American Journal of Water Science and Engineering
2025, Vol. 11, No. 3, pp. 51-59
https://doi.org/10.11648/j.ajwse.20251103.11

Research Article

Pollution Assessment and Distribution of Snails' Genera at a University Community Dam: Implications for Control Strategies

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Abstract

This study was carried out to evaluate the pollution level and distribution of snails' genera at a dam within a university community in order to develop efficient control strategies. Water samples and sediment samples were collected at twelve sampling points within the dam for eight weeks and analyzed for heavy metals (Manganese [Mn], Zinc [Zn], Iron (Fe), Cadmium [Cd] and Lead [Pb]) while snail genera were identified using standard procedure. Results were compared with the World Health Organization's (WHO) guideline limit (water quality [Mn = 0.4mg/L, Cd = 0.003mg/L, Pb=0.01mg/L]; sediment [Zn = 120mg/kg, Fe = 15mg/kg]). Data were analyzed using descriptive statistics and Spearman rank correlation at p=0.05. Concentrations of Mn (mg/L), Zn (mg/L) in the water sample were 17.5±01 and 11.3±2.6, respectively. These values were higher than the WHO's recommended limits. Lead and cadmium were not detected. Concentrations of manganese and zinc in the sediment samples were within the recommended limits. Iron concentration (690.3±120.9 mg/kg) exceeded the WHO's recommended limit. The snail genera identified were *Bulin*us species (65.0%), *Biomphalaria* species (24%) and *Lymnae* specie (11%). *Bulinus* (lunged snail) was the planorbid intermediate host of *Schistosoma haematobium*. A positive correlation existed between the concentration of manganese in sediment and the number of snail genera available ($r = 0.722$, $p < 0.01$). The concentration of metal in the sediment sample was higher than that in the surface water. Water and sediment had high concentration of iron and *Bulinus* snail species; an intermediate host of *Schistosoma haematobium* was identified. Continuous assessment of pollution level is highly essential and immediate control measure is encouraged to mitigate health risks associated with contact with this water body.

Keywords

Snails Genera, Sediment, Heavy Metal

1. Introduction

Pollution in freshwater systems, particularly dam reservoirs within university communities, has become a pressing concern in contemporary environmental management. This pollution can be due to both the natural and human-related activities [1]. Natural factors that influence water quality include hydrological, atmospheric, climatic, topographical and lithological [2, 3].

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Received: 25 June 2025; **Accepted:** 7 July 2025; **Published:** 25 August 2025

However, aquatic ecosystems within urban and institutional environments are increasingly vulnerable to anthropogenic pressures, with freshwater bodies acting as repositories for a range of pollutants. For instance, studies have reported that human activities that adversely affect water quality include mining, livestock farming, production and disposal of effluent water (e.g., industrial, municipal and agricultural), increased sediment run-off or soil erosion due to land-use change and heavy metal pollution [4-6].

Nevertheless, the nature of pollution in a community dam is complex, involving chemical, physical, and biological contaminants [7]. It also includes nutrient pollution, such as excessive nitrogen and phosphorus from fertilizers, leads to eutrophication, resulting in harmful algal blooms that reduce oxygen levels, harm aquatic life, and degrade water quality [8, 9]. Furthermore, the presence of pathogens, heavy metals, and hazardous chemicals can further exacerbate these effects, creating a range of ecological and public health challenges [10].

Over time, concerns have grown regarding the dam's water quality, sediment composition, and overall ecological health. One significant ecological concern is the proliferation of freshwater snails, many of which serve as intermediate hosts for parasitic diseases such as schistosomiasis. In many parts of sub-Saharan Africa, snail-borne diseases such as schistosomiasis remain endemic, with genera like *Biomphalaria* and *Bulinus* acting as intermediate hosts [11]. The distribution and abundance of these snail genera are closely linked to anthropogenic activities – agricultural runoff, sewage discharge, and domestic waste disposal [12, 13]; as well as water quality parameters, including nutrient levels, organic pollution, and heavy metal contamination [14, 15]. These snails not only reflect the ecological status of freshwater bodies but also serve as bioindicators of pollution, providing crucial data for environmental health monitoring.

However, university community dams, which are frequently utilized for residential, recreational, and research purposes, are susceptible to these types of pollution because of their close proximity to densely populated and activity-rich environments. Over time, monitoring various components of water quality – both chemical and biological – allows for the detection of changes in the aquatic environment and aids in the development of an understanding of ecosystem health. Those in charge of managing and safeguarding natural resources can use the combined data to produce information that will help them assess whether the state of the water resource is getting better or worse over time as a result of human use. Thus, in order to develop efficient control strategies, this study was carried out to evaluate the pollution level and snail species distribution at a dam within a university community.

