Original Research Article

WATER QUALITY RESPONSE TOANTHROPOGENIC ACTIVITIES IN MOLO RIVER,LAKE BARINGO BASIN

ABSTRACT

This study investigated the influence of human activities on water quality parameters in the Molo River, one of the major inflow rivers to 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. Multivariate analysis of variance was used to test for significant differences in water quality parameters between 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. These observations are likely attributable to a combination of factors, including deforestation, agricultural practices, and point source pollution, which were more prevalent in downstream areas compared to the less disturbed upstream stations. The findings highlight the significant influence of human activities on the water quality along Molo River. Understanding these interactions is crucial for developing effective pollution control strategies to protect the Molo River and Lake Baringo.

Keywords: Anthropogenic activities, water pollution, nitrogen, phosphorus

1. INTRODUCTION

Rivers play multifaceted roles, providing essential services for both humans and the environment. They supply water for various uses, from domestic needs to irrigation, recreation and industry [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 ground water [5]. The situation is exacerbated in developing countries, where raw sewage, partially treated wastewater, and industrial waste are discharged directly into rivers, contributing significantly to water quality degradation [4].

Molo River, one of the major tributaries of Lake Baringo, once provided clean water and abundant fish for local communities. However, it now exemplifies the threats faced by freshwater ecosystems. The river's course 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 along the river's path [6]. Predictions indicate that climate change will exacerbate these effects, placing additional stress on the lake's water levels. Lake Baringo's health is inextricably linked to the health of its feeder rivers, which include Molo and Perkerra. The lake's water level fluctuates significantly due to climatic conditions and seasonal rainfall patterns [7,8,9]. These fluctuations have an impact on the lake's physical and chemical properties, with low water periods resulting in increased turbidity caused by wind turbulence disturbing bottom sediments. Furthermore, the lake faces challenges from overgrazing and agricultural activities in its catchment areas, which cause water quality to deteriorate due to increased sedimentation [10,11]. The Lake Baringo basin is undeniably under human pressure. However, a critical piece of information remains elusive: a comprehensive assessment of riverine point and non-point pollution sources.

Understanding the water quality of riverine ecosystems offers a valuable lens into their current health. It reflects the current ecosystem's structure, function, and potential future trend in an ever-changing environment [12]. This knowledge is instrumental in formulating strategies to prevent pollution, manage land use effectively, and ultimately, protect ecological balance of Lake Baringo. The goal of this study was to investigate how human activities affect water quality parameters in the Molo River, one of the major rivers that feeds Lake Baringo. Establishing these connections will allow us to develop effective pollution control and management strategies for the entire basin. The knowledge will also allow us 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 the communities that rely on it.

2. MATERIAL AND METHODS

2.1 Study Area

The study was conducted in Molo River (Figure 1), one of the major feeder rivers of Lake Baringo, the other being Perkerra river. The Molo River is located between longitudes 035° 44.044′ E and 035° 51.846′ E, latitudes 00° 11.99232′ S and 00° 15.530′ S. The river originates from the Mau complex with an altitude ranging between 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 which directly contaminate the water. Car washing activities and livestock watering points also contribute to pollution in the river. The river faces additional threats further downstream in Salgaa town where flower farm discharges continue to be a source of concern and oil spills from heavy-duty vehicles transporting petroleum products across East Africa pose a significant risk [13].

