Nigerian Medical Journal
NIGERIA MEDICAL ASSOCIATION
Print ISSN 0300-1652, E-ISSN 2229-774X

Original Article

Evaluation and Impact of Pharmaceutical Residues from Hospital Waste in Lagos State on Dissolved Oxygen in Water

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Abstract

Background: This study assessed the influence of pharmaceutical residues from hospital waste on dissolved oxygen (DO) levels in water sources near four hospitals in Lagos State, Nigeria.
Methodology: A total of 35 water samples were collected from boreholes, wells, and taps adjacent to hospital waste sites and analyzed for ciprofloxacin, paracetamol, and bromazepam residues using high-performance liquid chromatography (HPLC), alongside DO measurements with a calibrated digital meter.
Results: Residue concentrations varied across sites, with paracetamol levels exceeding WHO guidelines in several samples, potentially contributing to the observed low DO (<2 mg/L) across all locations—well below thresholds for aquatic life (5–6 mg/L) and drinking water (>6.5 mg/L). Hospital location D exhibited the highest residue levels, followed by location B, while locations A, C, and the control (E) showed lower concentrations. Statistical analyses (t-tests) indicated no significant differences for ciprofloxacin and bromazepam relative to permissible limits ($p > 0.05$), but paracetamol was significantly elevated ($p < 0.05$).
Conclusion: These findings highlight an association between pharmaceutical residues and DO depletion, underscoring risks to aquatic ecosystems and human health. Recommendations include enhanced hospital waste segregation, advanced water treatment protocols, and policy reforms to enforce pharmaceutical disposal standards, aligning with SDGs 3, 6, and 11 for sustainable health and water management.

Keywords: Pharmaceutical residues; Impact; Hospital waste; Dissolved oxygen; Water.

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How to Cite: Lasore IC, Lajide L, Ololade ZS, Babayemi JO. Evaluation and Impact of Pharmaceutical Residues from Hospital Waste in Lagos State on Dissolved Oxygen in Water. Niger Med J 2025; 66 (5): 1766-1776. https://doi.org/10.71480/nmj.v66i5.874

Quick Response Code:

Introduction

Groundwater and surface water are vital for drinking and aquatic ecosystems, particularly in densely populated urban areas like Lagos State, Nigeria, where pollution threatens public health and SDG 3 (good health and well-being) [1]. Poor waste management exacerbates this issue, allowing contaminants to infiltrate water sources and degrade quality [2]. Numerous studies have documented pollution of drinking water sources by various wastes in developing nations [3]. In Lagos, indiscriminate waste disposal has intensified [4], contaminating aquifers and hindering SDG 6 (clean water and sanitation) and SDG 11 (sustainable cities) [5, 6, 7]. One example of such waste is hospital waste. Hospital waste, generated from medical activities in facilities like clinics and laboratories, comprises hazardous (10–25%) and non-hazardous materials, including pharmaceuticals that pose environmental risks if mismanaged [8, 9, 10]. Most medical waste comes from healthcare facilities such as blood banks, clinics, diagnostic labs, mortuaries, hospitals, and research institutes [11]. The World Health Organization categorizes medical waste into eight groups [12], as shown in Figure 1 below.

