Uniosun Journal of Engineering and Environmental Sciences (UJEES), Vol. 8 No. 3, March, 2026
DOI: 10.64980/ujees.v8i1.025 **Adejumo et al.**
Published: March 30, 2026

IMPACT OF LAND USE ON SURFACE WATER QUALITY OF AWBA STREAM AND DAM IN THE UNIVERSITY OF IBADAN, NIGERIA

S. A. ADEJUMO[1*], S. O. ADESOGAN[2], and Adesola ABISOLA[3]

[1]*Department of Urban and Regional Planning, Faculty of Environmental Design and Management, University of Ibadan.*
[2,3]*Department Civil Engineering, Faculty of Technology, University of Ibadan*

[*]*Corresponding Author: sambayo372@gmail.com*

Abstract
Adequate water supply has been a mirage in most of Nigerian University campuses mostly resulting to recurrent students' unrest. The most concern of students is quantitative provision with almost no attention given to the qualitative aspect of the water supply. This paper therefore examined some major landuses interfering with the source of raw water supply for purification and supply for the University of Ibadan campus community. Both observational and experimental research methods were adopted to source both primary and secondary information utilized. Water samples were collected from six different points along the course of the streams and the Dam. The water samples were analyzed in Laboratory for Physical, Chemical and Biological parameters. The study identified landuses such as fish and crop farms, open waste dumps, residential quarters and hostels buildings, academic buildings, automobiles mechanic building and zoological garden. Water analysis result revealed mean value of Temperature (29.7^{0}c), pH (6.80), TDS (188.33), Pb (0.78), Fe (2.89), Cd (0.04mg/l), Fl (2.92mg/l) and BOD (25.05mg/l). Water sample collection sites B, C and E had insignificant values of E.coli while other sites had values ranging from 15000cfu/ml to 20000cfu/ml. Both sites A and F had salmonella with 10000cfu/ml respectively while other sites had negligible values. Water quality index analysis using the WAWQI model revealed that none of the raw water is fit for direct consumption. The water analysis showed high concentration of lead, cadmium and BOD which could be attributed to effluents from residential hostels and open waste dumps. Similarly, Awba dam is polluted due to various landuses aborting the stream and its use for human consumption requires adequate treatment and quality monitoring are recommended in order to ensure water security.

Keywords
Landuse, water quality, open waste dumps, residential quarters and hostels, University of Ibadan campus community

1. INTRODUCTION

Water is an indispensable resource essential for sustaining life, maintaining ecosystem balance, and supporting economic development. It plays a critical role in agriculture, industry, domestic activities, and sanitation [1]. In agriculture, water is vital for irrigation, ensuring food security, and supporting livestock, which depend on clean water for productivity and health [2]. Domestically, water is indispensable for drinking, cooking, and hygiene, directly impacting public health and quality of life [3].

Despite the usefulness of water, its quality is increasingly threatened by human activities such as urbanization, agricultural practices, and improper waste disposal from different landuses. Some activities introduce contaminants that deteriorate both surface and groundwater quality, leading to significant public health and environmental concerns [4]. In Nigeria, rapid urbanization and industrialization have contributed to water quality degradation, intensifying the gap between water demand and supply [5]. This challenge is particularly acute in university campuses, where water supply issues frequently cause unrest among students due to shortage in quantity and quality.

The Awba Stream and Dam, situated within the University of Ibadan, serve as a vital water resource for the campus, providing raw water for purification, irrigation, recreation, and research. However, various land uses within its watershed area, including residential, agricultural, educational, and infrastructural developments, have adversely affected its water quality [6]. Infrastructural developments disturb the soil and increase sediment load, clogging waterways and reducing water cleanness [7]. The construction of academic buildings has been perceived to have contributed to increase of run off consequently accelerate the sedimentation and siltation in the dam. The implication of the persistent siltation and sedimentation have caused huge impact on the quality and quantity of water available to residents of the Campus community. Residential areas generate domestic waste and runoff, agricultural activities introduce fertilizers and pesticides, and infrastructural developments cause sedimentation and alter water flow patterns. Collectively, these activities degrade water quality, posing risks to aquatic ecosystems and human health [8].