2. Materials and Methods

2.1. Study Area

Awba Dam is a man-made lake which is about 700m long, 135m wide and with a maximum depth of 5.5m. It impounds about 227 million litres of water, the source of which is from two streams: the Shango from the west and Awba from the east. After treatment, the lake water is used for drinking purposes [16]. Awba dam is located in the south-western part of the University of Ibadan [17]. It was constructed in April 1964 by the British Government to store water for drinking, domestic and laboratory uses; to preserve the fishing culture within the University of Ibadan (UI) to facilitate hydro-biology and fishery reserve project and develop the dam for recreational and ecotourism site on the campus [18]. The water of the dam is subjected to occasional multi-directional water movement due to wind effects. This wind action is minimal during the dry season. The temperature of the lake ranges from 24.4℃ – 36.8℃. This results in the thermal stratification of the water meters above sea level. Awba Reservoir is popularly known as Awba Dam and it lies between the latitudes 7˚26' - 7˚27'N and longitudes 3˚53' - 3˚54'E. It is bounded on the North by Ijoma and Ekwumo roads, on the East by the Department of Zoology and on the West and South by staff Quarters and Faculty of Technology respectively [17]. The water level in the reservoir is regulated at a spill-way through which excess water flows out so the level remains almost constant throughout the rainy season. However, during the dry season, the water level recedes [19].

2.2. Water Sampling

A grid on the map of Awba Dam was used to delineate a total of twelve (12) sampling points within the dam for eight weeks based on accessibility and variation in the site ecology. Two-litre high-density polyethylene (HDPE) containers were thoroughly washed and thereafter rinsed three times with sample water at each sampling point. Unfiltered water samples were collected directly into pre-cleaned containers which were filled to the brim, freed of air bubbles and capped tightly to exclude air. Samples were transported immediately to the laboratory and refrigerated at 1–4℃ to assist preservation and analysed for physical parameters within six hours of collection. Two millilitres (2mL) of nitric acid (HNO_3) was used to preserve each of the water samples for heavy metal analysis.

2.3. Water Quality Parameters

Physico-chemical parameters like temperature, pH, dissolved oxygen (DO), total dissolved solids (TDS), and turbidity of Awba Dam surface water were measured. Temperature and pH were measured using a calibrated Jenway pH meter. Total dissolved solids (TDS) were measured with a Jenway model 470 conductivity/TDS meter. Turbidity was determined using HACH DR/2000 spectrophotometer at a wavelength of 450nm and expressed as NTU. Dissolved oxygen (DO) was determined using the electrometric method (Oxygen-detecting electrode). Phosphorus (PO_4^{3}-) and Nitrate (NO_3^-) concentrations were read from the calibration curve on the spectrophotometer while Potassium was read using a Flame photometer.

2.4. Water Sample Digestion

After collection, water samples were filtered through a 0.45 µm filter, the filtrate was acidified with nitric acid (HNO_3) according to standard procedure [20]. Heavy metals in the digested samples were analysed using Atomic Absorption Spectrophotometer. The instrument (Varian 200 spectra, by Buck scientific) was used to determine Lead (Pb), Cadmium (Cd), Manganese (Mn), Iron (Fe) and Zinc (Zn). Appropriate blanks were prepared for each parameter to ensure Quality Control and Quality Assurance. All analyses were carried out in triplicates. The Walkley-Black method (Walkley and Black 1934) was used for the determination of total organic carbon (TOC) as described in Klute [21].

2.5. Sampling of Sediment

Twelve sampling points were used for sediment samples collection. Grab sediment samples were collected between the hours of 8.00 a.m. and 9.00 a.m. through boat cruises. Samples were collected using a van veen grab sampler lowered into the bottom of the reservoir at each sampling point. Sediment sampling was done once a week for four weeks in the 12 sampling points within Awba Dam. A total of 48 sediment samples were collected. The samples were emptied into labelled polythene bags and transported to the laboratory for washing and air drying.

2.6. Extraction and Identification of Freshwater Snails from Sediment

Figure 1. *Estimation of the length of various snails in centimetre.*

Freshwater snails were extracted in the laboratory with the aid of a 4mm mesh size. Tap water was poured into a plastic bath and the sieve containing the sediment sample from each location was swirled to facilitate the extraction of the snails. The freshwater snails contained were sorted from the sediment and identified using different methods. The snails were classified into two groups according to Frest and Johannes [22] based on the features of the aperture (mouth; shell opening proper: the rim or border termed the peristome). The snails were held from the top (Apex) with the aperture and peristome directly facing the observer. The snails with the opening/aperture facing the left were classified as lunged (sinistral or left-handed) while those with the opening facing the right were categorised as gilled (dextral or right-handed) [23]. The snails were further identified to genera level using Identification key of East and Central African Freshwater Snails of Medical and Veterinary Importance [24]. The lengths of the various snails were estimated in centimetre using a ruler and a plain sheet of paper (Figure 1).

