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Radon assessment in ground water sources from Zaria and environs, Nigeria

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Groundwater (well and borehole) samples from various locations of Zaria and environs including Sabongari, Tudunwada, Danmagaji, Samaru and Bomo have been investigated for their ^{222}Rn concentrations by liquid scintillation counter. The concentration of ^{222}Rn in open well water was found to vary in the range (0.77-28.37) Bq/L and (2.32-48.80) Bq/L for borehole, with a geometric mean of 12.43 and 11.16Bq/L for borehole and well sources respectively. The results showed that ^{222}Rn concentration in borehole sources is higher than that of well water sources and were both greater than the maximum concentration limit (MCL) of 11.1Bq/L set by USEPA.

Key words: ^{222} Rn, groundwater, liquid scintillation counter.

INTRODUCTION

Water is the most abundant substance on earth, and it is the principal constituent of all living things. Man uses water for many purposes in areas such as power generation, agriculture and above all for domestic purposes. Water for human consumption should be free from chemical, microbiological and radiological contamination (Garba et al., 2008).

Natural sources contribute significant quantities of radiation toward the total radiation exposure that humans receive. Natural radiation account for the majority of human exposure to radiation with radon decay product being the largest contributor in spite of the increased use of manmade radiation in industries, medical centers and sceintific research establishments (Tso and Li, 1987).

The earth's crust contains trace amount of ^{238}U and ^{232}Th which decay to ^{222}Rn (radon) and ^{220}Rn (thoron gas), respectively (Tso and Li,1987). Most of the radon to which people are exposed emanates from soil and rock. The other sources of significance are building materials, potable water, and natural gas (UNSCEAR, 1993).

The link between residential radon and lung cancer among the general public is not unequivocal (Letourneau et al., 1994; Rousteenoja et al., 1996). However, in order to forestall risks of cancer among the general public, many national authorities and some international organizations (Ahmed, 1993; Colgan and Gutierrez, 1996) have already adopted reference levels for radon in air and water.

EXPERIMENTAL PROCEDURE

Sample collection and sampling sites

Forty four water samples were collected and analyzed for ^{222}Rn concentration from two different types of water sources namely; hand dug wells and hand pump operated boreholes randomly from Zaria metropolis, and environs, specifically Tudunwada, Danmagaji, Samaru and Bomo areas in Kaduna State, Nigeria (Figure 1a and b). The water samples from underground wells were collected with the aid of bailers, but the stagnant water in the wells was first purged by drawing it out and allowing the wells to refill. Several well volume purges were done to assure fresh samples were obtained while boreholes were operated for at least three minutes before sample collection. The samples were collected in a pre-cleaned plastic sample bottles and analyzed as soon as possible after collection, this was done so as to achieve maximum accuracy

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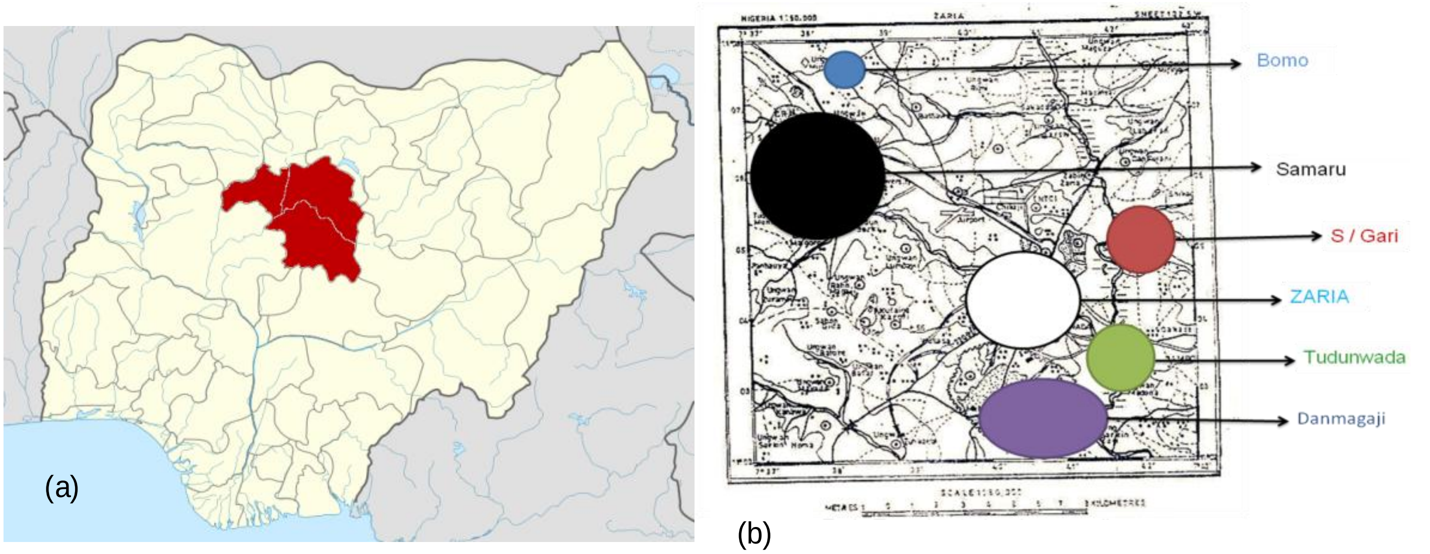

