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Assessment of Radon-222 Concentration in Ground Water from Dogarawa, Zaria, Kaduna State, Nigeria

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Abstract
Water is an essential component of life but unfortunately most people especially in rural settings don't have knowledge of the radiological purity of the water they utilize. This research aims to characterize the ground water of Dogarawa for the presence of Radon-222 using Sodium Iodide (NaI) scintillation detector. Thirty (30) samples of ground water (well and borehole) were collected and analyzed for radon concentration using Tri-carb 1000 TR liquid scintillation analyzer. The Annual Effective Dose (AED) and Excess Life time Cancer Risk (ELCR) to the people in the community were calculated. It was found that the mean Radon Concentration of the ground water analyzed was 27.19 BqL^{-1}. The mean Annual Effective Dose (AED) to infants, children and adults due to this concentration was found to be 0.3473, 0.2977 and 0.1984 mSvy^{-1} respectively. Furthermore, the resulting Excess Life time Cancer Risk (ELCR) to infants, children and adults was found to be 0.000955, 0.000819 and 0.000546 respectively. These results showed that the ground water utilized by people of Dogarawa is radiologically safe according to the guidelines on radiological safety parameters provided by some internationally recognized agencies/organizations. However, relative to some other guidelines, caution and action should be taken to reduce the radon concentration of the ground water. As such more research, using different methods should be carried out on the ground water of Dogarawa while the population is also enlightened on the dangers of the radioactive contamination of water and ways to mitigate it.

Keywords: Radon, radiation, Annual Effective Dose, Excess Lifetime Cancer Risk, Ground water

INTRODUCTION
Radiation is all over us. It is part and parcel of human life and has two main sources viz: natural sources and artificial sources. Our earth has been radioactive. Elements like, radium, radon and uranium have been in existence in different components of our environment (Kakati *et al*., 2014). Alpha particles, beta particles and gamma radiation are all types of radiation which come from radioactive substances. The intake of such into the body leads to internal contamination. Tissues and organs in our body come in contact with radiation through inhalation or ingestion and the most damage occurs in tissues which replicate fast (Abdulkarim *et al*., 2018).

Water containing radioactive elements is detrimental to man's health because it may lead to cancer. This danger depends on the nature of the radioactive contaminant, the contamination level, and the extent of its spread in the body. Waste materials when dumped in sites without proper soil protection measures create health hazards in the environment and especially when

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drinking water gets contaminated as a result. As mentioned earlier, alpha and beta particles as well as gamma photons from such water gradually makes living tissues prone to radiation exposure (Ogundare & Adekoya, 2015). According to literature, radionuclides in varying concentrations can be found in our water bodies. (Achuka *et al*., 2017).

Not all forms and levels of radiation are harmful. In fact, radiation has a number of benefits that can be found in medical, industrial and even domestic applications. It is although harmful to human life when its level exceeds some permissible levels in the human body. Radiation gets into the human body through three ways: ingestion (of food or water), inhalation or through dermal contact with the skin. Water is key to human life especially for its domestic uses in our homes. As water, which is well known as being consumed on a daily basis easily transports pollutants, its purity in terms of radioactive content is important and has received very much attention worldwide (Alomari *et al.*, 2019).

Unfortunately, not all people have access to 'safe drinking water' - safe in this context goes beyond its color, odor or taste because radionuclides in water are not discernible to the human sense organs. The presence of radionuclides in water is only detected through specific scientific investigations. Throughout history, groundwater has been in use, but then also its demand and consumption in the society and resultantly its contamination have exponentially increased over the past century (Brands *et al*., 2016). Albeit apparently abundant, clean water is among the most rare elements in our world (Audu, 2007**)**. Just 3 percent of supplied water in our world is in fresh or portable form and 77 percent of that (freshwater) is frozen (Alausa *et al*., 2017).

