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# Determination of Radon gas in bottled and sachet water in Ile-Ife, Nigeria

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**Abstract.** The environmental monitoring of radon contents in some bottled and sachet water were carried out, with the aid of an active radon device (RAD7) made by Durrige, USA. This study is aimed to determine the level of radon in selected bottled and sachets water in major market in Ile-Ife, with a view to establishing the health risks that could arise in consumption of the water. The results obtained in this study show that all the water samples were safe for consumption without any health implication from radiological point of view.

**Keywords:** Radon concentrations, Water consumption, Environmental monitoring, RAD7, Health risk.

## 1. Introduction

Radon is ubiquitous gas formed by the decay of parent radionuclide, Uranium-238, which is present in soils, rock and water [1, 2]. Due to the high rate of diffusion of radon, it can easily create its way to the entire household through opening in the walls, crack in the foundation, therefore makes radon unavoidable gas. The three significant isotopes of radon are  $^{222}\text{Rn}$ ,  $^{220}\text{Rn}$ , and  $^{219}\text{Rn}$ . These isotopes are significant because of their half-life [3]. Though the health hazard pose by  $^{222}\text{Rn}$  explains why it is most widespread phenomenon among other isotopes. Epidemiological studies have shown that there is a relationship between the occurrence of cancer and high level of radon [4], especially among the mine workers [5]. Radon is the major contributor of radioactivity in the earth's atmosphere; radon and its progenies have been established to be one of the causes of lung cancer among non-smokers. It is reported that it causes 21000 lung cancer deaths per year in the United State [4]. The hazard from radon can be through inhalation and ingestion of the short-lived decay products of radon [6]. Inhalation and ingestion of high level of radon from air and water respectively cause lung and stomach cancer respectively in humans. They are alpha particles, with low penetrating power, yet they transfer huge energy to the biological cells they interact with, this deposited energy is what initiates cancer. The radiation splits the water molecules and release free radicals. The reaction of this radical causes damages to DNA of the cells,



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thus causing abnormal of growth of the cells called cancer [7]. There is variation in the activity of radon content in different water types and this activity can be affected by the source, lithology of the aquifer host rock and processes at which the water is subjected to during its exploitation. The distance between the source of the water and the consumers, also has significant effect on the activity of radon level. If the distance is short, there are tendencies for its consumers to have more radon level compare to that of long distance. It has been established that quality water is the human birthright [8-15], therefore quality of water is not negotiable. There are many contaminants in unprocessed water, such as biological, chemical and radiological contaminants; in view of this many has been forced to be drinking processed water such as bottled water and sachet water. This is what formed the basis of this work, in order to assess the radiological contaminants in the bottled and sachet water in Ile-Ife. The aim of this study is to determine the radon concentrations present in sachet and bottled water across Ile-Ife, southwestern Nigeria. Some of the previous works on determination of the level of radon gas in drinking water include Oni et al. [1], Yusuff et al. [2], Oni and Adagunodo [5], and Mittal et al. [6].

## **2. Location and geology of the study area**

Ile-Ife is one of the ancient cities in southwestern Nigeria located in Osun State, with an area of 111 km<sup>2</sup>. It has an estimated population of about 501,000 [17]. The vegetation in Ile-Ife is composed of evergreen light forest, grasses and herbs. Rainy and dry seasons are the two notable seasons in the study area. The rainy season is characterized by heavy rainfall from April to October, while the dry season is from November to March. The average temperature of 24.5 and 28.8°C are the recorded mean values in the month of August and February, respectively [18].

Ile-Ife is located on the Basement Complex rocks of southwest Nigeria, which are composed of Older granite, Migmatite-gneiss Complex, and the Schist belt (Figure 1). The common rock types in the study area include banded gneiss, granite gneiss, and mica schist. These classifications and petrologic units of these rocks have been discussed by Ajayi and Adepelumi [19].