Specifically, improper waste disposal and agricultural practices within the watershed perceived to have introduced pollutants, including heavy metals, organic contaminants, and harmful pathogens, compromising the water quality of the Awba Dam [9]. The resultant water pollution not only affects the aquatic ecosystem but may have also escalates water treatment costs, making it unsuitable for direct consumption [10]. Given the significance of the Awba Dam as a water source for the University community, ensuring its quality and sustainability is critical. This study therefore, examined the impact of land use on the water quality of the Awba Stream and Dam with view to enhanced policy guide on land uses within the campus community for sustainability of water resources development.

The climate at the University of Ibadan shares similarities with other parts of Ibadan, featuring a tropical wet and dry climate characterized by a lengthy wet season and consistent temperatures year-round. The wet season in Ibadan typically lasts from March to October, with a break in rainfall occurring around August, commonly referred to as the 'August break.' This break divides the wet season into two distinct periods. University of Ibadan area shares the typical basement complex found in Southwest Nigeria. It consists mainly of metamorphic rocks dating back to the Precambrian period, along with a few granite and porphyry intrusions from the Jurassic period [11].

2. MATERIALS AND METHOD

2.1 Study area

The study area is the entire catchment area of Awba stream and dam in the University of Ibadan and its contiguous land use areas. Awba reservoir in the University of Ibadan (7º 26’ N, 3º 53’ E) is located in the south western region of Nigeria about 160 km from the Atlantic Ocean coast at an altitude of 185 m above sea level. The dam was built by the management of the University of Ibadan in 1972 within a total area of 7,374 square meters [12]. Its purpose was to provide water for irrigation and drinking purposes. Its embankment is made of riprap of large boulders on the upstream face and impermeable core to avoid seepage through the embankment and beneath the dam. The core consists of asphalt concrete membrane with a broad base which lowers the stress imposed on the foundation. The core has a height of 6.7m with maximum embankment height of 8.5m and dam crest width of 12.2meters. The dam also has a spillway that functions to release excess water from the reservoir when there is increased water level in the dam especially during the rainy season. The spillway below the core is 0.9m and the length of the embankment is 110m with a total volume of 38220 cubic meters. The dam has a capacity of approximately 277 million liters of impounded water. The geological composition of Ibadan and its surroundings, including the catchment area of the Awba Dam, falls within the pre-Cambrian rocks of southwestern Nigeria, which is part of Nigeria's basement complex in terms of its geology. Below is a diagram showing the overview of the Awba dam (Figure1).

