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Research Article

Determination of Natural Radionuclides Concentrations in Portable Water Supply of Northern Part of Kaduna State

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Abstract: In order to determine the natural radionuclides in portable water, samples were collected from fifty locations in Northern part of Kaduna state and were subjected to the investigation of the presence of naturally occurring radionuclides. The radionuclides investigated are potassium-40, uranium-238 and thorium-232 using sodium iodide detector (NaI (Ti)). Results showed that potassium-40 concentration in the water samples has minimum and maximum concentration as 0.124 and 0.849 Bq/L, respectively. The mean value of potassium-40 concentration found in water is 0.416 Bq/L. Also, uranium-238 and thorium-232 investigated in the samples gave mean concentration of 0.0011 and 0.00006 Bq/L, respectively. The results obtained from these analysis shows that samples have radionuclides activity concentration below the recommended value for the radionuclides.

Keywords: Activity concentration, guideline value, limit, radionuclide, uranium

INTRODUCTION

The naturally occurring radionuclides originate in the Earth's crust where uranium, thorium and potassium are widely distributed and detectable in all soils and rock. These parent nuclides are radioactive and each decays through a series of radionuclides to a stable isotopes. Measurements of natural radioactivity in drinking water have been ongoing in many parts of the world, mostly for the assessment of the risk resulting from water consumption (Onoja, 2011). Research has shown that Zaria is in the North-Western part of Nigeria which is on the base complex and most of its soils are granite this can lead to high concentration of potassium. With increase number of cancer patients and other related diseases in Nigeria today there hadn't been a clear fact as to their course. Hence, there is the need to investigate and see if there is a link from water consumption due to the presence of these radionuclides since different sicknesses have been associated with drinking water containing high concentration of radionuclides (EFS (Environmental Fact Sheet), 2004). Radionuclides dissolve easily in water. In some well water the concentration of these minerals exceed the concentration established in public drinking water standards (Wisser *et al*., 2003). The standards for the permissible amount of radioactivity in drinking water are called Maximum Contaminant Levels (MCLs). Bedrock wells (also called artesian or drilled) can contain elevated concentrations of any or all of these radionuclides, even if nearby bedrock wells have low concentrations (Othman and Yassin, 1996). Wells that derive water from sand and gravel deposits, also known as dug or point wells, generally have substantially lower concentrations of both radon gas and dissolved mineral radioactivity (EFS (Environmental Fact Sheet), 2004). The guideline levels for individual radionuclides content in drinking water are given in World Health Organization (WHO) water quality guideline 2008. These guideline levels of radionuclides in drinking water were calculated according to WHO and International Atomic Energy Agency (IAEA) guides on the basis of an annual dose criterion of 0.1 mSv/year from drinking 2 liters of water per day. Equation (1) is the formula for calculating these guideline values. (WHO, 2003):

$$GL = \frac{IDC}{h_{ing.} q} \quad \text{(FPTCHE, 2008)} \tag{1}$$

where,
GL = (Bq/mL) guideline value of radionuclide in drinking water
IDC = (mSv/year) individual dose criterion equal to 0.1 mSv/year for this calculation
h_{ing} = (mSv/Bq) dose coefficient for ingestion by adult
q = (L/year) annual ingested volume of drinking water assumed to be 730 L/year

The objective of the study is to quantify the concentration of natural radionuclides in drinking water from bore holes. These radionuclides are uranium, thorium and potassium. The research area of interest is taken from Zaria topographical sheet 21 of 1:250,000. This area is bounded between longitude 10° 41'26.1"-

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11° 20’11.5” and latitude 07° 12’49.2”-08°11’29.9”. Investigation of total alpha and beta particles has been carried out in these areas along with measurement of some physical parameters.

MATERIALS AND METHODS

A total of 50 water samples from bore hole were collected within Northern Kaduna in Nigeria 200 mL each of the samples was transferred into a 6.5 cm height plastic container. The samples in the containers were air tight and kept for one month to attain equilibrium. The natural radionuclides activity concentration of the samples was obtained using relative method. Also standard of natural origin were prepared in the same manner as the samples, these standards are uranyl nitrate (UO_3 $(NO_3)_2$ $6H_2O$) 502.18 mol/g, potassium chloride (Kcl) 74.55 mol/g and thorium nitrate (Th $(NO_3)_4$ $.5H_2O$) 570.13 mol/g. One gram of each of the standard was taken and dissolved into a 200 mL distilled water to form a standard solution. It is subtle that 1 g of uranyl nitrate contains 0.474 g of uranium which has activity of 0.0294 Bq/L, also 1 g of potassium chloride contains 0.534 g of potassium which has activity of 0.706 Bq/L and 1g of thorium nitrate contains 0.859 g of thorium with activity of 0.0175 Bq/L. The standard solution was kept to equilibrate before counting using NaI (Ti) detector with dimension 7.62×7.62 cm.

