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Physicochemical Analysis of Duu River, Monrovia, Liberia

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ABSTRACT

The Duu River is heavily polluted through varied human activity along its course. Despite the potential health hazards that the pollution of water bodies has on aquatic lives and persons who use the water bodies, river pollution persists. Samples from four points Slipway Community, Rock Spring Valley Community, Jallah Town 1 and Jallah Town 2 communities were subjected to both physical and chemical tests. The study identified uncontrollable dumping of wastes, defecation and institutional failures as root causes of pollution of the Duu River. The main anthropogenic causes were identified as indiscriminate dumping of refuse, channelling of raw sewage, defecation, discharge of untreated effluents from clinics and households waste into the Duu River. Physical tests showed that the Duu River was polluted since its turbidity exceeded Liberia Water Quality Standard (LWQS) class II (≤5 mg/l) for surface water. This indicated that Duu River is polluted with chromium wastes or chromium materials which was disposed and has leased into the river. The defecation and dumping of wastes into the river are on the increase among other human activities. On this note, building of toilet houses, providing of garbage cans, sanitizing citizens on how their activities can harm life in the river including themselves, timely collection of wastes and proper enforcement of laws were recommended.

Key words: Physicochemical, Duu River, Jallah Town

INTRODUCTION

Water supplies have been seriously threatened by human activity in recent years. Water quality for household use is impacted by pollution from a variety of sources, including home wastewater from industry, cities, and agriculture. Sanitary sewage discharged into Water bodies has a negative impact on humans, plants, and fauna (Martins, 2020). Water is essential to life. The biosphere that exists on the earth's outer layer would not be possible without it. Water covers more than 70% of the planet's surface, with 97% of it being in the sea, which is unfit for human use due to its high salt content (Yeleliere, Cobbina, & Duwiejuah, 2018). The understanding that water offers values for life and is a crucial factor for conservation worldwide has led to an increased need for study and optimum management techniques (David, & Kabo-bah, 2015). A river's chemical condition is initially impacted by pollution, which then methodically destroys the community and upsets the fragile food chain. Rivers' many uses are severely hampered by pollution, and even polluters like industry suffer as a result of rising river pollution (Joshi, Kumar, & Agrawal, 2009). Due to years of uncontrolled artisanal mining, inadequate waste management, and fast urbanization, Liberia's environmental degradation has reached critical levels, seriously impairing the country's water and soil resources (Tengbeh, 2026).

Freshwater is an important and limited resource that is readily contaminated. Freshwater quality is contaminated to the point where it can be deemed "polluted" (Walker, Baumgartner, Gerba, & Fitzsimmons, 2019). Weathering of rocks, evapotranspiration, wind-induced depositions, soil leaching, runoff from hydrological factors, and biological processes in the aquatic environment are some of the natural processes that lead to changes in the pH and alkalinity of the water, as well as phosphorus loading, an increase in fluoride content, and high concentrations of sulfates. As a result, water is becoming more scarce as the world's population grows (Khatri, & Tyagi, 2015).

Liberia is situated in West Africa, between latitudes 4 and 8 degrees, Liberia has an area of around 111,370 km2. Across the nation, daytime highs of 27 to 32°C and nighttime lows of 21 to 24°C are typical. January through March has the highest recorded temperatures, while August and September see the lowest. Cloud cover is a major factor in lower temperatures (Golder Associates, 2012).

Geographically, the nation is split into four regions: the northern highlands, the plateau and tablelands, the rolling hills, and the coastal lowlands (United Nations Environmental Programme (UNEP), 2004).

Because of Liberia's climate and topography, surface water provides a plentiful source of water. 15,050 km2 are submerged under water on 111,370 km2. Most of the major drainage basins flow from northeast to southwest perpendicular to the coast, eventually emptying into the Atlantic Ocean (UNEP, 2004).

The West African Monsoon (WAM) has a significant impact on precipitation in the northern parts of Liberia. WAM, or warm air from the Atlantic Ocean blowing over the continent, produces heavy precipitation throughout the wet season. May through October is considered the wet season, when over 1000 mm of rain fall on various coastal regions of Liberia each month.

The winds usually reverse during the winter, or dry season (December to March), bringing the drier Harmattan winds from the Sahara Desert to Liberia.

Because it is located closer to the equator and has a more tropical climate, southern Liberia experiences a more consistent amount of precipitation (Van Straaten, 2002). The entire yearly renewable freshwater supply in Liberia is thought to be around 300 km3 (Macdonald et al., 2012).

Since surface water is one of Liberia's many resources, pollution poses a major threat to both human existence and aquatic life. Infectious infections that arise from poor sanitation are the most dangerous consequences of water contamination. When a disease-causing microbe enters a body of water and infects aquatic life, illnesses result. These comprise intestinal parasites, typhoid, and the majority of viral, bacterial, and parasitic enteric illnesses. Amoebiasis, giardiasis, ascariasis, and hookworm are some of the most dangerous parasitic infections (Chea, S.K.P, 2018).

Since water is essential for life, every effort should be made to minimize pollution in the Duu River for the sake of both the country's aquatic ecosystem and its overall health.

One of the water resources in the counties of Margibi and Montserrado (Monrovia) is the Duu River. An assessment of the Duu River in Monrovia showed that residents living along its banks routinely disposed of trash, sewage (household and clinic), and excreted waste into the river. They also used the river for fishing and cleaning.

At the time of the inspection survey, residents along the banks in WestPoint, Waterside, Slipway, Bishop Brooks, Rock Spring, Jallah Town, Saye Town, Matadi, and Double Bridge expressed concern that the Duu River was too severely polluted to be used for residential purposes. According to observations, some people also build garages next to the river, which could endanger aquatic life. Despite the EPA's regulations governing the management of Monrovia's water resources, pollution still occurs, raising concerns about the massive pollution on the Duu River and its potential consequences on aquatic life as well as the health of those who live downstream.

According to studies done in the towns that border the Duu River, people fish and dispose of their waste in the river instead of using it for residential reasons. The test results for turbidity and phosphate indicate that inappropriate waste disposal by residents of the neighborhood poses a substantial threat to aquatic life and is causing a significant competition for oxygen among plants, animals, and algal blooms.

The study's conclusions serve as a baseline for future researchers who wish to look into animal death causes and the ways in which the national government might control the discharge of garbage into rivers.