Figures 1(a and b). Geographical and Toposheet maps showing the location of Kaduna state, Nigeria and the sampling sites respectively.

because the composition of the sample may change if allowed to stay longer than 3 days before carrying out the analysis.

Materials

Below is the list of materials used in this research as described by the American Society for Testing and Materials ASTM (1999). Plastic sample bottles (100 ml) were used for sample collection.

1. Disposable hypodermic syringe (20, 10, and 2 ml capacity) with 38 mm (1in) hypodermic needle.
2. Surgical globe.
3. Water for injection and distill water.
4. Scintillation vial (20 ml capacity) with polyethylene inner seal cap liners.
5. Scintillation cocktail.
6. Indelible ink and masking tape.
7. Liquid scintillation counter (Packard Tri-Carb LSA 1000TR).

Sample preparation and analysis

10 ml each of the samples were added into a scintillation vial containing 10 ml of the insta-gel scintillation cocktail. Having been sealed tightly, the vials were then shaken for more than two minutes to extract ^{222}Rn in water phase into the organic scintillator (ASTM, 1999).

Sample analysis

The prepared samples were analysed using liquid scintillation counter (Tri-Carb-LSA1000) located at the Center for Energy Research and Training (CERT), Ahmadu Bello University, Zaria, Nigeria. The samples were analysed after they were allowed to stay for three hours after preparation, to allow for radioactive equilibrium between ^{222}Rn and its daughter progeny to be established.

Calibration of the liquid scintillation counter was made prior to the analysis using IAEA ^{226}Ra standard solution. For the calibration, the ^{226}Ra standard samples were counted for 60 min. For background, background count measurements were also made for same period (60 min). The ^{222}Rn activity concentration was calculated using the equation

$$\mathrm{Rn(BqL)} = \frac{100\times(\mathrm{SC}-\mathrm{BC})\exp(\lambda t)}{60(\mathrm{CF})\times(\mathrm{D})} \quad (1)$$

Where, Rn, Radon level in Bq/L; SC, sample count rate (count min^{-1}); BC, background count rate (Count min^{-1}); K, calibration value; T, elapsed time from sampling to testing given in minutes (ASTM, 1999).

RESULTS

As stated earlier, two categories of water samples from hand dug wells and boreholes were collected and analyzed. The underground wells were to the depth of about 3-8 m, while the boreholes were from 100-700 m below the surface. A total of forty four samples comprising twenty two each of underground wells and boreholes were analyzed by liquid scintillation counting analyzer respectively. Table 1 shows the coordinates and the result of ^{222}Rn concentration obtained for all water samples analyzed while Figure 2 report the results as well as shows the mean ^{222}Rn concentration (Bq/L) for wells from all the sampling areas while Figure 3 shows the results as well as shows the mean ^{222}Rn concentration (Bq/L) for boreholes from all the sampling areas.