The detector is connected to an Ortec unit consisting of amplifier, high voltage power supply and a NIMBIM and a computer system coupled with maestro software for data acquisition and analysis of gamma spectra in samples. The peak energy of 1764 KeV gamma-line of Bi-214 is used to estimate the activity concentration of uranium in samples. Also, the energy of 2614.5 KeV gamma-line of Tl-208 is used to estimate the activity concentration of thorium in the samples. The single energy of 1460 Kev gamma-line of potassium-40 gives the direct activity concentration measurement of potassium-40. The operational high voltage was set at 900v, Preset time 29,000 sec., ADC setup at 1024 and Micro ace amplifier gain 15.002. The detector was calibrated with cesium-137 and cobalt-60 sources and the energy resolution is 39.5 and 22.2%, respectively. The configuration and geometry was maintained throughout the analysis. The individual radionuclide concentration calculated using relative method as in Eq. (2):

$$\frac{activity\ of\ U_1}{activity\ of\ S_1} = \frac{\sum U_1 - \sum b}{\sum S_1 - \sum b} \qquad (Onoja, 2011) \qquad (2)$$

where,

U1 = The unknown sample activity concentration in the unit of Bq/L
S1 = Activity of the standard source
∑U1 = Sum under the peak of U1 in cps
∑S1 = The sum under the peak S1 in cps

Table 1: Showing concentration of radionuclides in samples collected within Zaria

S/ID	Sample location	Concentration of radionuclide (Bq/L) Uranium -238	Thorioum -232	Potassium -40
R01	Kaya	0.000945	BDL	0.2751
R02	Gangara	0.002723	BDL	0.2746
R03	Yelwa	BDL	0.000018	0.1713
R04	Danmahawayi	0.001922	0.000005	0.1575
R05	Hunkuyi	0.001195	0.000064	0.5895
R06	Gwibi	0.001053	0.000025	0.3038
R07	Idasu	0.000265	0.000360	0.3543
R08	Anguwan Mataha Madaki	0.000499	0.000001	0.4975
R09	Anguwan Danyaya	0.001237	BDL	0.5266
R10	Kudan	0.002385	BDL	0.2452
R11	Samaru	0.000836	0.000044	0.4127
R12	Likoro	0.000357	0.000007	0.3799
R13	Kuzai	0.001426	BDL	0.2856
R14	Recifa	0.000703	0.000011	0.3590
R15	F.G.G.C. Zaria	0.001260	0.000035	0.6179
R16	Patika	0.002266	0.000043	0.2715
R17	Bomo	0.000496	BDL	0.4039
R18	Kakangi	0.001579	BDL	0.2803
R19	Karau-Karau	0.001006	0.000021	0.4972
R20	Kanawa	BDL	0.000019	0.3275
R21	Hanwa	BDL	0.000027	0.3815
R22	Bagaldi	BDL	BDL	0.5809
R23	Tukun	0.000733	BDL	0.3482
R24	Turawa	0.000496	BDL	0.5022
R25	Turanwan Giwa	BDL	0.000038	0.2759
R26	Giwa town	BDL	BDL	0.4879
R27	Zabi	0.000011	0.000241	0.7146
R28	Wazata	BDL	BDL	0.5657
R29	Hayin Liman	BDL	BDL	0.1948
R30	Kofar Gayan (Zaria city)	0.001406	0.000055	0.3880
R31	Aba	0.000659	0.000101	0.5745
R32	Yakasai	0.001735	BDL	0.4337
R33	Maigana	BDL	0.000054	0.1237
R34	Soba	BDL	0.000070	0.6356
R35	Shika	0.000893	BDL	0.3212
R36	Marmara	0.000081	0.000016	0.6265
R37	Kinkiba	0.001138	BDL	0.5389
R38	Yakawada	0.001165	BDL	0.4775
R39	Sharifai	BDL	0.000016	0.2387
R40	Danwata	0.002431	0.000005	0.7077
R41	Chikagi	0.000508	BDL	0.1394
R42	Danjaba	0.002682	0.000023	0.5854
R43	Garun Gwanki	0.001012	BDL	0.6115
R44	Dogarawa	0.001290	0.000065	0.3846
R45	Gamagira	BDL	0.000251	0.8489
R46	Gurbabiya	0.000662	0.000029	0.5108
R47	Gwanda	BDL	BDL	0.4274
R48	Hayimallam	0.001148	BDL	0.4114
R49	Unguwan Dafulani	0.000224	BDL	0.2816
R50	Zango	0.000981	0.000030	0.2723