Figure 1: Photography of Awba Dam, University of Ibadan

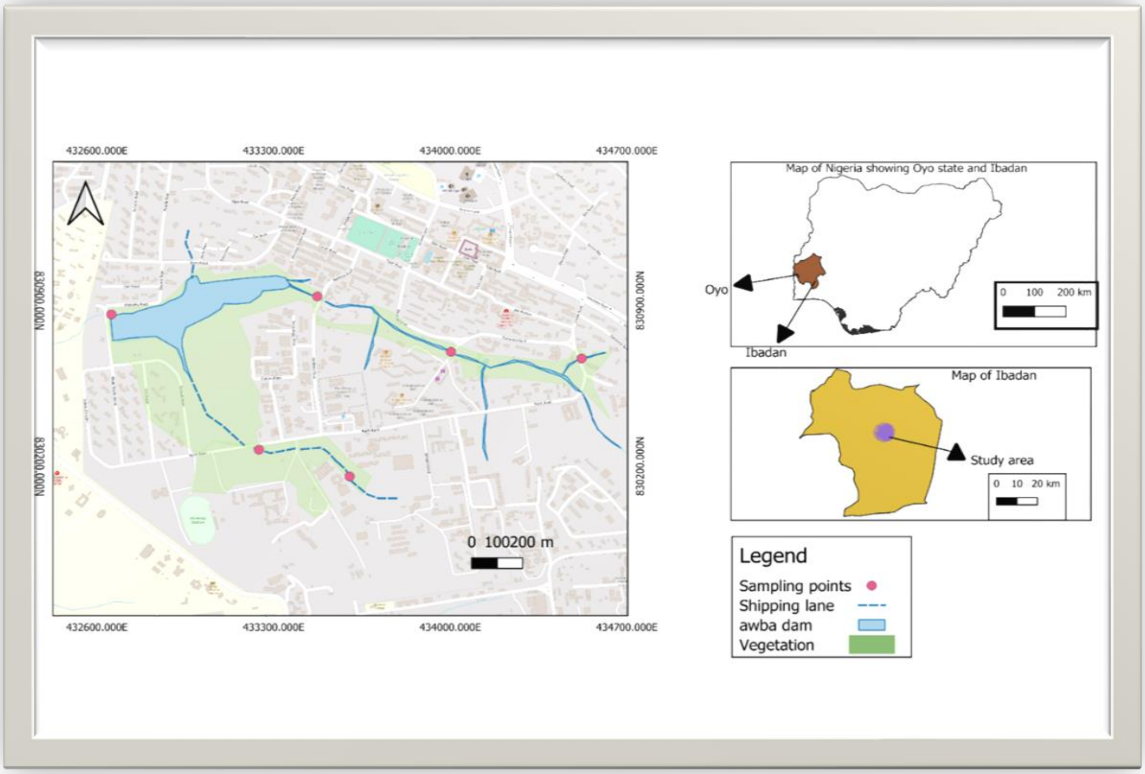

Figure 2: Awba Dam and points of sample collection

2.2 Material and Method

The study adopted both observational and experimental methods to collect data. Primary and secondary information were utilized. Water samples were collected from six different points along the course of the stream and the Dam (Figure 2). Samples were collected at the entry point of effluent of major landuses such as hall of residence, zoological garden, agricultural farm, fish farm, community market and sewerage treatment point along the stream. The samples were taken and analyzed in the Laboratory for Physical (Temperature, Turbidity, TDS-Total Dissolved Solids), Chemical (pH, Electrical Conductivity, Nitrates, Sulphate, Manganese, Cadmium, Fluoride, Iron and lead) and Bacteriological (Total Coliform Count, E-Coli, Bio-chemical Oxygen Demand, and Chemical oxygen demand) parameters using standard procedures (APHA, 2005). Weighted arithmetic water quality index and the Canadian Council of the Ministry of Environment - Water Quality Index were used to calculate the water quality index of the sampled locations. The calculations were done on Microsoft Excel, graphs were drawn using Figma, and the water quality index map as well as the map of the study area were gotten from QGIS.
The Canadian Council Ministry of Environment Water Quality Index was calculated by the formula below (Lumb, Halliwell and Sharma, 2006)

$$\text{CCME: } WQI = 100 - \frac{\sqrt{F1^2 + F2^2 + F3^2}}{1.732} \quad \text{……(1)}$$

Where:

$$F_1 = \left[\frac{number\ of\ failed\ parameters}{total\ number\ of\ parameters}\right] \times 100 \quad \text{……(2)}$$

F_2: termed the ‘frequency’, this is the percentage of individual tests values that do not meet with the objective values (failed tests). It is expressed as:

$$F_2 = \left[\frac{number\ of\ failed\ tests}{total\ number\ of\ tests}\right] \times 100 \quad \text{……(3)}$$

F_3: termed the ‘amplitude’, this is a measure of the amount by which test values fail to meet their objectives. The amplitude is calculated by an asymptotic function that scales the normalized sum of the excursions (*nse*) of the test values from the objectives to yield a value between 0 and 100 using:

$F_3 = [\frac{nse}{0.01(nse)+0.01}]$……………………………………………………………………………..(4)

If a test value falls below the objective value, the excursion for that test value is calculated as:

$$excursion = \left[\frac{failed\ test\ value}{objective}\right] - 1 \quad (5)$$

Conversely, if the test value exceeds the objective value, the excursion value is calculated as:

$$excursion = \left[\frac{objective}{failed\ test\ value}\right] - 1 \quad (6)$$

The *nse* then is the collective amount by which individual test values are out of compliance and is calculated by summing the excursions of individual tests from their objectives and dividing by the total number of tests (both those meeting objectives and those not meeting objectives). This is expressed mathematically as:

$$nse = \left[\frac{\sum_{1=1}^{n} excursion}{total\ number\ of\ test}\right] - 1 \quad (7)$$

The Weighted Arithmetic Water Quality Index was determined equation ……….................................… (8)