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LITERATURE REVIEW

The addition of any material (solid, liquid, or gas) or energy (heat, sound, or radioactivity) to the environment at a rate that is greater than its capacity to be distributed, diluted, decompose, recycled, or stored in a harmless form is known as pollution, and also known as environmental pollution (Nathanson, 2023). Inappropriate garbage disposal is another factor contributing to the "pollution" of the environment.

Pathogens (mainly from human and animal waste), organic matter (including plant nutrients from agricultural run-off, such as nitrogen or phosphorus), chemical pollution, and salinity (from irrigation, household wastewater, and mine runoff into rivers) are some of the pollutants that can affect freshwater ecosystems (Zigmond et al., 2019). Pharmaceuticals and personal care products (PPCPs) are a broad category of substances that comprise consumer non-medicinal chemicals found in soaps, sun screens, scents, and human and veterinary medications. PPCPs represent developing human health and environmental issues since many are made to be biologically low-dose active that targets particular biochemical pathways that are frequently preserved between species (Hawkinsa, Fosterb, & Glaberman, 2023).

Anthropogenic activities have resulted in a significant discharge of agricultural pollutants, domestic and industrial wastewater and other pollutants into natural water bodies, in addition to natural processes like rock weathering, hydrological runoff, and leaching from the soil. These activities have also significantly contributed to the decline in biodiversity and poor water quality of receiving aquatic environments (Mobasher, Bayrami, Asadi- Sharif, & Pouran, 2023). The extent and effects of plastic pollution and emerging pollutants like medicines in our waters are mainly unknown, but they are also putting our world's waterways at risk. Particularly susceptible to pollution is water. Water is more capable of dissolving chemicals than any other liquid on Earth, earning it the moniker "universal solvent" (DEENA ROBINSON, 2022 & nrdc, 2023).

Water pollution results from the easy dissolution and mixing of toxic materials from factories, municipalities, and farms (DEENA ROBINSON, 2022 & nrdc, 2023). Chapman (1996) defined pollution of the aquatic environment as "the introduction of substances or energy by man, directly or indirectly, that results in such deleterious effects as harm to human health, hazards to aquatic resources, obstruction of aquatic activities, including fishing, impairment of water quality with respect to its use in agricultural, industrial, and often economic activities, and reduction of amenities."

The general state of the aquatic environment is referred to as water quality (Chapman, 1996). There are numerous methods for characterizing the aquatic environment's quality. It can be accomplished by semi-quantitative and qualitative descriptions such as biotic indices, visual aspects, species inventories, odour, etc., or by quantitative measurements such as physico-chemical determinations (in the water, particulate matter, or biological tissues) and biochemical/biological tests (BOD/COD measurement, toxicity tests). These variables are measured both in the field and in the lab, yielding a variety of data types that may be analyzed using different methods (Chapman, 1996).

The three main causes of pollution in river water are transboundary, non-point, and point sources. Point source pollution is the term used to describe contamination that comes from a single source. Septic system leaks, chemical and oil spills, unlawful dumping, and wastewater (also known as effluent) released either legally or illegally by a company, oil refinery, or wastewater treatment plant are a few examples (Denchak, 2018). Diffuse forms of contamination are considered nonpoint sources of pollution. These could include debris thrown into streams from the land or runoff from storm or agricultural irrigation. The main source of water pollution in Liberia's waters is nonpoint source pollution, which is challenging to control because there isn't just one source of contamination (Denchak, 2018).

Urban lawns and agricultural fields contribute significantly to the nitrogen (N) and phosphorus (P) pollution in agricultural and urban watersheds (Zhu et al., 2008; Hayakawa et al., 2006). Vega et al. (1998) note that because surface runoff is seasonal and climate-related, it can be regarded as a diffuse source. Transboundary: It should go without saying that a line on a map cannot control water contamination (Denchak, 2018).

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When tainted water seeps into the waters of another nation, it causes transboundary pollution. Disasters such as oil spills or the gradual seepage of industrial, agricultural, or municipal discharges can lead to contamination (Denchak, 2018).

One of the main causes of river contamination is anthropogenic activity (UNEP, 2008). The primary causes of water contamination have been determined to be anthropogenic factors, including agricultural development, population increase, urbanization, industrialization, and shortcomings in market policy (UNEP, 2006).

In addition to being the largest user of freshwater resources worldwide—farming and animal production account for over 70% of the planet's surface water supplies—the agricultural industry also seriously contaminates water supplies (Denchak, 2018).

Agriculture is regarded as the activity that demands water resources the most globally due to its high demand and role in groundwater and surface water pollution. Overuse of agrochemicals, poor handling of animal waste and postharvest issues, and traditional irrigation techniques are among the factors contributing to agricultural pollution (Rey Romero, Domínguez, & • Oviedo Ocaña, 2020).

Rivers have been identified as both possible short- and long-term plastic sinks as well as the primary conduits for the movement of land-based plastic pollution into the marine environment. Because of the efficient retention provided by riverbanks, vegetation, and sediment in the many river compartments, rivers have gained attention in more recent times as plastic reservoirs (Pinto, 2024). Plastics accumulate in terrestrial, aquatic, and marine ecosystems—the latter being thought to be the final recipient—due to their slow rate of breakdown. This covers plastic that comes in a variety of sizes, from large plastic debris to tiny micro- and nano-plastics (Chakraborty, 2022). The main causes of plastic pollution are related to human activities carried out on land. Runoff or aerial dispersion from soils treated with sewage sludge (often used as soil fertilizer) or agricultural plastics, public littering, inadequate industrial disposal of end-of-life products, improper municipal waste management (e.g., open dumping grounds and ineffective wastewater treatment plants), and losses during product wear are examples of such undertakings(Chakraborty, 2022).

METHODOLOGY

Study Area

Four sampling points were chosen based on surrounding human activities on the Duu River. Sample point 1, Slipway community which is downstream, sample was collected under the Gabriel Tucker Bridge that connects both Bushrod Island and Providence Island to crown and Coleman Hills. There are no agriculture and industrial activities along this waters' edge, under this bridge, washing of clothes, washing of motorbikes and tricycles and rain waters from up Coleman Hills also dumped under this bridge. Just upper this sample point, sewages from community bathrooms, clinic and toilet houses (with no commodes and septic tanks) including all form of wastes are disposed into this river. Sample point 2, Rock Spring Valley, there is no agriculture and industrial activities along this waters' edge. At this sample point, sewages from community bathrooms, clinic and toilet houses (with no commodes and septic tanks) including all forms of wastes are disposed into this river. Sample point 3, Jallah Town 1, there is no agriculture and industrial activities along this waters' edge. Sewages from community bathrooms and toilet houses (with no commodes and septic tanks) including all forms of wastes are disposed into this river. Sample point 4, Jallah Town 2 which is upstream, there are no agriculture and industrial activities along this waters' edge. Sewages from community bathrooms and toilet houses (with no commodes and septic tanks) including all forms of wastes are disposed into this river.