In most rural communities, drinking water is sourced from ground water, which is accessed through dug wells and drilled bore holes. Large majority of the world's population survives on groundwater (Dankawu *et al*., 2021). As there is no adequate distribution of potable water, majority of Nigerians utilize groundwater as the basic source of their drinking water. Infact, 60% of drinking water used by the Nigerian population is from ground water. In most villages, residents fetch drinking water directly from hand-dug wells (Ajiboye *et al*., 2022). Threats of significant importance to the quantity of groundwater available, the effects of which are a concern to policy makers and planners include the following: exploration and extraction of fossil fuels, natural contaminants such as radium and arsenic, climate change, underground storage tanks, industrial contaminants, agriculture as well as pollution (Brands *et al*., 2016).

The pathways through which radon in ground water poses a radiological hazard to the human body when ingested are basically two. The first is gastrointestinal exposure which is a threat capable of causing stomach cancer and the second is respiratory tract exposure due to inhaling radon after its escape from water to air. It has been established that the detrimental effect of this can cause cancer of the lungs (Ajiboye *et al*., 2022).Ground water even though an indispensable resource is considered as the second smallest among the four major pools of water available on earth. Moreover, of all the components of the earth's hydrologic system, surface water and ground water are the ones in most use by humans. Therefore, ensuring that ground water is safe for human consumption is necessary (Achuka *et al*., 2017).

Dogarawa is a rural setting in Zaria, Kaduna State which is well known for farming practices. There are also some industries located near it. As such, this research seeks to analyze the ground water used by this community to ascertain its safety or otherwise in terms of the presence of the radioactive element, Radon, which is a source of radiation that can in turn be harmful to the people utilizing it in this community.

This research is novel in the sense that no similar work in the study area was found in the literature studied. It is however suggested that later researches in the studied area include PH test of samples. Also, similar researches should be extended to places neighbouring Dogarawa as there is possibility that the source of contaminants is coming from them.

MATERALS AND METHODS

Materials

The following materials were used in this research: -
Thirty (30) 0.5L Polypropylene bottles, Masking tape, Pen, FLO-SCINT A scintillation cocktail and Tri-carb 1000 Liquid Scintillation Analyzer (Serial No: 40067).

Study Area

Dogarawa is a locality in Zaria, Kaduna State of Nigeria situated north of Sakadadi. It lies in the latitude 11°11'49.7'' north and a longitude of 7°43'58.4'' east. The people of this community are well known for farming activities due to availability of farm lands in the area.

Methods

The stratified sampling technique was used. Dogarawa community was divided into fifteen strata. The strata was sparsely grouped in such a way that the whole community is adequately represented. Each stratum represented a significant part of the population. From each of these stratum, two samples of ground water were collected; one from a bore hole source and another from a well water source. A total of thirty (30) samples were collected (16 from well sources and 14 from borehole sources).