WAWQI: $WQI = \frac{\Sigma QnWn}{\Sigma Wn}$ …………………………………………..…..(9)

Where:
Qn = quality rating of nth water quality parameter, and
Wn = unit weight of nth water quality parameter
The equations below were applied for estimating the quality rating

$$Qn = \frac{(Vn - Vid)}{(Sn - Vid)} \times 100 \quad (10)$$

Where:
Vn = estimated value of nth water quality parameter,
Vid = ideal value for nth parameter (i.e. for pH, V id = 7.0, and 14.60 for DO but zero for the other parameters), and
Sn = standard permissible value of nth water quality parameter

Unit weight was calculated with: $Wn = \frac{K}{Sn}$... (11)

Where Sn = standard permissible value of nth parameter

K = constant of proportionality and it was determined with $K = \frac{1}{\Sigma(1 \div Sn)}$ …... (12)

3. RESULTS AND DISCUSSION

3.1 Description of Water Quality

3.1.1 Physical parameters

The temperature of the sampled water is varied from 25.3^{0}C to 33.3^{o}C and the pH varied from 6.37 to 7.20 (Table 1), which falls largely within the permissible limit of WHO and Standard Organization of Nigeria (SON) for drinking water (WHO, 2013 and SON, 2007). The average temperature was 29.7^{0}C which is above the acceptable limit of WHO and Standard Organization of Nigeria. The temperature may influence the amount of dissolved oxygen in water which in turn influences the survival of aquatic organisms in the dam.

3.1.2. Chemical Parameters

The presence of Total Dissolved Solid (TDS) in water is an indicator of contamination [13]. The TDS have mean value of 188.33mg/l which falls within the permissible limit of 500mg/l. The Electrical conductivity shows the number of materials dissolved in water and has a direct impact on the total dissolved solid [14]. The Mean value (78.82µs) of Electrical conductivity in the analysis falls below the specified limit of 1000µs. This implies that direct consumption may be injurious to body system until additional mineral is added. Similarly, Nitrates impact human health and is a great public health concern [15], however the mean nitrate concentration (0.04mg/l) in the samples falls within the permissible limit. The indicates later that farmers within the watershed are not using fertilizer on their farms.

The average concentration of Lead (0.78) and Iron (2.89) in the water samples were higher than the permissible limit of WHO and SON. Excessive concentration of iron in water stands to cause stomach upset [16] and negatively impact the human system and may results in a condition known as haemochromatosis wherein tissues are damaged due to prolonged iron accumulation. Disease conditions associated with excess iron intake includes siderosis, primary hepatocellular carcinoma and generally enhanced malignancy in experimental animals [17]. Furthermore, excess iron could be as a result of parent rock of the soil and the presence of organic matter that can reduce ferric iron to ferrous iron [18]. Similarly, excess concentration of Lead substance in water is toxic, therefore, bio-accumulation of lead in body tissues has neurotoxic, nephrotoxic, fetotoxic, and teratogenic effects on man and animals [19].

The mean Fluoride (Fl) of the sampled water is 2.92mg/l which is above the WHO limit of 1.50mg/l and this could be attributed to forages and grasses in the study area. In addition, the mean Cadmium level of the sample is 0.04mg/l which is far above the WHO limit of 0.003mg/l which shows that there is high Cadmium concentration in both streams that flow into the dam. This could be attributed to the rock type and anthropogenic activities along the stream course [20]. The mean value of Manganese concentration in the samples is 2.02mg/l which exceeds the WHO limit of 0.05mg/l. This is dangerous as it could lead to memory impedance, reduction of attention and motor skills problem and it could be attributed to the deposition of leachates (Evans, 2019) into the surrounding of Awba dam.
It is noteworthy to detect that the mean value of the following parameters: Zinc (0.18mg/l), Sulphate (3.24mg/l), Nitrate (0.40mg/l) and Copper (0.85mg/l) are within the maximum limit of WHO. This revelation showed that the raw water is not absolutely harmful but requires purification for safe consumption.