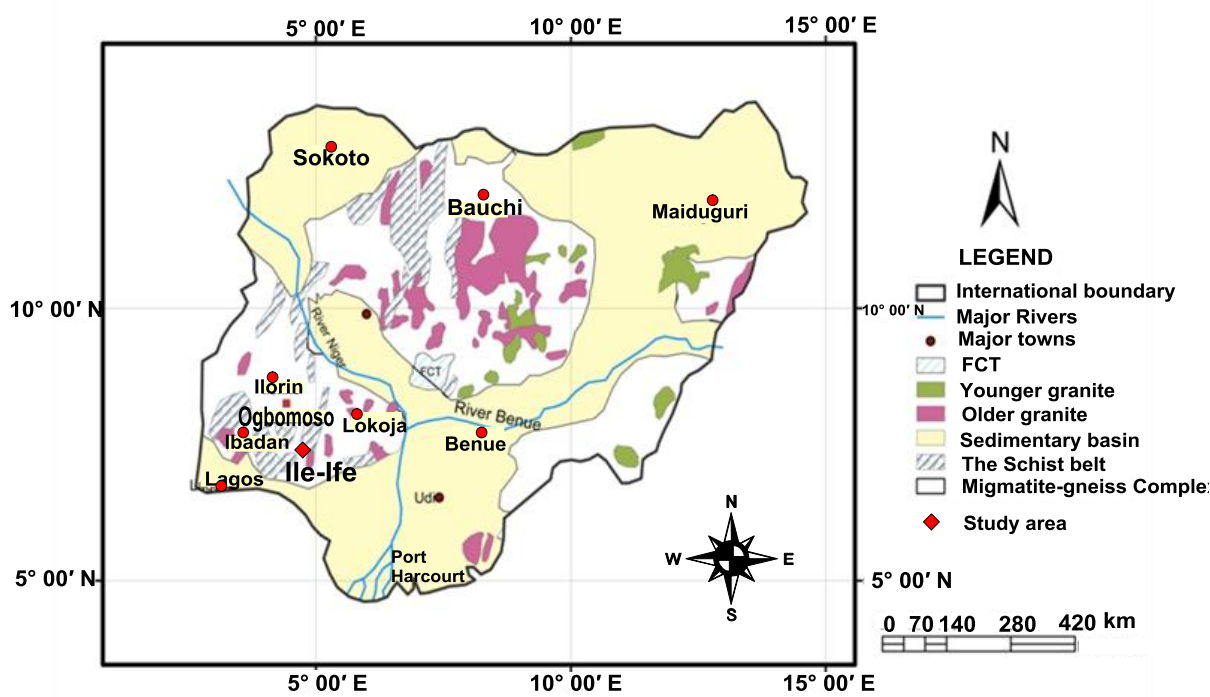


Figure 1: Geological map of Nigeria showing Ile-Ife (modified after [20]).

### 3. Materials and methods

Four (4) samples were bought per product with different seventeen (17) products across the major markets in Ile-Ife. This was done to ensure accuracy and that the mean value of each product was used for the final analysis. The sample water was poured into the prewashed jar (with distilled water) of 250 mL, the water jar was capped immediately, in order to have good representation of the samples, the capped jar were labelled [21]. The degassing of radon was avoided during the transfer of water into the prewashed jar [6, 22].

The samples were analysed using an active simple electronic radon monitoring device, manufactured by DurrIDGE Company, USA. The device uses alpha spectrometric technique. The detector is designed in such a way that it can measure radon from outdoor and indoor. But to determine concentration of radon in water, a water kit is attached to the device. During the samples measurement, it was ensured that relative humidity of the device was kept as low as 6%, by constant purging of the device as recommended in the manual [23]. RAD 7 was set to wat-250 for period of 5 minutes. The equipment was allowed to have break for 5 min and then count each water sample for duration of 30 min in five cycles. Radon concentration was determined by RAD7 taking into consideration the calibration of RAD7, volume of the closed air loop of the set up and the size of the vial used. The counting time was shorter than

3.8 days, which is the half-life of radon. This made RAD-7 outstanding in performance than other passive and active detectors for  $^{222}\text{Rn}$  measurement in water. Five runs were done for each sample. At completion of the runs, the device automatically displays the average results of the five runs. Decay correction factor must be considered during the measurement of radon, for a measurement when long times are required.

