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Assessment of Anthropogenic Impact on Ecosystem Service Safety of Agboyi River in Lagos, Southwestern, Nigeria

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ABSTRACT: The Agboyi River in Lagos, Nigeria provides important ecosystem services; however, anthropogenic activities are polluting the river, necessitating periodic monitoring. This study assessed the heavy metal content (lead, cadmium, chromium, copper, and arsenic) in water samples from the river. Additionally, we evaluated various physicochemical parameters, including pH, total dissolved solids (TDS), conductivity, hardness, magnesium, calcium, chloride, sulfate, and nitrate. The values of each heavy metal were used to calculate human average daily ingestion (ADI), average daily dermal exposure (ADDE), hazard quotient (HQ), and carcinogenic risk (CR). The physicochemical analysis revealed non-permissible levels of TDS, electrical conductivity, alkalinity, hardness, magnesium, calcium, sulfate, nitrate, chloride, and phosphate. The heavy metal analysis showed intolerable levels of lead, arsenic, cadmium, chromium, and copper. The ADIs for the heavy metals were within the recommended dietary intake (RDI), but their ADDEs exceeded the RDI, except for chromium. The HQ and CR for all heavy metals exceeded recommended limits. Seasonal variations were observed in the physicochemical parameters, with TDS, turbidity, acidity, nitrate, and phosphate being higher in the wet season, while other parameters were higher in the dry season. The water poses health hazards to users, indicating the need for river remediation.

KEYWORDS: Average daily oral exposure; carcinogenic risks; hazard quotient; lead; total dissolved solids

1. Introduction

Water, a fundamental necessity of life, plays a critical role in ensuring a continuous supply of food and maintaining a healthy environment for all living organisms. Beyond sustaining life, water is also essential for economic growth, tourism, recreation, and human settlements [1]. It is a universal solvent, facilitating the movement of nutrients, waste elimination, and providing lubrication and cushioning for various bodily functions [2]. Among the various sources of water, rivers stand out as primary sources for public water supply due to their accessibility. Rivers serve a multitude of purposes, including agriculture, public water supply, electricity generation, industrial activities, and support various ecosystem functions [3]. They not only connect human settlements but also bridge diverse cultures, beliefs, values, and lifestyles [4].

However, the rapid urbanization, industrialization, and agricultural practices driven by human activities have led to severe pollution of water sources, particularly rivers [5]. Discharge of waste laden with toxic chemicals from anthropogenic sources has a detrimental impact on water quality [6]. Among these contaminants, inorganic chemicals, especially heavy metals, are the most prevalent [7]. Commonly detected heavy metals in the environment include cobalt (Co), cadmium (Cd), lead (Pb), arsenic (As), nickel (Ni), mercury (Hg), zinc (Zn), manganese (Mn), chromium (Cr), molybdenum (Mo), copper (Cu), and antimony (Sb) [8]. High concentrations of heavy metals disrupt biological systems and harm aquatic organisms, leading to the degradation of aquatic ecosystems. To prevent these adverse effects on both humans and the environment, protective measures are imperative to ensure the quality of river water [6].

For a river like the Agboyi River in Lagos State, which plays a vital role in providing essential ecosystem services, it is essential to safeguard its water quality. The river serves as the primary water source for numerous settlements, supports fishing activities, and acts as a means of transportation, connecting many communities. Unfortunately, indiscriminate discharge of human waste, solid waste, and wastewater into the river poses a potential threat to its quality. Surprisingly, there is a lack of documented information regarding the water quality of the river, which could serve as a tool to raise public awareness. This study, therefore, aims to assess the safety of the ecosystem services provided by the river, with a particular focus on heavy metal concentrations.

2. Materials and Methods

2.1. Description of the study area.

Agboyi town, which lends its name to the Agboyi River, is situated within the Lagos metropolis, Lagos State, Nigeria. It is located between Longitude 3° 24' 10.8684" and Latitude N 6° 35.1429 (Figure 1). Lagos State is bounded by the Atlantic Ocean to the south, Ogun State to the north and east, and shares a border with the Republic of Benin to the west. Despite its small landmass of about 358,862 hectares (3,577 km2), which is less than 0.5% of Nigeria's total landmass [11], Lagos is a significant economic hub in Africa due to its dense population [12]. It stands as Nigeria's most populous and industrialized city [13]. The state's predominant vegetation is tropical [13], with an average yearly precipitation of approximately 950 mm and temperatures ranging between 25 °C and 40 °C [14]. The Agboyi River flows through the western part of the state [15], sharing boundaries with the Lagos Lagoon to the east and the River Ogun to the west, receiving inflows from both water bodies. This river serves various essential purposes, including providing water for domestic and industrial use, agriculture, fishing, and transportation for the local population. Unfortunately, municipal waste, human excrement, and waste products resulting from anthropogenic activities in the river's vicinity find their way into its waters [15]. Each street along the river generates at least 2.5 kg of waste per day, with a portion of it discharged into the river [16]. Therefore, it is imperative to conduct regular evaluations of the river's water quality to ensure it does not pose risks to those who depend on it, aquatic life, or the surrounding environment.