Sample collection

In 2025, samples were collected once a month September and December. In 2026, samples were collected once a month (February). Water samples were collected with a clean plastic and BOD bottles from downstream, midstream and upstream. The bottles were labelled prior to samples" collection. Sample bottles were rinsed

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with samples before collection. Sample bottles were filled until overflowing and closed underwater to minimize aeration (Table 1).

Analysis

Water samples from Duu River were subject to both physical and chemical tests. The physical test included

temperature, turbidity, and electrical conductivity (EC). The temperature was measured on site with thermometer after sample was collected at each sampling point. The EC was analyzed with conductivity meter probe and turbidity with multimeter. The chemical tests pH was measured with pH probe, nitrate was measured using cadmium reduction method, nitrite was measured using ferrous sulphate method, ammonia was measured using salicylate method, total iron was measured using FerroVer method, phosphate was measured with photometric/colorimetric, hexavalent chromium was measured using 1,5-diphenylcarbohydrazide method, DO was measured using high dissolved oxygen (HRDO) method, BOD5 was measured with BOD meter and COD was measured using manganese III digestion method.

RESULTS

Sample location

The samples were collected in September, December 2025 and February 2026 from Duu River (Figure 1). Physical characteristics in conducting the physical test, water sampled from the

Table 4.0 Water Sampling Points

Sample Point	Location	Direction of River Flow
Sample Point 1	Slipway community	⬆
Sample Point 2	Rock Spring Valley	⬆
Sample Point 3	Jallah Town 1	⬆
Sample Point 4	Jallah Town 2	⬆

Arrow indicates direction of river flow from upstream (Sample point 4) to downstream (sample point 1).

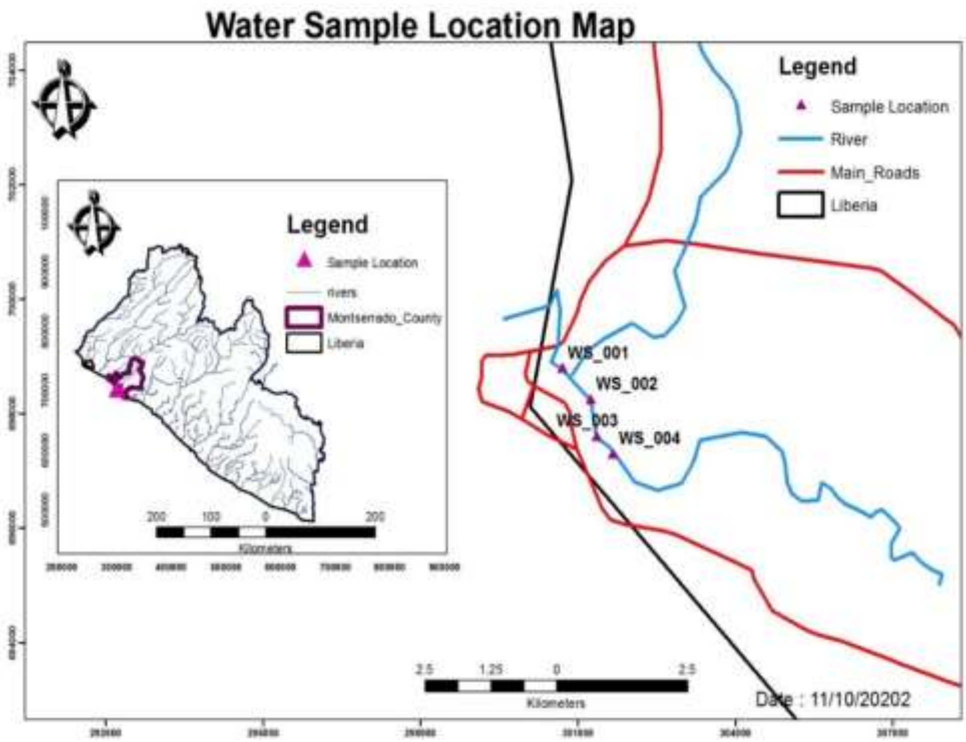

Figure 4.0 Water sample location map

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Table 4.2: Summary of the physicochemical characteristics of the Duu River across the three sampling rounds

Parameter	Unit	Min.	Max.	Mean ± SD	Median	CV (%)	Skew.	Fisher ratio	LWQS Class II
Temperature	°C	20.7	23.2	21.86 ± 0.79	21.85	3.6	0.13	0.21	—
Turbidity	NTU	4.79	13.2	8.04 ± 3.07	7.1	38.2	0.85	1.33	5
Electrical conductivity	µS/cm	165.5	1,417.00	334.57 ± 344.15	228.45	102.9	3.35	5.25	1,500.00
pH	—	6.22	8.05	7.04 ± 0.73	6.88	10.4	0.2	0.31	8.5
Nitrite	mg/L	0.012	0.185	0.077 ± 0.044	0.065	56.7	1.27	1.99	0.5
Nitrate	mg/L	7.3	38.9	20.82 ± 9.54	19.35	45.8	0.57	0.9	60
Ammonia	mg/L	0.005	0.06	0.014 ± 0.017	0.005	118.6	2.36	3.7	3
Total iron	mg/L	0.25	0.78	0.439 ± 0.168	0.425	38.2	0.85	1.34	1.5
Hexavalent chromium	mg/L	0.05	0.49	0.169 ± 0.131	0.13	77.4	1.72	2.71	0.1
Phosphate	mg/L	1.02	7.61	3.59 ± 2.03	3.18	56.6	0.61	0.95	0.02
Dissolved oxygen	mg/L	3.72	7.61	5.73 ± 1.52	6.14	26.6	-0.25	-0.39	—
Chemical oxygen demand	mg/L	5.22	15.39	8.55 ± 3.02	7.25	35.3	1.22	1.92	—
Biochemical oxygen demand	mg/L	6.12	10.26	7.42 ± 1.15	7.07	15.5	1.55	2.44	—

Note. N = 12 for every parameter (four stations × three sampling rounds). The Fisher ratio is the skewness divided by its standard error; values outside ±1.96 indicate significant departure from normality at the 5% level. Ammonia reported as not detected was substituted at half the limit of detection (0.005 mg/L). LWQS = Lagos Water Quality Standard; a dash indicates that no Class II limit is specified for the parameter.