A dose conversion factor was used to account for the period of production and the period the measurements were taken using decay correction factor (DCF).

$$\text{Time Constant} = \frac{3.825(\text{half - life of radon} \times 24\text{h/day})}{\ln 2} = 132.4 \text{ h}$$

$$\text{DCF} = \exp(-T/132.4 \text{ h}) \quad (1)$$

Where T is decay time in hours. DCF is a simple exponential function with a time constant. The results were corrected back to the sampling time by multiplying with the decay correction coefficient

#### Committed Annual effective Dose for Ingestion

Radon assessment of drinking water is exceptionally significant due to the health hazards, principally as a cause of lung and stomach abnormal growth of the cells called cancer [24]. Committed annual effective dose from ingestion was calculated using Equation 2 according to Somlai et al. [25], Ali et al. [26], and El-Taher [27].

$$E = k \times G \times C \times T \quad (2)$$

Where E = committed effective dose from ingestion (Sv)

K= Ingestion dose conversion factor of  $^{222}\text{Radon}$

G= water consumption, 2L per day (World Health Organisation [28]).

C= Concentration of radon, Bq/L.

T= Duration of consumption, 1 year (WHO 2008).

## 4. Results and Discussion

A total of sixty-eight (68) water samples from seventeen (17) brands were analysed for radon concentration. Tables 1 and 2 showed the obtained results from the water samples. The mean activity of concentration of radon in selected brand of bottled water samples range from 0

Bq/l to 9.45 Bq/l with overall mean of 2.44 Bq/l, while for sachets water samples range from 0.04 Bq/l to 0.51 Bq/l with overall mean of 0.25 Bq/l. It was observed that radon concentration in bottled water samples were greater than that of sachet water samples. Comparing the results obtained for both bottled and sachets water samples with recommended reference value of 100 Bq/l by World Health Organisation (WHO), it was observed that the results obtained in this work were found to be lower than the recommended value. The variation in the obtained results could be due to variation in amount of uranium of the bed rock basement of the sources of water, procedure adapted during the process and storage duration [26, 29]. The higher values were found in Aqua Alba and lowest values were found in sample Cway and Awwal respectively. In the two samples radon were not found. This could be as a result of processing that samples were subjected to before they were released for public consumption. The average doses ingested were also estimated and it is shown in the Tables 1 and 2. In as much as dose ingested are functions of radon concentration, therefore the ingested and inhaled doses were found to be higher where the radon concentration is found higher.

Table 1: Results of Radon concentration measurement in commercial bottled water and its annual effective dose

Sample name	A <sup>0</sup> (Bq/l)	A (Bq/l) Original decay radon	Annual effective dose ingestion adult (usv/y)	Annual effective dose ingestion children (usv/y)
Aqua Alba	1.6057	9.4493	$6.8979 \times 10^{-5}$	$1.3796 \times 10^{-4}$
Aquarealm	2.0178	0.67945	$4.9599 \times 10^{-6}$	$9.9120 \times 10^{-6}$
Aquadana	0.8282	6.6254	$4.8365 \times 10^{-5}$	$9.6731 \times 10^{-5}$
Eva	0.0588	0.2153	$1.5717 \times 10^{-6}$	$3.1434 \times 10^{-6}$
Mr. V	0.0704	$7.5328 \times 10^{-4}$	$5.4989 \times 10^{-5}$	$1.0998 \times 10^{-4}$
Mokuro	0.0234	0.1302	$9.5046 \times 10^{-7}$	$1.9009 \times 10^{-6}$
Cway	0	0	0	0
Bigi	0.0234	$5.1948 \times 10^{-4}$	$3.7922 \times 10^{-9}$	$5.5366 \times 10^{-14}$
OAU	0.0469	$7.2226 \times 10^{-4}$	$5.2725 \times 10^{-9}$	$1.0545 \times 10^{-8}$
Awwal	0	0	0	0
<b>AVERAGE</b>	<b>0.46746</b>	<b>2.4428</b>	<b><math>1.7982 \times 10^{-4}</math></b>	<b><math>3.5964 \times 10^{-4}</math></b>
<b>MAXIMUM</b>	<b>2.0178</b>	<b>9.4493</b>	<b><math>4.8365 \times 10^{-5}</math></b>	<b><math>1.0998 \times 10^{-4}</math></b>
<b>MINMUM</b>	<b>0</b>	<b>0</b>	<b>0</b>	<b>0</b>