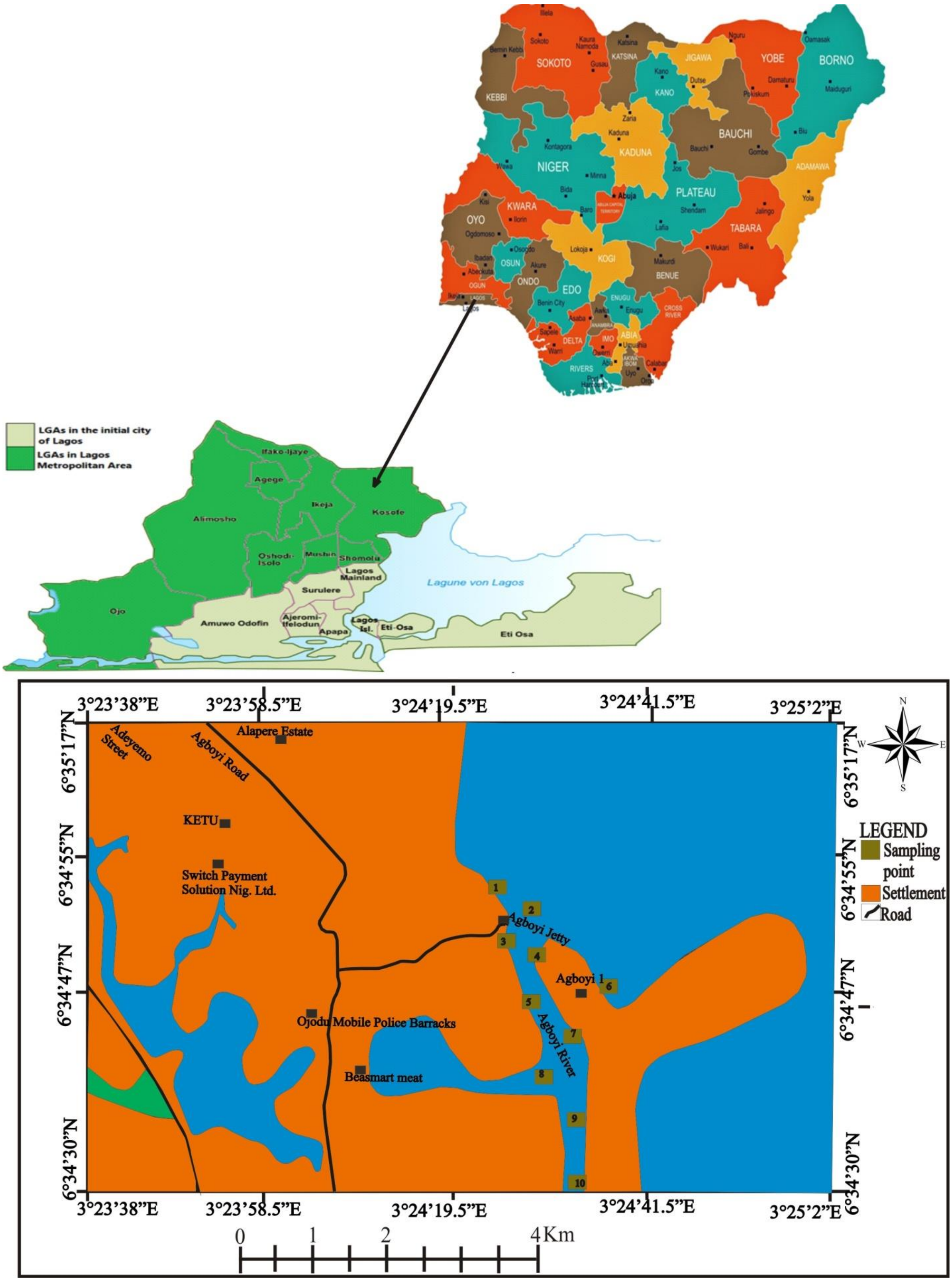

Figure 1. Locations of the study area (drawn using ArcGIS 10.3 software).

2.2. Water sample collection and preparation.

Sampling was conducted over four sessions, one per month, in triplicate, during both the wet and dry seasons of 2022, resulting in a total of 24 samples. Water was collected randomly from various strata and banks of the river at different times of the day. These samples were combined, placed in 1000-mL plastic bottles, securely sealed, and stored in a refrigerator at 4 °C.

2.3. Determination of physicochemical parameters.

The physicochemical properties were assessed using the American Public Health Association's guidelines [17]. Nitrates, sulphates, calcium, magnesium, and phosphates were measured using a DR 2000 spectrophotometer (Model 50150). A pH meter manufactured by the Pye Unicam was used to quantify pH, while an Avial Chloride Meter was utilized for chloride occurrences. To evaluate hardness, a complex EDTA titration was utilized. Turbidity and electrical conductivity were determined by a turbidimeter and an EC meter. Total dissolved solids were measured using an HM digital TDS meter (model TDS-4).