3.1.3 Biological parameters

The mean concentration of BOD in the samples is 25.05mg/l which exceeds the WHO limit of 2.0mg/l. The value makes the raw water dangerous for direct consumption for both man and aquatic life as it indicates high level of eutrophication [21] and could be attributed to the surrounding vegetation and residential building. The COD values fall within the WHO limit of 80mg/l with values ranging from 31.20 to 34.45 which suggests that wastes within the study area is largely organic.
Bacteriological contamination of the samples was examined and analysis showed that only sample collected from waterworks (Site B) is absolutely free from total coliform. The WHO sets the limit of zero (0) for bacteriological contamination for total coliform and site B was the only site that is free while other sites had coliform of values ranging from 10000cfu/ml to 30000cfu/ml. Sites B, C and E had negligible values of E.coli while other sites had values ranging from 15000cfu/ml to 20000cfu/ml. Both sites A and F had salmonella with 10000cfu/ml respectively while other sites had negligible values. The high bacteriological contamination concentration at certain sites could be attributed to contamination of sewage due to proximity to influents from residential hostels and central sewerage point contiguously situated near Awo hostel and Queen Idia Hostels.

Table 1: Physico-chemical analysis and descriptive statistics of surface water quality of Awba dam/stream

Parameters	**A**	**B**	**C**	**D**	**E**	**F**	**Mean**	**WHO**	**SON**
Temp	25.3	33.3	30.1	29.7	30.3	29.5	29.7	25.00	25.90
Ph	6.87	7.20	6.71	6.80	6.37	6.83	6.80	6.5 -8.5	6.5-8.5
EC	71.20	62.30	90.40	89.60	102.10	57.30	78.82	400.00	1000.00
TDS	191	184	189	215	197	154	188.33	500.00	500.00
DO average	6.65	5.80	6.40	6.30	6.15	5.80	6.18	5.00	5.00
COD	31.55	34.15	32.60	34.45	32.60	31.20	32.76	80	--------
BOD	22.30	24.30	27.05	26.60	24.35	25.70	25.05	2	--------
Mn	3.01	2.04	1.94	2.09	1.43	1.62	2.02	0.05	0.10
Pb	0.60	1.09	0.71	0.69	0.51	1.08	0.78	0.01	0.01
Fl	3.41	2.63	3.74	2.12	2.59	3.01	2.92	1.50	1.00
Fe	3.28	2.81	3.62	2.08	2.61	2.98	2.89	0.30	0.30
NO3	0.41	0.36	0.49	0.30	0.29	0.55	0.40	50.00	50.00
SO4	4.21	3.13	2.26	3.24	2.97	3.65	3.24	100.00	100.00
Cu	0.42	0.93	0.79	1.02	0.81	1.12	0.85	1.20	1.20
Cd	0.03	0.08	0.04	0.01	0.05	0.03	0.04	0.003	0.003

Zn	0.20	0.16	0.08	0.24	0.10	0.32	0.18	3.00	5.00
Total coliform	2.5x10^4	Negligible	2.0 x10^4	1.0 x10^4	1.0 x10^4	3.0 x10^4	1.58 x10^4	0	0
E.Coli	1.5 x10^4	negligible	1.0 x10^4	negligible	Negligible	2.0 x10^4	7.5 x10^3	0	0
Salmonella	1.0 x10^4	negligible	negligible	negligible	Negligible	1.0 x10^4	3.33 x10^3	0	0

3.2 Weighted Arithmetic Water Quality Index (WAWQI)

The analysis revealed the range of Weighted Arithmetic Water Quality Index from 642 to 776 (Table 2) which implies that the samples collected at different points are not good for direct consumption without proper purification. Acceptable water for drinking should contain WQI <50 while poor (unacceptable for drinking) may have WQI ≥ 100.

Table 2: Sample locations and summary of water quality index results using the WAWQI model

	Sample collection point	**Coordinates**	**WQI**	**Description**
A	Downstream Awba Dam	$07^0$26.548N $003^0$53.190E	642	Unfit for drinking
B	Waterworks	$07^0$26.100N $003^0$53.674E	698	Unfit for drinking
C	Independence-Azikwe Hostels area	$07^0$26.470N $003^0$53.931E	776	Unfit for drinking
D	Zoological garden	$07^0$26.592N $003^0$53.641E	763	Unfit for drinking
E	St. Anne's hostel	$07^0$26.380N $003^0$53.197E	705	Unfit for drinking
F	Awolowo Hostel	$07^0$26.252N $003^0$53.592E	739	Unfit for drinking

