estimation Method

The annual effective dose of Radon by inhalation was estimated using equation (3.4) as: He = C × F× T × D

He = Annual effective dose ($mSvy^{-1}$), C = Radon concentration (Bql^{-1}), F = Equilibrium factor, T = Indoor occupancy time (hy^{-1}), and D = Dose conversion factor ($mSvh^{-1}/Bql^{-1}$) [29]:

Dose Contribution to the Lung due to Inhalation

It is the product of the lung tissue weighted factor (0.1199) and the corresponding inhalation dose using the Equation below:

$Dose\ to\ the\ Lung\ (D_{lung})$ = He × 0.1199 (3.5)

3 Results and Discussion

3.1 Data Presentation

The mean radon activity concentrations of the fifteen samples of water, taken from six different locations within Nasarawa Local Government Area of Nasarawa State, Nigeria, were measured with a Liquid Scintillation Counter. The data obtained from the study area were analyzed using the radiological hazard parameters, which are: Annual Effective Dose by Ingestion Estimation Method
E_{ing} = K x G x C x T x 1000, Dose Contribution to the Stomach due to Ingestion
$Dose\ to\ the\ Stomach\ (D_{stomach}) = E_{ing} \times 0.1196$
Annual Effective Dose by Inhalation Estimation Method He = C × F× T × D, Dose Contribution to the Lung due to Inhalation
$Dose\ to\ the\ Lung\ (D_{lung})$ = He × 0.1199

Table 2 presents the calculated radiological hazard indices.

Table 2: The calculated radiological hazard indices of the study area.

Sampling ID	CRn) (Bq/L)	E_{ing} (mSv/y)	E_{inh} (mSv/y)	D_{stom} (mSv/y)	D_{lung} (mSv/y)
EDB1	0.8863	0.841	11.180	0.1007	1.3405
EDB2	0.8785	0.833	11.082	0.0996	1.3287
EDB3	0.8887	0.843	11.210	0.1008	1.3440
EDB4	0.8754	0.831	11.042	0.0994	1.3239
EDB5	0.8752	0.831	11.040	0.0994	1.3237
EDW1	0.89105	0.846	11.240	0.1012	1.3477
EDW2	0.8775	0.833	11.069	0.0996	1.3272
EDW3	0.8866	0.841	11.184	0.1006	1.3409
EDW4	0.8824	0.837	11.131	0.1001	1.3346
EDW5	0.8888	0.843	11.211	0.1008	1.3442
MUB1	0.8832	0.838	11.141	0.1002	1.3358
MUB2	0.8759	0.831	11.050	0.0994	1.3298
MUB3	0.8793	0.834	11.091	0.1008	1.3302
MUB4	0.8761	0.831	11.051	0.0994	1.3250
MUB5	0.9048	0.859	11.413	0.1027	1.3684
Mean	**0.8807**	**0.838**	**11.142**	**0.1599**	**1.3363**
Minimum	**0.8719**	**0.831**	**11.040**	**0.0994**	**1.3237**
Maximum	**0.9048**	**0.859**	**11.413**	**0.1027**	**1.3684**

3.2 data analysis

Concentration of Rn-222 (mean)
The radon activity concentrations represented above range from 0.9048 to 0.8719 Bq/L with a mean of 0.6188 Bq/L, which is higher than values when compared to the maximum permissible average limit of 0.10 Bq/L that has been set by the Nigerian Standards for Drinking Water Quality.

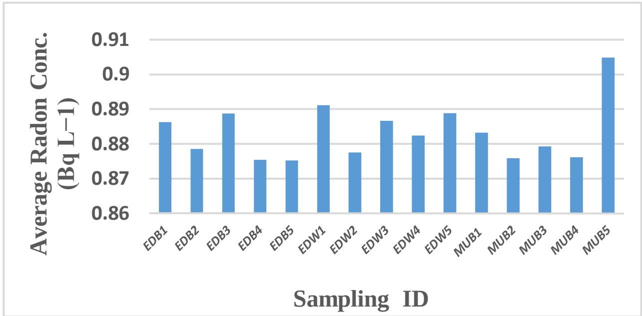

Fig.2: Comparison of Rondon concentration with the world's average.

