Anthropogenic Influences on Water Quality in Molo River, Lake Baringo Basin

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Original Research Article

ABSTRACT

This study investigated the influence of human activities on water quality parameters in the Molo River, one of the major inflow rivers of Lake Baringo. Monthly measurements of physical and chemical parameters were conducted for six months (February-July 2023) at sampling stations established along the river to represent areas with different human activities. Analysis of variance was used to test for significant differences in water quality parameters among sampling stations. The results revealed significant downstream increases ($p < 0.05$) in water temperature, electrical conductivity, pH, total dissolved solids (TDS), and nutrients (total nitrogen, ammonium nitrogen, total phosphorus, and soluble reactive phosphorus) compared to upstream stations. Conversely, dissolved oxygen (DO) levels exhibited a downstream decrease. Sachangwan emerged as the most polluted sampling station with elevated levels of conductivity, total dissolved solids, total phosphorus, soluble reactive phosphorus, and ammonium nitrogen. In contrast, Sirindet recorded low pollutant levels. These observations are likely attributable to deforestation, agricultural practices, and point source pollution, which were more prevalent in downstream stations compared

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to the less disturbed upstream stations. The findings highlight the significant influence of human activities on the water quality along the Molo River. Understanding these interactions is crucial for developing effective pollution control strategies to protect the Molo River and Lake Baringo.

1. INTRODUCTION

Rivers play multifaceted roles, providing essential services for both humans and the environment and supplying water for domestic needs, irrigation, recreation and industries [1]. Furthermore, rivers are biodiversity hotspots, teeming with a remarkable variety of plant and animal life. Historically, human settlements have flourished near rivers, highlighting their profound influence on societal development [2]. However, urbanization, agriculture and deforestation are significantly impacting the quality of water in riverine ecosystems which can have a ripple effect on the distribution and diversity of aquatic organisms [3,4]. Land use plays a major role in water quality degradation through nonpoint sources which are major contributors of contaminants to both surface and groundwater [5]. The situation is exacerbated in developing countries, where raw sewage or partially treated wastewater, and industrial wastes are discharged directly into rivers, contributing significantly to water quality degradation [4].

Molo River, one of the major feeders of Lake Baringo, once provided clean water and abundant fish for local communities. However, it now exemplifies the threats faced by freshwater ecosystems. The course of the river intersects a landscape shaped by various human activities. Deforestation in the upper reaches (Kuresoi and Olembusi) has significantly reduced forest cover, leading to soil erosion, decreased rainfall, and low water levels in the river [6,7]. Agricultural practices, excessive water extraction for irrigation, and land degradation further compound these challenges [6]. Predictions indicate that climate change will exacerbate these effects, placing additional stress on Lake Baringo`s water levels [8-11]. The lake`s health is inextricably linked to the health of its feeder rivers, which include Molo and Perkerra. In addition, the lake's water level fluctuates significantly due to climatic conditions and seasonal rainfall patterns [7,12,13]. These fluctuations affect the physical and chemical properties of the lake, with low water periods resulting in increased turbidity caused by wind turbulence disturbing bottom sediments.

Increased sedimentation due to overgrazing and agricultural activities in the lake`s catchment is degrading the quality of water in the lake [14,15]. However, the influence of human activities on water quality along Lake Baringo`s feeder rivers remain understudied despite the undeniable human pressure,

Understanding the water quality of riverine ecosystems provides invaluable insight into their current health and reflects the current ecosystem's structure, function, and potential future trends in an ever-changing environment [16]. This knowledge is instrumental in formulating strategies to prevent pollution, manage land use effectively, and ultimately, protect the ecological balance of aquatic systems. The goal of this study was to examine the effects of human activities on water quality in the Molo River, one of the major rivers that feed Lake Baringo. Findings from this study can inform the development of effective pollution control measures and management strategies for the entire basin. Additionally, the findings can used to predict pollution risks, develop better water quality management plans, and make informed urban planning decisions, resulting in a healthier future for both the lake and communities that depend on it.