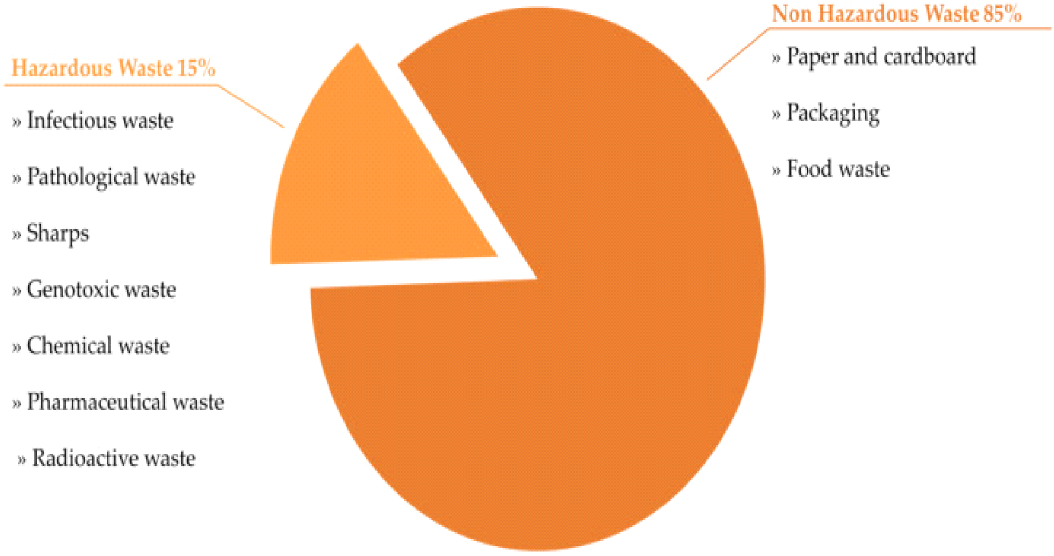

Figure 1: Standard waste composition in health facilities [13].

Pharmaceutical residues, including active ingredients and metabolites, enter water bodies via hospital wastewater, improper disposal, and leaching [14, 15]. Even trace levels can disrupt ecosystems, promote antibiotic resistance, and cause endocrine disruption in organisms [16, 17, 18, 19, 20]. In Nigeria, knowledge gaps in pharmaceutical waste handling amplify these risks, violating SDG 12 (responsible consumption) [21]. For instance, paracetamol, a common analgesic, can form toxic metabolites harmful to aquatic life [22]. Domestic households are the main source of pharmaceutical pollution, while hospitals and nursing homes contribute less overall [23, 24]. However, some drugs are predominantly from healthcare settings, such as anticancer agents, endocrine therapies, and contrast agents (70–90%), while analgesics, antihypertensives, and anti-inflammatory drugs mainly originate from households [25, 26]. Pharmaceutical residues in soil span many drug classes: antibiotics (penicillin, tetracycline, sulfonamides) [27], anti-inflammatories (ibuprofen, diclofenac) [26], hormones (estrogens, androgens) [28], and psychotropics (antidepressants, tranquillizers) [29]. High antibiotic residues in wastewater treatment plants can influence the fate of antibiotic resistance genes (ARGs) [30], with studies showing increased antibiotic resistance in receiving water and soil [31]. Contamination of food and water raises risks of infections, reproductive and developmental issues, cancers, and effects from chiral pharmaceuticals [32]. UNESCO classifies human pharmaceuticals as emerging contaminants. Through improper disposal and sewage discharge, they increase biochemical oxygen demand by adding organic pollutants, depleting dissolved oxygen in aquatic systems. Detecting and eliminating these residues is crucial to achieving the 2030 Agenda for Sustainable Development goals [33]. This study evaluates the impact of pharmaceutical waste on dissolved oxygen in the studied environment.

Dissolved oxygen (DO), essential for aquatic metabolism, fluctuates due to photosynthesis, respiration, and decomposition [34, 35]. Pharmaceuticals may indirectly lower DO by stimulating microbial activity that increases biochemical oxygen demand (BOD) [36]. Additionally, their presence in water may affect the availability of nutrients, which may affect the growth and respiration of phytoplankton and can vary the DO levels. It may also sorb to sediments, changing the oxygen demand of the sediment and changing the DO levels in the overlying water [37]. This study examines pharmaceutical residues (ciprofloxacin, paracetamol, bromazepam) and their potential association with low DO in water near Lagos hospitals, using HPLC and DO metering, to inform waste management strategies.