Table 4.3: Compliance of the measured parameters with the LWQS Class II limits

Parameter	Unit	LWQS Class II	Maximum observed	Max. ÷ limit	Samples exceeding	% exceeding
Turbidity	NTU	5	13.2	2.64	10 of 12	83.33
Electrical conductivity	µS/cm	1,500.00	1,417.00	0.94	0 of 12	0
pH	—	8.5	8.05	0.95	0 of 12	0
Nitrite	mg/L	0.5	0.185	0.37	0 of 12	0
Nitrate	mg/L	60	38.9	0.65	0 of 12	0
Ammonia	mg/L	3	0.06	0.02	0 of 12	0
Total iron	mg/L	1.5	0.78	0.52	0 of 12	0
Hexavalent chromium	mg/L	0.1	0.49	4.9	7 of 12	58.33
Phosphate	mg/L	0.02	7.61	380.5	12 of 12	100

Note. Parameters for which no Class II limit is specified (temperature, dissolved oxygen, chemical oxygen demand and biochemical oxygen demand) are omitted from this table.

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Table 4.4: Variation in the physicochemical parameters of the Duu River across the three sampling rounds

Parameter	Unit	Jul-25	Dec-25	Feb-26	H	p-value	ε^2
Temperature	°C	21.77 ± 0.97^{a}	22.25 ± 0.39^{a}	21.55 ± 0.93^{a}	1.746	0.418	0
Turbidity	NTU	11.55 ± 2.46^{a}	6.22 ± 1.13^{a}	6.35 ± 1.62^{a}	6.5	0.039	0.5
Electrical conductivity	µS/cm	499.47 ± 612.09^{a}	257.17 ± 50.56^{a}	247.05 ± 51.18^{a}	0.808	0.668	0
pH	—	7.77 ± 0.35^{a}	6.68 ± 0.69^{a}	6.67 ± 0.57^{a}	5.654	0.059	0.406
Nitrite	mg/L	0.04 ± 0.02^{a}	0.10 ± 0.06^{a}	0.08 ± 0.02^{a}	5.654	0.059	0.406
Nitrate	mg/L	15.50 ± 8.16^{a}	20.45 ± 9.76^{a}	26.52 ± 9.50^{a}	2.577	0.276	0.064
Ammonia	mg/L	0.01 ± 0.00^{a}	0.01 ± 0.01^{a}	0.03 ± 0.03^{a}	1.483	0.476	0
Total iron	mg/L	0.43 ± 0.12^{a}	0.47 ± 0.22^{a}	0.42 ± 0.19^{a}	0.183	0.912	0
Hexavalent chromium	mg/L	0.09 ± 0.05^{a}	0.21 ± 0.19^{a}	0.20 ± 0.11^{a}	3.399	0.183	0.155
Phosphate	mg/L	3.08 ± 1.20^{a}	4.08 ± 3.10^{a}	3.60 ± 1.84^{a}	0.269	0.874	0
Dissolved oxygen	mg/L	3.89 ± 0.12^{a}	6.28 ± 1.09^{ab}	7.02 ± 0.36^{b}	7.731	0.021	0.637
Chemical oxygen demand	mg/L	12.08 ± 2.46^{b}	6.44 ± 0.94^{a}	7.15 ± 1.11^{ab}	7.538	0.023	0.615
Biochemical oxygen demand	mg/L	8.05 ± 1.64^{a}	7.46 ± 0.91^{a}	6.73 ± 0.44^{a}	2.423	0.298	0.047

Note. Values are mean ± standard deviation, n = 4 per sampling round. Means within a row that do not share a superscript letter differ significantly at the 5% level under Dunn's post-hoc test with Bonferroni adjustment; means sharing a letter do not differ. H is the Kruskal-Wallis statistic on 2 degrees of freedom and ε^2 the epsilon-squared effect size. Where the Kruskal-Wallis test was not significant, all three rounds are assigned the same letter. Turbidity is significant overall but no pairwise comparison survives the Bonferroni adjustment, a known consequence of the small number of observations per round.

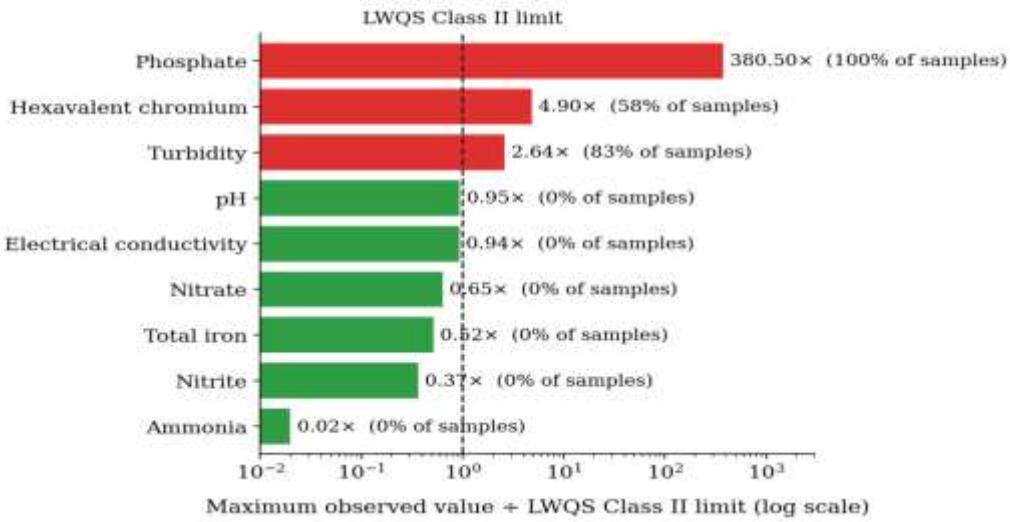

Figure 4.2: Magnitude of exceedance of the LWQS Class II limits across the measured parameters

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Note. Bars to the right of the broken line exceed the regulatory limit. The horizontal axis is logarithmic.