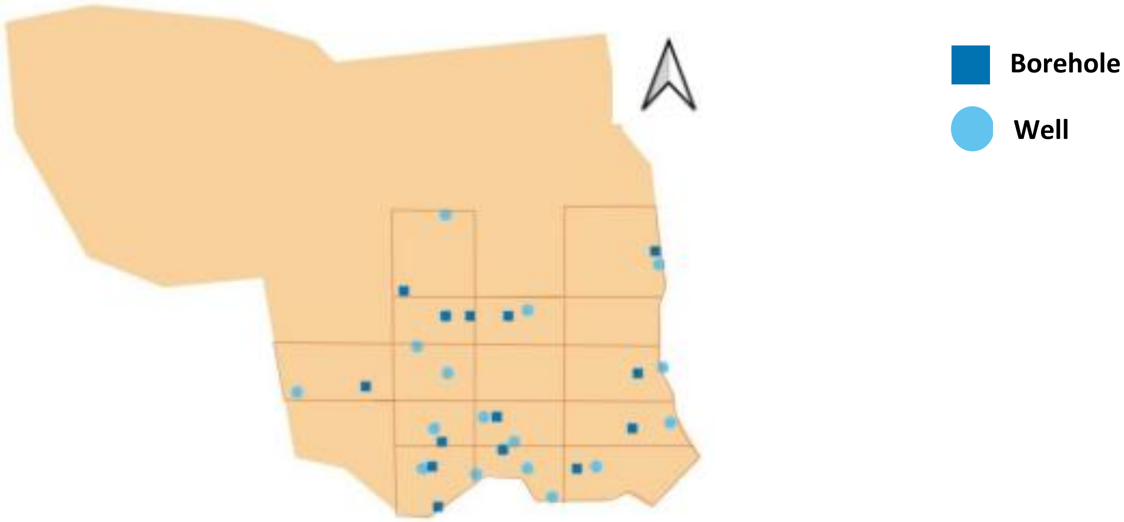

Figure 1: Stratified map of Dogarawa (11°11'49.7''N, 7°43'58.4''E) showing the sample locations

Sampling and Sample Preparation

Thirty (30) water samples were randomly collected from wells and boreholes in twenty mils (20ml) polypropylene bottles and labeled with the code D1a, D1b, D2a, D2b, etc. The labels with 'a' represent well water samples while the labels with 'b' represent bore hole water samples. Care was taken to rinse the bottles with the sample water before sampling. Upon fetching the water, the bottles were capped and properly tightened. The samples were then taken to the Centre for Energy Research and Technology (CERT), Zaria for analysis using Liquid Scintillation Counting (LSC).

Sample Analysis

Determination of Radon Concentration, Annual Effective Dose and Excess Lifetime Cancer Risk

Radon concentration in the water samples was determined using the equation described by Bello, 2019 as follows:

$$R_c = \frac{100 \times (Ns - Nb) \exp \lambda t}{60 \times 5 \times 0.964} \quad (1)$$

where R_c = Radon concentration (BqL^{-1}); N_s = total count rate of the sample with unit of count $min.^{-1}$; N_b = count rate of background with unit of count min^{-1}; t = the time taken between collection of samples and counting them; λ = radon decay factor, 2.11×10^{-6} (sec^{-1}); 100 is used in conversion from per 10 ml to per liter (l^{-1}); 60 is used in conversion from min to sec; 5 (500%) is the number of emissions per disintegration of radon which is 3 α and 2 β, assuming 100% detection efficiency for each and 0.964 = the fraction of radon in the cocktail in a vial of 22 ml capacity, based on the assumption that it contains 10 ml cocktail, 10 ml water and 2 ml air.

Using the obtained radon concentration of the water samples, the Annual Effective Dose (AED) was calculated using the formulae described by Dankawu *et al*. (2021) as follows:

$$AED = R_c \times K \times G \times 1000 \quad (2)$$

Where AED is the Annual Effective Dose ($mSvY^{-1}$); R_c = the radon concentration;
K = the dose coefficient (given respectively for infants, children and adults as 7×10^{-8}, 2×10^{-8}, and 10^{-8}); G = the water ingestion rate given respectively for infants, children and adults as 182.5 LY^{-1}, 547.5 LY^{-1} and 730LY^{-1} and 1000 is the conversion coefficient from Sv to mSv.

The Excess Lifetime Cancer Risks (ELCR) was further calculated using the equation described by Dankawu *et al*. (2021) as follows:

$$ELCR = AED \times DL \times RF \quad (3)$$

Where AED is the annual effective dose ($mSvY^{-1}$); DL = life expectancy which is 55.02 years and RF, the fatal risk factor per Sievert. In case of stochastic effects, ICRP-60 uses 0.05 as RF value for the public.

RESULTS AND DISCUSSION

Results

Using equation 1, Table 1 shows the radon concentration of the samples analyzed using the Tricarb 1000 liquid scintillation counter.

