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ORIGINAL RESEARCH

Radon Assessment in Water Samples in a University Community in Osogbo Osun State

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Abstract:
Introduction: Radon is a radioactive gas and one of the leading causes of cancer at high concentrations globally. Inhalation or ingestion of radon-contaminated water through drinking, cooking, or bathing has reportedly increased human health risks. Measuring radon levels in water helps assess the potential health risks associated with ingestion and inhalation.
Aims: In this study, the assessment of radon activity in water in some selected places within a university community in Osogbo, Osun State, Nigeria, was carried out.
Materials and Methods: Fifteen (15) water (groundwater and borehole water) samples were collected, and the radon concentration was measured using a DURRIDGE RAD7 H_2O accessory radon detector.
Results: The results of the radon activity ranged from 6.3 ± 1.7 Bq/L to 60.8 ± 5.6 Bq/L with a mean of 21.33 ± 2.95 Bq/L. Nine (9) out of the fifteen (15) water samples measured were observed to be higher than EPA's maximum contaminant level of 11.1 Bq/L, while the other six (6) water samples were within the range. The annual effective dose values lie within 3 -10 mSv/yr., reported by the International Commission on Radiological Protection.
Conclusion: Water within the university community in Oshogbo, Osun State, is recommended for regular radon monitoring due to the high radon concentration above the Nigerian Standard for Drinking Water Quality.
To Keywords: radon, Osogbo, water, RAD7 H_2O

1. INTRODUCTION

Radon (^{222}Rn) is a radioactive gas with a half-life of 3.82 days. It is evident that radon is the dose-transporting agent in the ^{238}U decay series. Radon is abundant in nature, and present in soil, water, and air. Its concentration in the earth's crust depends on the fundamental geology of the area [1]. Radon is highly mobile and can move quickly from rocks and soil, through a pressure-driven flow to air and surrounding water. Generally, when radon decays, it releases alpha beaters which if inhaled or ingested, can cause damage to several living tissues. The formation of free radicals from the ionization of water which makes up almost 70% of the human body can lead to unnatural reproduction of cells and consequent risks of malignant disease [2].

Water is a vital constituent of Earth's streams, lakes, and oceans, as well as the fluid in which most living organisms move. It covers about 71% of the Earth's surface [3]. It is important for all existing life forms, especially humans. Water can be used for several purposes by humans, including transportation, power generation, agriculture, and other domestic activities. As a result, its availability and quality in terms of contamination from radiological, microbiological, chemical, and other sources is a delicate and important issue [4]. Unfortunately, in most developing countries, such as Nigeria, access to clean and potable drinking water is a major challenge, causing most people to rely primarily on untreated surface and groundwater sources for consumption [4].

Surface and underground waters contain radionuclides in various concentrations depending on their origin. Radon is released into waters as a result of natural processes like the decay of its parent nuclide 226Ra and predominantly dissolution from the surrounding geological environment (rocks, soils) [5, 6]. Inhalation of radon dissolved in and released from water meant for human consumption accounts for 89% of an individual's estimated cancer risk [2]. Consequently, estimation of radon plays an important role in community health assessment, and awareness of radon levels in household water supplies is significant for protecting humans against the effects of exposure.

Various radon levels have been introduced to protect human health from exposure to radon from drinking water consumption. The U.S. Environmental Protection Agency (USEPA) set a reference level of maximum contaminant level (MCL) for radon in drinking water as 300 pCi/L or 11.1 Bq/L Conversely, in 2004, the WHO set Guidelines for Drinking-Water Quality for radon concentration level as 100 Bq/L [7]. The WHO also recommended a committed effective dose equal to 100 µSv/yr for consumption of drinking water [7, 8]. If the radon concentration exceeds 100 Bq/L, the WHO recommends that treatment of the water source should be undertaken to reduce the radon levels to well below 100 Bq/L [7].