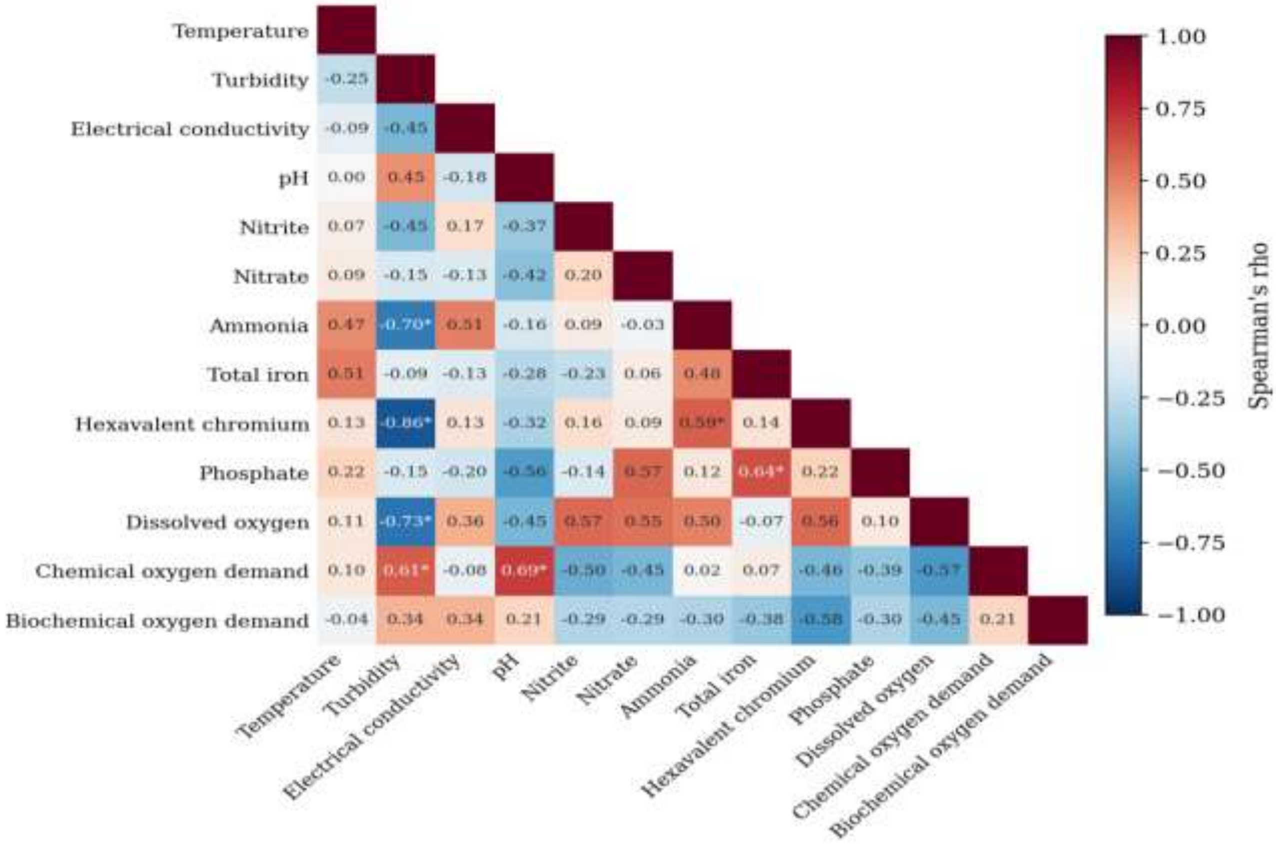

Figure 4.3: Matrix of rank correlations among the physicochemical parameters of the Duu River

Note. Values are Spearman's rank correlation coefficients. An asterisk marks an association significant at the 5% level.

Table 4.5: Water quality index of the Duu River by sampling station and sampling round

Sampling round	Station	Water quality index	Classification
Jul-25	S1	9,129.09	Unsuitable for drinking
Jul-25	S2	16,041.77	Unsuitable for drinking
Jul-25	S3	16,351.22	Unsuitable for drinking
Jul-25	S4	7,132.80	Unsuitable for drinking
Dec-25	S1	22,538.65	Unsuitable for drinking
Dec-25	S2	30,057.07	Unsuitable for drinking
Dec-25	S3	4,042.14	Unsuitable for drinking
Dec-25	S4	7,840.61	Unsuitable for drinking
Feb-26	S1	20,189.11	Unsuitable for drinking
Feb-26	S2	20,866.47	Unsuitable for drinking
Feb-26	S3	7,319.51	Unsuitable for drinking
Feb-26	S4	8,639.26	Unsuitable for drinking

Note. Classification follows the weighted arithmetic scale: 0–25 excellent, 26–50 good, 51–75 poor, 76–100 very poor, above 100 unsuitable for drinking. The index takes values of this magnitude because the phosphate

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sub-index alone ranges from 5,100 to 38,050, phosphate having been recorded at between 51 and 381 times its permissible limit.

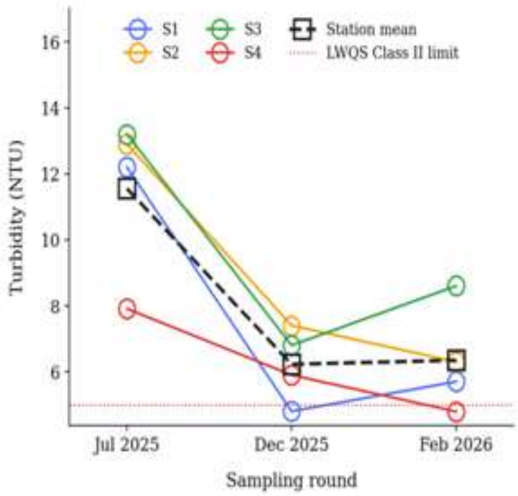

Figure 4.4: Trend in turbidity (NTU) at the four sampling stations across the three sampling rounds
Note. Each coloured line traces one sampling station; the broken black line traces the station mean. The dotted red line marks the LWQS Class II limit of 5.00 NTU.

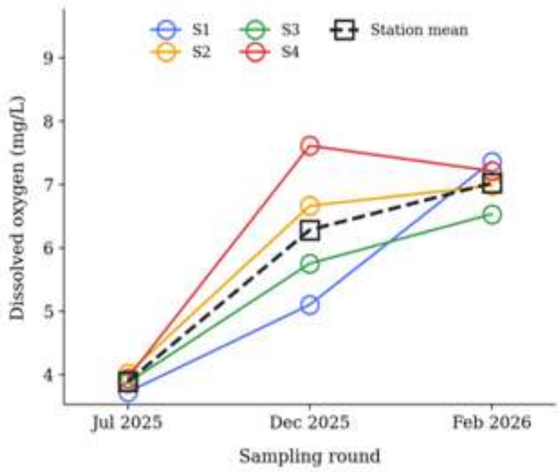

Figure 4.5: Trend in dissolved oxygen (mg/L) at the four sampling stations across the three sampling rounds
Note. Each coloured line traces one sampling station; the broken black line traces the station mean.

