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OSUN CHAPTER

ASSESSMENT OF HEAVY METAL CONTAMINATION AND SELF-CLEANSING CAPACITY OF THE OSUN RIVER, SOUTHWESTERN NIGERIA

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ABSTRACT

The Osun River, a vital water resource in Southwestern Nigeria and a cultural landmark, faces increasing pollution pressure from urbanization and industrial activities. This study assesses its current water quality and self-cleansing capacity by analyzing spatial variations in physicochemical parameters and heavy metal concentrations. Water samples were collected from five locations along the river's course during the dry season and analyzed using standard methods, including Atomic Absorption Spectrophotometry (AAS). Results indicated that heavy metals typically associated with intensive mining (Cd, Cr, Co, Pb, Cu, Ni) were below detectable limits. However, iron (Fe) concentrations (0.38 - 2.82 mg/L) consistently exceeded the World Health Organization (0.3 mg/L) and Nigerian (0.3 mg/L) standards across all but the most downstream site. A clear downstream trend of decreasing turbidity, iron, and zinc concentrations was observed, demonstrating the river's natural self-purification capacity. Despite this, high turbidity levels (up to 53.51 NTU) in urban stretches indicate significant organic and particulate pollution. The study concludes that while the Osun River retains a measurable self-cleansing ability, it is contaminated with Fe and suspended solids, necessitating improved wastewater management and continuous monitoring to safeguard public and ecosystem health in line with SDG 6 targets.

1. INTRODUCTION

Access to clean water is a fundamental human right and a cornerstone of public health and sustainable development, explicitly targeted by United Nations Sustainable Development Goal 6 (UN, 2015). However, freshwater ecosystems, particularly rivers in developing nations, are under unprecedented threat from rapid urbanization, industrialization, and agricultural intensification (Kumar *et al.*, 2023). In Nigeria, surface water bodies are the primary source for domestic, agricultural, and cultural activities for a significant portion of the population, yet they increasingly serve as conduits for untreated waste, leading to severe degradation (Ogunlade *et al.*, 2022).

Globally, riverine ecosystems are subjected to a complex mixture of pollutants from point and non-point sources. While traditional industrial discharges remain a concern, recent studies highlight the growing significance of urban runoff, improper solid waste disposal, and effluents from informal economic sectors (Li & Wang, 2023). In Sub-Saharan Africa, the capacity for wastewater treatment has not kept pace with population growth and urbanization, leading to the direct discharge of largely untreated sewage and industrial effluent into water bodies (Ogunlade *et al.*, 2022). Furthermore, artisanal and small-scale gold mining (ASGM) has been identified as a major source of heavy metals like mercury and lead in tropical rivers, with long-term consequences for ecosystem and human health (Adimalla & Taloor, 2021). Beyond conventional pollutants, emerging contaminants such as pharmaceuticals, personal care products, and microplastics are now being detected in surface waters, adding another layer of complexity to water quality management (Kumar *et al.*, 2023).

Self-purification is the intrinsic capacity of a river to restore its chemical, physical, and biological integrity after receiving a pollutant load. This capacity is governed by hydrodynamic factors (flow velocity, depth, turbulence), biogeochemical processes (microbial metabolism, redox reactions, adsorption), and environmental conditions (temperature, pH, solar radiation) (Zhang *et al.*, 2022). The process can be conceptually divided into zones of degradation, active decomposition, recovery, and cleaner water, with the rate of recovery heavily dependent on the pollutant load and the river's assimilative capacity (Uddin *et al*., 2021).

A critical benchmark of self-purification is the dynamic balance between biochemical oxygen demand (BOD) and dissolved oxygen (DO). Microbial decomposition of organic waste consumes DO, while re-aeration from the atmosphere replenishes it. When the deoxygenation rate exceeds the re-aeration rate, hypoxia or anoxia can occur, leading to a collapse of the aquatic ecosystem (Wang *et al*., 2023). The self-purification capacity is not limitless; it can be overwhelmed by excessive pollutant loads, leading to a permanent state of degradation. Recent research emphasizes the need to quantify this capacity using integrated models that account for multiple stressors to set scientifically sound discharge limits and restoration goals (Uddin *et al*., 2021; Zhang *et al.*, 2022). In developing regions, understanding this natural resilience is especially crucial where financial resources for building advanced wastewater treatment infrastructure are limited.

The Osun River, flowing through the culturally significant Osun-Osogbo sacred grove - a UNESCO world heritage site - epitomizes this challenge. It is a lifeline for over 20 communities but is perceived to be under threat from pollution, including potential contamination from illicit artisanal gold mining activities (Adimalla & Taloor, 2021). Such pollution can introduce toxic heavy metals (e.g., Pb, Cd, Hg) and other contaminants, posing severe risks to human health, including cancer, neurological damage, and organ failure, and disrupting aquatic biodiversity (Ukah *et al*., 2023). Despite these concerns, a systematic, recent assessment of its water quality and innate resilience is lacking.