2.7. Data Analysis

Data from the laboratory analyses were recorded in a prepared spreadsheet and entered into Statistical Package for Social Sciences (SPSS) version 20. The descriptive statistics – mean and standard deviation – were determined and used to summarise the data. Spearman-rank correlation was computed to document the relationship between heavy metals across the sampled media (sediment and water), and the number of snail genera available in the Awba Dam surface water. Prior to doing a spearman correlation analysis, the data were ranked. Each value in both variables was replaced by its rank while tied values were given the average of their ranks. The level of statistical significance was set at 5%.

3. Results

3.1. Physico-chemical Parameters of Water from Awba Dam

The Physico-chemical properties of the surface water in Awba Dam are presented in Table 1. The mean value of pH, temperature and dissolved oxygen were 7.2±0.11, 20.4±0.3 ℃ and 7.01±0.7 mg/L, respectively. The levels of the Physico-chemical parameters determined were within the stipulated limits except for the turbidity, which was very high. The turbidity value was 34.38±4.8 Nephelometric Turbidity Unit (NTU), which is higher when compared to 5 NTU recommended by Standard Organization of Nigeria (SON). The mean concentration of Nitrogen (N), Phosphorous (P), and Potassium (K) was 0.06±0.01 mg/L, 0.05±0.02 mg/L, and 5.6±1.27 mg/L, respectively. Concentrations of NPK fell within the World Health Organization's (WHO) defined standards. Cadmium and Lead were not detected in the water samples. Mean concentration of Manganese (Mn), Zinc (Zn), and Iron (Fe) in the water sample were 117.5±01 mg/L, 11.3±2.65 mg/L, and 55.2±1.9 mg/L, respectively. These values were above the recommended limits by SON.

Table 1. Physical and chemical variables of water in Awba Dam, Ibadan, Nigeria.

Parameters (Units)	Awba Dam (mean±SD)	SON's standards	WHO's Guideline limit
Physicochemical			
pH	7.2±0.1	6.5-8.5	6.5-8.5
Temperature (℃)	20.5±0.3	Ambient	Ambient
Dissolved oxygen (mg/L)	7.01±0.7	NS	7.5
Conductivity (µS/cm)	69.80±3.9	1000	NS
Total dissolved solid (mg/L)	41.7±2.2	500	NS
Turbidity (NTU)	34.4±4.6	5	NS
Nutrients			
N (mg/L)	0.06±0.01	NS	10
P (mg/L)	0.05±0.02	NS	5
K (mg/L)	5.6±1.2	NS	NS
Heavy metal			
Mn (mg/L)	117.5±0.01	0.2	0.4
Zn (mg/L)	11.3±2.7	3	NS
Fe (mg/L)	55.2±1.9	0.3	NS
Cd (mg/L)	ND	0.003	0.003
Pb (mg/L)	ND	0.01	0.01

Note: ND = Not Detected (Detection Limit: Cd=, Pb=), NS = Not Stated

3.2. Physico-chemical Parameters of Sediments from Awba Dam

Physico-chemical parameters of sediment samples from Awba Dam are presented in Table 2. The mean pH and conductivity values of the sediment were 5.3±0.8 and 107.9±94.1 µS/cm, respectively. The pH value fell below the guideline limit recommended by WHO. Mean Total Organic Carbon (%) of the sediment samples was 1.15±0.82. Concentration of Mn, Fe, Zn, Cd and Lead in the sediment were 262.9±21.8 mg/kg, 69086.3±120.9 mg/kg, 78.7±45.09 mg/kg, 0.05±0.01 mg/kg, and 1.39±0.27 mg/kg, respectively. The concentration of Mn, Fe, Zn, Cd and Lead was within the guideline limit, except Iron. Iron concentration exceeded the guideline limit of 15 mg/kg recommended by WHO.

Table 2. Physical and chemical parameters of sediment in Awba Dam.