2. MATERIALS AND METHODS

2.1 Study Area Description

The study was conducted in the Molo River (Fig. 1), one of the major feeder rivers of Lake Baringo, the other being Perkerra River. The river is located between $0^o11.99232'$ S to $0^o15.530'$ S latitude and $35^o44.044'$ E to $35^o51.846'$ E longitude. It originates from the Mau complex at elevations ranging from 1908 and 2437 m above sea level (Chebet et al., 2020). The area experiences two peak rainy seasons in April to May and November to December with a dry season from November to February. The average temperature is 23°C during the wet season with a maximum of 27°C during the dry season and a minimum of 12°C in the coolest season. February is the hottest month, and June is the coolest. As the river flows

through Molo town, it becomes increasingly impacted by human activities including, farmlands, domestic discharges, and waste effluent from flower farms. Car washing activities and livestock watering points also contribute to pollution in the river. As the river flows downstream towards Salgaa town, pollution intensifies due to chemicals from flower farms and oil spills from heavy-duty vehicles transporting petroleum products across East Africa pose a significant pollution risk [17].

2.2 Sampling and Sample Analysis

To determine the influence of human activities on water quality, sampling stations were selected along the river with varying levels of human activities. Sirindet (SNT) served as a reference station, with minimal anthropogenic influence, providing a baseline for comparison. Kibunja Molo Bridge (KMB), Molo Quarry (MQY), and Sirwe (SRE) stations were in agricultural areas, capturing potential contamination from agricultural runoff. Salgaa Bridge (SBE) station targeted the effects of flower farm waste pollutants and oil spills from heavy vehicles while Ravine Nakuru Bridge (RNB), Mogotio Upper (MBR), Lororo Bridge (LBE), and Sachangwan (SCN) stations were located downstream to capture the cumulative effects of agricultural runoff, untreated domestic sewage, and industrial effluents on the river's health. Selected physical and chemical parameters including temperature (°C), dissolved oxygen, conductivity, pH and Total Dissolved Solids (TDS) were measured *in-situ* using a portable water quality meter (HACH HQ40d, Loveland, Colorado, USA). Water samples were collected directly from the river using pre-treated 1-liter polyethylene bottles for analysis of dissolved nutrients. The water samples were labeled, stored in cooler boxes and then transported to the laboratory for analysis of dissolved nutrients including Total Nitrogen (TN), Total Phosphorus (TP), Ammonium-nitrogen (NH_4-N), and Soluble Reactive Phosphorus (SRP) using standard analytical procedures [18].
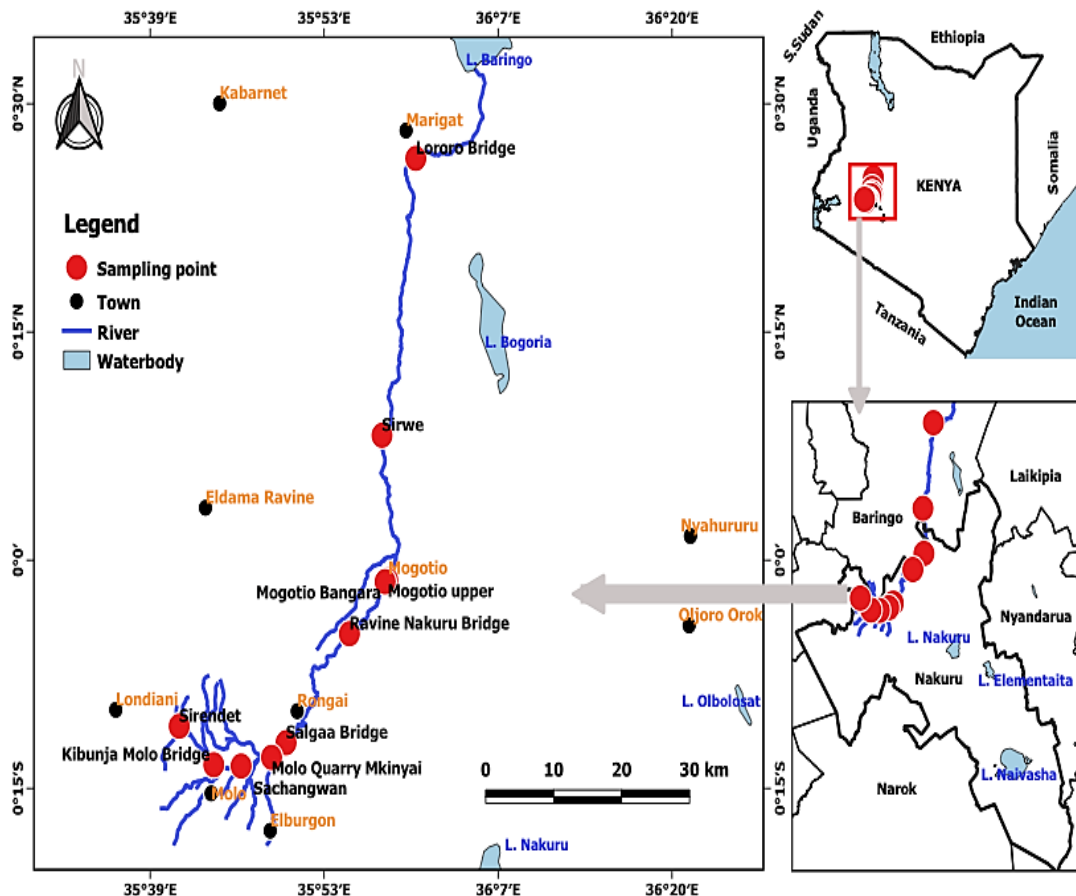