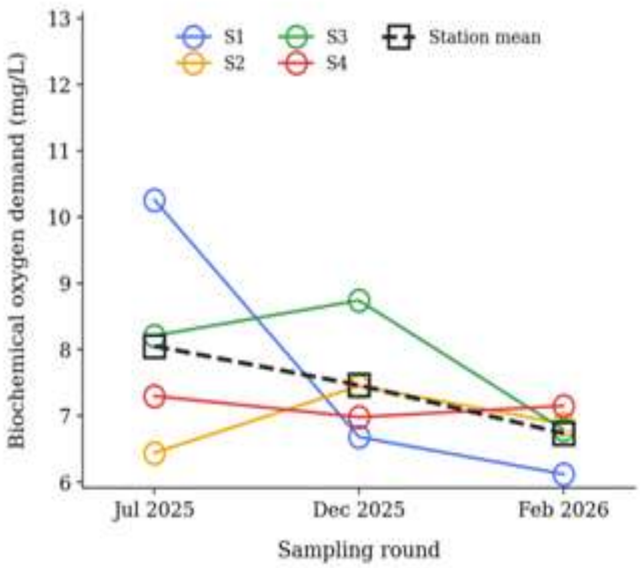

Figure 4.6: Trend in biochemical oxygen demand (mg/L) at the four sampling stations across the three sampling rounds
Note. Each coloured line traces one sampling station; the broken black line traces the station mean.

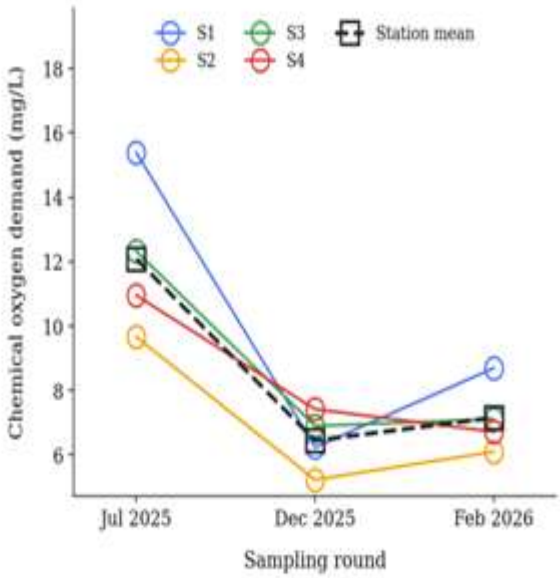

Figure 4.7: Trend in chemical oxygen demand (mg/L) at the four sampling stations across the three sampling rounds
Note. Each coloured line traces one sampling station; the broken black line traces the station mean.

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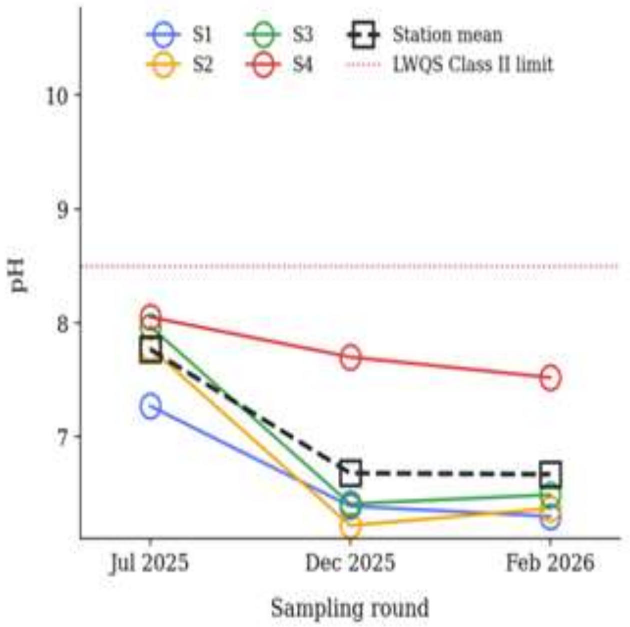

Figure 4.8: Trend in pH at the four sampling stations across the three sampling rounds
Note. Each coloured line traces one sampling station; the broken black line traces the station mean. The dotted red line marks the LWQS Class II limit of 8.50.

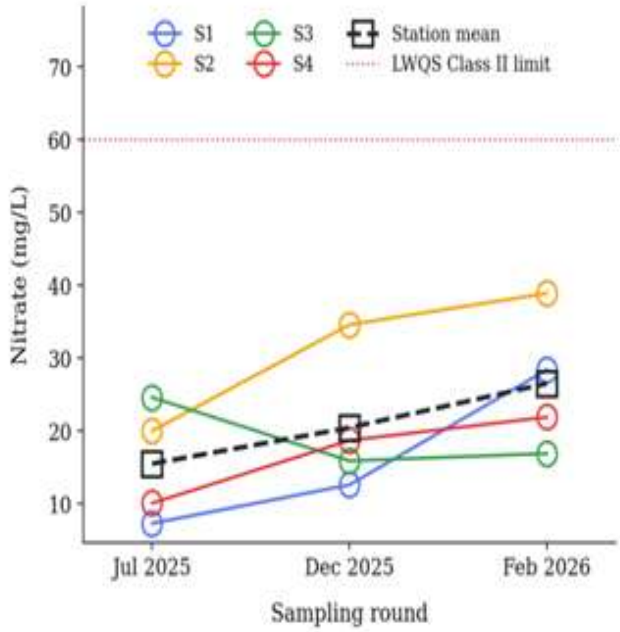

Figure 4.9: Trend in nitrate (mg/L) at the four sampling stations across the three sampling rounds
Note. Each coloured line traces one sampling station; the broken black line traces the station mean. The dotted red line marks the LWQS Class II limit of 60.00 mg/L.