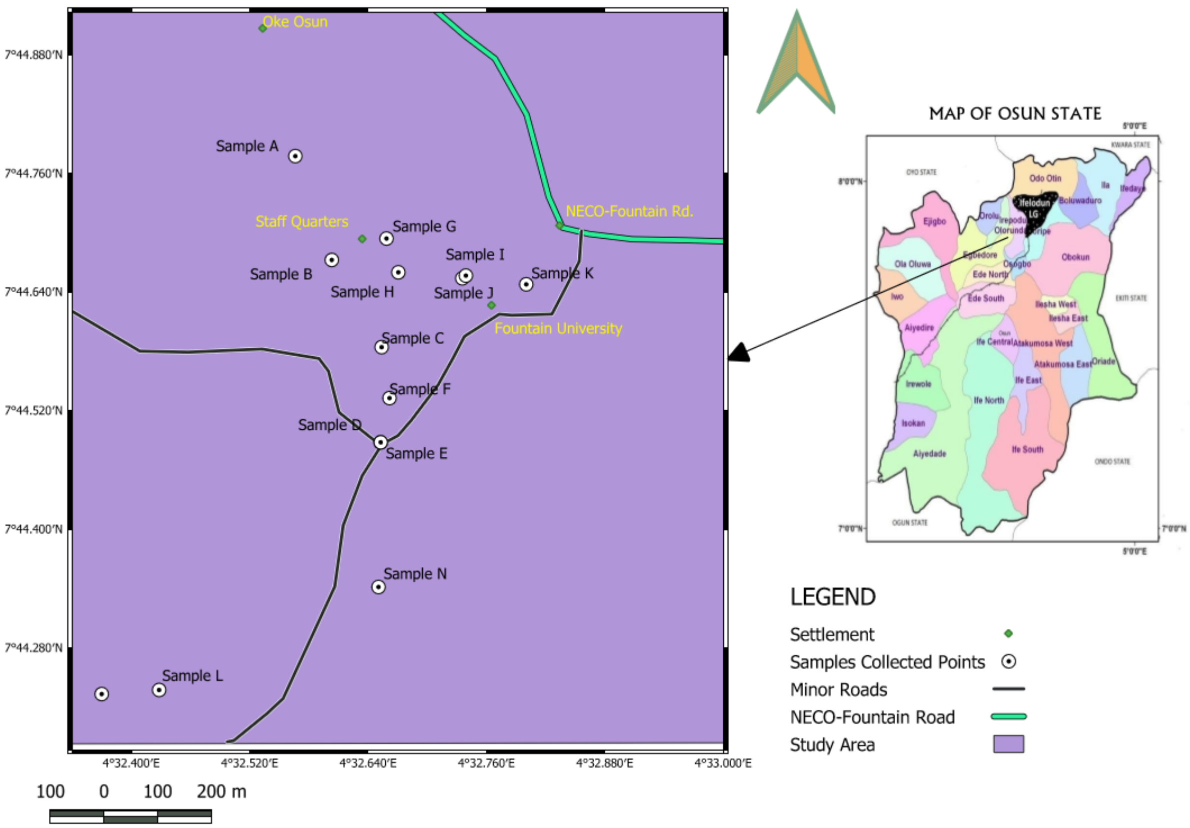
Globally, radon is known as one of the leading causes of lung cancer [9]. Ali Mohamed, Salama [10] reported radon concentration in water samples collected within Ojo Axis of Lagos State, Nigeria to be above the concentration the safe limits of 11.1 Bq/L, as per EPA regulations. In a developing country like Nigeria, where there is no national campaign for radon measurement and protection has been launched; instead, personal efforts on a small scale for academic purposes and the Nigeria Society for Radiation Protection (NSRP), a new organization, have been made to examine the level of radon concentration in a few areas across the country.

This current study examines the concentration of radon in drinking water sources at Fountain University Osogbo. The annual effective dose from the consumption of radon in water via inhalation and ingestion was also calculated and compared with the WHO recommended value.

2. MATERIAL AND METHODS

2.1 STUDY AREA

Osogbo is the capital of Osun State in Southwest, Nigeria which lies on 7046' North and 4034' East, covering a landmass area of about 2875 km^2. The town has been in existence for over 400 years, with a population of above 700,000 people. Osogbo is a commercial and industrial center, which attracts tourists from across the globe because of its annual Osun Osogbo festival.



Location Map of the Study Area showing Points of Samples Collected

Figure 1: Map of the study area (Oshogbo)

2.2 SAMPLE COLLECTION

In this study, water samples were collected from fourteen different points within the University campus, and purified bottled water used as control. Samples were collected in a clean sample collection bottle with tight covers, surface water were collected with the aid of a bailer, the ground water in the well was first purged by drawing it out severally to ensure fresh samples were obtained.