Materials and Methods

Sampling Location Description

Ayobo, Ipaja, Yaba and Ikeja are located in Lagos State, South-Western Nigeria (Fig. 2 - 5). Lagos State is situated on the southwest coast of Nigeria and is home to one of the top twenty most populous cities worldwide. The entire population of the state is estimated to be 21 million, with an area of 3577 km². Lagos State is located between latitudes 6˚22'N and 6˚52'N and longitudes 2^42'E and 3˚42'E. It is separated into twenty (20) Local Government Areas (LGAs) and thirty-seven (37) Local Council Development Areas (LCDAs) for organized and thorough government. It is divided into five divisions: Ikeja, Badagry, Ikorodu, Lagos, and Epe Divisions [38]. For the purpose of this study, the water samples were taken from four hospital locations from Ayobo, Ipaja, Ikeja and Yaba. Below is a map of the four hospital locations where water samples were collected:

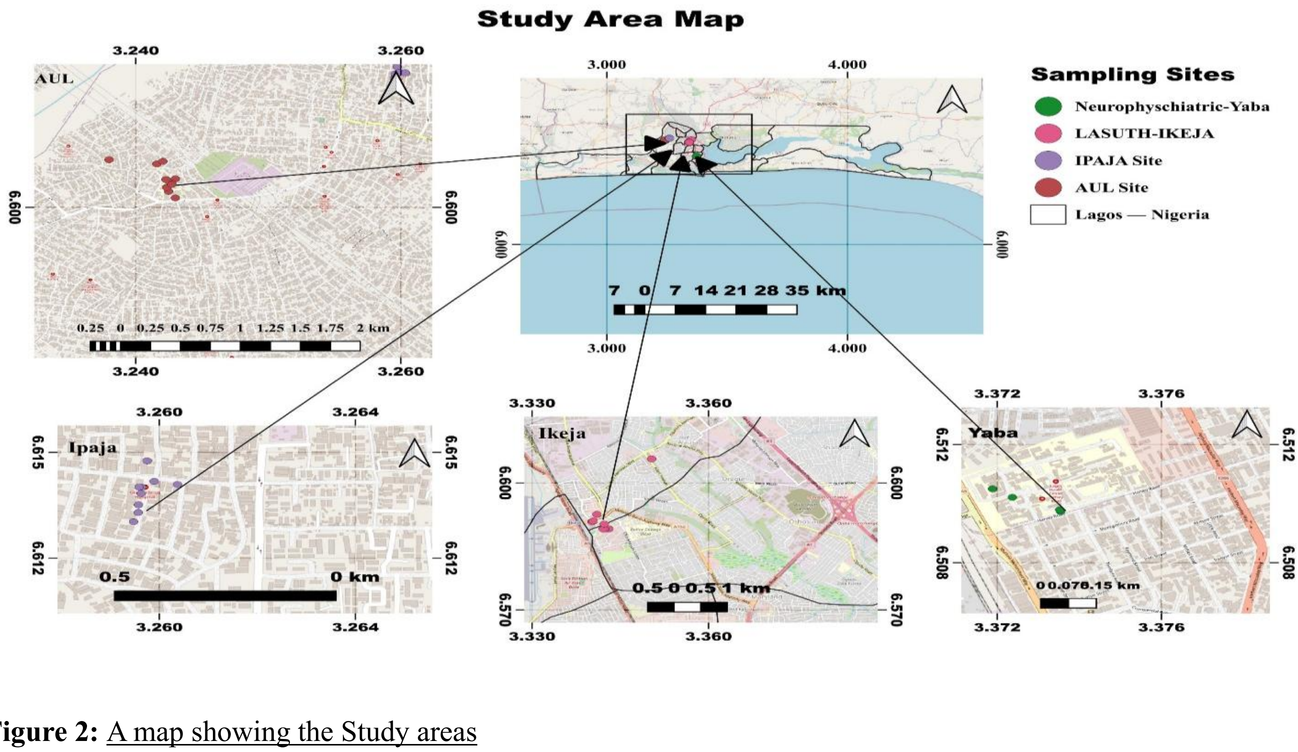

Figure 2: A map showing the Study areas

Sampling Methods

Water samples were collected from locations within four hospitals and some from neighbouring wells, boreholes and tap water. The water samples were collected from different locations, viz-a-viz, an Eatery,