Table 2: Results of Radon concentration measurement and cancer risk assessment in commercial sachet water

Sample name	A (Bq/l)	A0 (Bq/l)	Annual effective dose ingestion adult (usv/y)	Annual effective dose ingestion children (usv/y)
OAU	0.3182	0.0894	$6.53 \times 10^{-7}$	$1.306 \times 10^{-6}$
MOKURO	0.5068	0.1424	$1.0395 \times 10^{-6}$	$2.079 \times 10^{-6}$
MATJEL	0.2475	0.0685	$5.0005 \times 10^{-7}$	$1.0001 \times 10^{-6}$
TG PEARL	0.0479	0.0135	$9.855 \times 10^{-8}$	$3.4806 \times 10^{-6}$
LEO BRIGHT	0.1765	0.0496	$3.6208 \times 10^{-7}$	$1.7403 \times 10^{-6}$
LAFFAX	0.3418	0.0960	$7.008 \times 10^{-7}$	$8.7016 \times 10^{-7}$
DEE COMMUNIOM	0.1060	0.0298	$2.1754 \times 10^{-7}$	$4.3508 \times 10^{-7}$
<b>AVERAGE</b>	<b>0.2492</b>	<b>0.0699</b>	<b><math>5.1022 \times 10^{-7}</math></b>	<b><math>1.5587 \times 10^{-6}</math></b>
<b>MAXIMUM</b>	<b>0.5068</b>	<b>0.1424</b>	<b><math>1.0395 \times 10^{-6}</math></b>	<b><math>3.4806 \times 10^{-6}</math></b>
<b>MINIMUM</b>	<b>0.0479</b>	<b>0.0135</b>	<b><math>9.855 \times 10^{-8}</math></b>	<b><math>8.7016 \times 10^{-7}</math></b>

## 5. Conclusion

Radon concentrations have been determined for both bottled and sachet water samples obtained in major markets in Ile Ife and its environs. The maximum of radon was found in Aqua Alba water samples. Apart from the channel of abstraction of the water which could influence the level of radon concentration in the analyzed water, the processes involved during production of the packaged water could also influence it. From the results obtained in this work, it could be concluded that all the analyzed water samples showed lower radon concentration than the WHO recommended value of 100 Bq/l. Therefore, the analyzed water samples are safe for consumption. However, periodic monitoring is recommended in the study area to ensure radiological safety.

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## References

- [1]. Oni O.M., Yusuff I.M., Adagunodo T.A. (2019). Measurement of Radon-222 concentration in soil-gas of Ogbomoso southwestern Nigeria using RAD7. *International Journal of History and Scientific Studies Research*, 1(3): 1-8.
- [2]. Yusuff I.M., Adagunodo T.A., Omoloye M.A., Olanrewaju A.M. (2019). Interdependency of Soil-gas Radon-222 Concentration on Soil Porosity at different Soil-depths. *IOP Conf. Series:*

