ISSN (Print): 2476-8316
ISSN (Online): 2635-3490
Dutse Journal of Pure and Applied Sciences (DUJOPAS), *Vol. 6 No. 2 June 2020*

Evaluation of Radon Concentration and Annual Effective Dose in Sachet Drinking water in Damaturu, Yobe State, Nigeria

[1]Habu Tela Abba*, [2]Dahiru Umaru

[1,2]Department of Physics,
Yobe State University,
Damaturu, Nigeria.

Email: htelaabba@gmail.com

Abstract
Radon has been one of the most leading causes of kidney cancer globally. In this study, samples of sachet drinking water consume in Damaturu metropolis have been collected and measured for radon concentration. The measured radon concentration varies from 4.42±0.25 Bq L^{-1}in W_5 (Uspy) to 20.21±2.73 Bq L^{-1} in W_{30}(Boloram). Annual effective dose due to ingestion ranged from 0.023 to 0.148 mSv for adults and from 0.046 to 0.295 mSv for children. In general, fifteen (15) out of thirty (30) samples have radon concentration values greater than recommended limits set by USEPA and WHO. The results revealed that, concentrations of radon were observed to be higher in areas where the basement complex is thinly covered by the chad formation. Thus, the findings of this study suggest boiling and exposing ground water in air for some time before using it for drinking to reduce radon concentration level in drinking water as well as reducing the health risk towards the public.

Keywords: Radon concentration, Sachet water, Annual effective dose, Damaturu.

INTRODUCTION

Water is one of the most important naturally occurring resources and vital for human and non-human survival. It constitutes majority (70%) of our body weight with number of essential functions in the body such as metabolizing and transporting the food we eat(Yusof et al., 2001). Commercial sachet water has become one of the main drinking water sources, especially in developing countries, but an increasing trend of its consumption is also visible in Nigeria, of which Yobe state is not exceptional. High demand of drinking water in the city due to growth in population has led to many brands of sachet water available for sale. Human beings are constantly exposed to radiation externally and internally from natural sources in the environment through inhalation and ingestion by food and consumption of water (UNSCEAR, 2000). It is known that, groundwater contains natural occurring radionuclides materials (NORMs) in varying concentration depending on the mineralogical and geochemical composition of the rock formation bearing the aquifer (Abba et al., 2018; Langmuir, 1978). The main contributors to radiation dose in water are largely due to uranium and thorium decay chains which are present in the Earth's crust which are leached down to groundwater. Groundwater from wells and boreholes usually contains higher

**Author for Correspondence*

radon concentrations than surface waters. In some extreme circumstances, very high radon concentrations can be found in drinking-water supplies from these sources(WHO, 2017). Among the NORMs, ^{238}U is the most commonly occurring radioisotopes in groundwater which is found to be in secular equilibrium with radium,^{226}Ra, unless if the ratio is altered by environmental and geological factors(Abba et al., 2018; Cline et al., 1983). Ground water obtained from very deep aquifers were reported to usually show higher loads of natural radionuclides compared to surface water and water from shallower wells(Rožmarić et al., 2012). These radionuclides are referred to as natural radiation sources and they get into the human body through many pathways such as inhalation of radon gas, ingestion of food and drinking water. Drinking water that are obtained from drilled rocks in the region of acidic rock formations such as granites, syenites, pegmatite, acid volcanic rocks and gneisses may have uranium concentration greater than 5 ppm and radon concentration of 50–500 Bq/l or considerably higher (Garba, 2011; IAEA, 2001).