 Niger Med J 2025;66(5): 1786 - 1795 **ISSN**: 0300-1652, **E-ISSN**: 2229-774X, **Publisher**: Nigerian Medical Association. Sept. - Oct, **2025**

Worship centres, Students' halls of residence, Cafeterias, Schools, Business centres, Emergency centres, Clinics, and Laboratories. The water samples were collected from various distances from one to another to ensure a thorough analysis.

Evaluating Pharmaceutical Residues in Water

Thirty-five (35) water samples were selected for the pharmaceutical residues analysis (ciprofloxacin, paracetamol and bromazepam) based on poor waste storage methods observed in the hospitals assessed. The samples were collected from water sources (boreholes and wells) at close proximity to the hospitals' waste storage sites, and some from buildings very close by to ensure a reliable analysis. This is done to avoid the possibility of pharmaceutical residues from external sources interfering with the results of this study, and so help to detect the drug residues emanating from the hospitals directly into the environment. The water samples were properly stored to prevent analyte degradation[39], filtered, and the desired pharmaceutical analyte extracted by the solid-phase extraction (SPE) method [40] and taken for HPLC analysis. High-Performance Liquid Chromatography (HPLC) was employed for the determination of pharmaceutical residues in this study due to its precision, sensitivity, and versatility.

Evaluating Dissolved Oxygen (DO) in Water

The DO in the water samples were determined in situ using a calibrated Digital DO Meter (Model No: 612–R).

Results And Discussion

Descriptive Statistics of Pharmaceutical Residues Detected in Water Samples at Selected Locations Across Four Hospitals

The mean (mean ± SD) of the pharmaceutical residues detected in the water samples obtained from the four different locations (hospitals) are presented in Table I below.

Table I: Concentration (µg/ml)of pharmaceutical residues detected in water samples from the selected hospitals' environments

Pharmaceutical Residues	Mean ± SD
Ciprofloxacin residue (µg/ml)	8.73 ± 10.40
Paracetamol residue (µg/ml)	3.49 ± 1.75
Bromazepam residue (µg/ml)	2.47± 3.88

Table I above shows the mean values of the pharmaceutical residues obtained from the water samples in the four hospitals' environments. The result shows the mean of ciprofloxacin residues found in the water across the four hospitals' locations to be 8.73 µg/ml, the mean of paracetamol residues 3.49 µg/ml, while that of Bromazepam residues is 2.47 µg/ml. A comparison of the concentration of pharmaceutical residues detected in water at the four hospitals' locations and the control hospital (Location E) is shown in the bar chart below (Figure 3):

Niger Med J 2025;66(5): 1786 - 1795 **ISSN**: 0300-1652, **E-ISSN**: 2229-774X, **Publisher**: Nigerian Medical Association. Sept. - Oct, **2025**