Fig. 1. Sampling stations along River Molo, Lake Baringo Basin

2.3 Data Analysis

Water quality variables were presented as (means ± standard deviation) of three replicates. Before analysis, the data was normalized using the Kolmogrov-Smirnov test. One-way analysis of variance was used to determine any variations in water quality parameters in different sampling stations, followed by a post hoc Tukey's honest significant difference test to determine specific significant differences. Differences between the means were considered significant at α = 0.05. Data was analyzed using IBM SPSS for Windows (Version 21.0, SPSS Inc. Chicago, Illinois, USA).

3. RESULTS

Results revealed significant variations in water quality parameters across sampling stations. Upstream stations SNT and KMB exhibited significantly cooler water temperatures (19.7-20.0°C) compared to downstream stations (MBR, LBE, SRE, SCN) which were warmer, averaging around 25-28°C (Table 1). Similar patterns were observed in pH and TDS levels where upstream stations (SNT and KMB) had lower pH levels (neutral pH) whereas downstream stations (LBE, SRE and SCN) were more alkaline with pH levels ranging from 8.4 to 8. 8. SNT, KMB, and MQY had significantly low TDS concentrations, ranging from 44.8 to 66.7 mg/L and downstream stations (LBE, SRE, and SCN) showed significantly higher TDS levels, ranging from 101.9 to 116.3 mg/L. Levels of DO were significantly lower at the downstream stations SRE (5.4 ± 0.1 mg/L) and SCN (5.1 ± 0.1 mg/L) compared to the upstream stations (SNT, MBR, SBE, and LBE) which exhibited higher DO levels, ranging from