If radon, the heaviest radioactive noble gas, gets into the body, it continues to decay by emitting high energy radiation known alpha particle (α) predominantly, because of this, there is concern for damage of our body critical component (DNA) if the alpha particle is in contact with the cells, for instance, through the ingestion of water(Kandari et al., 2016). The damage may be sufficiently severe to cause cancer and possibly as developmental malformations in children and developing foetus(Maxwell et al., 2015). Radon has been the number one cause of lung cancer among non-smokers and is also responsible for about 21,000 lung cancer death every year (USEPA, 1999). Several studies have been conducted globally and in Nigeria to assess the level of radon concentration in drinking water (Fujimoto, 1998; Garba, 2011; Kandari et al., 2016; Sroor et al., 2001; Stoulos et al., 2003; Verdoya et al., 2009) while data on radiological drinking water quality in Damaturu are still not available. According to Rožmarić et al. (2012) radiological studies in drinking water have led many developing countries to ban the use of tap water as drinking water.

To our knowledge, radiological data on the drinking water sources are lacking in Damaturu. Therefore, this study evaluates the quality of ground water, in terms of radon concentration in in different brand of sachet water that are used as a public drinking water in Damaturu metropolis. The results are compared with world standards to ascertain the quality of drinking water in the study area. The need for this kind of investigation can be stated as follows:

i. Reports by World Health Organisation (WHO, 2008) and UNICEF (2012) have ranked Nigeria as one of the most populous country without safe and adequate drinking water.
ii. Groundwater based sachet water is the most common source of drinking water in Damaturu.
iii. Need to identify sachet water that comes from unsafe and radionuclide rich aquifer bearing rock formation.
iv. Need to educate the inhabitants on the potential health problems associated with high concentration of radon and related radionuclides in drinking water.

MATERIALS AND METHODS

Location of the study area and geology.

Damaturu metropolis has an area of 408 km² with an estimated population of 69,952 in 2010 (NPC, 2006) and lies between the latitude of $11^0 39' 30'' - 11^0 47' 00''$ N and longitude $11^0 54' 00'' - 12^0 02' 00''$ E in the north-eastern region of Nigeria as provided in sheet 87 prepared by the Federal Survey of Nigeria (F.S.N).Geologically, it is mainly constituted of crystalline and sedimentary bedrocks, underlain by basement complex. The crystalline rocks are found in pockets places in the southern part of the area. The crystalline rocks are represented by older granites of pre Cambrian origin and younger granites of Jurassic era (195 – 135 years). The sedimentary rocks are found to be uncomfortably overlaid the crystalline rocks which is overlaid by a large expanse of Quaternary Chad formation(Olayinka et al., 1999; Raji and Alagbe, 2000).Map showing the study area is shown in Fig. 1.