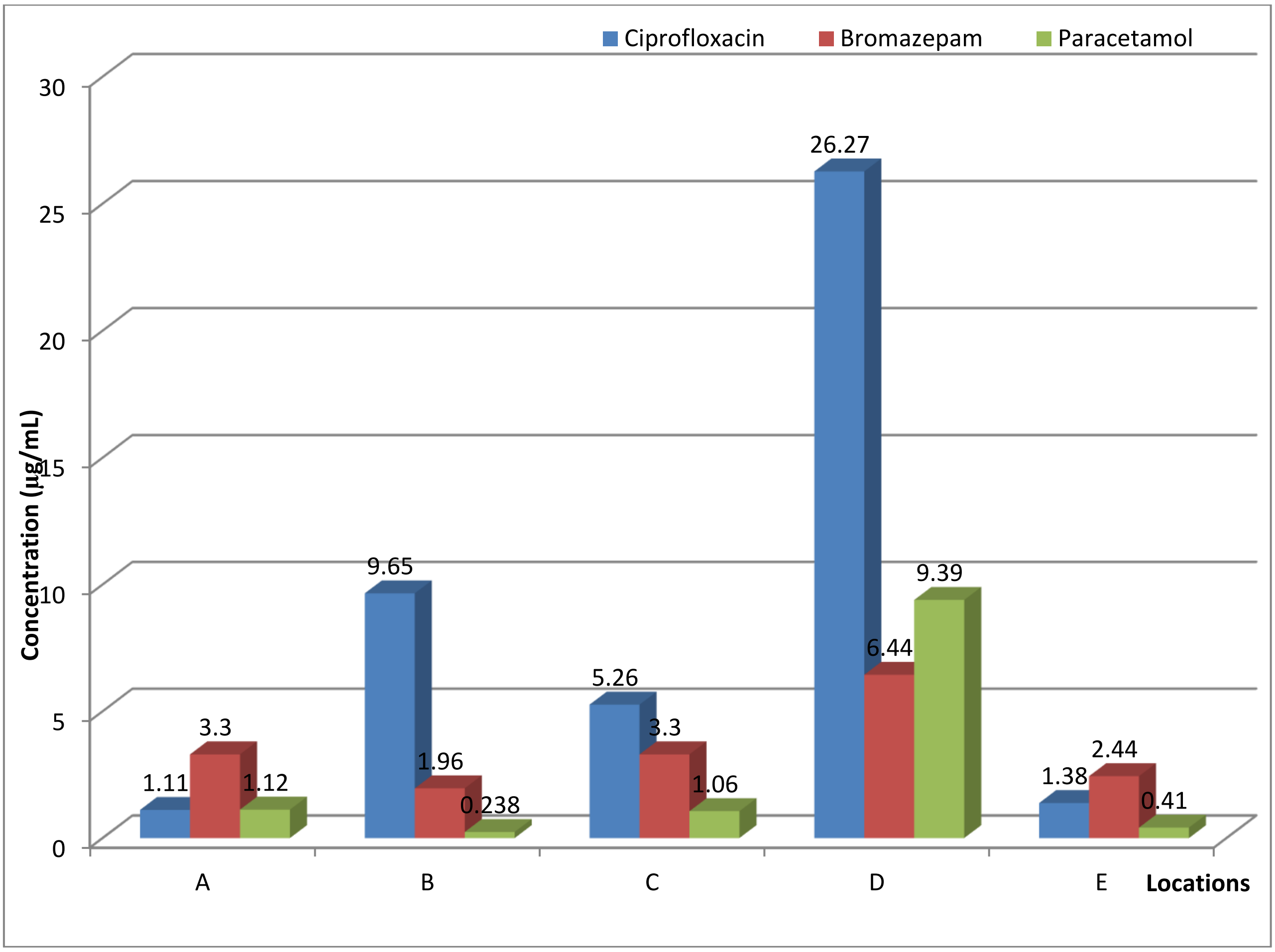

Figure 3: Pharmaceutical residue concentration in water (µg/ml)across the four hospitals and the control Location E

Comparison of the Pharmaceutical Residue concentration in water (µg/ml)obtained with the WHO Permissible Limits

Table II. One Sample t-test for Pharmaceutical Residues in Water

Residues	Mean Calculated	T	ρ
Ciprofloxacin residue detected in water (µg/ml)	8.73	1.878	0.134
Paracetamol residue detected in water (µg/ml)	3.49	4.46	0.011*
Bromazepam residue detected in water (µg/ml)	2.20	1.42	0.228

df (4); ***Significant values (p<0.05) are marked*; Permissible Limit (WHO) (< 0.00005 µg/ml)***

Niger Med J 2025;66(5): 1786 - 1795 **ISSN**: 0300-1652, **E-ISSN**: 2229-774X, **Publisher**: Nigerian Medical Association. Sept. - Oct, **2025**