6.3 to 6.5 mg/L. SNT recorded low EC (93.5 ± 5.1 µS/cm) which was significantly lower than the downstream station SCN, which exhibited a three-fold increase in EC (233.7 µS/cm). Stations MQY, SBE, and RNB recorded similar levels of EC.
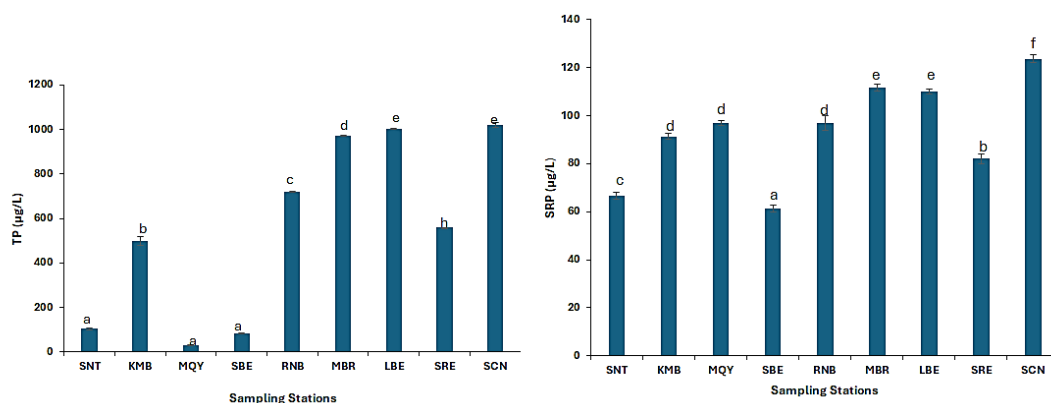
Total phosphorus (TP) concentration varied significantly across sampling stations (Fig. 2). Stations SNT (103 ± 5.5 µg/L), MQY (32.0 ± 2.5 µg/L), and SBE (84.0 ± 2.5 µg/L) had significantly lower TP levels than all other stations ($p < 0.05$). Other stations had significantly higher TP concentrations, with mean values ranging from 500 ± 12.5 to 1003.5 ± 5.4 µg/L. SCN had the highest TP concentration (1021 ± 10.5 µg/L), which was 32 times higher than the level in MQY. Additionally, all stations showed significantly high levels of soluble reactive phosphorus (SRP) ($p < 0.05$). SCN station had the highest SRP concentration (124.1 ± 5.4 µg/L), almost double the level recorded in SBE (61.2 ± 1.5 µg/L).

Significant spatial variation in TN was observed across sampling locations along the river (Fig. 3). Upstream stations (SNT, SBE, and MBR) showed significantly higher TN concentrations than downstream stations (LBE, RNB, and SCN) ($p < 0.05$). The TN levels in upstream stations varied from 802.6 ± 10.2 µg/L (SNT) to a maximum of 1280.8 ± 5.8 µg/L (MBR). Downstream stations had significantly lower values, ranging from 59.5 ± 1.8 µg/L (LBE) to 228.7 ± 2.5 µg/L (RNB). Notably, the highest TN concentration in MBR was 22 times higher than the lowest concentration in LBE, indicating a significant decrease in TN as the river flows downstream.

Table 1. Physico-chemical parameters along Molo River during the study period

Sampling Stations	pH	Temp (°C)	DO (mg/L)	EC (µS/cm)	TDS (mg/L)
			Parameters		
SNT	7.0± 0.2[a]	19.7 ±0.6[a]	6.5 ±0.1[c]	93.5 ± 5.1[a]	44.8 ± 3.5[a]
KMB	7.0 ± 0.2[a]	20.0 ± 1.1[a]	5.5 ±0.2[ab]	122.7 ± 8.1[b]	50.6 ± 4.2[b]
MQY	8.1±0.2[b]	24.0 ± 1.2[bc]	5.8 ± 0.3[bc]	152.3 ± 6.5[c]	66.7 ± 3.3[c]
SBE	7.5 ±0.5[a]	20.0 ± 2.1[a]	6.3 ± 0.4[c]	151.3 ± 2.5[c]	72.5 ±5.2[d]
RNB	7.5 ± 0.1[a]	22.0 ± 1.0[ab]	5.6 ± 0.2[ab]	152.0 ± 3.2[c]	81.8 ± 6.6[e]
MBR	7.3 ±0.3[a]	25.0 ± 1.0[bc]	6.4 ± 0.2[c]	192.0 ± 5.2[d]	95.7 ± 5.6[f]
LBE	8.4 ±0.1[bc]	28.3 ±0.6[d]	6.3 ± 0.2[c]	201.3 ± 4.3[e]	101.9 ± 7.5[g]
SRE	8.4 ±0.1[bc]	27.3 ± 1.5[d]	5.4 ± 0.1[ab]	210.0 ± 5.1[f]	108.4 ± 6.4[h]
SCN	8.8 ±0.2[c]	26.0 ± 1.1[cd]	5.1 ±0.1[a]	233.7 ± 4.0[g]	116.3 ± 5.5[i]