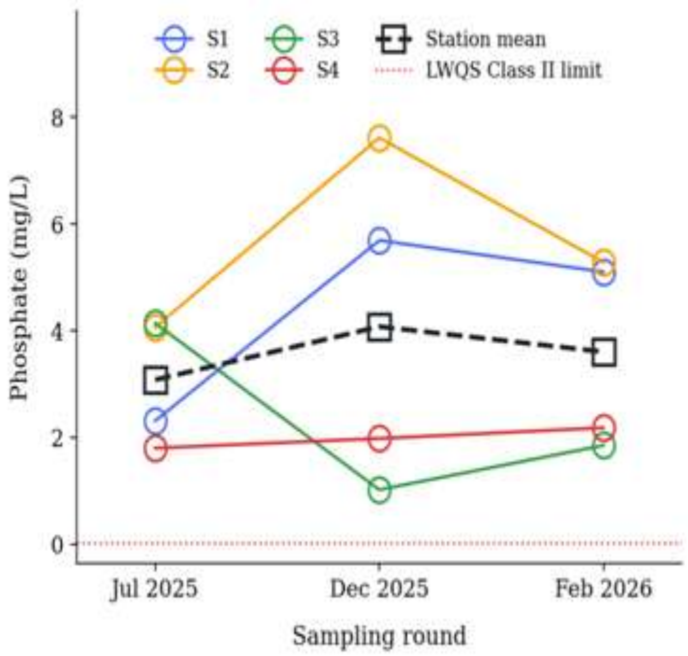

Figure 4.10: Trend in phosphate (mg/L) at the four sampling stations across the three sampling rounds
Note. Each colored line traces one sampling station; the broken black line traces the station mean. The dotted red line marks the LWQS Class II limit of 0.02 mg/L.

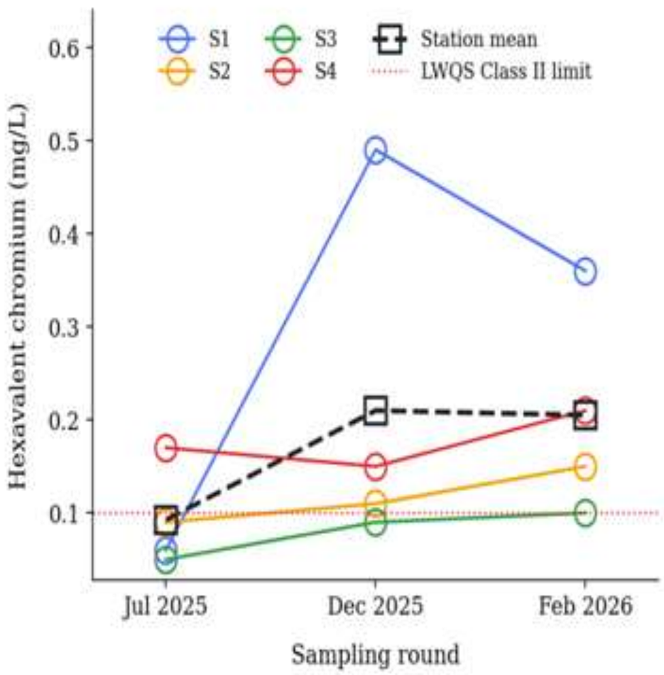

Figure 4.11: Trend in hexavalent chromium (mg/L) at the four sampling stations across the three sampling rounds
Note. Each colored line traces one sampling station; the broken black line traces the station mean. The dotted red line marks the LWQS Class II limit of 0.10 mg/L.

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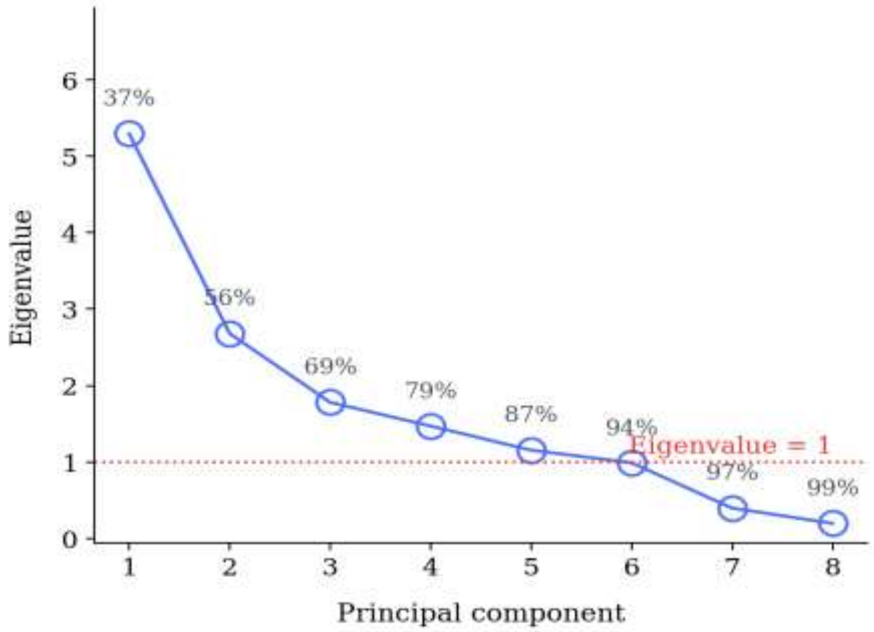

Figure 4.12: Scree plot of the principal component analysis of the physicochemical data

Note. Annotations give the cumulative percentage of variance accounted for. The dotted line marks an eigenvalue of unity.

II limit of 0.10 mg/L.