Table III below shows that the Ciprofloxacin residue (8.73µg/ml) detected in the water sampled was not significantly different from the WHO recommended value [t (4) = 1.878, ρ > 0.05]. Also, Bromazepam (2.47µg/ml) detected in the water was also not significantly different from the recommended residue expected to be found in water sample [t (4) = 1.42, ρ > 0.05], but the paracetamol residue (3,49) found in the sample water was significantly higher than the WHO recommended value [t (4) = 4.46, ρ < 0.05]. This finding suggests that either paracetamol, an analgesic (pain killer), is more in use or easily thrashed because it is cheaper than ciprofloxacin and Bromazepam. However, all three pharmaceutical residues are not permissible in water sources in the concentrations detected. The table below (Table III) shows the mean ± standard deviation of DO levels of thirty-five water samples taken from various locations around the hospitals. These locations are selected based on the history of unsuccessful fish farming businesses in those environments.

Table III: DO concentration (mg/L)detected in water samples from the selected hospitals' environments

Locations	Dissolved Oxygen (mg/L) (Mean ± SD)
I	0.44 ± 0.31
II	0.20 ± 0.00
III	0.70 ± 0.07
IV	0.14 ± 0.70

The recommended DO level for any water source meant for fish farming is DO 5 – 6 mg/Land DO > 6.5-8 mg/Lfor drinking water [41]. However, from Table 3 above, the mean ± SD values of the dissolved oxygen available in all water samples from the four locations show water sources with extremely low DO levels. The result shows the mean of dissolved oxygen available in the water sampled across location I to

be 0.44 ± 0.31 mg/L, mean of dissolved oxygen available in the water sampled across location II to be 0.20 ± 0.00 mg/L, mean of dissolved oxygen available in the water sampled across location III to be 0.70 ± 0.07 mg/Lwhile that of water sampled across location IV is 0.14 ± 0.70 mg/L. The range of DO across the four locations is therefore 0.14–0.70 mg/L,which is too low a threshold for fish survival. A comparison of the concentration of mean of dissolved oxygen(mg/L) available in the water across the four locations is shown in the bar chart below (Figure 3).