Rivers possess a natural, though finite, ability to mitigate pollution through self-purification processes, including dilution, sedimentation, and microbial degradation (Zhang *et al*., 2022). Understanding this capacity is critical for developing effective river management strategies. This study therefore aims to determine the current spatial concentration of physicochemical parameters and heavy metals along a segment of the Osun River, and also evaluate its self-cleansing ability based on observed longitudinal trends in pollutant concentrations, providing a contemporary baseline for regulatory action.

2. MATERIALS AND METHODS

Study area

The Osun River originates from Igede-Ekiti in Ekiti State and flows 267 km southwards through Southwestern Nigeria before emptying into the Lagos Lagoon and the Atlantic Ocean (NPC, 2006). The study area covered both pre-urban and urban stretches of the river as it passes through Osogbo, the capital of Osun State. The region experiences a tropical climate with an average annual rainfall of 350 mm and temperatures ranging from 19°C to 38°C (NPC, 2006).

Sampling and analysis

Field sampling was conducted in December, during the dry season, when pollutant concentrations are typically highest due to reduced dilution (Henry & Heinke, 2005; Mehrdadi *et al.*, 2006). Surface water samples were collected in pre-cleaned 75cl plastic bottles from five strategic locations under highway bridges spanning the river shown in Plate 1 and the locations' corresponding coordinates are presented in Table 1.

Table 1: Sampling Locations and Morphometric Details

Sample ID	Location Name	Coordinates	Elevation (m)	Description
S1	Osunjela, Osogbo	7°44'17.7"N, 4°32'09.1"E	290	Upstream, mixed residential/commercial area.
S2	August 9 Bridge, Ijetu, Osogbo	7°44'36.4"N, 4°33'21.4"E	270	Urban flow, activities include fishing.
S3	Ebunoluwa Area, Ofatedo, Osogbo	7°46'27.6"N, 4°30'35.9"E	260	Urban flow.
S4	Oke Gada, Ede	7°44'53.7"N, 4°26'08.6"E	236	Town reliant on river for domestic/agricultural use.
S5	Asejire, Ibadan	7°21'19.2"N, 4°07'40.7"E	124	Downstream, near Nigerian Bottling Company; boundary of Osun and Oyo states.

The distance covered from the station S1 to S2 is 2.29 km, while S2 to S3, S3 to S4, and S4 to S5 are 6.12 km, 8.68 km, and 55.31 km respectively.

Samples were transported to the laboratory on ice and analyzed for physicochemical parameters including pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Turbidity using their respective meters (Hanna Instruments). Heavy metals (Fe, Zn, Mn, Cd, Cr, Co, Pb, Cu, Ni) were analyzed using an Atomic Absorption Spectrophotometer (AAS, Model: PerkinElmer PinAAcle 900T). Standard analytical procedures as outlined by the American Public Health Association (APHA, 2017) were followed.


(a) (b)

Plate 1: River Samples from (a) August 9 Bridge, Ijetu, Osogbo (b) Ebunoluwa Area, Ofatedo

3. RESULTS AND DISCUSSION

Spatial variation of physicochemical parameters

The results of the physicochemical analysis are summarized in Table 2. The pH of the river was slightly acidic to neutral, ranging from 6.56 to 6.81, which is within the acceptable range for natural waters and below the WHO upper guideline of 8.5. The low pH values could enhance the mobility of certain metal ions. Electrical Conductivity (EC) and Total Dissolved Solids (TDS) showed a gradual increase downstream (from 148 µS/cm to 168 µS/cm and 73 mg/L to 86 mg/L, respectively), possibly indicating cumulative input of dissolved ions from surface runoff and minor anthropogenic discharges (Ayoko *et al*., 2007). However, all values were well within WHO (EC: 1000 µS/cm; TDS: 1000 mg/L) and Nigerian (TDS: 500 mg/L) standards.

Turbidity was a parameter of major concern. It was highest at the urban sites S1 and S2 (50.71 and 53.51 NTU respectively) and decreased progressively to 0.84 NTU at the most downstream site (S5). This pattern, visualized in Figure 1b, strongly suggests the settling of suspended solids and particulate matter as the river flows, a primary physical self-purification mechanism. The high turbidity in urban stretches exceeds the Nigerian standard of 5 NTU, indicating significant erosion or organic waste input.