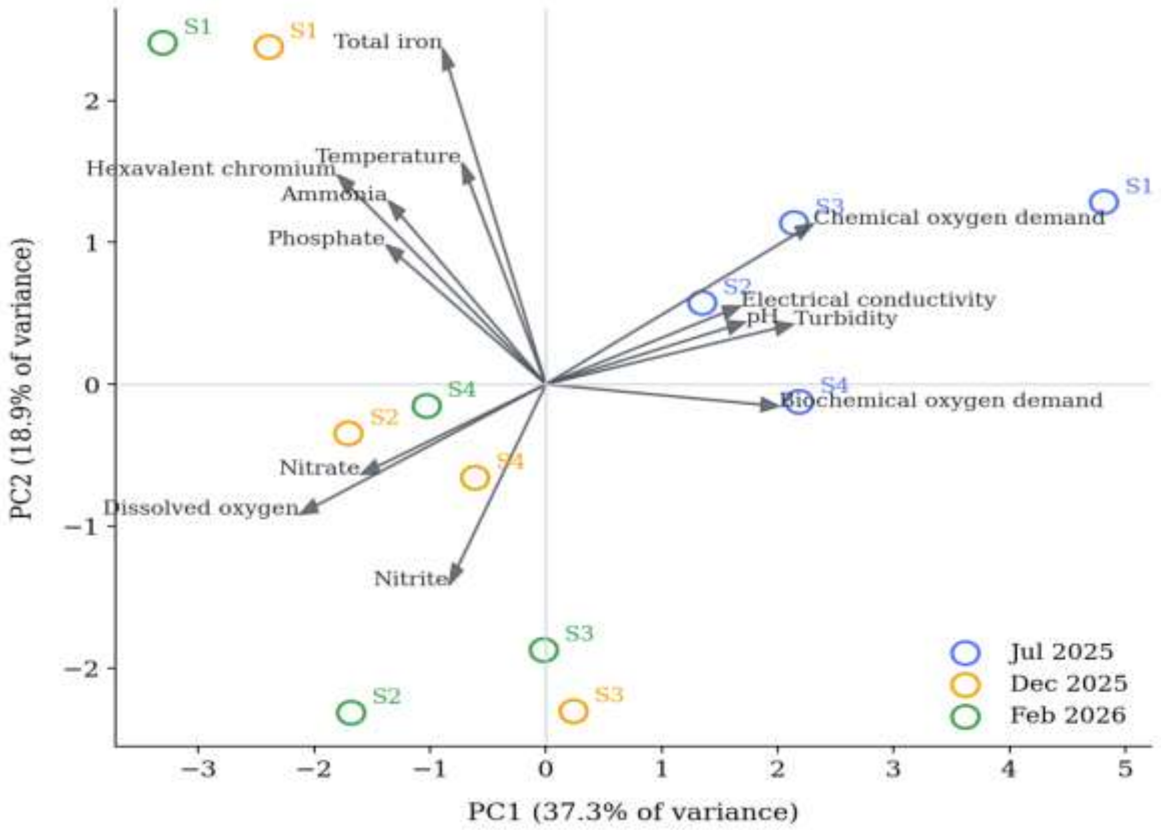

Figure 4.13: Biplot of the first two principal components of the physicochemical data

Note. Markers are sample scores, labelled by station; arrows are parameter loadings. The Kaiser-Meyer-Olkin measure was 0.345, below the 0.50 threshold of sampling adequacy, and the twelve observations are fewer than the thirteen parameters analysed; the component structure is therefore exploratory.

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DISCUSSION

The DUU River's physicochemical evaluation showed significant variation in the water quality conditions throughout the course of the three test periods and four monitoring stations. Temperature was comparatively constant, while electrical conductivity, ammonia, and hexavalent chromium displayed the most variation. Acidity and alkalinity were typically within acceptable bounds, as indicated by the overall mean pH being close to neutral. Turbidity, hexavalent chromium, and phosphate were the main issues with water quality. All 12 samples had phosphate levels above the LWQS Class II standard, with a maximum of 7.61 mg/L—roughly 380 times the allowable limit. In 7 out of 12 samples, hexavalent chromium surpassed its limit, while in 10 out of 12 samples, turbidity exceeded its limit. These results show significant suspended particles, nutritional enrichment, and possible chemical pollution of the river. The overall poor state of the river was confirmed by the Water Quality Index (WQI). With WQI levels greater than 100, all 12 samples were deemed unfit for consumption. Phosphate and hexavalent chromium combined accounted for 94.73% of the relative weighting in the index, which contributed significantly to the exceptionally high index values. While phosphate and hexavalent chromium did not significantly change over time, statistical analysis revealed significant variations across sampling times for dissolved oxygen, chemical oxygen demand, and turbidity. While PCA revealed that five components explained 87.32% of the total variance and identified Station S1 as a particularly unique sample location, correlation analysis revealed sets of parameters that varied together.

Overall, the results show that the DUU River is experiencing significant water-quality stress, especially from turbidity, phosphate, and hexavalent chromium. The findings corroborate the necessity of ongoing surveillance, the identification of pollution sources, the management of pollutant inputs, and actions to shield the river from more deterioration and possible threats to the health of people and the environment.

CONCLUSION

Water plays a crucial role in aquatic life and sustenance of man. The Duu River which flowed through double bridge at Stephen Tolbert Estate, Matadi, Saye town, Jallah town, Rock spring community, Bishop Brooks Community, Slipway and joint the sea at waterside is polluted mostly through human activities which have serious implications on aquatic lives and human who lived along the banks and downstream. The water samples of Duu River were subjected to both physical and chemical analysis. The analysis showed that the water samples from Duu River did not meet LQWS Class II surface water standards. Phosphate was one of the parameters that did not meet LQWS Class II surface water standards and this indicated that the river was mainly polluted through human sources. The study identified the main causes of pollution of the Duu River to be indiscriminate dumping of refuse into the river, channeling of raw sewage into the river, defecation in the river, discharge of untreated effluents from clinics and households into the river. The main causes are induced by rapid population growth, institutional failure and natural factors.

The rapid growth of population along the banks of Duu River, has triggered an increase in wastes generation and disposal, this impose the demand for sanitation services as most citizens are not able to provide garbage cans and build toilet houses.

Institutional failures are among the causes of pollution. There are institutions that have been charged with the responsibility of managing wastes and protecting water resources in Liberia. These institutions include the EPA, LWSC and Monrovia City Cooperation, which in no time have provided trainings on sanitation, collected wastes and provided garbage cans. Due to their failures coupled with rapid population growth, it had imposed serious threats to aquatic lives and people living downstream of Duu River.

Natural factor is one of the causes of pollution. When it rains, surface runoff carries sand, silt, particulate matter and organic matter into the Duu River.

The interplay of rapid population growth, institutional failure and natural factor creates an enabling environment for residents of the Duu River basin to engage in human activities that lead to the pollution of the Duu River. These activities include the indiscriminate dumping of refuse into the river, channeling of raw

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sewage, defecation in the river and discharge of untreated effluents form clinics and households into the Duu River. For the regularly defecation into the river, it had led to increase in the BOD and COD levels with a reduction in the DO content of the river.

The pollution of the Duu River has the effect of reducing the quality of the water. Reduction in the quality of the river water translates into a loss of facility such as drinking, cooking, washing and bathing. In addition, pollution of the Duu River has contributed to the incidence of water related diseases. Human who will come into contact with the river water will experience water-related diseases as malaria, skin infection, eye infection and diarrhea.

Conflict of Interests

The authors have not declared any conflict of interests.

Declarations

Competing interests: The authors state that they have no conflicts of interest.

Ethics approval and consent to participate: are irrelevant.

Consent for publishing: is also irrelevant.

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