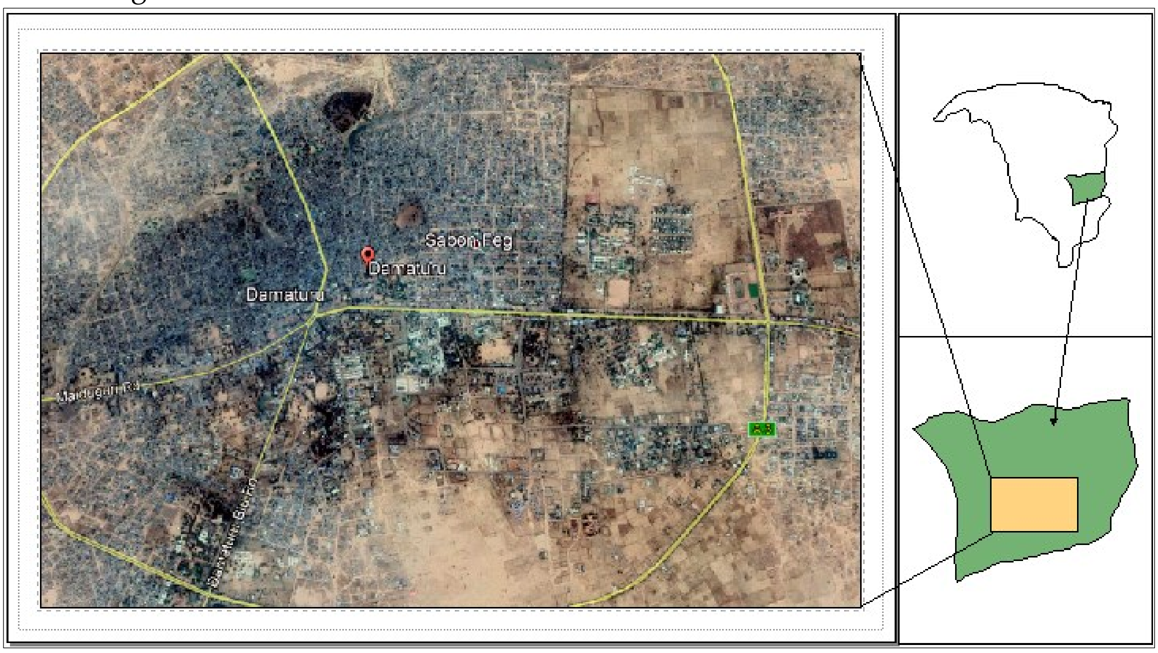

Figure 1: Map of the study area

Sampling and preparation

Thirty (30) sachet drinking water samples of different brand were collected for the analysis as presented in Table 1. A litre of each sample was collected in accordance with IAEA standard. To prevent build up in organic materials, reduce loss of radioactive materials and changes in the state of ions in the samples, nitric acid (HNO_3) was used to wash the containers. The containers were rinsed with the water before proper collection for the radon measurement. Each water sample was sealed off in 250 mL vial for 3−4 hours and was measured thereafter. Coordinates of sampling locations were used to plot map that shows the geographic distribution of registered sachet water companies where the samples are collected using ArcMap software (Fig. 2).

Table1: Coordinates of samples locations, Sample ID and brand name of each sachet water

S/N	Latitude	Longitude	Sample ID	Name
1.	11.660747°	11.942715°	W1	Boloram
2.	11.709159°	11.952783°	W2	Walid
3.	11.708766°	11.962148°	W3	Saliha
4.	11.730596°	11.991736°	W4	Herritage
5.	11.770734°	11.946400°	W5	USPY
6.	11.746488°	12.010754°	W6	M.S
7.	11.721795°	12.001786°	W7	Gambib
8.	11.740030°	11.961031°	W8	Jauro
9.	11.961031°	11.950359°	W9	De-Fadila
10.	11.746965°	11.962366°	W10	Talio Table Water
11.	11.748275°	11.950270°	W11	Ramadan
12.	11.750272°	11.965590°	W12	Aisha
13.	11.670955°	11.948120°	W13	YSU
14.	11.705831°	11.967990°	W14	Zam Safe
15.	11.733926°	11.954346°	W15	Umsat
16.	11.743222°	11.982929°	W16	Jidda
17.	11.748058°	11.988856°	W17	Muspoly
18.	11.761007°	11.951229°	W18	Wadi
19.	11.759139°	11.949596°	W19	Hayako
20.	11.767707°	11.959195°	W20	Grand Bintu
21.	11.762599°	11.968237°	W21	YAROMAH
22.	11.728858°	11.938864°	W22	Kupti
23.	11.716956°	11.962582°	W23	Nahar
24.	11.758077°	11.977592°	W24	Kintapo
25.	11.750857°	11.972832°	W25	Darma
26.	11.742382°	11.976115°	W26	Nauwaru
27.	11.739425°	11.966973°	W27	A.U. Khalifa
28.	11.728984°	11.963881°	W28	Gambib
29.	11.736581°	11.996020°	W29	Buratai
30.	11.734905°	12.005983°	W30	Damaturu