2.4. Determination of heavy metals.

A UNICAM (model 969) atomic absorption spectrometer (AAS) was used to quantify the occurrence of lead (Pb), arsenic (As), cadmium (Cd), chromium (Cr), and copper (Cu) as outlined in Yahaya et al. [18]. Ten (10) ml of HNO_3 were placed in 100 ml of a water sample and heated with increasing temperature, from 100 °C to 265 °C. The digestion took over an hour to be completely done, which was confirmed when white fumes appeared. After cooling, the digest was placed into a calibrated flask, filled with distilled water to the 50-ml mark, and then poured into a plastic bottle and labelled. The standard stock of each sample was prepared and serially diluted to concentrations of 5 ppm, 10 ppm, 20 ppm, and 25 ppm. These diluents were used to generate a suitable curve, which was used to calibrate the instrument. The diluents were then fed into the AAS to determine the levels of each heavy metal.

2.5. Quality control and assurance.

Analytical grade chemicals were used to produce all the reagents used. The containers of each reagent were cleansed properly with soap and ultrapure water. Blank samples were analyzed concurrently with the water samples to check background contamination. Furthermore, each heavy metal was evaluated three times, with the results being repeatable with a 95% confidence level.

2.6. Health risk assessment.

2.6.1. Non-carcinogenic risk.

The non-carcinogenic health risks of daily consumption of the water were postulated using equations 1, 2, 3, and 4 [19, 20].

$$ADI = \frac{CoH \ x \ IR \ x \ EF \ x \ ED}{ABW \ x \ AT} \quad (1)$$

Note that ADI in equation 1 was used to represent average daily ingestion of water in mg/kg/day, same way CoH represents the concentration of heavy metals (mg/l), IR is short for ingestion rate, measured in l/day = 2, EF denotes exposure frequency, calculated in days/year = 365, ED is abbreviated for exposure duration, measured in years = 55, ABW means average body weight in kg = 65, and AT stands for average time, obtained by multiplying ED and EF = 20075.

$$ADDE = \frac{CoH \ x \ ESSA \ x \ AF \ x \ DAF \ x \ EF \ x \ ED}{ABW \ x \ AT} \quad (2)$$

ADDE means average daily dermal exposure in mg/kg/day; ESSA stands for exposed skin surface area (cm^3) = 28,000; AF is the adherence factor ($kg/m^2/day$) = 0.7; DAF denotes dermal absorption factor (cm/h) = 0.0006 for Cu, 0.0006 for Cd, 0.0002 for Cr, 0.004 for Pb, and 0.0006 for As.

$$HQ \ for \ Oral = \frac{ADI}{RFD} \quad (3)$$

$$HQ \ for \ Dermal = \frac{ADDE}{RFD} \quad (4)$$

In equations 3 and 4, HQ stands for hazard quotient, while RFD represents the reference dose in mg/l/day. The RFD (oral/dermal) Pb, Cd, Cr, Cu, and As = 0.0035/0.000525, 0.0005/0.00001, 0.0003/0.00006, 0.04/0.012, and 0.0003/0.0008. A HQ greater than 1 was deemed toxic.

2.6.2. Carcinogenic risks

The carcinogenic risks of the water were calculated from equations 5 and 6.

$$CR \ for \ Oral = ADI \ x \ CSF \quad (5)$$

$$CR \ for \ dermal = ADDE \ x \ CSF \quad (6)$$

In equations 5 and 6, CR is short for carcinogenic risk of heavy metals, and CSF represents cancer slope factor (mg/kg/day). The CSF for Pb is 0.0085, Cd is 6.3, Cr is 0.5, Cu is 0.00, and As is 1.5. A CR value greater than 10^{-6} was considered potentially carcinogenic.

2.7. Data analysis.

Values of the various parameters of the water samples were computed with Excel software version 22 as mean ± standard deviation (SD). The same software was also used to compute the ADI, ADDE, HQ, and CR. The test of significance among values was consummated using the student's t-test, in which values having $p \leq 0.05$ were deemed significant.

3. Results and Discussion

3.1. Physicochemical parameters of the water samples.

Table 1 presents the physicochemical parameters of water samples collected from the Agboyi River in Lagos. With the exception of pH and Mg levels during the dry season, all the physicochemical parameters exceeded the World Health Organization's (WHO) recommended thresholds. Seasonal variations were evident, with TDS, turbidity, acidity, nitrate, and phosphate being higher in the wet season, while other parameters showed elevated levels during the dry season. Significant differences ($p<0.05$) were observed between the two seasons for some of these parameters, indicating potential hazards to human health and ecosystems. The elevated TDS levels in the water suggest substantial waste discharge into the Agboyi River, comprising both organic and inorganic compounds [21]. Such excessive TDS levels raise concerns about potential risks of renal and cardiac diseases for water consumers [22]. The wet season saw higher TDS levels, possibly due to erosional, urban, and agricultural runoff.