Parameters (Unit)	Awba dam Sediment (Mean±SD)	Guideline limits WHO
Physicochemical		
pH	5.34±0.84	6.5-8.5
Conductivity (µS)	107.9±94.1	NS
Total Organic Carbon (mg/Kg)	1.15±0.82	NS
Heavy metal		

Parameters (Unit)	Awba dam Sediment (Mean ±SD)	Guideline limits WHO
Mn (mg/kg)	262.9±21.8	NS
Fe (mg/kg)	690.3±120.9	15
Zn (mg/kg)	78.7±45.09	120
Cd (mg/kg)	0.05±0.01	NS
Pb (mg/kg)	1.39±0.27	NS

Note: NS = Not Stated

3.3. Distribution of Snail Genera from Sediment Samples in Awba Dam

Figure 2 depicts the distribution of snail genera identified in the Awba Dam surface water. A total of 262 freshwater snails belonging to three genera—Bulinus, Biomphalaria and Lymnae—were identified from the dam. The proportions of the snail genera found in the dam were Bulinus species (65%), Biomphalaria species (24%) and Lymnae species (11%). Two snail genera —Bulinus and Biomphalaria—belonged to the category lunged snail while Lymnae specie was a gilled snail. Bulinus (Lunged snail) is the planorbid intermediate host of Schistosoma haematobium which is found in the venules surrounding the bladder of an infected person and causes urinary schistosomiasis. Also, genus Biomphalaria (Lunged snail) is a planorbid and an intermediate host for Schistosoma mansoni which inhabits the mesenteries around the intestine causing intestinal schistosomiasis.

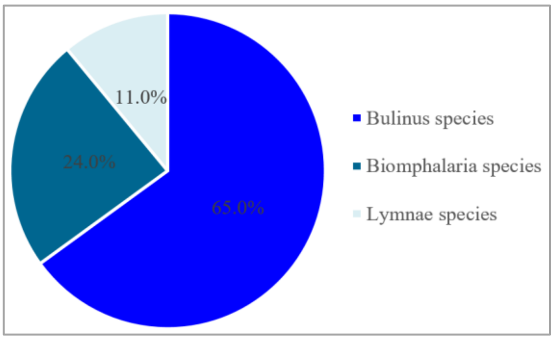

Figure 2*. Distribution of snail genera from sediment samples in Awba Dam.*

3.4. Correlation Between Heavy Metal Concentration in Sediment and Water, and the Number of Snail Genera Available in Awba Dam Surface Water

Table 3 presents the correlation between heavy metal concentration in the water and sediment, and the available snail genera. The table revealed that there was a positive correlation between the concentration of manganese in sediment and the number of snail genera available ($r = 0.722$, $p < 0.01$). This is an indication that an increase in manganese concentration in the sediment favors an increase in the number of snail genera available. The concentration of iron in sediment was found to be positively related to the number of snail genera available ($r = 0.592$, $p < 0.05$). The concentration of lead in the sediments positively correlated with the number of snail genera available ($r = 0.896$, $p < 0.01$). Likewise, a significant correlation existed between the concentration of Mn, Fe, and Pb in water samples; and the number of Snail genera available. However, there was no significant correlation between the concentration of Zinc in the media (sediment and water) and the number of snail genera available.

Table 3*. Correlation between heavy metal concentration in media (sediment and water) and the available snail genera.*

Media	Heavy metals	Available Snail
	Mn	0.722^{**}
Sediment	Fe	0.592^{*}
	Zn	0.411
	Pb	0.896^{**}
	Mn	0.624^{*}
Water	Fe	0.858^{**}
	Zn	0.127
	Pb	0.658^{*}

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed)

Similarly, there was a positive correlation between the temperature of water and the number of gilled snail genus available in the water ($r = 0.771$, $p < 0.05$). This result indicated that an increase in temperature favors the existence of more gilled snail in the dam surface water. However, a negative correlation existed between the pH of the water and the number of gilled snail genus available in the Awba Dam surface water ($r = -0.738$, $p < 0.05$). There was no significant correlation between the temperature and pH of the water and the number of lunged snail genus available in the Awba Dam surface water as presented in Table 4.

Table 4. *Correlation matrix between water temperature, pH and snail category.*

	pH	Temperature	Lunged Snail	Gilled Snail
pH	1			
Temperature	-0.843**	1		
Lunged Snail	0.039	-0.129	1	
Gilled Snail	-0.738*	0.771*	-0.059	1