The borehole water samples were collected after evacuating the existing water in the pipe. The containers were rinsed with water to be collected and later with concentrated Nitric acid. To avoid contamination, the water was preserved with concentrated Nitric acid to minimize precipitation and absorption of particles in the water on the container walls [11]. The bottles were also brimmed without any head space to prevent Carbon dioxide from being trapped, as it can easily dissolve in water resulting in a different chemistry [12]. To achieve accuracy, samples were transferred to the laboratory immediately and analyzed within twenty-four hours to maintain the sample composition. A sample, containing one of the selected water sources (stream, well and borehole water) was taken from each of the fifteen sampling locations.

2.3 EXPERIMENTAL SETUP

Radon detector (RAD-7) manufactured by DURRIDGE COMPANY Inc, in USA, was used to measure radon concentration in the water samples. RAD7-H_2O gives results after 30 minutes of analysis with a sensitivity that matches or exceeds that of the liquids scintillation method. The accuracy of radon in water utilizing RAD7 was affected by some factors such as the technique of sampling, sample size, counting time, temperature, relative humidity, and background effects. The detection lower limit (LLD) is less than 0.37 Bq/L. RAD-7 is a portable radon detector using the RAD H_2O technique (Fig. 2) with fast measurement.

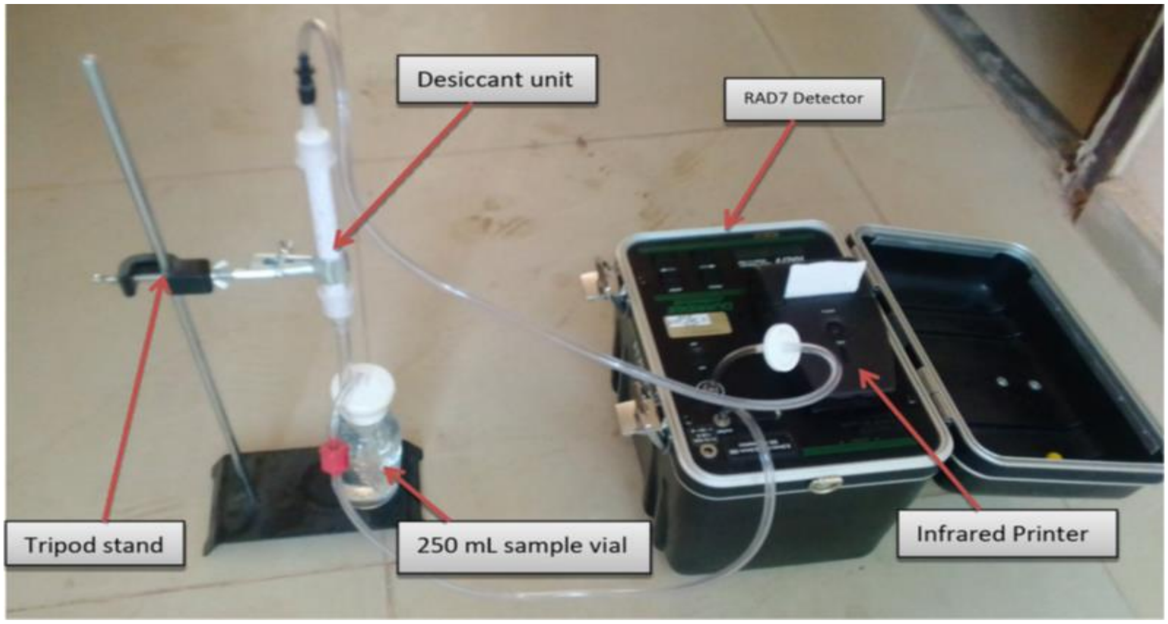


Figure 2: The setup of the RAD7 detector used to measure Rn-222 activity in water samples.

2.4 Evaluation of Annual Effective Dose

The average annual effective dose from ingestion and inhalation of Radon in water was estimated using equations 1 and 2 provided by UNSCEAR as reported by [13, 14]. According to the world health organization (WHO) and the Council of European Union (EU), the average annual effective dose of Radon in drinking water has a permitted value of 0.1 mSv/yr [15].