The high-water hardness, turbidity, and electrical conductivity, along with the cloudy appearance of the water, may be attributed to the elevated TDS levels [21]. Turbidity was more pronounced during the wet season, likely due to agricultural and urban runoff carrying suspended materials into the river [23]. Such turbidity can limit light penetration for photosynthetic plants and reduce biodiversity [24]. On the other hand, increased hardness and electrical conductivity were noted during the dry season, attributed to reduced river water volume, leading to higher concentrations of ions and anions, including magnesium, calcium, chlorides, nitrate, phosphate, and sulfate, all of which can have health implications. Excessive magnesium intake can lead to serious electrolytic imbalances, potentially fatal if left untreated [26]. High calcium intake through water is suspected to be linked to coronary diseases [27], while excessive chloride, phosphate, and sulfate intake can cause acidosis, resulting in chronic metabolic acidosis [28]. In aquatic environments, elevated nitrate, phosphate, and sulfate ions can stimulate rapid water plant growth, leading to algal blooms and a subsequent depletion of dissolved oxygen, which can suffocate and kill aquatic life [29]. The alkalinity of the water in both seasons exceeded permissible limits, likely due to high salt concentrations [25]. Earlier studies by Olawusi-Peters [30] and Uzoma et al. [31] reported similar findings in the Agboyi River, highlighting a consistent issue. Aside from these two studies, there are no other documented studies on the river that can be compared with the current research

Table 1. Physicochemical properties of water samples from Agboyi River, Lagos.

Parameters	Units	Concentration		Limit [32]
		Dry season	Wet season	
pH	-	6.41±0.05[a]	6.82±0.03[a]	6.5-8.5
Colour	-	Cloudy	Cloudy	-
Turbidity	NTU	80.00[a]	150.00[b]	5.0
Odor	-	Foul smells	Foul smells	-
Electrical conductivity	µS/cm^3	4581.67±2.08[a]	3410.10±2.16[b]	≤ 1000
TDS	mg/l	2749.11±1.25[a]	2888.33±7.23[b]	≤ 1000
Alkalinity	mg/l	226.43±1.10[a]	210.62±0.13[b]	≤ 200
Acidity	mg/l	64.20±0.1[a]	70.17±0.28[b]	≤ 200
Hardness	mg/l	1063.30±5.13[a]	1015.67±2.08[b]	≤ 200
Calcium	mg/l	425.11±0.84[a]	406.44±0.03[b]	≤ 200
Magnesium	mg/l	154.73±0.50[a]	147.64±0.02[a]	≤150.0
Chloride	mg/l	824.37±0.19[a]	804.55±0.02[b]	≤ 250
Sulphate	mg/l	1405.39±0.32[a]	1307.85±0.02[b]	≤ 750
Nitrate	mg/l	123.91±0.21[a]	180.95±0.01[b]	≤ 50
Phosphate	mg/l	6.36±0.06[a]	8.10±0.1[b]	≤ 0.1

WHO = World Health Organization; along the rows, values with different superscripts ”a” and “b” are statistically different at $p \leq 0.05$.

3.2. Levels of heavy metals in the water samples.

The levels of heavy metals (Pb, As, Cu, Cd, and Cr) in the samples are revealed in Table 2. The heavy metals were all above the WHO recommended values and only lead showed a significant seasonal variation in concentrations. This result further proves the potential toxicity of the Agboyi River water. There is no safe level of Pb in humans and it affects several organs and systems in the body [33]. Moreover, Pb can build up in aquatic organisms, causing oxidative damage, such as immune and neurotransmitter malfunctions [34]. The occurrence of

Pb in the water tested suggests sources such as pesticides, lead acid batteries, fertilizers, metallurgical, mining waste, petrochemical, and chemical wastes [35]. In aquatic organisms, arsenic (As) is a poisonous semi-metal that can damage livers, induce apoptosis, and cause reproductive abnormalities [36]. Long-term human exposure to As via drinking water can cause cancer, skin lesions, cardiovascular disease, diabetes, and mental retardation [37]. Industrial effluents, agricultural waste, domestic sewage discharge, and mining are top sources of As in the River Agboyi water [38]. Consuming large quantities of soluble Cu salts can cause gut and liver problems in humans [39]. Chronic exposure of aquatic organisms to Cu can reduce survival, growth, and infertility [40]. Possible sources of Cu in the water samples include mining, agriculture, metal smelting, and electrical waste, as well as pesticide use [40]. Chronic human exposure to Cd can cause kidney, liver, bone, and blood damage [41]. In aquatic environments, chronic exposure to Cd decreases growth, reproduction, and immune function [42]. Likely sources of Cd in the water samples are plastics, batteries, electroplating, paint, pigments, and fertilizers, as well as sewage and municipal waste [43]. Human ingestion of hexavalent Cr can cause tumors and inflammation of the alimentary tract [44]. In aquatic organisms, Cr can cause cellular and genetic abnormalities [45]. Possible sources of Cr in the water samples include medical wastes, textiles, tanneries, electroplating, printing, and photographic wastes [45, 46]. Studies by Olawusi-Peters [30] and Uzoma et al. [31], which were mentioned earlier, found non-tolerable levels of some heavy metals in the Agboyi River, which is consistent with the findings of the current study.