** Correlation is significant at the 0.01 level (2-tailed).
*Correlation is significant at the 0.05 level (2-tailed)

4. Discussion

This study assessed the pollution dynamic at a dam within the university community, using the heavy metal concentration in water, sediment and available snail genera as indicators of pollution. The pH concentration of the dam surface water was within the permissible limits of 6.5 to 8.5 [25]. The study found that turbidity of the water was higher than the acceptable limit. This could be an indication that there is increase in particulate matter at the surface water brought into the dam by surface run-off during the wet season. High turbid waters had been associated with microbial contamination [26, 27]. The concentrations of Zinc, Manganese and iron detected in the Awba Dam surface water were above the permissible level. However, Cadmium and Lead were not detected. Previous studies had reported high iron concentration in water [28, 29]. High concentration of iron at the dam could be a good indication of man-induced pollution which could be attributed to the recent dredging of the dam. The high concentration of Zn, Mn and Iron gives a convincing indication that Awba Dam is contaminated with these metals. The study revealed that the values of the nutrients (nitrate, phosphate and potassium) were within the permissible limits. The presence of these nutrients in the Awba Dam could be linked directly to runoff from the surrounding environment and contributory water bodies; mainly effluent from the institution's zoological garden which flows into the surface water. However, phosphate, potassium and nitrate levels detected in the dam water might play an important role in supporting the growth of the aquatic plants.

The pH of the sediment fell within the permissible limit. Studies have reported similar findings [30, 31]. The higher concentrations of metals measured in the sediment indicated that lower pH favoured metal accumulation. This concurs with findings of several studies that sediments are the major depository of metals; holding more than 99% of the total amount of a metal present in the aquatic system [32-34]. The Total Organic Carbon found in this study indicated that there was 36% of Carbon concentration in the Awba Dam sediment. The low TOC in Awba Dam can be due to a fast mineralisation rate caused by the DO and pH levels, which were within the permissible limits. Organic matter breakdown (mineralisation) reduces sediment carbon and nutrient concentrations. Previous studies had documented that mineralisation rates are faster when dissolved oxygen is present in water bodies than under anoxic conditions [35, 36].

All the five heavy metals (Pb, Cd, Mn, Fe and Zn) analysed were detected in the sampled sediment, and this is because sediments accumulated more heavy metal than the water. This phenomenon has been observed by several studies [37-39]. A higher concentration of metals in the sediment than in surface water may also be connected with the fact that pollutants discharged into the aquatic environment do not remain in an aqueous state but rather get adsorbed onto the sediments. In this study, Iron (Fe) had the highest concentration in the sediment and also the only heavy metal above WHO's permissible limit. This result was similar to previous findings where iron occurred at high concentration in Nigerian soils [40, 41]. Although, iron is one of the essential elements for the maintenance of human life, its presence at an elevated concentration in aquatic ecosystems can cause toxicity, representing environmental risks to local biodiversity and compromising human health through the consumption of contaminated water and fish [42-44]. Toxicity of iron in humans has been found to bring about vomiting, cardiovascular collapse and diarrhea, while iron deficiency may lead to the failure of the blood clotting process [45]. The levels of Zn, Cd and Pb in the sediment samples were within permissible limits and guidelines provided by WHO.

This study identified a large proportion of lunged snails – *Bulinus* and *Biomphalaria* – in Awba Dam. Previous studies in Nigeria had identified numerous species of snail genera, including *Melanoides*, *Biomphalaria*, *Bel-lamya*, *Bulinus*, *Lymnaea*, *Cleopatra*, *and Physa*, in community dams [46-49].

Snails of the genus *Biomphalaria* serve as intermediate hosts of *S. mansoni* while Snails of the genus *Bulinus* serve as the intermediate hosts of *S. haematobium*. *Schistosomiasis* is a water-based parasitic disease transmitted by planorbid gastropods and which is considered the second most important parasitic infection after malaria in terms of public health and economic impact [50]. Human schistosomiasis in Africa occurs in two forms (intestinal and urogenital), caused by the digenetic trematodes: *Schistosoma mansoni* and *Schistosoma haematobium*, respectively [50].

5. Conclusion

Sediment contamination is a widespread environmental problem that can potentially pose a threat to a variety of aquatic ecosystems. This study revealed that the concentrations of Iron, Zinc, Manganese, and Lead were higher in sediment compared to those in surface water. Awba Dam is contaminated with heavy metals, especially Fe, Mn and Zn. The major genera of snail identified in the dam were *Bulinus*, *Biomphalaria* and *Lymnae*. High concentration of Fe, Mn and Zn in Awba Dam can be a convincing indication of pollution from anthropogenic sources. The snail species found in the water body and the heavy metals found in the sediments are indicators of risk which call serious attention in public health. Hence continuous assessment and appropriate pollution prevention is highly encouraged to improve the quality of water and sediments in the dam to eliminate hazards and thereby mitigate health risks associated with contact with this water body.

Abbreviations

LGA	Local Government Area
WHO	World Health Organization
SON	Standard Organization of Nigeria
Fe	Iron
Mn	Manganese
Zn	Zinc
mg/L	Milligram Per Litre
DO	Dissolved Oxygen
TOC	Total Organic Carbon
HDPE	High-Density Polyethylene

Acknowledgments

The authors would like to appreciate the efforts of Mr. Michael Idowu for his assistance in identifying the snails sampled in this research.