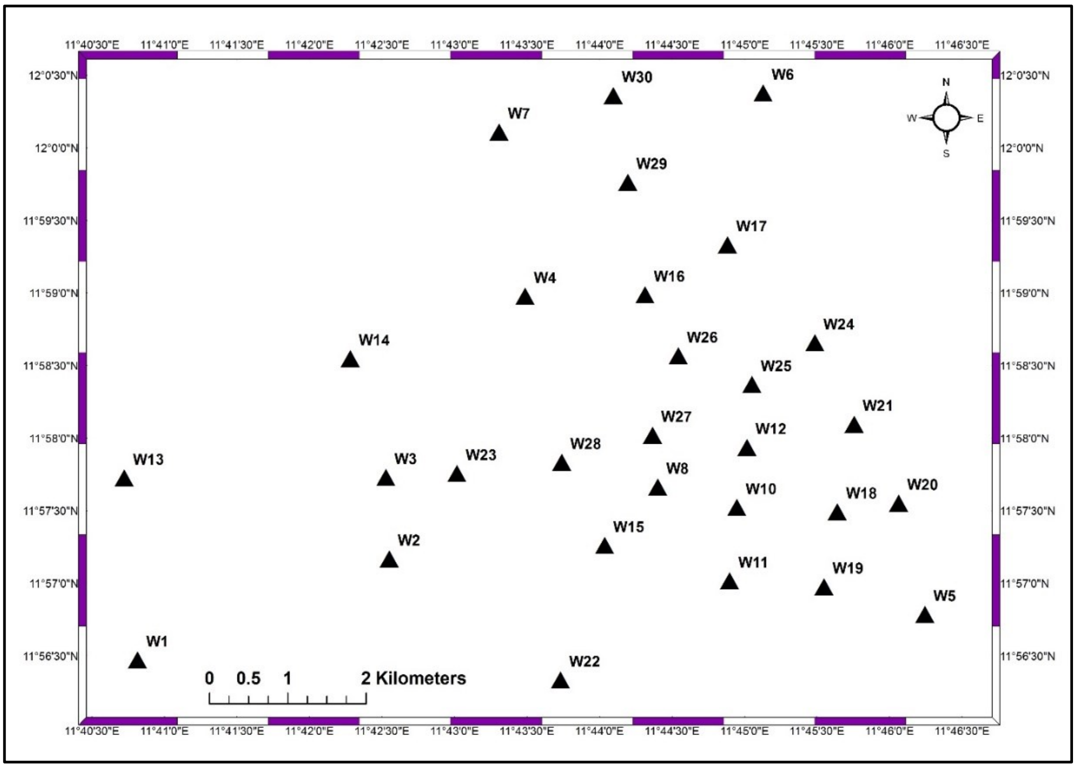

Figure 2: Sample Locations

Experimental technique

Radon concentration in the samples were measured using Rad7 instrument manufactured by an American company, Durridge (Fig. 3). The instrument RAD7 associated with H_2O, was specifically developed to perform radon concentration measurement in water and is able to produce results after 0.5 hour analysis.RAD7 radon detector was used to measure the concentration in each sample. The detector is a sophisticated measuring instrument and has been used by research scientist and professional worldwide. The instrument has a nominal sensitivity of 0.013 Bq m^{-3} with $\pm$5% absolute accuracy. A radon nucleus decays within the cell leaving a transformed nucleus, ^{218}Po, as a positively charged ion. The electric field within the cell drives ^{218}Po ion on the detector and sticks to it. The short-lived ^{218}Po decays by emitting alpha particles upon the active surface of the detector. The alpha particles released has 50% probability of entering the detector and producing an electrical signal proportional, in strength, to the energy of the alpha particle. Subsequently alpha particles of different energy are emitted by the same nucleus. Different isotopes produce alpha particles of varying energies producing signal of varying strength. The different signal are amplified, filtered and sorted out by the Rad7 according to their strength and use the ^{218}Po signal only to determine the concentration of radon (DURRIDGE, 2015).