Table 2. Levels of heavy metals.

Heavy metal	**Concentration (mg/l)**		**Limit [32]**
	Dry season	**Wet season**	
Pb	0.67±0.02 [a]	1.07±0.01 [b]	≤ 0.01
As	0.03±0.02 [a]	0.05±0.01 [a]	≤ 0.01
Cu	2.96±0.12 [a]	2.76±0.01 [a]	≤ 0.05
Cd	0.08±0.04 [a]	0.07±0.01 [a]	≤ 0.003
Cr	0.13±0.03 [a]	0.14±0.01 [a]	≤ 0.05

WHO = World Health Organization; along the rows, values with different superscripts ‘’a and b’’ are statistically different at $p \leq 0.05$.

3.3. Non-carcinogenic risks of the water samples.

Tables 3 and Table 4 present the Average Daily Ingestion (ADI), Average Daily Dermal Exposure (ADDE), and Hazard Quotients (HQ) of the heavy metals in the water samples. The ADIs for the heavy metals were within the recommended dietary intake (RDI), with the exception of Cr. However, the ADDE of the heavy metals exceeded the RDI. Meanwhile, their HQs surpassed the threshold of 1.

Table 3. Average daily ingestion (ADI) and average daily dermal exposure (ADDE) to heavy metals.

Heavy metal	**Values (mg/l)**	
	Dry season	**Wet season**
Pb	5.885 [a]	9.428 [b]
As	3.000 [a]	5.000 [b]
Cu	6.507 [a]	2.135 [b]
Cd	5.000 [a]	4.400 [b]
Cr	13.000 [a]	13.333 [a]

Along the rows, values with different superscripts “a” and “’b”’ are statistically different at p ≤ 0.05.

These findings confirm the potential health risks associated with heavy metal exposure, as mentioned earlier. It's important to note that these health risk assessments are based on the average lifespan of resident Nigerians, which is approximately 55 years. Therefore, individuals using this water source and living beyond 55 years may be at a higher risk of experiencing the adverse effects of heavy metals.

Table 4. Hazard quotient (HQ) of heavy metals via dermal exposure (ADDE).

Heavy metal	Values (mg/l)	
	Dry season	Wet season
Pb	1616.00^{a}	2590.00^{b}
As	6.25 ^{a}	11.25 ^{b}
Cu	446.25 ^{a}	416.08 ^{b}
Cd	1459.00 ^{a}	1279.00 ^{b}
Cr	116.60 ^{a}	133.30 ^{b}

Along the rows, values with different superscripts “a” and “’b”’ are statistically different at $p \leq 0.05$.

3.4. Carcinogenic risks of the water samples.

Tables 5 and 6 show the carcinogenic risk of oral and dermal exposure to carcinogenic heavy metals in the water samples, namely Pb, As, Cd, and Cr. The carcinogenic risks of oral and dermal exposure to the heavy metals were greater than the threshold of 10^{-6}. Possible carcinogenesis of Pb include prevention of DNA synthesis, DNA damage, and disruption of DNA repair [47, 48]. Potential carcinogenic pathways for As include DNA repair inhibition and epigenetic disruptions [49]. Cd carcinogenesis involves inhibition of apoptosis and DNA damage repair as well as epigenetic damage [50]. Hexavalent Cr causes cancer by making reactive oxygen species that damage DNA [13]. Trivalent Cr damages the cell membrane and makes the DNA more likely to be damaged by toxic substances [13].

Table 5. Carcinogenic risks of oral ingestion of heavy metals.

Heavy metal	Values (mg/l)	
	Dry season	Wet season
Pb	0.00017 ^{a}	0.00028^{b}
As	0.000007 ^{a}	0.00225 ^{b}
Cu	0.015750 ^{a}	0.013060^{b}
Cd	0.002000 ^{a}	0.002150 ^{a}
Cr	0.00017 ^{a}	0.00028^{b}

Along the rows, values with different superscripts ‘’a’’ and ‘’b’’ are statistically different at $p \leq 0.05$.

Table 6. Carcinogenic risks of dermal exposure to heavy metals.

Heavy metal	Values (mg/l)	
	Dry season	Wet season
Pb	0.00686 ^{a}	0.010955^{b}
As	0.00750 ^{a}	0.01050 ^{b}
Cd	0.91050 ^{a}	0.80010^{b}
Cr	0.00050 ^{a}	0.0040^{b}

Along the rows, values with different superscripts ‘’a’’ and ‘’b’’ are statistically different at $p \leq 0.05$.