Mean values (± standard deviation) within a column with different superscripts are significantly different (a > b > c, $p < 0.05$). Temp: temperature, DO: dissolved oxygen, EC: Electrical conductivity, TDS: total dissolved solids

Fig. 2. Total phosphorus (TP) and Soluble reactive phosphorus (SRP) concentration along River Molo, Lake Baringo Basin during the study period
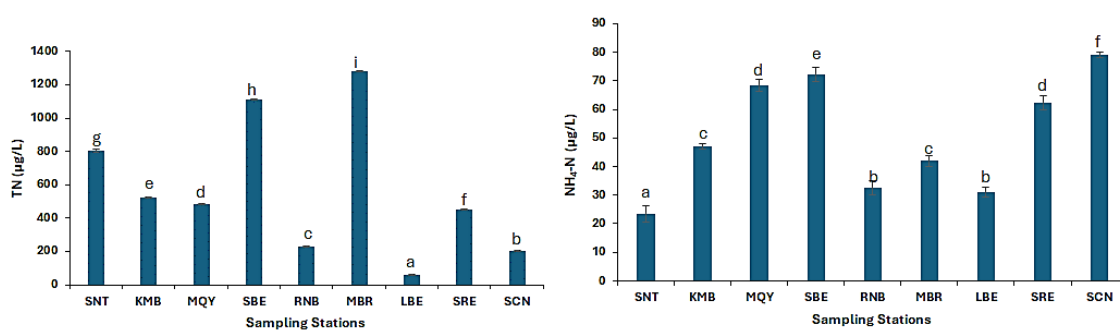
Fig. 3. Total nitrogen (TN) and ammonia nitrogen (NH₄-N) concentration along River Molo, Lake Baringo basin during the study period

4. DISCUSSION

The observed increase in water temperature, electrical conductivity, pH, and TDS in downstream stations can be attributed to a combination of human activities and natural processes. Reduced canopy cover caused by deforestation in the downstream stations allows more light to reach the water surface leading to increased temperature compared to upstream stations with increased canopy cover [19,20]. Studies by [21,19,22] reported similar results, attributing high levels of total dissolved solids (TDS), temperature, pH, and electrical conductivity (EC) in downstream stations to human activities such as farming along the riparian zone, livestock grazing and watering points, and erosion of the riverbanks. Removal of riparian vegetation along rivers significantly impacts riverbed composition, flow regimes, and water quality parameters [4,20,22,23,24]. The high electrical conductivity downstream was likely caused by dissolved and suspended materials originating from human and animal activities runoff into the river [4,23]. Additionally, agricultural practices introduce pollutants like fertilizers and pesticides, increasing electrical conductivity and total dissolved solids. The release of hot water from cooling plants along the Molo River further elevated downstream temperatures. Moreover, headwater streams naturally exhibit cooler temperatures compared to downstream stations due to their higher elevation. It is well established that as water flows downstream, it accumulates the impacts of various activities, including erosion and sedimentation from agriculture, ultimately leading to a decline in overall water quality [4,20]. Lake Baringo basin generally experiences hot weather however, this study might have not captured the full extent of temperature variation since samples were collected early in the morning and late afternoon when the weather was somehow humid.