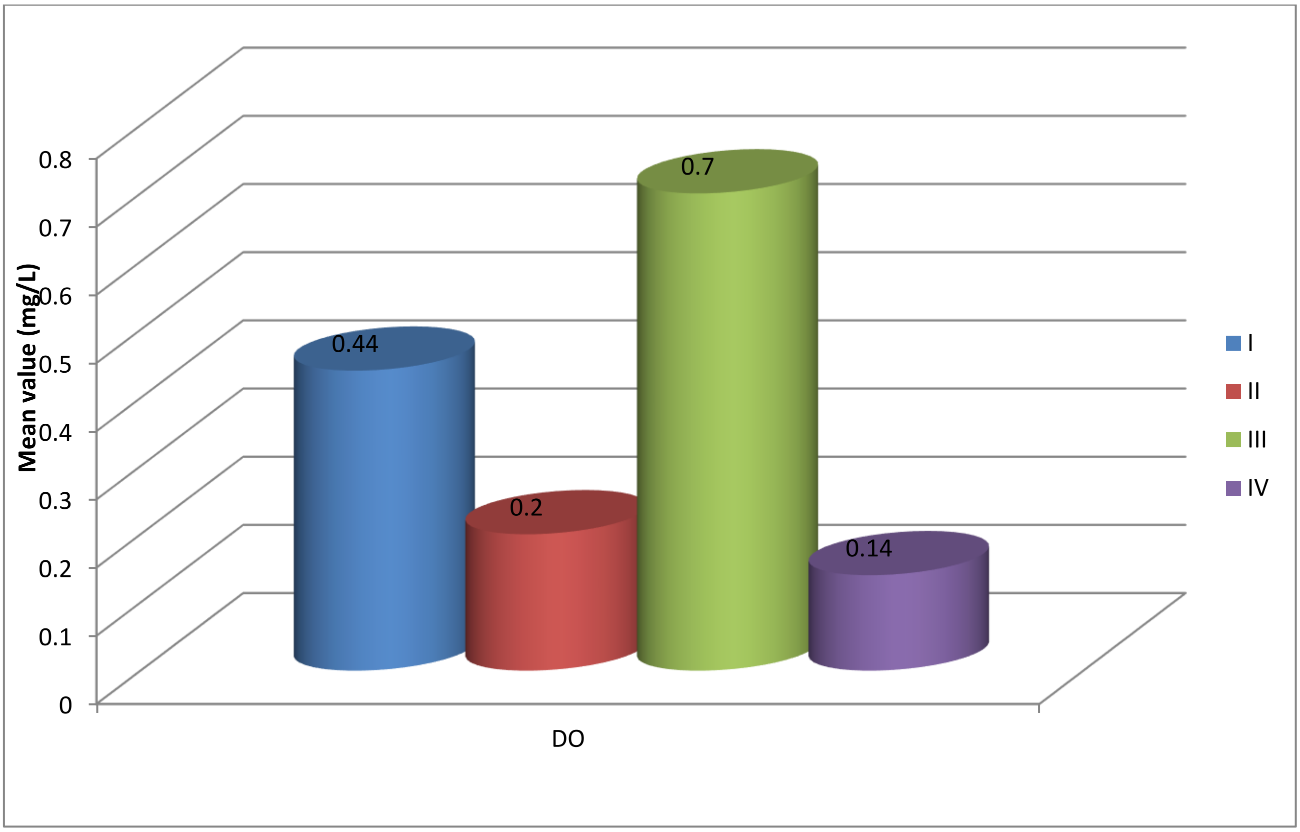

Figure 4: DO concentration (mg/L) in sampled water sources across four locations

These low DO values align with failed local fish farming attempts and suggest an association with pharmaceutical residues, which may elevate BOD via microbial decomposition [36]. Paracetamol's elevated levels could exacerbate this through organic loading, though other factors (e.g., eutrophication) warrant further exploration. Site D's high residues correlate with the lowest DO, indicating localized pollution hotspots influenced by runoff and human activity. This poses risks to aquatic biodiversity and human health via bioaccumulation [19, 32]. Compared to global studies, these concentrations mirror hospital effluent impacts in developing regions [23, 24], emphasizing the need for targeted interventions.

Conclusion

Pharmaceutical residues from hospital waste in Lagos are associated with critically low DO in nearby water sources, threatening aquatic life and water usability. Elevated paracetamol levels, particularly at sites B and D, highlight disposal vulnerabilities. To address this, hospital waste policies should be prioritized, segregation and incineration mandated, pharmaceutical screening in water treatment integrated, and monitoring under SDGs 6 and 11 should be enforced. This is because effective waste management, considering fish farming, is essential for ensuring environmental sustainability, economic feasibility, and public health in Lagos State, Nigeria. It will significantly influence the fish farming sector and support Sustainable Development Goal 11 (SDG 11), which emphasizes the development of sustainable cities and communities [6]. Future studies should include controls, longitudinal sampling, and mechanistic analyses (e.g., BOD assays) to confirm causal pathways and evaluate remediation efficacy. This study is in agreement with Manole et al., 2023 [22], who stated that the discharge of pharmaceutical residues via hospital waste into the ecosystem constitutes a multifaceted challenge with far-reaching implications for human, animal, and environmental health; however, it is limited by a lack of control sites or reference points. Further research is needed to establish the link between pharmaceutical contamination of groundwater and depletion of DO.

Authors Contributions

Conceptualization, I.C.; writing-original draft preparation, I.C.; writing-review and editing, Z.S., J.O.; literature review, L.L. All authors have read and agreed to the published version of the manuscript.

Funding

This study was funded by the authors.

Conflicts of Interest

The authors declare that there is no conflict of interest.

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