4. Conclusions

The Agboyi River water exhibited elevated levels of physicochemical parameters, including TDS, electrical conductivity, alkalinity, hardness, magnesium, calcium, sulphate, nitrate, chloride, and phosphate, all exceeding permissible limits. Heavy metals such as Pb, As, Cr, Cd, and Cu were also detected above recommended values. Furthermore, the ADDE (except for Cr), HQ, and CR of all heavy metals exceeded the recommended limits. Seasonal variations were evident in the physicochemical parameters, with TDS, turbidity, acidity, nitrate, and phosphate being higher in the wet season, while other parameters showed higher values in the dry season. In contrast, no significant seasonal variations were observed in the levels of heavy metals. These results indicate potential health and ecosystem risks associated with the Agboyi River water. It is advisable to treat the water before use, necessitating the remediation of heavy metals in the river. Discouraging waste dumping in and around the river and promoting the treatment of wastewater before discharge are crucial measures. Local health and environmental authorities should ensure the safety of river water for drinking and domestic use, emphasizing the importance of periodic water quality assessments.

Acknowledgments

Not applicable.

Competing Interest

Authors declared no competing interest.

References

[1] Kılıç, Z. (2020). The importance of water and conscious use of water. *International Journal of Hydrology*, *4*, 239–241. https://doi.org/10.15406/ijh.2020.04.00250.

[2] Jéquier, E.; Constant, F. (2010). Water as an essential nutrient: the physiological basis of hydration. *European Journal of Clinical Nutrition*, *64*, 115–123. https://doi.org/10.1038/ejcn.2009.111.

[3] Tickner, D.; Parker, H.; Moncrieff, C.R.; Oates, N.; Ludi, E.; Acreman, M. (2017). Managing Rivers for Multiple Benefits–A Coherent Approach to Research, Policy and Planning. *Frontiers in Environmental Science*, *5*, 4. https://doi.org/10.3389/fenvs.2017.00004.

[4] Anderson, E.P.; Jackson, S.; Tharme, R.E.; Douglas, M.; Flotemersch. J.E.; Zwarteveen, M. (2019). Understanding rivers and their social relations: A critical step to advance environmental water management. *WIREs*, *6*, e1381. https://doi.org/10.1002/wat2.1381.

[5] Balogun, M.A.; Anumah, A.O.; Adegoke, K.A. (2022). Environmental health impacts and controlling measures of anthropogenic activities on groundwater quality in Southwestern Nigeria. *Environmental Monitoring and Assessment*, *194*, 384. https://doi.org/10.1007/s10661-022-09805-z.

[6] Yahaya, T.; Oladele, E.; Sifau, M.; Muhammad, A.; Obijaku, E. (2020). Characterization and cytogenotoxicity of water samples from Challawa River in Kano, Northwest Nigeria Songklanakarin *Journal of Science and Technology*, *43*, 1–8. https://doi.org/10.14456/sjst-psu.2021.126.

[7] Azrina, A.; Khoo, H.E.; Idris, M.A.; Amin, I.; Razman, M.R. (2011). Major inorganic elements in tap water samples in Peninsular Malaysia. *Malaysian Journal of Nutrition*, *17*, 271– 276.

[8] Bhargava, P.; Gupta, N.; Vats, S.; Goel, R. (2017). Health Issues and Heavy Metals. *Austin Journal of Environmental Toxicology*, *3*, 1018.

[9] Awaisu, H.A.; Ishaya, K.S.; Ogah, A.T.; Shuaibu, A. (2019). Evaluation of Water Quality of Domestic Water Sources in Nasarawa Town, Nasarawa Local Government Area, Nasarawa State, Nigeria. *The Environmental Studies*, *2*, 30-42.

[10] Bassey, E.B.; Ogah, T.A.; Magaji, J.I.; Stephen, O.O. (2021). The suitability of well water for domestic purpose, in Gwagwalada area council, Abuja Nigeria. *Global Journal of Pure and Applied Sciences*, *27*, 145-152. https://doi.org/10.4314/gjpas.v27i2.7.

[11] The Lagos Megacity. Water, Megacities, and Global Change. (accessed June 13, 2022) Available online: http://eaumega.org/wp-content/uploads/2016/05/EN-Lagos-Monograph.pdf.

[12] Idris, J., Fagbenro, A. (2019). Lagos the Mega-City: A Report on How the Metropolis Handled an Outbreak of the Ebola Epidemic. In Socio-cultural Dimensions of Emerging Infectious Diseases in Africa. Tangwa, G., Abayomi, A., Ujewe, S., Munung, N., Eds.; Springer: Cham, Switzerland. https://doi.org/10.1007/978-3-030-17474-3_21.

[13] Yahaya, T.; Alkali, A.; Ada, J.O.; Abdulazeez, A.; Ufuoma, S.; Tayo, B.; Kalgo, B.Y. (2022). Health Risks of Ecosystem Services in Ologe Lagoon, Lagos, Southwest Nigeria. *Pollution, 8*, 681–692. https://doi.org/10.22059/POLL.2021.333654.1265.

