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HOSPITAL LIQUID WASTE AND URBAN RIVER WATER QUALITY IN BAYELSA STATE, NIGERIA: IMPLICATIONS FOR ENVIRONMENTAL HEALTH, WATER SECURITY AND RESILIENCE

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Introduction

Bayelsa State, located in Nigeria's Niger Delta, depends heavily on rivers, creeks and wetlands for domestic water use, fishing and agriculture. However, inadequate hospital wastewater management may contribute to the degradation of freshwater resources through the discharge of effluents containing organic matter, nutrients, disinfectants, pharmaceutical residues and potentially toxic metals. Where wastewater treatment is inadequate, these contaminants may enter urban rivers used by downstream communities, increasing environmental health concerns and threatening water security. Despite growing concern about environmental pollution in the Niger Delta, locally specific evidence integrating water quality assessment, pollution indices and multivariate analysis remains limited. This study investigated hospital liquid waste and associated water quality changes in receiving urban rivers in Bayelsa State, Nigeria, to inform environmental monitoring and public health protection (Odipe *et al*., 2018; Raimi *et al*., 2022a; 2022b; Tomquin *et al.,* 2026; Omidiji *et al.,* 2026). The study assessed the physicochemical characteristics, nutrient concentrations, and heavy metal contamination of hospital effluents and receiving urban rivers in Bayelsa State. Specifically, it examined spatial differences between hospital discharge points, upstream reference locations, and downstream river sections; evaluated pollution using the Water Pollution Index (WPI) and Heavy Metal Evaluation Index (HEI); and explored potential pollution-source associations using Principal Component Analysis (PCA).

Methodology

Twelve composite water samples were collected during the dry season, from October 2024 to March 2025, comprising five hospital discharge points and seven riverine locations representing upstream

and downstream sections of receiving rivers. In-situ parameters, including temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO), salinity and turbidity, were measured using a Bante 900P portable multiparameter instrument. Nutrients and related parameters, including nitrate, nitrite, ammonium, phosphate, sulphate and total hardness, were determined using a PalinTest UV-7100 photometer. Chemical oxygen demand (COD) and biochemical oxygen demand (BOD) were analysed using HACH digestion and BOD instruments. Iron (Fe), zinc (Zn), copper (Cu), manganese (Mn), nickel (Ni), chromium (Cr), cadmium (Cd) and lead (Pb) were determined by flame atomic absorption spectrometry following wet digestion. WPI and HEI were calculated using applicable reference limits, while PCA was performed using Origin and SPSS to explore patterns of covariation among measured parameters. Quality assurance included spike-recovery tests (83–109.2%) and precision checks (relative standard deviation below 10%). The limited number of composite samples constrained the ability to characterise within-site variability and establish robust statistical power. Accordingly, spatial comparisons and multivariate findings require cautious interpretation, particularly where independent replication is limited.

Results

Water quality varied across sampling locations, with reported spatial differences at $p < 0.05$; however, the strength of this inference depends on the underlying replication and statistical assumptions. Hospital effluents and downstream locations exhibited elevated EC, reaching 942.67 µS/cm, and turbidity exceeding 500 NTU, alongside increased TDS relative to upstream reference locations. Phosphate concentrations reached 101.37 mg/L, while nitrate reached 15.68 mg/L in hospital effluents, indicating substantial nutrient enrichment and potential eutrophication risks. Maximum reported concentrations of Fe (26.3 mg/L), Zn (6.44 mg/L) and Cd (0.12 mg/L) in hospital effluents exceeded the reference limits applied in the study. WPI values ranged from 4.72 to 11.63 at hospital discharge points and downstream locations, which were classified as highly polluted under the study's classification scheme. Upstream sites had WPI values below 0.75 and were classified as non-polluted to good. At one reported river comparison, WPI increased from 0.648 upstream to 3.06 downstream, indicating deterioration following the discharge zone. HEI results also indicated high heavy metal pollution at critical downstream sites, using the study's classification threshold of HEI > 20. PCA explained 67.25% of the variance in physicochemical parameters, 73.70% in nutrients and 54.03% in heavy metals. For the heavy metal dataset, cadmium, zinc and manganese loaded strongly on the first principal component, suggesting a shared contamination pattern potentially associated with hospital discharges. Chromium and nickel dominated the second component, indicating a potentially mixed influence of anthropogenic activities and geogenic processes. These statistical associations support the identification of candidate pollution sources but do not independently establish source identity or causation.

Conclusion

Hospital effluents were associated with substantial deterioration in receiving river water quality, particularly in nutrient enrichment, physicochemical parameters and selected heavy metals. The WPI and HEI results identified pollution hotspots, while PCA provided complementary evidence of contaminant associations that may guide further source investigation. Nevertheless, the 12-composite-sample dataset, limited information on independent replication and restriction to dry-season sampling constrains the generalisability of the findings. The results should therefore be interpreted as a preliminary, location-specific assessment rather than a definitive estimate of annual pollution or community exposure. The observed contamination raises concerns for communities relying on affected rivers for domestic activities, fishing and agriculture. Potential health implications depend on contaminant concentrations, exposure pathways, duration and frequency of contact, and the effectiveness of water treatment; adverse clinical outcomes were not assessed directly in this study. Bayelsa State environmental and health authorities should strengthen enforcement of applicable wastewater discharge standards, require appropriate treatment of hospital effluents, and establish routine monitoring of hospital discharges and receiving waters. Monitoring should cover both wet and dry seasons and include adequately replicated upstream, discharge-point

and downstream samples. Future studies should report the statistical tests, independent sampling units and replication structure explicitly, assess uncertainty in pollution indices, and combine environmental measurements with targeted exposure assessment. These measures would strengthen the evidence base for environmental health governance, water security and resilient freshwater management in the Niger Delta.

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