The annual effective dose due to the ingestion of radon from the underground E(ing) was calculated using equation (1),

$$E_{ing} = C_{Rn}\ (BqL^{-1})\ \text{x}\ D_w\ \text{x}\ CF_{ing}\ \text{x T} \qquad (1)$$

where, C_{Rn} is the mean radon (^{222}Rn) activity concentration in water, D_w is the daily water intake (2 L/day), CF_{ing} is the ingesting dose conversion factor of radon (10^{-8} Sv/Bq), and T is equal to 365 day/yr

Also, the annual effective dose of inhalation $E_{(inh)}$ of radon from water is obtained from equation (2), [16]

$$E_{inh} = Rn^{222}\text{conc. } (BqL^{-1})\ \text{x}\ R_w\ \text{x}\ D_{cf}\ \text{x}\ EQ_F\ \text{x T} \qquad (2)$$

where, C_{Rn} is the mean radon (^{222}Rn) activity concentration in water, R_w is the ratio of radon in air to radon in water (10^{-4}), D_{cf} is the dose conversion factor of radon (9 nSv/hr(Bq/m^3))$^{-1}$, EQ_F is the indoor equilibrium factor between radon and its progeny (0.4) and T is indoor time (7000 hr/yr), [17, 18].

2.5 Evaluation of Cancer Risk Factor

In addition to the estimated annual effective dose, cancer and hereditary risk were also estimated to ascertain human health risks due to exposure to radon-contaminated water. Ionizing radiation is known for its chronic risk of somatic or hereditary damage of human tissues, thus nominal lifetime risk coefficient of fatal cancer (C_RF) recommended in the ICRP recommendations of the members of the public was taken as 5.5×10^{-2}. For hereditary effects, the detriment-adjusted nominal risk coefficient (H_EF) for the whole population as reported by ICRP for stochastic effects after exposure to low dose rates was estimated at 0.2×10^{-2}. The risk to the population was then estimated using the risk coefficient reported by ICRP and assumed 70 years lifetime of continuous exposure of the population to low-level radiation. According to

Khattak, Khan [14] , the cancer risk (C_R) and hereditary effect (H_E) was calculated using equations 3 and 4:

` $C_R = E(Sv) \times C_R F$ (3)

$H_E = E\ (Sv) \times H_E F$ (4)

3. RESULTS AND DISCUSSION

The minimum, maximum and mean radon concentration values obtained in the water samples were 6.30 ± 1.60 Bq/L in S9 and 60.80 ± 5.60 Bq/L in S3, and 21.33 ± 2.95 Bq/L respectively. Eighty percent (80%) of the samples (12 out of 15) had values less than 40.0 Bq/L, with the other three samples having 40 Bq/L, 40.10 Bq/L and 60.8 Bq/L. Sixty percent (60%) of the water samples were found to have values higher than 11.1 Bq/L which is the MCL (maximum contaminant level) but observed that all the water samples had radon concentration of less than 100 Bq/L which is the upper bound limit as recommended by the European Union. There is no trend or relationship between the radon concentration, pH, and temperature in all the tested water samples. All the samples have concentration above 0.1 Bq/L which is the standard set by the Nigerian Standard for Drinking Water Quality [19].

The annual effective dose due to ingestion varied from 0.05 mSv/yr to 0.44 mSv/yr, with an average value of 0.11 mSv/yr. Also, the annual effective dose due to inhalation of radon in water ranges from 0.02 mSv/yr to 0.6 mSv/yr, with a mean value of 0.11 mSv/yr. The estimated annual effective dose due to ingestion and inhalation of radon in sampled water in the University Community in Osogbo Osun State, Nigeria was within 3-10 mSv/yr recommended by ICRP.

Table 1: Radon concentration in sampled water in university community in Osogbo, Osun State