Table 2: Physicochemical Parameters and Heavy Metal Concentrations

Parameter	S1	S2	S3	S4	S5	WHO Standard	NIS Standard
pH	6.72	6.81	6.64	6.56	6.58	6.5-8.5	-
Turbidity (NTU)	50.71	53.51	40.06	27.18	0.84	-	5
EC (µS/cm)	148.00	142.00	152.00	168.00	168.00	1000	1000
TDS (mg/L)	73.00	72.00	77.00	85.00	86.00	1000	500
Sulphate (mg/L)	2.78	4.17	3.05	2.32	0.07	100	100
Iron (mg/L)	2.82	2.73	2.71	2.42	0.38	0.3	0.3
Zinc (mg/L)	0.331	0.302	0.288	0.169	0.109	3.0	3.0
Manganese (mg/L)	0.01	0.01	0.01	0.01	0.00	0.2	0.2
Cadmium (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	0.003	0.003
Lead (mg/L)	<0.001	<0.001	<0.001	<0.001	<0.001	0.01	0.01

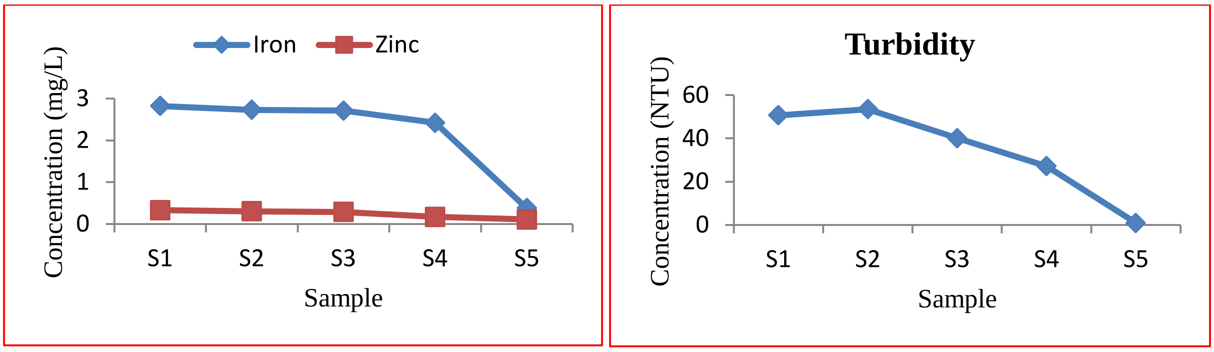
Note: All values for Cd, Cr, Co, Cu, and Ni were below detection limits (<0.001 mg/L).

Heavy metal contamination and self-cleansing evidence

A significant finding was that critical heavy metals often linked to gold mining - Cadmium (Cd), Chromium (Cr), Cobalt (Co), Lead (Pb), Copper (Cu), and Nickel (Ni) - were all below the detection limit of the AAS (<0.001 mg/L) at all sampling points. This suggests that, at the time of sampling, gold mining activities were not a primary source of these specific toxic metals in the river's water column.

However, iron (Fe) was present at concentrations exceeding the WHO (2011) and Nigerian standard of 0.3 mg/L at sites S1 through S4 (Figure 1a). The source is likely natural (lateritic soils) combined with anthropogenic inputs like corroding infrastructure. The consistent decrease from 2.82 mg/L (S1) to 0.38 mg/L (S5) demonstrates a clear self-cleansing trend, likely through oxidation and subsequent sedimentation of iron hydroxides.

Similarly, Zinc (Zn) concentrations, though within permissible limits ((WHO, 2011): 3.0 mg/L), decreased from 0.331 mg/L to 0.109 mg/L downstream as shown in Figure 1a, further indicating the river's capacity to reduce metal loads over distance. This removal can occur via adsorption to suspended particles and sediments.



(a) (b)

Figure 1: Conceptual graph showing decreasing trends for (a) Iron and Zinc, (b) Turbidity

4. CONCLUSION AND RECOMMENDATIONS

This study provides a contemporary assessment of the Osun River's water quality, revealing a complex picture. The absence of detectable levels of potent carcinogens like Cd and Pb is a positive finding, alleviating immediate concerns about gold mining wastewater being a major contributor to dissolved metal pollution. Furthermore, the river demonstrates a resilient self-cleansing capacity, effectively reducing turbidity, iron, and zinc concentrations over a flowing distance of approximately 55 km. However, the river is not pristine. The persistently high turbidity and iron levels in its urban stretches indicate significant contamination from eroded sediments and other anthropogenic sources, compromising its utility and ecological health. This underscores the ongoing challenges faced by urban rivers in developing countries.

Based on these findings, the following recommendations are made:

- Integrated watershed management strategies to reduce erosion and control urban runoff in the Osogbo metropolitan area should be implemented.
- While mining metals were low, the high turbidity indicates other pollution sources. Regulatory bodies should strengthen monitoring and enforcement of effluent discharge standards for industries and municipal waste.
- Future research should employ a multi-media approach, analyzing river sediments and biota for heavy metals and emerging contaminants to gain a comprehensive understanding of the pollution burden.
- Community-based monitoring and protection programs for the Osun River should be fostered, leveraging its cultural significance to drive conservation efforts aligned with SDG 6 principles.

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