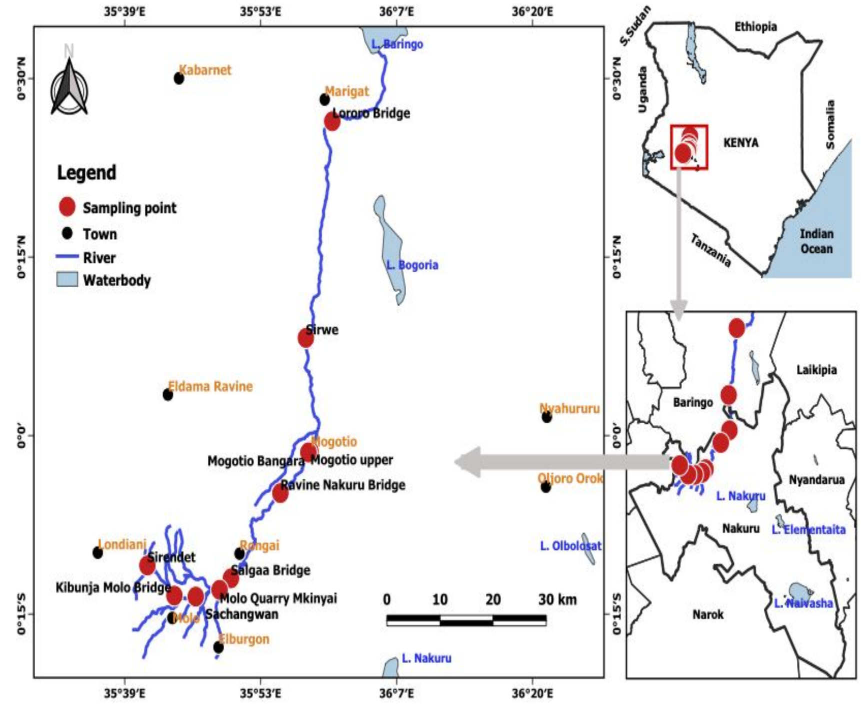

Fig. 1. Sampling stations along River Molo, Lake Baringo Basin

2.2 Sampling and sample analysis

To determine the influence of anthropogenic activities on water quality, sampling stations were selected along the river with different 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 Sachagwan (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 (oC), dissolved oxygen (mgL-1), conductivity (µScm-1), 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, preserved with sulfuric acid and stored in cooler boxes at temperatures of about 40C. The preserved samples were then transported to the laboratory for analysis of dissolved nutrients including Total Nitrogen (TN), Total Phosphorus (TP), Ammonium-nitrogen (NH4-N), and Soluble Reactive Phosphorus (SRP) using standard analytical procedures [14].

2. 3 Data analysis

Water quality variables were presented as (means ± standard deviation) of three replicates. Prior to 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 $\alpha = 0.05$. 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 lower 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 showed similar levels of EC.

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

SAMPLING STATIONS	PARAMETERS				
	pH	**Temp (°C)**	**DO (mg/L)**	**EC (µS/cm)**	**TDS (mg/L)**
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

Total phosphorus (TP) concentration varied significantly across sampling stations (Figure 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).

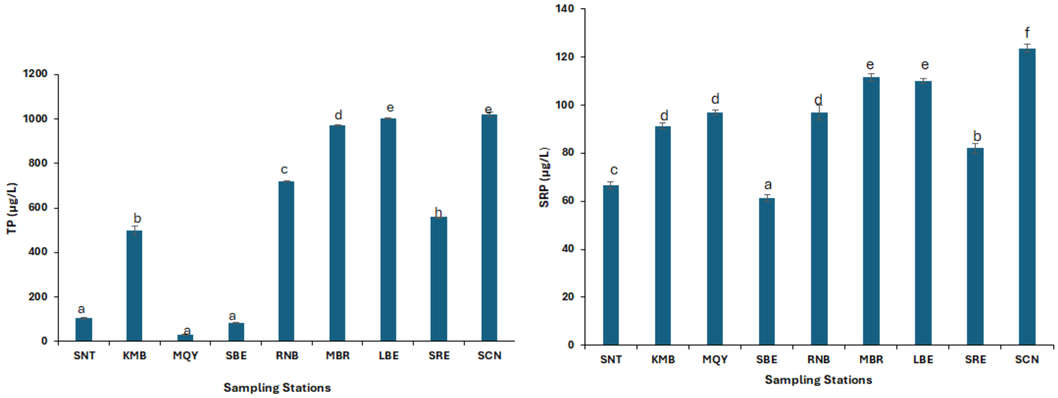

Fig. 2. Total phosphorus (TP) and Soluble reactive phosphorus (SRP) concentration along River Molo, Lake Baringo Basin during the study period

Significant spatial variation in TN was observed across sampling locations along the river (Figure 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.

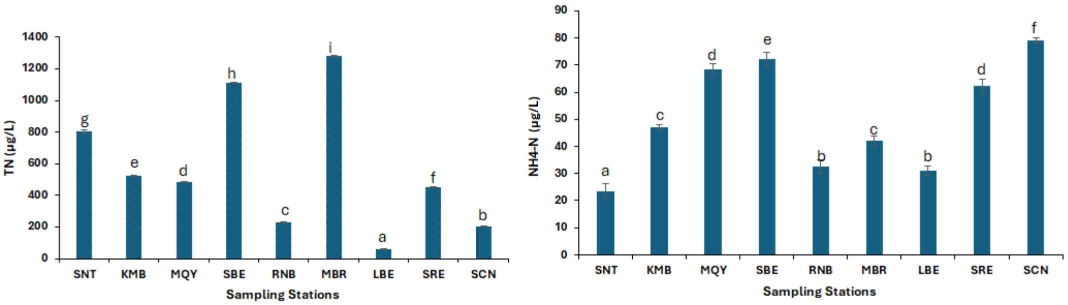

Fig. 3. Total nitrogen (TN) and ammonia nitrogen (NH4-N) concentration along River Molo, Lake Baringo basin during the study period