3.3 Canadian Council Ministry of Environment Water Quality Index (CCME-WQI)

The Canadian Council Ministry of Environment Water Quality Index (CCME-WQI) categorized the WQI into three: Excellent (95-100), Good (80-94), Fair (65-79) and Poor (0-44). The values between 45-64 oscillates between fair or poor. The calibration showed that all samples collected for analysis (Table 3) are regarded as poor and unfit for direct consumption. This revelation showed that the land uses and anthropogenic activities are impacting on the quality of the stream water. The impact usually increases the cost of water purification consequently result to occasional water shortage when there is insufficient fund for necessary chemical.

Table 3: Sample locations and summary of water quality index results using the CCME-WQI model

	Sample collection point	Coordinates	WQI	Description
A	Downstream Awba dam	$07^0$26.548N $003^0$53.190E	30.92	Poor
B	Waterworks	$07^0$26.100N $003^0$53.674E	37.59	Poor
C	Independence-Azikwe Hostels area	$07^0$26.470N $003^0$53.931E	33.71	Poor
D	Zoological garden	$07^0$26.592N $003^0$53.641E	37.31	Poor
E	St. Anne's hostel	$07^0$26.380N $003^0$53.197E	38.31	Poor
F	Awolowo Hostel	$07^0$26.252N $003^0$53.592E	30.27	Poor

4. CONCLUSION

The Awba Dam was designed and built by the University to harvest raw water from Awba stream and its tributary within the University campus. The dam was built at the confluence point of the two streams aborting senior staff residential quarter and green space behind the Faculty of Engineering. The first stream drains from off campus through the University fish farm, Independence, Nnamdi Azikwe and Balewa Halls of residence, Zoological Garden and the Faculty of Sciences while the second stream have its source around Queen Idia hostel flow through Obafemi Awolowo hostel and AOO (Private) hostel. The dam was built to supply raw water for purification at waterworks to provide potable water for the university community. The water samples collected for analysis at major landuse point revealed that different anthropogenic activities within the study areas are impacting on the quality of the stream water. Essentially, the water quality must have been affected by human activities such as agricultural practice, waste water from hostels which are among main sources of contaminates to water in the dam. Indiscriminate waste disposal is the reason for the high organic contaminants noticed in the samples. This was observed around junior staff residential quarters behind Independence hostel along Barth Road, Similarly, the Aquaculture farm wastes are discharge into the stream. The farm and liquid effluents from hostels are the main source of the bacteriological contaminants. The dam water has a high content of lead, manganese, fluoride, cadmium and iron contaminants and this reveals that the dam is contaminated with heavy metal. The is largely because of indiscriminate disposal of waste which leached into the stream and later deposited into the dam. In conclusion, the water quality results have shown that Awba dam water is polluted and its use for human consumption needs to be subjected to adequate treatment and quality monitoring.

This study recommends a restriction and regulation in human activities along the University watershed. There should be spirited effort to create awareness on the dangers associated with raw water consumption especially for people living close to the Awba stream. Adequate water monitoring is encouraged to ensure compliance with environmental laws and the authorities responsible for waste management should support the sewage disposal system that terminates at waste treatment facilities. Adequate treatment of raw water at the university treatment plant for safe consumption is suggested. The University should develop extant law against indiscriminate waste disposal and application of chemical fertilizer within the campus community. Periodic inspection of sewerage manhole chambers by relevant Unit in the Works and Maintenance Department with prompt repair of sewerage leakage and stringent monitoring of sewerage system in the University community to forestall liquid waste discharge into stream and eventual pollution of Awba dam.

REFERENCES

[1] Cosgrove, W. J., and Loucks, D. P. (2015). Water management: Current and future challenges and research directions. *Water Resources Research*, *51*(6), 4823-4839.

[2] FAO. (2020). Water for Sustainable Food and Agriculture. Food and Agriculture Organization of the United Nations.

[3] World Health Organization (2019). Guidelines for Drinking-water Quality: Fourth Edition Incorporating the First Addendum, *World Health Organization*.

[4] Ohwo, O., and Abotutu, A. (2015). Environmental impact of urbanization in Nigeria. *British Journal of Applied Science & Technology*, *9*(3), 212-221.