Table 1: Radon concentration of the samples

S / N	Sample ID	Location	^{222}Rn Conc. (BqL^{-1})
1	D1a	Sabon Fegi	12.16646
2	D1b		98.27102
3	D2a	Unguwar Malam Barau	14.72323
4	D2b		46.23026
5	D3a	Layin Sarki	9.371049
6	D3b		33.81683
7	D4a	Bayan Makabarta	6.970832
8	D4b		16.86692
9	D5a		21.53074

10	D5b	Kasan Gada	23.61079
11	D6a	Layin Sardauna	25.46799
12	D6b*		26.38414
13	D7a	Layin Markaz	25.57753
14	D7b		35.39627
15	D8a	Unguwar - Yarabawa	57.60794
16	D8b		49.12857
17	D9a	New Layout	27.92616
18	D9b		24.1023
19	D10a	Kwantaresha	18.03422
20	D10b		58.9722
21	D11a	Layin Barazana	47.1009
22	D11b		23.9638
23	D12a	Unguwar Nomi	9.722116
24	D12b		5.83327
25	D13a	Bagadaza	14.21748
26	D13b		28.09602
27	D14a	Primary	12.70119
28	D14b		14.64179
29	D15a	Kasan Waya	16.31146
30	D15b		10.78868
	Mean		**27.1844**

* - means no borehole water source in the area

It can be observed that borehole water sources tend to have higher concentrations of radon than well water sources. This can be attributed to the fact that well water sources receive more disturbance than borehole water sources and as such it is easier for the radon gas to escape. Escape of radon can also be said to be more probable in well water sources because they are mostly uncovered.

Using equation 2, Table 2 shows the resulting Annual Effective Dose (AED) to infants, children and adults due to the radon concentrations obtained.

Table 2: Annual Effective Dose to infants, children and adults

S / N	Sample ID	AED ($mSvy^{-1}$)		
		Infants	**Children**	**Adults**
1	D1a	0.155426	0.133223	0.088815
2	D1b	1.255412	1.076068	0.717378
3	D2a	0.188089	0.161219	0.10748
4	D2b	0.590592	0.506221	0.337481
5	D3a	0.119715	0.102613	0.068409
6	D3b	0.43201	0.370294	0.246863
7	D4a	0.089052	0.076331	0.050887

8	D4b	0.215475	0.184693	0.123129
9	D5a	0.275055	0.235762	0.157174
10	D5b	0.301628	0.258538	0.172359
11	D6a	0.325354	0.278874	0.185916
12	D6b*	0.337057	0.288906	0.192604
13	D7a	0.326753	0.280074	0.186716
14	D7b	0.452187	0.387589	0.258393
15	D8a	0.735941	0.630807	0.420538
16	D8b	0.627617	0.537958	0.358639
17	D9a	0.356757	0.305791	0.203861
18	D9b	0.307907	0.26392	0.175947
19	D10a	0.230387	0.197475	0.13165
20	D10b	0.75337	0.645746	0.430497
21	D11a	0.601714	0.515755	0.343837
22	D11b	0.306138	0.262404	0.174936
23	D12a	0.1242	0.106457	0.070971
24	D12b	0.07452	0.063874	0.042583
25	D13a	0.181628	0.155681	0.103788
26	D13b	0.358927	0.307651	0.205101
27	D14a	0.162258	0.139078	0.092719
28	D14b	0.187049	0.160328	0.106885
29	D15a	0.208379	0.178611	0.119074
30	D15b	0.137825	0.118136	0.078757
	Mean	**0.347281**	**0.297669**	**0.198446**

Mean AED to infants can be seen to be higher than that to children which is in turn higher than that to adults. This may be due to the biological complexities of the categories relative to each other.

The Excess Lifetime Cancer Risk (ELCR) to infants, children and adults using equation 3 is given in Table 3.

Table 3: Excess Lifetime Cancer Risk to Infants, Children and Adults

S/N	Sample ID	ELCR		
		Infants	**Children**	**Adults**
1	D1a	0.000428	0.000366	0.000244
2	D1b	0.003454	0.00296	0.001974
3	D2a	0.000517	0.000444	0.000296
4	D2b	0.001625	0.001393	0.000928
5	D3a	0.000329	0.000282	0.000188
6	D3b	0.001188	0.001019	0.000679
7	D4a	0.000245	0.00021	0.00014