S/N	Longitude	Latitude	C_{Rn} (Bq/L)	E_{ing} (mSv/yr)	E_{inh} (mSv/yr)
S1	$4^0$32’33.97”E	$7^0$44’46.65”N	20.60 ± 3.30	0.15	0.05
S2	$4^0$32’36.19”E	$7^0$44’40.34”N	22.00 ± 3.40	0.20	0.60
S3	$4^0$32’39.22”E	$7^0$44’34.05”N	60.80 ± 5.60	0.44	0.20
S4	$4^0$32’39.16”E	$7^0$44’29.27”N	40.10 ± 4.50	0.30	0.10
S5	$4^0$32’40.28”E	$7^0$44’29.27”N	6.30 ± 1.70	0.05	0.02
S6	$4^0$32’39.70”E	$7^0$44’31.97”N	8.60 ± 1.90	0.06	0.20
S7	$4^0$32’39.52”E	$7^0$44’41.65”N	40.00 ± 4.20	0.30	0.10
S8	$4^0$32’40.24”E	$7^0$44’39.59”N	31.90 ± 3.70	0.23	0.08
S9	$4^0$32’44.13”E	$7^0$44’39.23”N	6.30 ± 1.60	0.05	0.02
S10	$4^0$32’44.33”E	$7^0$44’39.39”N	7.60 ± 1.80	0.06	0.02
S11	$4^0$32’48.01”E	$7^0$44’38.86”N	30.80 ± 3.50	0.22	0.08
S12	$4^0$32’25.70”E	$7^0$44’14.24”N	14.50 ± 2.60	0.10	0.04
S13	$4^0$32’22.21”E	$7^0$44’13.99”N	8.80 ± 2.0	0.06	0.02
S14	$4^0$32’39.03”E	$7^0$44’20.49”N	6.40 ± 1.90	0.05	0.02
S15	Control		15.30 ±2.50	0.11	0.04