Author Contributions

Yahaya Maryam: Conceptualization, Data curation, Formal Analysis, Investigation, Resources, Software, Validation, Visualization, Writing – original draft

Adejumo Mumuni: Conceptualization, Data curation, Formal Analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – review & editing

Oloruntoba Omoladun Elizabeth: Conceptualization, Data curation, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – review & editing

Funding

The authors received no external funding for this work.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Uddin M. G., Nash S. and Olbert A. I. (2021). A review of water quality index models and their use for assessing surface water quality. Ecol. Indicat. 122, 107218 https://doi.org/10.1016/j.ecolind.2020.107218

[2] Magesh N., Krishnakumar S., Chandrasekar N. and Soundranayagam J. P. (2013). Groundwater quality assessment using wqi and gis techniques, dindigul district, Tamil nadu, India. Arabian J. Geosci. 6, 4179–4189.

[3] Mahmood A. (2018). Evaluation of raw water quality in wassit governorate by canadian water quality index. In: MATECWeb of Conferences, EDP Sciences, 05020.

[4] S ́anchez E., Colmenarejo M. F., Vicente J., Rubio A., Garc ́ıa M. G., Travieso L. and Borja R. (2007). Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. Ecol. Indicat. 7, 315–328.

[5] Lobato T., Hauser-Davis R., Oliveira T., Silveira A., Silva H., Tavares M. and Saraiva A. (2015). Construction of a novel water quality index and quality indicator for reservoir water quality evaluation: a case study in the amazon region. J. Hydrol. 522, 674–683.

[6] Yousefi M., Ghoochani M. and Hossein Mahvi A. (2018). Health risk assessment to fluoride in drinking water of rural residents living in the poldasht city, northwest of Iran. Ecotoxicol. Environ. Saf. 148, 426–430. https://doi.org/10.1016/j.ecoenv.2017.10.057

[7] Kumar R., Qureshi M., Vishwakarma D. K., Al-Ansari N., Kuriqi A., Elbeltagi A. and Saraswat A. (2022). A review on emerging water contaminants and the application of sustainable removal technologies, Case Studies in Chemical and Environmental Engineering, 6, 100219, https://doi.org/10.1016/j.cscee.2022.100219

[8] Chislock M. F., Doster E., Zitomer R. A. and Wilson A. E. (2013). Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems. *Nature Education Knowledge* 4(4): 10.

[9] Akinnawo S. O. (2023). Eutrophication: Causes, consequences, physical, chemical and biological techniques for mitigation strategies, *Environmental Challenges*, 12, 100733, https://doi.org/10.1016/j.envc.2023.100733

[10] Mitra S., Chakraborty A. J., Tareq A. M., Emran T. B., Nainu F., Khusro A., Idris A. M., Khandaker M. U., Osman H., Alhumaydhi F. A. and Simal-Gandara J. (2022). Impact of heavy metals on the environment and human health: Novel therapeutic insights to counter the toxicity, Journal of King Saud University - Science, (34) 3, 101865, https://doi.org/10.1016/j.jksus.2022.101865

[11] World Health Organization (WHO). (2023). *Schistosomiasis fact sheet*. Retrieved from https://www.who.int/news-room/fact-sheets/detail/schistosomiasis

[12] Ekpo U. F., Alabi O. M., Oluwole A. S. and Sam-Wobo S. O. (2008). Helminthiasis and hygiene conditions of schools in Ikenne, Ogun State, Nigeria. *PLoS Neglected Tropical Diseases*, 2(11), e146.

[13] Dida G. O., Gelder F. B., Anyona D. N., Abuom P. O., Onyuka J. O., Matano A. S., Adoka S. O., Ouma C., Kanangire C. K., Ofulla A. V. O. and Owuor P. O. (2014). Distribution and abundance of schistosomiasis and fascioliasis host snails along the Mara River in Kenya and Tanzania. *Infectious Diseases of Poverty*, 3(1), 1–9.

[14] Brown D. S. (1994). *Freshwater snails of Africa and their medical importance* (2nd ed.). Taylor & Francis.

[15] World Health Organization. (2020). *Ending the neglect to attain the Sustainable Development Goals: A road map for neglected tropical diseases 2021–2030*. https://www.who.int/publications/i/item/9789240010352

[16] Sharma B. M. and Sridhar M. K. C. (1981). The productivity of Pistia Stratiotes L. in eutrophic lake. 24. 4: 277-289.

[17] Taiwo P. O. (2001). Research article phytoplankton density in awba dam at different stations. *International Journal of Current Research* 7: 55-57.