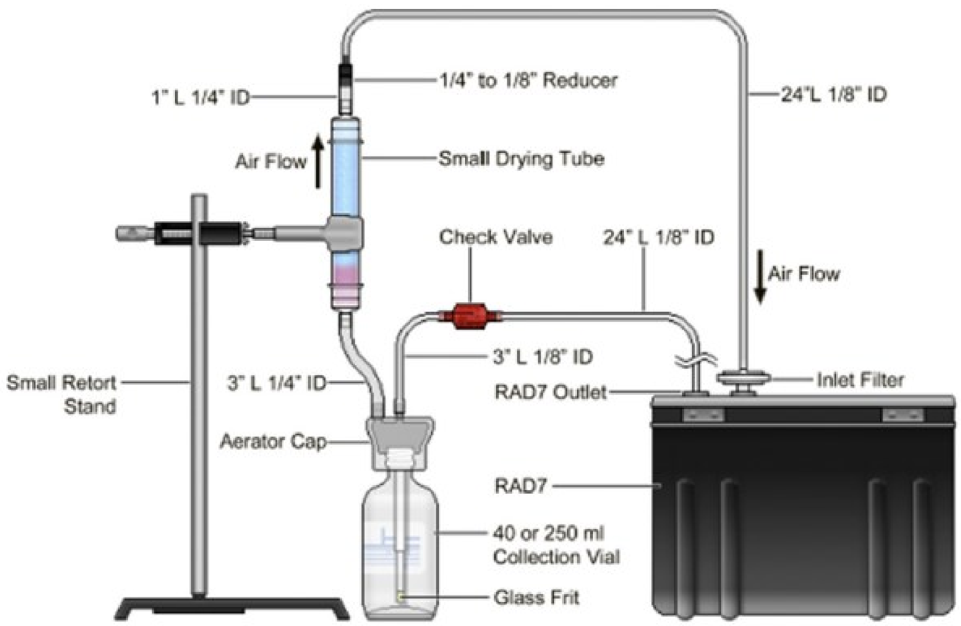

Figure 3: Systematic diagram of water sample on Rad7 experimental setup(DURRIDGE, 2015).

Annual effective dose due to ingestion

Drinking water that contains radioactive gas radon and its progeny can contribute to increase in radiation exposure to humans internally. Annual effective dose due to ingestion is calculated as follows(Inácio et al., 2017):

$$E_{ing} = K_{ing} \times C_{Rn} \times C_W \times t \quad (1)$$

where E_{ing} is the annual effective dose expressed in mSv y^{-1}, K_{ing} is a factor converting concentration to ingestion dose ($1 \times 10^{-8} SvBq^{-1}$ for adults and $2 \times 10^{-8} SvBq^{-1}$ for children), C_{Rn} is the radon concentration in the water in the unit of Bq L^{-1}, C_W is the average water consumption rate which is given by 2 litres per day(Inácio et al., 2017; WHO, 2017), and this gives 730 litres per annum.

RESULTS AND DISCUSSION

Results of measurement of radon concentration conducted in sachet drinking water samples collected across the metropolis of Damaturu allowed the evaluation of annual effective dose due to internally radiation exposure from the radioactive gas, radon, and its associated progenies for adults and the children consuming the sachet water. Sample ID for each sachet water and its corresponding radon concentration as well as annual radiation dose due to ingestion for adults and children are presented in Table 2.

Table 2: Concentration of ^{222}Rn (Bq L^{-1}) in water samples and respective effective annual dose due to ingestion for adults and children