8	D4b	0.000593	0.000508	0.000339
9	D5a	0.000757	0.000649	0.000432
10	D5b	0.00083	0.000711	0.000474
11	D6a	0.000895	0.000767	0.000511
12	D6b*	0.000927	0.000795	0.00053
13	D7a	0.000899	0.00077	0.000514
14	D7b	0.001244	0.001066	0.000711
15	D8a	0.002025	0.001735	0.001157
16	D8b	0.001727	0.00148	0.000987
17	D9a	0.000981	0.000841	0.000561
18	D9b	0.000847	0.000726	0.000484
19	D10a	0.000634	0.000543	0.000362
20	D10b	0.002073	0.001776	0.001184
21	D11a	0.001655	0.001419	0.000946
22	D11b	0.000842	0.000722	0.000481
23	D12a	0.000342	0.000293	0.000195
24	D12b	0.000205	0.000176	0.000117
25	D13a	0.0005	0.000428	0.000286
26	D13b	0.000987	0.000846	0.000564
27	D14a	0.000446	0.000383	0.000255
28	D14b	0.000515	0.000441	0.000294
29	D15a	0.000573	0.000491	0.000328
30	D15b	0.000379	0.000325	0.000217
	Mean	**0.000955**	**0.000819**	**0.000546**

Resultant from AED, it can also be observed that the ELCR to infants is higher than that to children which is in turn higher than that to adults.

Discussion

The mean value for radon concentration in the groundwater of Dogarawa community has been found as 27.1844 BqL^{-1}. This value is greater than twice the maximum permissible limits recommended by USEPA and WHO, 11.1 BqL^{-1} and 10 BqL^{-1} respectively as reported by Bello (2019) but below the Maximum Contaminant Level of 100 BqL$^{=1}$ set by the European commission as reported by Dankawu *et al*. (2021).

The relatively high level of radon concentration can be well attributed to the fact that the community is well known for intensive farming activities especially in the past. During those farming practices, agricultural chemicals, including pesticides, herbicides and fertilizers used could have contained radioactive elements which accumulated with time in the ground water, leading to its contamination.

Findings from this study have revealed that the mean Annual Effective Dose to infants, children and adults respectively were found to be 0.3473, 0.2977 and 0.1984 mSvy^{-1}

respectively. These values exceed the WHO, UNSCEAR and EU permissible limits of 0.1 and 0.2 $mSvy^{-1}$ for adults and children respectively as reported by Dankawu *et al*. (2021) and Bello, 2019. This furthermore highlights the high concentration of radon present in the ground water of this community as stated above.

Findings from this study have found that the value for the Excess Life time Cancer Risk (ELCR) to infants, children and adults in the groundwater of Dogarawa community were found to be 0.000955 (≈ 9.6 E-4), 0.000819 (≈ 8.2 E-4) and 0.000546 (≈ 5.5 E-4) respectively. Explicitly, these values imply that about 10 people in every 10,000 infants, about 8 people in every 10,000 children and about 6 people in every 10,000 adults are likely to suffer from cancer in their lifetime. These values relative to the traditional range of 'acceptable risk' proposed by US EPA (1E-4 to 1E-6) can be said to be quite alarming. However, relative to some state water guidelines in New England States viz Massachusetts, Connecticut, Rhode Island, New Hampshire which have guidelines for lifetime cancer mortality risk of 7E-3, 3E-3, 3E-3, 1E-3 respectively (MCDCP, 2006), the ELCR values for Dogarawa community can be said to be quite 'safe'. Nevertheless, caution needs to be taken as the ELCR to infants especially is close to the guideline set for New Hampshire state. Also, compared with the world average value of 0.29 E-3 as reported by Divya and Prakash (2018), significant measures need to be taken toward reducing radon concentration in the groundwater used by this community.

CONCLUSION

Compared to some internationally accepted levels of radiological risk, it can be said that the ground water of Dogarawa community is quite safe. But as no level of radioactive contamination is considered safe, measures should be taken towards mitigating radon concentration levels in the ground water of this community especially because relatively high levels have been detected in some areas (Sabon Fegi - 98.27102 BqL^{-1}, Unguwar Yarabawa - 57.60794 BqL^{-1}, Kwantaresha - 58.9722 BqL^{-1}).

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