[18] University of Ibadan Directorate of Public Communication. (2020). The Awba dam, University of Ibadan, Nigeria https://www.ui.edu.ng/gallery/awba-dam-university-ibadan

[19] Tyokumbur E. T., Okorie T. G. and Ugwumba A. O. (2002). Limnological assessment of the effluents on the Macro-invertebrates fauna of Awba stream and reservoir Ibadan, Nigeria. *The zoologist* 2: 59-69.

[20] APHA. (2005): *Standard methods for the examination of water and wastewater* (21st ed.). Washington, DC: American Public Health Association.

[21] Klute A. (1986). Water retention: Laboratory methods. In: Klute, A., Ed., Methods of Soil Analysis, Part 1, Physical and Mineralogical Methods, ASA and SSSA, Madison, 635-662.

[22] Frest T. J. and Johannes E. J. (1999). Field Guide to Survey and Manage Freshwater Mollusk Species. BLM/OR/WA/PL-99/045+1792. https://www.blm.gov/or/plans/surveyandmanage/files/01-aquatic_guide.pdf

[23] Mark S. (2006). Sinistral snails. Stillman newsletter

[24] Mandahl-Barth G. (1962). Key to the identification of east and central African freshwater snails of medical and veterinary importance. Bull. World Health Organ. 27: 135-150.

[25] World Health Organization (WHO). (2011). Guidelines for Drinking Water Quality. Fourth Edition 118-120. World Health Organization, Geneva.

[26] Farrell C., Hassard F., Jefferson B., Leziart T., Nocker A. and Jarvis P. (2018). Turbidity composition and the relationship with microbial attachment and UV inactivation efficacy, Science of the Total Environment, Volume 624; 638-647, https://doi.org/10.1016/j.scitotenv.2017.12.173

[27] Some S., Mondal R., Mitra D., Jain D., Verma D. and Das S. (2021). Microbial pollution of water with special reference to coliform bacteria and their nexus with environment, Energy Nexus, 1: 100008, https://doi.org/10.1016/j.nexus.2021.100008

[28] Hossain M. A., Haque M. I., Parvin M. A. and Islam M. N. (2023). Evaluation of iron contamination in groundwater with its associated health risk and potentially suitable depth analysis in Kushtia Sadar Upazila of Bangladesh, Groundwater for Sustainable Development, 21: 100946, https://doi.org/10.1016/j.gsd.2023.100946

[29] Rahman I., Wahab M. A., Akter M. and Mahanta T. R. (2023). Iron in Drinking Water and its Impact on Human Health –A Study in Selected Units of Jalalabad Cantonment. Bangladesh Armed Forces Med J. 56(2): 58-64. https://doi.org/10.3329/bafmj.v56i2.73013

[30] Ogunlaja, A. and Ogunlaja O. O. (2007). Physicochemical analysis of water sources in Ubeji Communities and their Histological impact on organs of albino mice. *J. Appl. Sci. Environ. Manag.* 11.4: 91-94.

[31] Shakirat T. K and Akinpelu T. A. (2013). Study of heavy metals pollution and physico-chemical assessment of water quality of River Owo, Agbara, Nigeria. *International Journal of Water Resources and Environmental Engineering* 5.7: 434-341.

[32] Chindah A. C. and Braide S. A. (2003). Cadmium and Lead concentrations in fish species of a brackish wetland/upper Bonny Estuary, Niger Delta. *JNES.* 2.3: 5-11.

[33] Ideriah T. J. K., David-Omiema S. and Ogbonna D. N. (2012). Distribution of Heavy Metals in Water and Sediment along Abonnema Shoreline, Nigeria. Resources and Environment. 2(1): 33-40 https://doi.org/10.5923/j.re.20120201.05

[34] Aziz S., Ullah R., Alwahibi M. S., Elshikh M. S. and Alkahtani J. (2021). Profiling of toxic metals from fish (tor putitora), water and sediments with microbial and chemical water quality appraisals, Saudi Journal of Biological Sciences, 28 (4): 2527-2533, https://doi.org/10.1016/j.sjbs.2021.01.056

[35] Kristensen E., Ahmed S. I. and Devol A. H. (1995). Aerobic and anaerobic decomposition of organic matter in marine sediment: Which is faster? *Limnology and Oceanography* 40.8: 1430-1437.

[36] Peter S., Isidorova A. and Sobek S. (2016), Enhanced carbon loss from anoxic lakesediment through diffusion of dissolvedorganic carbon, J. Geophys. Res. Biogeosci., 121, 1959–1977, https://doi.org/10.1002/2016JG003425

[37] Adejare L. I., Balogun K. J. and Shelle R. O. (2011). Hydrochemistry and levels of some heavy metals in samples of Ibeshe, Lagos lagoon complex, Nigeria. *Journal of American Science* 7.1: 625-632.