Frequency distribution pattern for ^{222}Rn from wells in five community areas that comprised Zaria and environs in Kaduna State with a mean of 11.16 Bq/L.

Frequency distribution pattern for ^{222}Rn from wells in five community areas that comprised Zaria and environs in Kaduna State with a mean of 12.43 Bq/L.

Table 1. Coordinates and ^{222}Rn concentration in water samples from the sampling points.

S/N	Sample ID	Latitude	Longitude	^{222}Rn Conc. (Bq/L)	Standard deviation
1	BB1	11.07	7.37	10.73	3.28
2	BB2	11.12	7.38	28.37	5.33
3	BW1	11.11	7.38	26.73	5.17
4	BW2	11.16	7.63	6.99	2.64
5	BW3	11.17	7.60	4.67	2.16
6	DB1	11.05	7.41	11.14	3.34
7	DB2	11.09	7.71	10.72	3.27
8	DB3	11.08	7.69	27.05	5.20
9	DW1	11.02	7.71	4.39	2.10
10	DW2	11.09	7.71	16.29	4.04
11	DW3	11.05	7.41	48.80	6.99
12	DW4	11.09	7.71	6.69	2.59
13	DW5	11.05	7.42	5.62	2.37
14	SB1	11.74	7.23	20.03	4.48
15	SB2	11.54	7.11	21.73	4.66
16	SB3	11.07	7.42	6.11	2.47
17	SB4	11.08	7.40	5.67	2.38
18	SW1	11.08	7.40	4.25	2.06
19	SW2	11.08	7.40	6.60	2.57
20	SW3	11.16	7.63	9.35	3.06
21	SW4	11.51	7.65	9.20	3.03
22	SW5	11.14	7.69	43.61	6.60
23	TB1	11.05	7.43	7.09	2.66
24	TB2	11.06	7.44	13.26	3.64
25	TB3	11.05	7.43	3.63	1.91
26	TW1	11.08	7.77	4.35	2.09
27	TW2	11.07	7.43	2.60	1.61
28	TW3	11.05	7.43	2.67	1.63
29	TW4	11.06	7.43	3.87	1.97
30	ZB1	11.06	7.72	8.02	2.83
31	ZB2	11.03	7.43	4.07	2.02
32	ZB3	11.02	7.43	21.31	4.62
33	ZB4	11.03	7.42	3.05	1.75
34	ZB5	11.07	7.72	8.89	2.98
35	ZB6	11.07	7.69	15.63	3.95
36	ZB7	11.06	7.71	6.39	2.53
37	ZB8	11.02	7.42	3.11	1.76
38	ZB9	11.03	7.42	0.77	0.88
39	ZB10	11.04	7.43	2.90	1.70
40	ZW1	11.07	7.76	2.42	1.56
41	ZW2	11.03	7.42	8.13	2.85
42	ZW3	11.06	7.69	6.43	2.54
43	ZW4	11.03	7.42	2.32	1.52
44	ZW5	11.03	7.42	16.60	4.07

DISCUSSION

^{222}Rn concentration in water depends much on the source of radon emanation which may likely be as a result of natural processes or industrial activities and other human activities in the area where the wells are

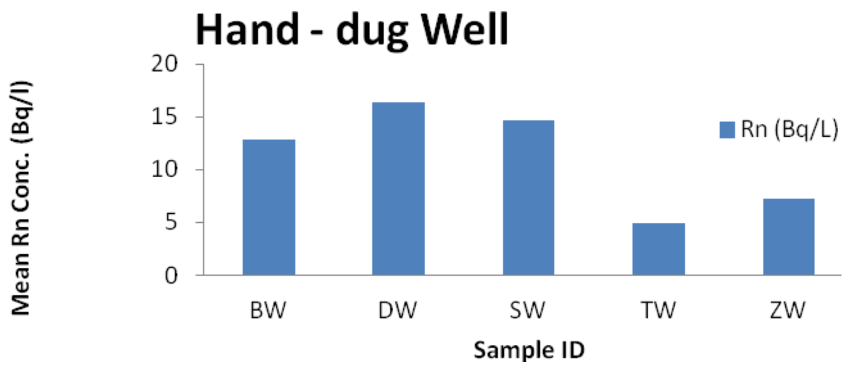

Figure 2. Mean ^{222}Rn concentration obtained from hand-dug well water sources.