[14] Ipaye, T.O.; Ogunbajo, A.B. (2020). Pollution and Portability Assessment of Ground Water Sources in Maidan-Orile, Mile-12, Lagos State. *Global Scientific Journal, 8*, 2155–2160.

[15] Olawusi-Peters, O.O. (2010). Physico-Chemical parameters and fish richness in Agboyi creek, Lagos state, Nigeria. *Biological and Environmental Sciences Journal for the Tropics, 15*, 1–14.

[16] Ayeni, A.O.; Acquah, E. (2015). An evaluation of municipal solid waste management in Agboyi–Ketu Local Council Development Area (LCDA), Lagos State. *Sokoto Journal of the Social Sciences, 5*, 1–16.

[17] Standard Methods for the Examination of Water and Wastewater. (accessed June 13, 2022) Available online: https://www.standardmethods.org/doi/book/10.2105/SMWW.2882?.

[18] Yahaya, T.; Abdulganiyu, Y.; Abdulazeez, A.; Dikko, C.O.; Bashar, M.D.; Mohammed, F.U.; Mohammed, A.Z.; Liman, U.U. (2022). Characterization and Health Risk Evaluation of Water and Fish Samples obtained from Ogun River in Lagos. *Journal of Materials and Environmental Science, 13*, 424-534.

[19] Muhammad, S.; Shah, M.T.; Khan, S. (2011). Health risk assessment of heavy metals and their source apportionment in drinking water of Kohistan region, northern Pakistan. *Microchemical Journal, 98*, 334–343. https://doi.org/10.1016/j.microc.2011.03.003.

[20] Yahaya, T.; Oladele, E.; Salisu, T.F.; Izuafa, A.; Afolayan, F.; Abdulgafar, I.B.; Bello, A. (2022). Quality Assessment of Groundwater in Mowe, Ogun State, Nigeria. *Tropical Journal of Natural Product Research, 6*, 811–817.

[21] Weber-Scannell, P.K.; Duffy, L.K. (2007). Effects of Total Dissolved Solids on Aquatic Organisms: A Review of Literature and Recommendation for Salmonid Species. *American Journal of Environmental Sciences, 3*, 1–6. https://doi.org/10.3844/ajessp.2007.1.6.

[22] [22] Meride, Y.; Ayenew, B. (2016). Drinking water quality assessment and its effects on residents' health in Wondo genet campus, Ethiopia. *Environmental Systems Research, 5*, 1. https://doi.org/10.1186/s40068-016-0053-6.

[23] Eliku, T.; Leta, S. (2018). Spatial and seasonal variation in physicochemical parameters and heavy metals in Awash River, Ethiopia. *Applied Water Science, 8*, 177. https://doi.org/10.1007/s13201-018-0803-x.

[24] Teng, W.; Wang, G.; Li, Q. (2007). Effects of Water Turbidity on the Photosynthetic Characteristics of *Myriophyllum spicatum* L. *Asian Journal of Plant Sciences, 6*, 773–780. https://doi.org/10.3923/ajps.2007.773.780.

[25] Tsegay, T.; Haftom, Z. (2016). Seasonal Variation in Physico-Chemical Parameters of Tekeze Reservoir, Northern Ethiopia. *Animal Research International, 13*, 2413–2420.

[26] Cascella, M.; Vaqar, S. (2022). Hypermagnesemia. StatPearls Publishing: Treasure Island, United States of America.

[27] Nerbrand, C.; Agréus, L.; Lenner, R.A. (2003). The influence of calcium and magnesium in drinking water and diet on cardiovascular risk factors in individuals living in hard and soft water areas with differences in cardiovascular mortality. *BMC Public Health, 3*, 21. https://doi.org/10.1186/1471-2458-3-21.

[28] Edeogu, C.O. (2007). Nitrate, Sulphate, Phosphate and Chloride Status of Staple Food Crops, Soils and Water as Indicator of Environmental Base Anion Pollution Load in Ebonyi State, Nigeria. *Journal of Biological Sciences, 7,* 745-751. https://doi.org/10.3923/jbs.2007.745.751.

[29] Isiuku, B.O.; Enyoh, C.E. (2020). Pollution and health risks assessment of nitrate and phosphate concentrations in water bodies in South Eastern, Nigeria. *Environmental Advances, 2,* 100018. https://doi.org/10.1016/j.envadv.2020.100018.

[30] Olawusi-Peters, O.O. (2014). The effect of environmental waste discharge on the hydrochemistry of Agboyi creek, Lagos state. *Journal of Natural, Science, Engineering and Technology, 13,* 75–81.

[31] Uzoma, E.C.; Obinna, C.L.; Nnamdi, A.H. (2015). Cellular biomarker responses of bagrid catfish, Chrysichthys nigrodigitatus in a contaminated coastal ecosystem. *African Journal of Biotechnology, 14*, 2114–2123. https://doi.org/10.5897/AJB2014.14265.

[32] Guidelines for drinking-water quality. (accessed Dec 24, 2021) Available online: https://www.who.int/publications-detailredirect/9789241549950.