S/N.	Sample ID	Radon Level (Bq L^{-1})	(E_{ing})Adults (mSv y^{-1})	(E_{ing})Children (mSv y^{-1})
1.	W1	20.21±2.73	0.148	0.295
2.	W2	16.60±2.88	0.121	0.242
3.	W3	8.67±2.64	0.063	0.127
4.	W4	11.89±1.48	0.087	0.174
5.	W5	4.42±0.87	0.032	0.065
6.	W6	8.13±1.85	0.059	0.119
7.	W7	8.46±0.58	0.062	0.124
8.	W8	3.14±0.62	0.023	0.046
9.	W9	14.63±0.63	0.107	0.214
10.	W10	8.15±1.83	0.059	0.119
11.	W11	5.70±0.33	0.042	0.083
12.	W12	6.21±0.85	0.045	0.091
13.	W13	18.64±1.80	0.136	0.272
14.	W14	6.32±0.76	0.046	0.092
15.	W15	8.90±0.71	0.065	0.130
16.	W16	9.16±0.80	0.067	0.134
17.	W17	7.80±1.30	0.057	0.114
18.	W18	10.80±0.25	0.079	0.158
19.	W19	17.40±2.30	0.127	0.254
20.	W20	15.30±1.53	0.112	0.223
21.	W21	17.50±2.41	0.128	0.256
22.	W22	15.70±1.62	0.115	0.229
23.	W23	11.20±0.81	0.082	0.164
24.	W24	11.80±0.53	0.082	0.164
25.	W25	15.60±1.26	0.114	0.228
26.	W26	12.84±0.57	0.094	0.187
27.	W27	12.43±0.33	0.091	0.181
28.	W28	14.31±0.60	0.104	0.209
29.	W29	14.56±1.28	0.106	0.213
30.	W30	13.12±1.16	0.096	0.192