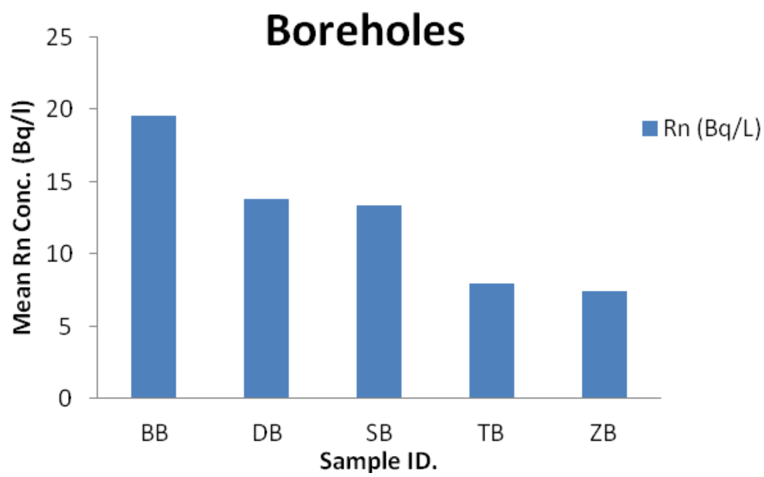

Figure 3. Mean ^{222}Rn concentration obtained from borehole water sources.

located. Different works have been reported by many researchers on ^{222}Rn concentration in wells and boreholes water. Zhou et al. (2001) used Radon (Rn) bubbler and α scintillation cell method described by Yang et al. (1988) to study radon in ground water samples collected from Fujian Province in which they found that the radon concentration has exceeded the maximum contaminant level (MCL) of 11.1 BqL^{-1} for drinking water set by USEPA (1991). In Zaria, radon concentration in borehole water was determined and the results obtained showed that the concentration of radon is lower than the maximum contamination level MCL value suggested by USEPA reported by Khalip (2009) and Lawal (2008).

From the forgoing, it can be stated that high radon concentration in groundwater is highly dependent on the type of geologic rock aquifers (Cho et al., 2004). Result from this study showed that the mean ^{222}Rn concentration in both wells and borehole were slightly higher than the maximum concentration limit of 11.1 Bq/L and world average value of 10 Bq/L for drinking water (Mustapha et al., 2002) and this may be attributed to the fact that radon readily dissolves in water under pressure which lead to the radon accumulation in groundwater (Cho et al., 2004). High concentration of ^{222}Rn has been of great concern about its health effects. Therefore, either drinking groundwater or bathing can give rise to exposure of humans to its radiation and may result in cancer and even death in extreme saturation (USEPA, 1999). Cothern (1990) showed that approximately 1-7% of lung cancer fatalities in the USA are due to indoor radon levels arising from groundwater. This may be due to the wide distribution of its daughter products in the environment, soils and the natural water (Garba et al., 2008; Mustapha et al., 2002). The high ^{222}Rn concentration may be as a result of ^{222}Rn release from the surrounding geological formation.

Concern for exposure to radiation from ^{222}Rn sources has necessitated studies to reduce/mitigate the dangers. International organizations have established recommended limits for ^{222}Rn concentration in water but

Nigeria has not introduced any legal regulation concerning permissible radon concentration in water yet; therefore, there is need for radon concentration in water to be investigated thoroughly so that guidelines for regulations on the radon concentrations in Nigeria may be established.

Conclusion

^{222}Rn concentration in groundwater sources from Zaria and its environs in Northern Nigeria have been determined. Data obtained from the study found 16.36 and 12.43Bq/L as the mean ^{222}Rn concentrations for both wells and boreholes respectively which was slightly higher than the maximum concentration limit of 11.1 Bq/L set by USEPA (1991) and world average value of 10 Bq/L set by World Health Organization (WHO, 1996; NSCEAR, 1993). This study also recommended the Government of establishing limits for radon in drinking water to guide regulatory functions.

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