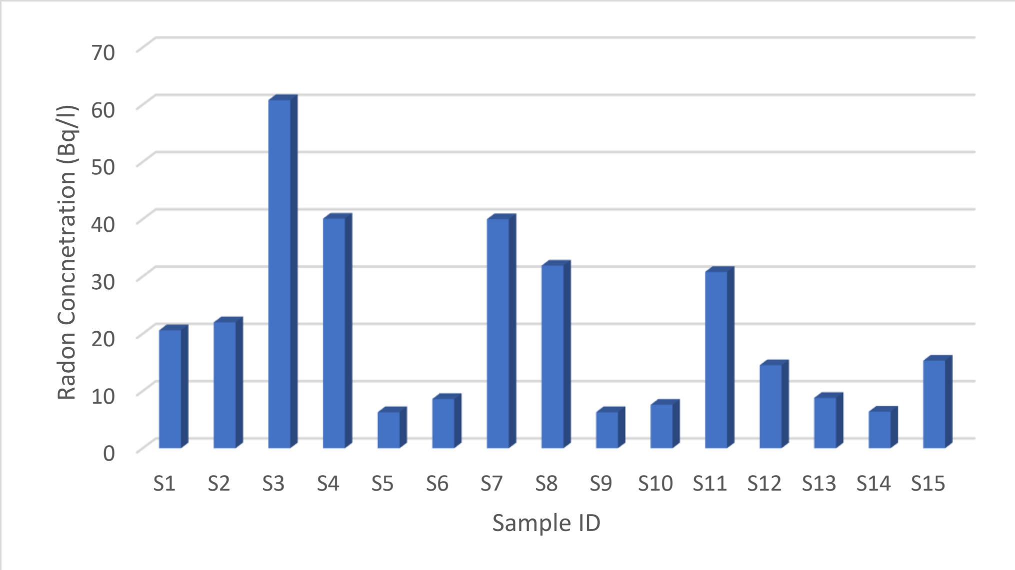


Figure 3: Radon concentration (Bq/l) in sampled water

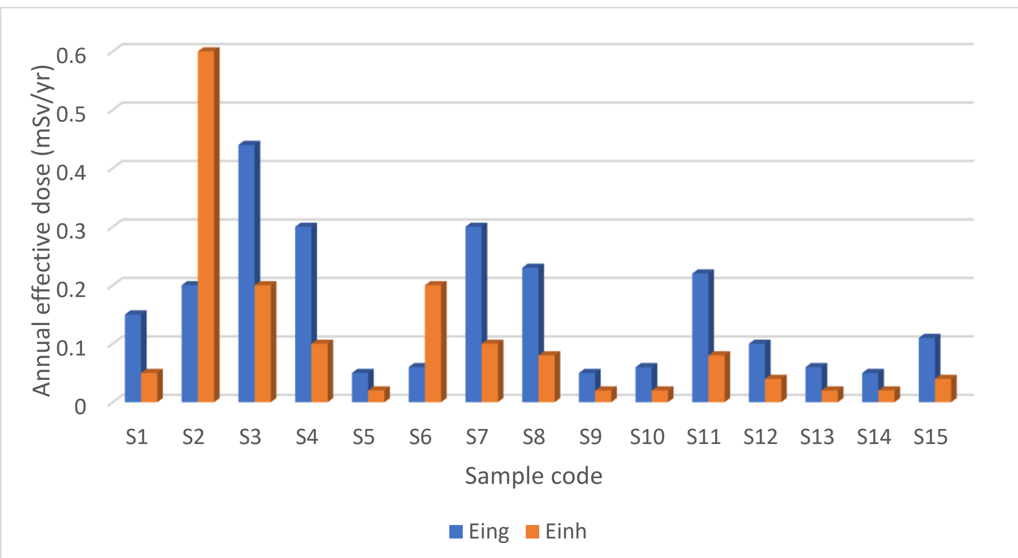


Figure 4: Annual effective dose (mSv/yr) due to ingestion and inhalation of radon in sampled water

The result of the estimated cancer risk and hereditary effect of ingestion of radon vary from 2.75×10^{-3} in S9 to 2.42 $\times10^{-2}$ in S3, and 1.00×10^{-4} in S5 to 8.80 $\times10^{-4}$ in S3 in sampled water, with average values of 8.73×10^{-3} and 3.17×10^{-4}, respectively. Similarly, cancer risk and hereditary effect due to inhalation of radon in sampled water range from 1.10×10^{-3} in S9 to 3.30×10^{-2} in S2, and 4.00×10^{-5} in S10 to 1.20×10^{-3} in S2, with mean values of 5.58×10^{-3} and 2.12×10^{-4} respectively. The estimated cancer risk and hereditary effect due to ingestion and inhalation of radon is found within the negligible cancer fatality risk value of 1.0×10^{-6} to 1.0×10^{-4}, reported by the World Health Organization (WHO).

Table 1: Estimated Cancer Risks and Hereditary Effects of radon due to ingestion and inhalation

Sample ID	Ingestion		Inhalation	
	C_R	H_E	C_R	H_E
S1	8.25×10^{-03}	3.00×10^{-04}	2.75×10^{-03}	1.00×10^{-04}
S2	1.10×10^{-02}	4.00×10^{-04}	3.30×10^{-02}	1.20×10^{-03}
S3	2.42×10^{-02}	8.80×10^{-04}	1.10×10^{-02}	4.00×10^{-04}
S4	1.65×10^{-02}	6.00×10^{-04}	5.50×10^{-03}	2.00×10^{-04}
S5	2.75×10^{-03}	1.00×10^{-04}	1.10×10^{-03}	4.00×10^{-05}
S6	3.30×10^{-03}	1.20×10^{-04}	1.10×10^{-02}	4.00×10^{-04}
S7	1.65×10^{-02}	6.00×10^{-04}	5.50×10^{-03}	2.00×10^{-04}
S8	1.27×10^{-02}	4.60×10^{-04}	4.40×10^{-03}	1.60×10^{-04}
S9	2.75×10^{-03}	1.00×10^{-04}	1.10×10^{-03}	4.00×10^{-05}
S10	3.30×10^{-03}	1.20×10^{-04}	1.10×10^{-03}	4.00×10^{-05}
S11	1.21×10^{-02}	4.40×10^{-04}	4.40×10^{-03}	1.60×10^{-04}
S12	5.50×10^{-03}	2.00×10^{-04}	2.20×10^{-03}	8.00×10^{-05}
S13	3.30×10^{-03}	1.20×10^{-04}	1.10×10^{-03}	4.00×10^{-05}
S14	2.75×10^{-03}	1.00×10^{-04}	1.10×10^{-03}	4.00×10^{-05}
S15	6.05×10^{-03}	2.20×10^{-04}	2.20×10^{-03}	8.00×10^{-05}

4. CONCLUSION

The results in this study showed that nine (9) of the water samples had radon concentration values higher than the 11.1Bq/L MCL recommended by USEPA. This requires action for radon reduction in the study area. It was also observed that all the water samples were well above 0.1 Bq/L, the standard set by the Nigerian Standard for Drinking Water Quality [19]. Therefore, the water samples from the sites are not safe for domestic use. Hence, regular monitoring of water within the University Community in Osogbo Osun State is recommended.

COMPETING INTERESTS

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

AUTHORS' CONTRIBUTIONS

Olaoye MA designed and supervised the study, Muniru EO did the sampling and performed the experiment, Jegede OA did the literature search and review, Olagbaju PO did the calculations and developed the first draft, Adegbola RB read and approved the final manuscript, and Mustapha AO conceptualize, read, and approve the final manuscript.

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