[5] Adejumo, S. A. (2020). Characteristics and challenges of teenage water vendors in traditional markets in Ibadan, Nigeria, *AJPSSI African Journal for the Psychological Study of Social Issues, V*ol.23 no.1 issues page 56-66

[6] Adeleke, A. O., Usikalu, M. R., & Akinyemi, M. L. (2020). Assessment of heavy metals in water, sediment, and fish of Awba Dam, University of Ibadan, Ibadan, Nigeria. *Heliyon*, 6(8), e04786.

[7] Mcgrane, S. J. 2016. Impact of Urbanisation on hydrological and water quality Dynamics, And Urban Water Management: A Review. Hyrological Sciences journal, 61 (31), 2295-2311

[8] Balogun, O., Adeolu, A., & Olalekan, A. (2021). Comprehensive water quality assessment of a tropical reservoir using water quality index and multivariate statistical techniques. *Environmental Science and Pollution Research*, 28(21), 27025-27038.

[9] Olaifa, F. E, Ewutanure, S. J. and Adeleke, I. E. (2024) physicochemical, heavy metal and microbial analyses of awba dam water, university of Ibadan, Ibadan, Nigeria, animal research international 21(1): 5231 – 5240

[10] Ibrahim, M. A., Agboola, O. J., & Adeyemo, A. O. (2020). Mitigating the impact of land use on water quality in urban areas: A case study of the Awba Dam watershed. *Environmental Management*, 65(4), 559-572.

[11] Zhe S., Houmin L., Lixing L., Jianhua, D.,and Jie M. (2021) Iron Isotopes and Trace Element Compositions of Magnetite from the Submarine Volcanic-Hosted Iron Deposits in East Tianshan, NW China: New Insights into the Mineralization Processes. *Journal of Earth Science*, 32(1): 219-234. doi: 10.1007/s12583-020-1060-0

[12] Jibiri, N. N., and Akomolafe, I. R. (2016). Radiological assessment and geochemical characterization of the sediments of Awba Dam, University of Ibadan, Nigeria. *Radiation Protection and Environment*, *39*(4), 222.

[13] Muhammad, H. (2019). Total Dissolve Salts (TDS). 10.13140/RG.2.2.11858.30406.

[14] Corwin, D. L., and Yemoto, K. (2020). Salinity: Electrical conductivity and total dissolved solids. *Soil science society of America journal*, *84*(5), 1442-1461.

[15] Ward, M. H., Jones, R. R., Brender, J. D., De Kok, T. M., Weyer, P. J., Nolan, B. T., ... and Van Breda, S. G. (2018). Drinking water nitrate and human health: an updated review. *International journal of environmental research and public health*, *15*(7), 1557.

[16] Izah S.C., Iyang, I. R., Angaye, T.C and Okawa, I P (2016) A Review of heavy metal concentration and potential health implication of beverages consumed in Nigeria. Toxics, 5(1), 1 https://doi. org/10.3390/toxics5010001

[17] Kew, M. C. (2009). Hepatic iron overload and hepatocellular carcinoma. *Cancer letters*, *286*(1), 38-43 [18] Chen, C., and Thompson, A. (2021). The influence of native soil organic matter and minerals on ferrous iron oxidation. *Geochimica et Cosmochimica Acta*, *292*, 254-270.

[18] Chen, C., Hall, S.J., Coward, E.and Thompson, A. (2020). Iron- mediated organic matter decomposition in humid soil can counteract protection. Nature communication, 11, 2255. https://doi. org/10.1038/s41467-020-16071-5

[19] Hoekman , T. (2005) Heavy Metals Toxicology.http://www.luminethydro/heavymet;htm Heavy Metal Toxicity (HMT) Files. Heavy Metal Toxicity. http:// tuberose .com/.html

[20] Oyem, H. H., Oyem, I. M., and Usese, A. I. (2015). Iron, manganese, cadmium, chromium, zinc and arsenic groundwater contents of Agbor and Owa communities of Nigeria. *SpringerPlus*, *4*(1), 1-10.

[21] Vasistha, P., and Ganguly, R. (2020). Water quality assessment of natural lakes and its importance: An overview. *Materials Today: Proceedings*, *32*, 544-552./2156-9614-7.15.51