Annual Effective Dose Rate for Ingestion and Inhalation
The samples have an annual effective dose from ingestion and inhalation of drinking and groundwater that is higher than the maximum permissible limit of 0.2 mSv/y if consumed by children and the maximum limit of 0.1 mSv/y if consumed by adults, which is recommended by the WHO and the European Union Commission. The annual effective

dose of ingestion ranges from 0.859 to 0.831mSv/y, with the mean of 0.838mSv/y. The annual effective dose for inhalation ranges from 11.413 to 11.040mSv/y, with a mean of 11.142mSv/y

The highest value of 0.9048 is a strong Pearson correlation, which also exists between the annual effective ingestion dose and radon activity concentration for the measured water samples. This agrees with the WHO report, which says that "a higher radon dose is received from inhaling radon compared with ingestion".

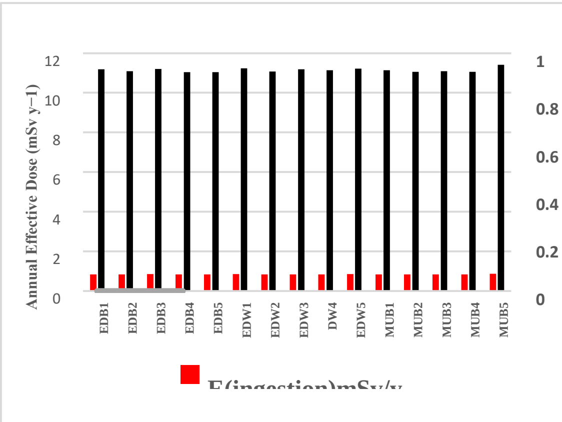

Fig. 4.2: Comparison of the annual effective dose of inhalation and ingestion.

4 Discussion of findings

The research aimed at the evaluation of radon-222 concentration levels in drinking water sources at Mararraba-udege quarrying and mining site in Nasarawa LGA, Nasarawa State, Nigeria. The mean radon activity concentrations of the fifteen samples of water, taken from six different locations within Nasarawa Local Government Area of Nasarawa State, Nigeria, were measured with a Liquid Scintillation Counter. Three (3) readings are taken at each point, and the average is calculated at each point where sampled. The data collected ranged from 0.9048 to 0.8719 Bq/L with a total mean of 0.8807 Bq/L and was analyzed using radiological hazard parameters, which are:

The annual effective dose (AED) in (mSv-1) for inhalation and ingestion of Radon from the water sources. The overall mean AED due to inhalation of Radon is calculated to be 11.413 mSvy-1, with an average of 11.142, for ingestion is 0.859 with an average of 0.838mSvy-1 respectively. This value is higher than the permissible limit of 1.3mSv/y for inhalation and 0.1-0.2mSv/y for ingestion set by WHO (WHO, 2004). For both adults, children, and infants. For consumption of well water only, the average AED is 0.111, 0.166, and 0.193 mSvy-1, respectively, for adults, children, and infants, As for Surface water only, 114.9, 172.4 and 201.2 μSvy-1 respectively These values are higher than the WHO permissible limit of 0.1 mSv/year for adults and also higher than the permissible limit of 0.2mSvy-1 for children [29- 31].

5 Conclusion

The assessment of radon concentration in water sources from Nasarawa, local government area, Nasarawa State, Nigeria. Has been carried out using a Liquid Scintillation Counter. It was observed that the radon concentration for all the water sample types is higher than the permissible level of 11.1 Bq/L set by the US EPA. The overall AED due to inhalation of Radon in the water sources is found to be higher than the permissible limit of 0.1-0.2mSv/year set by WHO.

Therefore, the inhabitants of the Nasarawa local government area are not safe from radiological health-related effects that may result from the inhalation of radon gas. As for ingestion, the results show that both adults, Children, and infants are not safe from radiological health risk. Consumption of water from the Study Area over a prolonged period of time is not completely safe and may result in radiological health hazards.

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