4. DISCUSSION

The observed increase in water temperature, electrical conductivity, pH, 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 [15, 16]. Studies by [17] and [15, 18] reported similar results, attributing high levels of total dissolved solids (TDS), temperature, pH, and electrical conductivity (EC) in downstream stations to human activities. These activities include farming along the riparian zone, livestock grazing and watering points, and erosion of the riverbanks. The high electrical conductivity downstream was likely caused by dissolved and suspended materials originating from these human and animal activities runoff into the river [4,19]. Additionally, agricultural practices introduce pollutants like fertilizers and pesticides, raising electrical conductivity and total dissolved solids.

Several studies have shown that removal of riparian vegetation along rivers influences the physical and chemical properties of water, riverbed composition and flow regimes [4, 16, 18, 19,20]. While Lake Baringo's basin experiences generally hot weather, this study might not have fully captured the pronounced variation in temperature because samples were collected early in the morning and late afternoon when the weather was somehow humid. Besides, 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 areas 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, 16].

Dissolved oxygen is a vital requirement for aquatic life, including fish. However, downstream stations in this study exhibited low DO levels. This decline can be attributed to increased organic matter decomposition, sediments, and siltation [4,15,19]. 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 [21]. Human activities including 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 [22]. 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. [22] 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 because excessive nutrient loads can trigger algal blooms. These blooms deplete dissolved oxygen and disrupt the health of aquatic ecosystems. This study investigated four key nutrient parameters including total phosphorus (TP), soluble reactive phosphorus (SRP), total nitrogen (TN), and ammonium nitrogen (NH4-N). The observed downstream increases in TN and NH4-N concentrations likely originated from the overuse of nitrogen-based fertilizers in nearby agricultural areas. Fertilizer runoff is a recognized pathway for nutrient introduction into waterways [4,15,18]. This is further supported by the significantly higher ammonia and total nitrogen levels recorded at stations situated closer to agricultural activities. The high phosphorus concentrations observed in this study could be attributed to a combination of agricultural and geological sources. Agricultural fertilizer runoff is a well-known source of phosphorus in waterways [15,18]. However, the underlying geology of the study area also played a significant role. The Kenyan Rift Valley is well-known for its phosphate rock (gypsum) deposits. The weathering of these rocks or naturally nutrient-rich soils can release phosphorus into the river, resulting in high concentrations [13].

While research indicates that phosphorus has low mobility and solubility in soil [23], surface runoff and erosion can significantly increase their solubility in surface waters. This increased mobility allows phosphorus to more easily enter the water column. Excess phosphorus has been shown to harm aquatic ecosystems by causing algal blooms. These blooms cloud the water, reducing sunlight availability for other aquatic plants and disrupting overall ecosystem health [23]. The observed high levels of soluble reactive phosphorus (SRP) in upstream stations during this study 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 [16]. This disturbance releases previously settled nutrients back into the water column, leading to a temporary increase in downstream SRP concentrations. This phenomenon of seasonal resuspension contributing to elevated SRP levels has been observed in other East African rivers [24,25].

As water flows downstream from its source, it accumulates nutrients from various sources, potentially explaining the observed higher nutrient levels in downstream stations compared to upstream ones. These sources can include agricultural runoff from farmlands, industrial discharges, and wastewater treatment plants [16]. Wastewater treatment plants and industrial discharges can act as point sources of pollution, directly releasing concentrated nutrients like nitrogen and phosphorus into the river [15]. This can significantly elevate nutrient levels compared to upstream stations with minimal human activity. Similar findings were reported in the Molo and Nyangores rivers by [13, 16], respectively. These studies attributed elevated nutrient levels and variations in other physical-chemical parameters along the river to human activities like livestock grazing and watering near the river, excessive use of fertilizers in agriculture, discharge of untreated or partially treated wastewater, and sedimentation caused by agricultural runoff. In essence, the variation in physical-chemical parameters observed along the river serves as an indicator of 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 provides compelling evidence that human activities are significantly impacting the water quality of the Molo River. Downstream stations exhibited elevated water temperature, electrical conductivity, pH, TDS, and nutrients, while dissolved oxygen (DO) levels decreased compared to upstream areas. The observed decrease in water quality poses a significant threat to the health of the Molo River and Lake Baringo. Effective pollution control strategies must be implemented to change these trends and ensure the long-term health of this critical water resource. These strategies could include promoting sustainable agricultural practices, restoring riparian zones, and improving wastewater treatment infrastructure. Future research should investigate long-term ecological effects of these water quality changes, as well as possible mitigation strategies.

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