[38] Ambedkar G. and Muniyan M. (2012). Analysis of heavy metals in water, sediments and selected freshwater fish collected from Gadilam River, Tamilnadu, India. *International Journal of Toxicology and Applied Pharmacology* 2.2: 25- 30.

[39] Edward J. B., Idowu E. O., Oso J. A. and Ibidapo O. R. (2013). Determination of heavy metal concentration in fish samples, sediment and water from Odo-Ayo River in Ado-Ekiti, Ekiti-State, Nigeria. *International Journal of Environmental Monitoring and Analysis.* 1.1: 27-33.

[40] Asaolu S. S., Ipinmoroti K. O., Olaofe O. and Adeeyinwo C. E. (1997). Interrelationship of metal concentration in water, sediment and fish samples from Ondo Coastal area, Nigeria. *African Journal of Science* 1: 55-61.

[41] Asaolu S. S. and Olaofe O. (2004). Bio-magnification factors of some heavy and essential metal in sediments, fish and crayfish from Ondo State Coastal Region. *Biological Science Research* 6: 13-39.

[42] Sang C., Zheng Y., Zhou Q., Li D., Liang G. and Gao Y. (2019). Effects of water impoundment and water-level manipulation on the bioaccumulation pattern, trophic transfer and health risk of heavy metals in the food web of Three Gorges Reservoir (China). Chemosphere, 232, 403-414, https://dx.doi.org/10.1016/j.chemosphere.2019.04.216

[43] Kortei N. K., Heymann M. E., Essuman E. K., Kpodo F. M., Akonor P. T., Lokpo S. Y., Boadi N. O., Ayim-Akonor M. and Tettey C. (2020). Health risk assessment and levels of toxic metals in fishes (Oreochromis noliticus and Clarias anguillaris) from Ankobrah and Pra basins: Impact of illegal mining activities on food safety. Toxicology Reports, 7, 360-369. https://dx.doi.org/10.1016/j.toxrep.2020.02.011

[44] Yu B., Wang X., Dong K. F., Xiao G. and Ma D. (2020). Heavy metal concentrations in aquatic organisms (fishes, shrimp and crabs) and health risk assessment in China. Marine Pollution Bulletin, 159, 111505. https://dx.doi.org/10.1016/j.marpolbul

[45] Akan C. J., Abbagambo T. M., Chellube M. Z. and Abdulrahman I. F. (2012). Assessment of Pollutants in Water and Sediment Samples in Lake Chad, Baga, North Eastern Nigeria. *Journal of Environmental Protection* 3: 1428-1441.

[46] Abdulkadir F. M., Maikaje D. B. and Umar Y. A. (2017). *Ecology and Distribution of Freshwater Snails in Gimbawa Dam, Kaduna State, Nigeria*. *Nigerian Journal of Chemical Research*, 22(2), 98–106.

[47] Auta T., Alkali E. and Michael E. A. (2019). Population dynamics, diversity and distribution of freshwater snails in Zobe Dam, Dutsin-Ma, north-western Nigeria. *Asian Journal of Environment & Ecology*, 8 (4), 1–7. https://doi.org/10.9734/ajee/2018/v8i430078

[48] Sanu K. M., Istifanus W. A., Musa M. S. and Mao P. S. (2020). The diversity of fresh water snail fauna in Kiri Dam, Adamawa State, North Eastern Nigeria. *GSC Biological and Pharmaceutical Sciences*, *11*(2), 99–104. https://doi.org/10.30574/gscbps.2020.11.2.0118

[49] Dogara M. M., Alhaji G. K., Balogun J. B., Abubakaar M. M., Barde A. A., Surajo A. R., Muhammad S. I., Dawaki S. S. and Isah U. M. (2022). Distribution and abundance of freshwater snails in Warwade Dam, Dutse, Northern Nigeria. *Dutse Journal of Pure and Applied Sciences*, 8(1b), 69–81. https://doi.org/10.4314/dujopas.v8i1b.9

[50] Tumwebaze I., Clewing C., Dusabe M. C., Tumusiime J., Kagoro-Rugunda G., Hammoud C. and Albrecht C. (2019). Molecular identification of Bulinus spp. intermediate host snails of Schistosoma spp. in crater lakes of western Uganda with implications for the transmission of the Schistosoma haematobium group parasites. *Parasites & Vectors*, *12*(1), 2-2. https://doi.org/10.1186/s13071-019-3811-2