- Journal of Physics: Conf. Series, 1299: 012099. <https://doi.org/10.1088/1742-6596/1299/1/012099>.
- [3]. Faweya E.B. Olowomofe, O.G, Akande,H.T and Adeniyi Adewumi (2018) Radon emanation and heavy metals assessment of historical warm and cold spring in Nigeria using different matrices. *Environ Syst Res*7,22. <https://doi.org/10.1186/s400068-018-0125-x>
- [4]. Akinnagbe. D.M, Orosun, M.M. Orosun, R.O. Osanyinlusi, O. Yusuk, K.A. Akinyose, F.C. Olaniyan, T.A.and Ige, S.O.(2018). Assessment of Radon concentration of ground water in Ijero Ekiti. *Manila Journal of Science II*. pp 32-41.
- [5]. Oni E.A. and Adagunodo T.A. (2019). Assessment of radon concentration in groundwater within Ogbomoso, SW Nigeria. IOP Conf. Series: Journal of Physics: Conf. Series, 1299: 012098. <https://doi.org/10.1088/1742-6596/1299/1/012098>.
- [6]. Oni, E.A. O.M. Oni, O.O. Oladapo, I.D. Olatunde and F.E. Adediwura (2016). Measurement of Radon Concentration in Drinking Water of Ado-Ekiti, Nigeria *Journal of Academia and Industrial Research (JAIR)* 4(8):190-192
- [7]. Edsfeldt C. (2001) The radium distribution in some Swedish soils and its effect on radon emanation. Royal Institute of Technology, Stockholm, p 52
- [8]. Sunmonu L.A., Adagunodo T.A. Olafisoye E.R. and Oladejo O.P. (2012). The Groundwater Potential Evaluation at Industrial Estate Ogbomoso Southwestern Nigeria. *RMZ-Materials and Geoenvironment*, 59(4), 363–390.
- [9]. Oladejo O.P., Sunmonu L.A., Ojoawo A., Adagunodo T.A. and Olafisoye E.R. (2013). Geophysical Investigation for Groundwater Development at Oyo State Housing Estate Ogbomosho, Southwestern Nigeria. *Research Journal of Applied Sciences, Engineering and Technology*, 5(5), 1811–1815.
- [10]. Adagunodo T.A., Sunmonu L.A., Ojoawo A., Oladejo O.P. and Olafisoye E.R. (2013). The Hydro Geophysical Investigation of Oyo State Industrial Estate Ogbomosho, Southwestern Nigeria Using Vertical Electrical Soundings. *Research Journal of Applied Sciences, Engineering and Technology*, 5(5), 1816–1829.
- [11]. Adagunodo T.A., Akinloye M.K., Sunmonu L.A., Aizebeokhai A.P., Oyeyemi K.D., Abodunrin F.O. (2018). Groundwater Exploration in Aaba Residential Area of Akure, Nigeria. *Frontiers in Earth Science*, 6: 66. <https://doi.org/10.3389/feart.2018.00066>.
- [12]. Adagunodo T.A. (2018). Simple Approach to Groundwater study for Domestic uses in Rural Area. *Journal of Fundamental and Applied Sciences*, 10(3): 129 – 143. <http://dx.doi.org/10.4314/jfas.v10i3.11>.
- [13]. Joel E.S., Olasehinde P.I., Adagunodo T.A., Omeje M., Akinyemi M.L., Ojo J.S. (2019). Integration of Aeromagnetic and Electrical Resistivity Imaging for Groundwater Potential Assessment of Coastal Plain Sands Area of Ado-Odo/Ota in Southwest Nigeria. *Groundwater for Sustainable Development*, 9: 100264. <https://doi.org/10.1016/j.gsd.2019.100264>.
- [14]. Joel E.S., Olasehinde P.I., Adagunodo T.A., Omeje M., Oha I., Akinyemi M.L., Olawole O.C. (2020). Geo-investigation on Groundwater Control in some parts of Ogun State using Data from Shuttle Radar Topography Mission and Vertical Electrical Soundings. *Heliyon*, 6(1): e03327. <https://doi.org/10.1016/j.heliyon.2020.e03327>
- [15]. Bayowa O.G., Adagunodo T.A., Olaleye O.A., Adeleke A.E., Usikalu M.R., Akinwumi S.A. (2020). Hydrological Investigation for near Surface Aquifers within Lekki Peninsula, Lagos, Southwestern Nigeria. *Nature Environment and Pollution Technology*, 19(2): 511 – 520. <https://doi.org/10.46488/NEPT.2020v19i02.007>.
- [16]. Mittal, S., Rani, A., Mehra, R. (2015). Estimation of radon concentration in soil and groundwater samples of Northern Rajasthan, India, *Journal of Radiation Research and Applied Sciences*. <http://dx.doi.org/10.1016/j.jrras.2015.10.006>