Dissolved oxygen is a vital requirement for aquatic life, including fish. However, downstream stations in this study exhibited low DO levels due

to increased organic matter decomposition, sediments, and siltation [4,19,23]. High organic matter can significantly reduce dissolved oxygen (DO) in aquatic ecosystems during decomposition. Microorganisms break down this organic matter for energy. However, this breakdown process consumes dissolved oxygen from the water [25]. Human activities including the discharge of organic-rich effluents into the rivers, excessive use of fertilizers, stormwater runoff from farmlands carrying organic materials like animal waste and decomposing plant debris likely contributed to high organic matter levels along the river. Furthermore, the high temperatures observed downstream could have contributed to the reduction in DO. Warmer water contains less dissolved oxygen, which is detrimental to aquatic life [26]. It is important to note, however, that the recorded DO levels, were not critically low enough to compromise the survival and health of aquatic life. He et al. [26] emphasized the complex interplay of natural and human-induced factors, including water flow patterns, chemical reactions, respiration of organisms, pollution inputs, nutrient concentrations, and decomposition processes to DO fluctuations in aquatic ecosystems.

Maintaining appropriate nutrient levels in surface water is critical for effective water quality management as excessive nutrient loads can trigger algal blooms. These blooms deplete dissolved oxygen and disrupt the health of aquatic ecosystems. The downstream increase in total nitrogen and ammonium nitrogen concentrations likely originated from the overuse of nitrogen-based fertilizers in nearby agricultural areas. Fertilizer runoff is a recognized pathway for nitrogen and phosphorus introduction into waterways [4,19,22]. This is further supported by the significantly higher ammonia and total nitrogen levels recorded at stations situated closer to agricultural activities. High phosphorus concentrations could be attributed to a combination of agricultural and geological sources [19,22]. The Kenyan Rift Valley is well-known for its phosphate rock (gypsum) deposits suggesting that the underlying geology of the study area might be a contributing factor. Weathering of these rocks or naturally nutrient-rich soils can release phosphorus into the river, resulting in high concentrations [17].

Although phosphorus is relatively immobile and insoluble in soil [27], surface runoff and erosion can greatly increase its solubility in surface waters. The increased mobility allows phosphorus to enter the water column more easily, potentially leading to algal blooms. The blooms cloud the water, reducing sunlight availability for other aquatic plants and disrupting overall ecosystem health [27]. High levels of soluble reactive phosphorus (SRP) in upstream stations might be attributed to seasonal variations and the resuspension of previously settled phosphorus from the riverbed. High flow events, such as floods common during the wet season, can disturb bottom sediments releasing previously settled nutrients back into the water column. This results in a temporary increase in downstream SRP concentrations [20]. The seasonal resuspension of bottom sediments contributing to elevated SRP levels has been observed in other East African rivers [20,28,29]. Moreover, as water flows downstream from its source, it accumulates nutrients from agricultural runoff, industrial discharges, and wastewater treatment plants, potentially explaining the observed higher nutrient levels in downstream stations compared to upstream sampling stations [20]. Wastewater treatment plants and industrial discharges can act as point sources of pollution, directly releasing concentrated nutrients like nitrogen and phosphorus into the river [19]. This can significantly elevate nutrient levels compared to upstream stations with minimal human activity. Similar findings were reported in the Molo and Nyangores rivers [17,20]. Significantly high nutrient levels were linked to human activities including livestock grazing near the river, excessive use of fertilizers in agriculture, discharge of untreated or partially treated wastewater, and sedimentation caused by agricultural runoff. The variation in physical-chemical parameters observed along rivers indicates the degree of human influence, with agricultural and industrial areas exhibiting significantly higher levels of total dissolved solids (TDS), temperature, electrical conductivity (EC), and nutrients.

5. CONCLUSION

This study demonstrates that human activities can have a significant impact on water quality in riverine ecosystems. Downstream stations had higher water temperature, electrical conductivity, pH, TDS, and nutrients, but lower dissolved oxygen (DO) levels compared to upstream stations. The decrease in water quality poses a serious threat to the health of the Molo River and Lake Baringo. Effective pollution control strategies, such as sustainable agricultural practices, efficient wastewater treatment systems, and restoration of riparian zones,

should be implemented to reverse these trends and ensure the long-term health of this critical water resource. Future research should investigate the long-term ecological implications of water quality changes, as well as potential mitigation strategies.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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