[33] Lead poisoning. (accessed June 3, 2022) Available online: https://www.who.int/news-room/fact-sheets/detail/lead-poisoning-and-health.

[34] Lee, J.W.; Choi, H.; Hwang, U.K.; Kang, J.C.; Kang, Y.J.; Kim, K.I.; Kim, J.H. (2019). Toxic effects of lead exposure on bioaccumulation, oxidative stress, neurotoxicity, and immune responses in fish: A review. *Environmental Toxicology and Pharmacology, 68*, 101–108. https://doi.org/10.1016/j.etap.2019.03.010.

[35] Dongre, R.S. (2020). Lead: Toxicological Profile, Pollution Aspects and Remedial Solutions. In Lead Chemistry. Chooto, P., Ed.; IntechOpen: London, UK. https://doi.org/10.5772/intechopen.93095.

[36] Han, J.M.; Park, H.J.; Kim, J.H.; Dal-Sang, D.S.; Kang, J. (2019). Toxic effects of arsenic on growth, hematological parameters, and plasma components of starry flounder, Platichthys stellatus, at two water temperature conditions. *Fisheries and Aquatic Science, 22,* 3. https://doi.org/10.1186/s41240-019-0116-5.

[37] Arsenic. (accessed June 3, 2022) Available online: https://www.who.int/news-room/fact-sheets/detail/arsenic.

[38] Routh, J.; Luo, C.; Luo, D. (2021). Arsenic in the Pearl River Delta and its related water body, South China: occurrence and sources, a review. *Geoscience Letters, 8,* 12. https://doi.org/10.1186/s40562-021-00185-9.

[39] Taylor, A.A.; Tsuji, J.S.; Garry, M.R. (2020). Critical Review of Exposure and Effects: Implications for Setting Regulatory Health Criteria for Ingested Copper. *Environmental Management, 65*, 131–159. https://doi.org/10.1007/s00267-019-01234-y.

[40] Aquatic Life Criteria – Copper. (accessed June 3, 2022) Available online: https://www.epa.gov/wqc/aquatic-life-criteria-copper.

[41] Cadmium in Drinking Water. (accessed June 3, 2022) Available online: https://wqa.org/learn-about-water/common-contaminants/cadmium#.

[42] Aquatic Life Ambient Water Quality Criteria Update for Cadmium. (accessed June 3, 2022). Available online: https://www.epa.gov/sites/default/files/2016-03/documents/cadmium-final-factsheet.pdf.

[43] Javed, M.T.; Tanwir, K.; Akram, S.M.; Shahid, M.; Niazi, N.K.; Lindberg, S. (2019). Phytoremediation of Cadmium-Polluted Water/Sediment by Aquatic Macrophytes: Role of Plant-Induced pH Changes. In Cadmium Toxicity and Tolerance in Plants. Hasanuzzaman, M., Prasad, M.N.V., Fujita, M., Eds.; Academic press: Cambridge, USA, pp 495-529. https://doi.org/10.1016/B978-0-12-814864-8.00020-6.

[44] Zhitkovich, A. (2011). Chromium in Drinking Water: Sources, Metabolism, and Cancer Risks. *Chemical Research and Toxicology, 24*, 1617–1629. https://doi.org/10.1021/tx200251t.

[45] Bakshi, A.; Panigrahi, A.K. (2018). A comprehensive review on chromium induced alterations in fresh water fishes. *Toxicology Reports, 5*, 440–447. https://doi.org/10.1016/j.toxrep.2018.03.007.
[46] Achmad, R.B.; Auerkari, E. (2017). Effects of Chromium on Human Body. *Annual Research & Review in Biology*, *17*, 1-8. https://doi.org/10.9734/ARRB/2017/33462.
[47] Joint WHO/FAO Food Standards Program Code Alimentarius Commission 13th Session. Report of the Thirty-Eight Session of the Codex Committee on Food Hygiene, Houston, Texas, USA. (accessed June 3, 2022) Available online: https://www.fao.org/UNFAO/Bodies/codex/28/index_en.htm.
[48] Silbergeld, E.K.; Waalkes, M.; Rice, J.M. (2000). Lead as a carcinogen: experimental evidence and mechanisms of action. *American Journal of Industrial Medicine*, *38,* 316–323. https://doi.org/10.1002/1097-0274(200009)38:3%3C316::AID-AJIM11%3E3.0.CO;2-P.
[49] Huang, C.; Ke, Q.; Costa, M.; Shi, X. (2004). Molecular mechanisms of arsenic carcinogenesis. *Molecular and Cellular Biochemistry*, *255*, 57–66. https://doi.org/10.1023/b:mcbi.0000007261.04684.78.
[50] Bishak, Y.K.; Payahoo, L.; Osatdrahimi, A.; Nourazarian, A. (2015). Mechanisms of cadmium carcinogenicity in the gastrointestinal tract. *Asian Pacific Journal of Cancer Prevention*, *16,* 9–21. https://doi.org/10.7314/apjcp.2015.16.1.9.