- [17] Egu, K. (2011, March 15) Ile Ife, Nigeria (ca. 500 B.C.E.). Retrieved from <https://www.blackpast.org/global-african-history/ile-ife-ca-500-b-c-e/>
- [18]. Bayowa O. G., Ilufoye D. T. and Animasaun A.R. (2011). Geoelectric investigation of Awba earth dam embankment, University of Ibadan, Ibadan, Southwestern Nigeria, for anomalous seepages, *Ife Journal of Science*, 13, (2), 227-238.
- [19]. Ajayi T.R. and Adepelumi A.A. (2002). Reconnaissance soil-gas radon survey over the faulted crystalline area of Ile
- [20]. Adagunodo T.A., Adejumo R.O., Olanrewaju A.M. (2019). Geochemical Classification of Groundwater System in a Rural Area of Nigeria. In: Chaminé H., Barbieri M., Kisi O., Chen M., Merkel B. (eds) *Advances in Sustainable and Environmental Hydrology, Hydrogeology, Hydrochemistry and Water Resources. Advances in Science, Technology & Innovation (IEREK Interdisciplinary Series for Sustainable Development)*. Springer, Cham. [https://doi.org/10.1007/978-3-030-01572-5\\_31](https://doi.org/10.1007/978-3-030-01572-5_31).
- [21]. Stringer C, Burnett WC (2004) Sample bottle design improvements for radon emanation analysis of natural waters. *Health Phys* 87:642–646
- [22]. Oni MO, Oladapo OO, Amuda DB, Oni EA, Olive-Adelodun AO, Adewale KY, Fasina MO (2014) Radon concentration in groundwater of areas of high background radiation level in southwestern Nigeria. *Niger J Phys* 25(1):64–67
- [23]. Durrige Company Inc. (2012). RAD7 RAD H<sub>2</sub>O Radon in water accessory user manual.
- [24]. IARC (1989) International Agency for Research on Cancer. *Summaries & Evaluation*. Vol. 43
- [25]. Somlai, K., Tokonami, S., Ishikawa, T., Vancsura, P., Gáspár, M., Jobbágy, V., ... Kovács, T. (2007). <sup>222</sup>Rn concentrations of water in the Balaton Highland and in the southern part of Hungary, and the assessment of the resulting dose. *Radiation Measurements*, 42, 491-495. <http://dx.doi.org/10.1016/j.radmeas.2006.11.005>
- [26]. Ali N., Khan, E.U., Akhter., P. Khan, F., and Waheed, A.(2010). Measurement of Radon and size fractionation of Aerosol through Solid State Detectors. *Radiation Protection Dosimetry*. 141(2), 183-191.
- [27]. El-Taher A. (2012) Measurement of radon concentrations and their annual effective dose exposure in groundwater from Qassim area, Saudi Arabia. *J Environ Sci Technol* 5:475–481. <https://doi.org/10.3923/jest.2912-475.481>
- [28]. World Health Organization (WHO) (2008) Guidelines for drinking water quality. In: *Radiological aspects*. World Health Organization, Geneva, pp 214–217
- [29]. Yadolah Fakhari, Morteza Kargosha, Ghazaleh Langrarizadeh, Yahya Zandsalimi, Leila Rasouli Amirhajelu, Mahboubeh Moradi, Bigard Moradi and Maryam Mirzaei (2016). Effective dose radon 222 of the tap water in children and adults people; Minab City, Iran. *Global Journal of Health Science* 8(4): 234-243