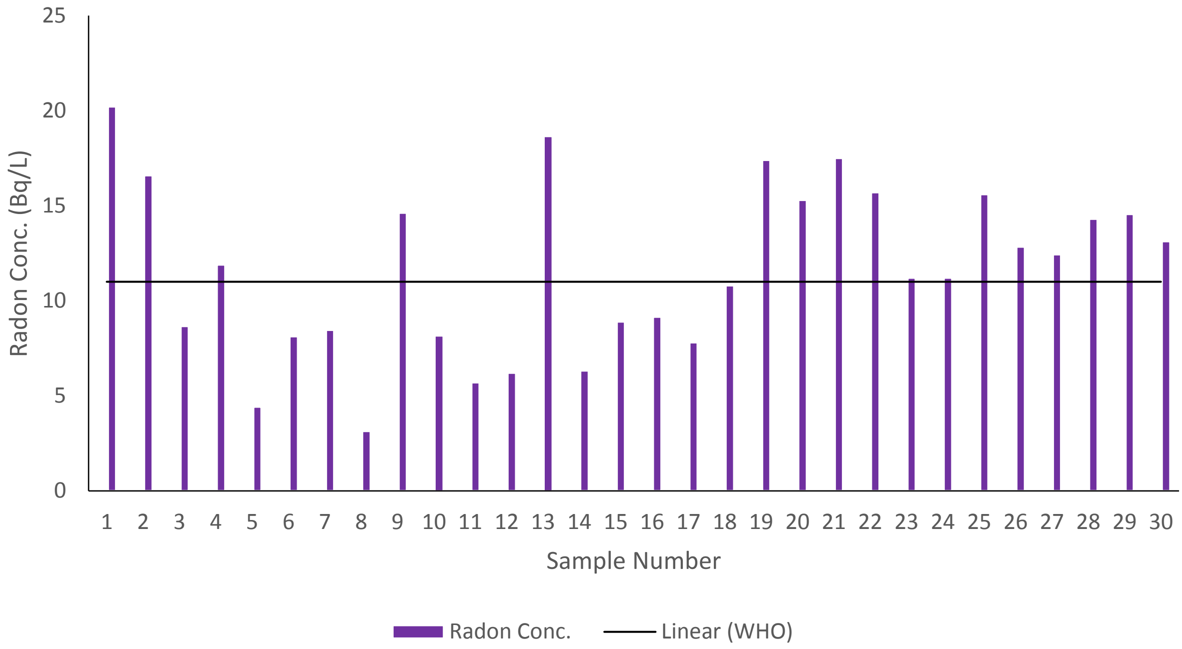

Figure 4: Radon concentration compared to recommended limit

The results were found to vary from 4.42±0.25 Bq L^{-1} observed in W_5 (Uspy) to 20.21±2.73 Bq L^{-1}measured in W_{30} (Boloram). It can be seen from figure 4 that, radon concentration in fifteen (15) out of thirty (30) water samples analysed are found to exceed the maximum value of radon in drinking water of 11 BqL^{-1} recommend by USEPA (1999) and the average value of 10 BqL^{-1} set by(WHO, 2017). In general, the results show that, higher concentration of radon is associated with areas where the basement complex is thinly covered by the chad formation.The results for the annual effective dose ranged from 0.023 mSv to 0.148 mSv for adults and from 0.046 mSv to 0.295 mSv for children. It can also be seen (Table 2), values for annual effective dose are evaluated to be higher than recommended limit of 0.1 mSv for drinking water (WHO, 2017) for both adults and children. The United Nations Scientific Committee on the Effects of Atomic Radiation suggests that, the contribution of ingestion of radon in water for the total mean annual dose should not exceed 0.002mSv(UNSCEAR, 2000).

Table 3 compared the results of this study with those reported from other parts of the world. The maximum value obtained for this work is lower than those obtained by Inácio et al. (2017) in Portugal; Xinwei (2006) in China and Prasad et al. (2009) in India and was found to exceed those obtained by Oner et al. (2009) in Turkey and Al-Nafiey et al. (2014) in Cameroun Highland, Malaysia. The variation could be attributed to the geological settings and possibly physiographic nature of different regions.

Table 3: Radon concentration (Bq L^{-1}) in the water of other parts of the world

Region	Min.	Max.	Reference
Turkey	0.28	1.08	(Oner et al., 2009)
India	1.00	336	(Prasad et al., 2009)
China	12.0	127	(Xinwei, 2006)
Malaysia	0.21	0.29	(Al-Nafiey et al., 2014)
Covilh~ a's county, Portugal	2.00	1690	(Inácio et al., 2017)
Damaturu, Nigeria	4.42	20.21	Present work

CONCLUSION

Uranium, parent material of the radioactive gas radon, ^{222}Rn, is widely distributed globally and is found in dissolved form in ground water, its concentration of which depends on mineral composition that made up the geological formation of different regions and locations. From the radiological health viewpoint, radon has a remarkable health effects in humans such as kidney related cases. Ground water has been the major source of drinking for developing countries like Nigeria. Therefore, this study measured the concentration of radon in sachet water that is being used as drinking water by the largest population of Damaturu metropolis. The results indicate that fifteen (15) out of thirty (30) water samples analysed using RAD7 device are found to exceed the maximum and average values of radon in drinking water recommended by USEPA and WHO. The higher concentration values were observed in samples obtained in areas where the basement complex is thinly covered by the chad formation. This concludes that, there is some level of health implication radiologically associated with some of the sachet water being consume in the city. Accordingly, the study recommends boiling and exposing ground water in air for some time before using it for drinking.

REFERENCES

Abba, H T, Wan Hassan, W M S, Saleh, M A, Aliyu, A S, Ramli, A T, Abdulsalam, H, 2018. Geological influence on the activity concentration of terrestrial radionuclides 226Ra, 232Th and 40K in the Jos Plateau, Nigeria. Isotopes in environmental and health studies:1-13.

Al-Nafiey, M S, Jaafar, M S, Bauk, S, 2014. Measuring radon concentration and toxic elements in the irrigation water of the agricultural areas in Cameron Highlands, Malaysia. Sains Malaysiana 43:227-231.

Cline, W, Adamovitz, S, Blackman, C, Kahn, B, 1983. Radium and uranium concentrations in Georgia community water systems. Health physics 44:1-12.

DURRIDGE, C, 2015. Radon in water accessory. Revision 2015-07-28 Edition. F.P.T. Committee on Drinking Water Guidelines for Canadian Drinking Water.

Fujimoto, K, 1998. Correlation between indoor radon concentration and dose rate in air from terrestrial gamma radiation in Japan. Health physics 75:291-296.

Garba, N N, 2011. Determination of Radon concentration in Zaria and Environs water sources using Liquid Scintillation Counter. MSc. Thesis, Physics, Ahmadu Bello University.