RESULTS AND DISCUSSION

Table 1 shows the results of activity concentration of natural radionuclides in potable water from borehole water supply system. These radionulides are uranium-238, thorium-232 and potassium-40. The average activity concentration of uranium, thorium and potassium was found to be 0.000833, 0.00005039 and 0.4191 Bq/L, respectively. The minimum and maximum values for these radionuclides were 0.003 and 0.000011 Bq/L for Uranium-238, 0.00038 and 0.000001 Bq/L for Thorium-232 and 0.419 and 0.124 Bq/L for potassium-40, respectively. Results show that out of the 50 sample analyzed, 100% of the sample has traceable amount of potassium-40 activity concentrations in the samples, 44% of the sample has thorium-232 activity concentration while 26% of the

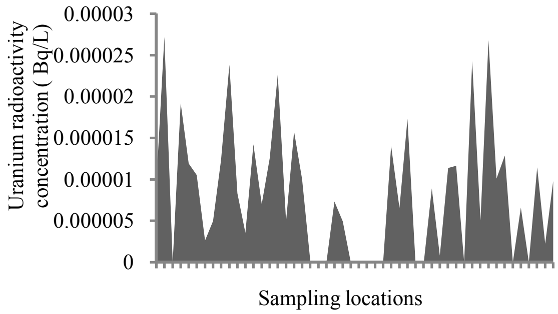

Fig. 1: Is an area plot uranium-238 concentrations against sampling locations

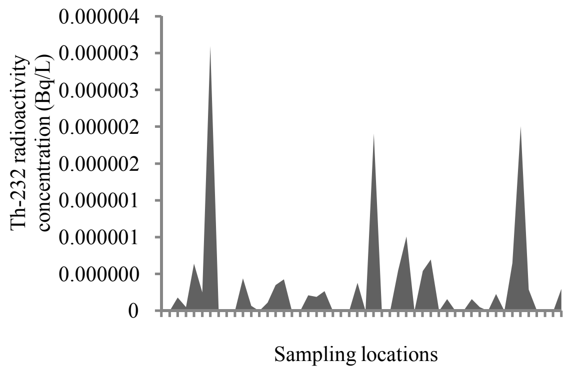

Fig. 2: Is an area plot thorium-232 concentrations against sampling locations

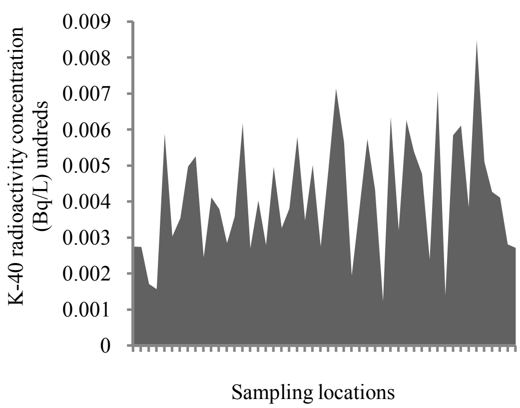

Fig. 3: Is an area plot potassium-40 concentrations against sampling locations

sample has uranium-238 concentration. However 40% of the total sample contains these three radionuclides in appreciable level of concentrations.

From this study it was observed that the radionuclide activity concentrations discovered were below the standard set by the Environmental Protection Agency. The range of thorium in natural water is set at 1.0-10 mBq/L whish is extremely low, uranium set range is 10-100 mBq/L although higher concentration above 100 mBq/L have been observed in areas with uraniferous granitic intrusions. The new drinking water regulation being proposed by the Environmental Protection Agency does not include a listing for K-40 but specifies that the maximum allowable Concentrations limit for beta and photon emitters should correspond to a committed effective dose equivalent of 4 mrem/a from annual intake at the rate of two litters of drinking water per day. Figure 1 to 3 is plot of the activity concentration against sampling locations. Examination of these figures shows that the potassium activity concentrations are widely spread and the concentration is densely distributed in the sampling location. Followed in the same pattern of distribution, is the distribution of the uranium concentration. Thorium-232 with least concentrations has the least spread distribution in these locations. This agrees with the fact that generally thorium concentration in water is in a very low concentration level.

CONCLUSION

The high concentration observed in the spread of potassium-40 in the water samples could be due to the enhancement of natural potassium on land as a result of mans' activities such as fertilizer and manure application on farm land, as well as drop-out from animals. These during raining season are washed into water bodies or leached into the soil. Samples which activity concentrations are not detected are reported as Below Detection Limit (BDL).

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