IAEA, 2001. Water for people, water for life. The United Nation World Water Development Report. http://www.unesdoc.unesco.org/images/ 0012/001295/129556e.pdf.

Inácio, M, Soares, S, Almeida, P, 2017. Radon concentration assessment in water sources of public drinking of Covilhã's county, Portugal. Journal of Radiation Research and Applied Sciences 10:135-139.

Kandari, T, Aswal, S, Prasad, M, Bourai, A, Ramola, R, 2016. Estimation of annual effective dose from radon concentration along Main Boundary Thrust (MBT) in Garhwal Himalaya. Journal of radiation research and applied sciences 9:228-233.

Langmuir, D, 1978. Uranium solution-mineral equilibria at low temperatures with applications to sedimentary ore deposits. Geochimica et Cosmochimica Acta 42:547-569.

Maxwell, O, Wagiran, H, Lee, S, Embong, Z, Ugwuoke, P, 2015. Radioactivity level and toxic elemental concentration in groundwater at Dei-Dei and Kubwa areas of Abuja, north-central Nigeria. Radiation Physics and Chemistry 107:23-30.

NPC, 2006. National population Commission (NPC):. Provisional of 2006 Census Results. Abuja, Nigeria.

Olayinka, A, Abimbola, A, Isibor, R, Rafiu, A, 1999. A geoelectrical-hydrogeochemical investigation of shallow groundwater occurrence in Ibadan, southwestern Nigeria. Environmental geology 37:31-39.

Oner, F, Yalim, H, Akkurt, A, Orbay, M, 2009. The measurements of radon concentrations in drinking water and the Yeşilırmak River water in the area of Amasya in Turkey. Radiation protection dosimetry 133:223-226.

Prasad, Y, Prasad, G, Choubey, V, Ramola, R, 2009. Geohydrological control on radon availability in groundwater. Radiation Measurements 44:122-126.

Raji, B, Alagbe, S, 2000. A topo-geochemical sequence study of groundwater in Asa drainage basin, Kwara State, Nigeria. Environmental Geology 39:544-548.

Rožmarić, M, Rogić, M, Benedik, L, Štrok, M, 2012. Natural radionuclides in bottled drinking waters produced in Croatia and their contribution to radiation dose. Science of the total environment 437:53-60.

Sroor, A, El-Bahi, S, Ahmed, F, Abdel-Haleem, A, 2001. Natural radioactivity and radon exhalation rate of soil in southern Egypt. Applied Radiation and Isotopes 55:873-879.

Stoulos, S, Manolopoulou, M, Papastefanou, C, 2003. Assessment of natural radiation exposure and radon exhalation from building materials in Greece. Journal of Environmental Radioactivity 69:225-240.

UNSCEAR, 2000. Sources and effects of ionizing radiation:. New York: United Nations., UNSCEAR 1993 report to the General Assembly with scientific annexes / United Nations Scientific Committee on the Effects of Atomic Radiation.

USEPA, 1999. Health risk reduction and cost analysis for radon in drinking water. Federal register 64(38), 9559, Washington.

Verdoya, M, Chiozzi, P, De Felice, P, Pasquale, V, Bochiolo, M, Genovesi, I, 2009. Natural gamma-ray spectrometry as a tool for radiation dose and radon hazard modelling. Applied Radiation and Isotopes 67:964-968.

WHO, 2008. World Health Organization. Meeting the MDG Drinking water and Sanitation Target: the Urban and Rural Challenge of the Decade. WHO Library Cataloguing-in-Publication Data.

WHO, 2017. Guidelines for drinking water quality (4th ed.). Geneva: World Health Organization

Xinwei, L, 2006. Analysis of radon concentration in drinking water in Baoji (China) and the associated health effects. Radiation protection dosimetry 121:452-455.

Yusof, A, Mahat, M, Omar, N, Wood, A, 2001. Water quality studies in an aquatic environment of disused tin-mining pools and in drinking water. Ecological engineering 16:405-414.