Ethiopian Journal of Environmental Studies & Management 10(10): 1234 – 1249, 2017.
ISSN:1998-0507 doi: https://ejesm.org/doi/v10i10.1
Submitted: June 9, 2017 Accepted: December 13, 2017

CHARACTERIZATION OF ANTHROPOGENIC ACTIVITIES INFLUENCING SURFACE WATER QUALITY ALONG MOLO RIVER ECOLOGICAL SYSTEM, KENYA

***KIBITOK, N.K.,[1] MOTURI, W.M.[2] AND OGENDI, G.M.[2]**
[1]Egerton University, Animal Science Department, P.O. Box 536-20115, Egerton-Kenya
[2]Egerton University, Environmental Science Department, P.O. Box 536-20115, Egerton-Kenya
*Corresponding author: nicholasbitok@yahoo.com

Abstract
Surface water is progressively subjected to stress as a result of anthropogenic activities. Systematic observation and characterization of anthropogenic activities along Molo River was done in 2014 to evaluate their effects on surface water quality. Portable GPS receiver was used to identify geographic locations of 23 sites purposively selected; based on their relative positions to the point of anthropogenic activities and included a reference located in the upper reaches. An observation schedule was used to collect data during dry and rainy-season. Chemical parameters were determined by spectrophotometry using standard methods and physical parameters measured in-situ using Wisenschafflich-Technische Werkstätten and pen type Dist 3 Model Meter probes. Data were analyzed using descriptive and inferential statistics. The frequency of occurrence and percentages were computed. Analysis of variance (ANOVA) was used to analyze mean concentrations of various physical-chemical parameters and various sampling occasions. Maximum NO_2 was (45.42 ± 3.4 $mg\cdot L^{-1}$), NO_3 (44.1 ± 0.1 $mg\cdot L^{-1}$), SRP 50.25 ± 0.4, DO_2 was 0.3 ± 0.0 $mg\cdot L^{-1}$, conductivity (616 ± 1.4 µS/cm), and TDS 405.8 ± 8.1 $mg\cdot L^{-1}$ while NH_4-N 79.69 ± 1.2 $mg\cdot L^{-1}$, TN 109.36 ± 09 $mg\cdot L^{-1}$, pH was 12.525 ± 8.0 and T ºC 21.4 ± 0.2 ºC. Mean TP was 13.21 ± 1.78 mgL^{-1} and 2.43 ± 1.70 mgL^{-1} highly significant at $p<0.05$ i.e. $p= 0.0001$. Results indicate that there were significant differences in the means of NO_2-N, NO_3-N, NH_4-N, TN, DO, EC, T°C, and TDS (p=0.0038, 0.0001, 0.0001, 0.0001, 0.0001, 0.0001, 0.0021, and 0.0001) respectively. Observed activities comprised urban-construction/dumping of waste adjacent to riparian-buffer-zones recording 18.4%, domestic animals watered at the river 28.09%, people crossing river using vehicle/motorbikes and/or on-foot 39.2%, children playing in the river 12.9%,water abstraction 11.9%, sand harvesting/quarrying 0.16%, septic tanks-leaks, waste discharged into the river 4% and Washing linen 4.4%.. Washing vehicle/cars/motorbike was highest at the site denoted M3, recording 265 observations. Frequency and intensity of human activities closely relate the results on physical-chemical parameters, interference from direct human activity than natural phenomenon explains the finding. The river water is unsuitable for human consumption.

Key Words: *Physical-chemical parameters, Surface water, Pollution, Sub-urban-rural town*

Introduction

Globally, studies on effects of anthropogenic activities in sub-urban areas are in many ways less advanced than those in urban areas. Anthropogenic activities along streams and rivers in the world modify the ecological status of the receiving water body (Baykal *et al.*, 2000; Ogbogu *et al.*, 2002; Arimoro *et al.*, 2009, and Osakwe *et al.*, 2014). Authors have shown how Shanghai's significant economic growth and urbanization have brought about changes to the mega city's urban spatial structure and increased the amount of stress, in form of waste and pollutants, on the ecosystem. These changes have significantly affected Shanghai's water quality.

Cities in the developing world facing similar challenges include Calcutta, Istanbul, Mexico City, and Sao Paulo (Baykal *et al.*, 2000; Wenwei *et al.*, 2003). Soro *et al*. (2009) study on water and sediments of the Ebrié lagoon showed high levels in physical-chemical parameters. According to these authors, this lagoon is subject to anthropogenic pollution due to discharge of untreated or inadequately treated domestic and industrial sewage. In the urban environment sewage discharges are a major component of water pollution. It contributes to oxygen demand and nutrient loading which promotes growth of toxic algae and other aquatic plants. Research from many parts of the world has shown a relationship between increasing anthropogenic activities and decreasing quality of receiving aquatic ecosystems in countries such as China (Cheung *et al.,* 2003; Huang *et al.,* 2015; Yang *et al*., 2015).

There has been observed progressive deterioration in water quality (physical-chemical and biological characteristics) damage of life support systems and natural environment in Molo river ecological system (Mwangi *et al.,* 2008). Clean drinking water is insufficient, waterborne diseases are recurrent, frustrating United Nations Millennium Declaration Goals (MDGs), signed in September 2000 and Kenya Vision 2030 for fresh water availability. This phenomenon is attributed to anthropogenic causes which have not been systematically documented; evidence is provided herein which can be used to develop mitigation strategies for river water pollution and criteria for water resource management.

Methodology

Description of the Study Area

The study was carried out in Tributaries of Molo River in Molo and Elburgon sub-urban town in Nakuru District, Nakuru County of Kenya (Mwangi *et al*., 2008). Twenty-three sites including a reference site located in the upper reaches and others in the lower stretches were identified and purposively selected based on their relative positions to the point of anthropogenic activities. Geographic locations were established with a portable GPS receiver. These sites included (hydrological pathways and source of effluents) points of waste discharges (from sewer discharge) and entry points of run-offs from intensive farming areas such as flower farms, industrial waste and urban/residential waste as shown in Fig. 1.

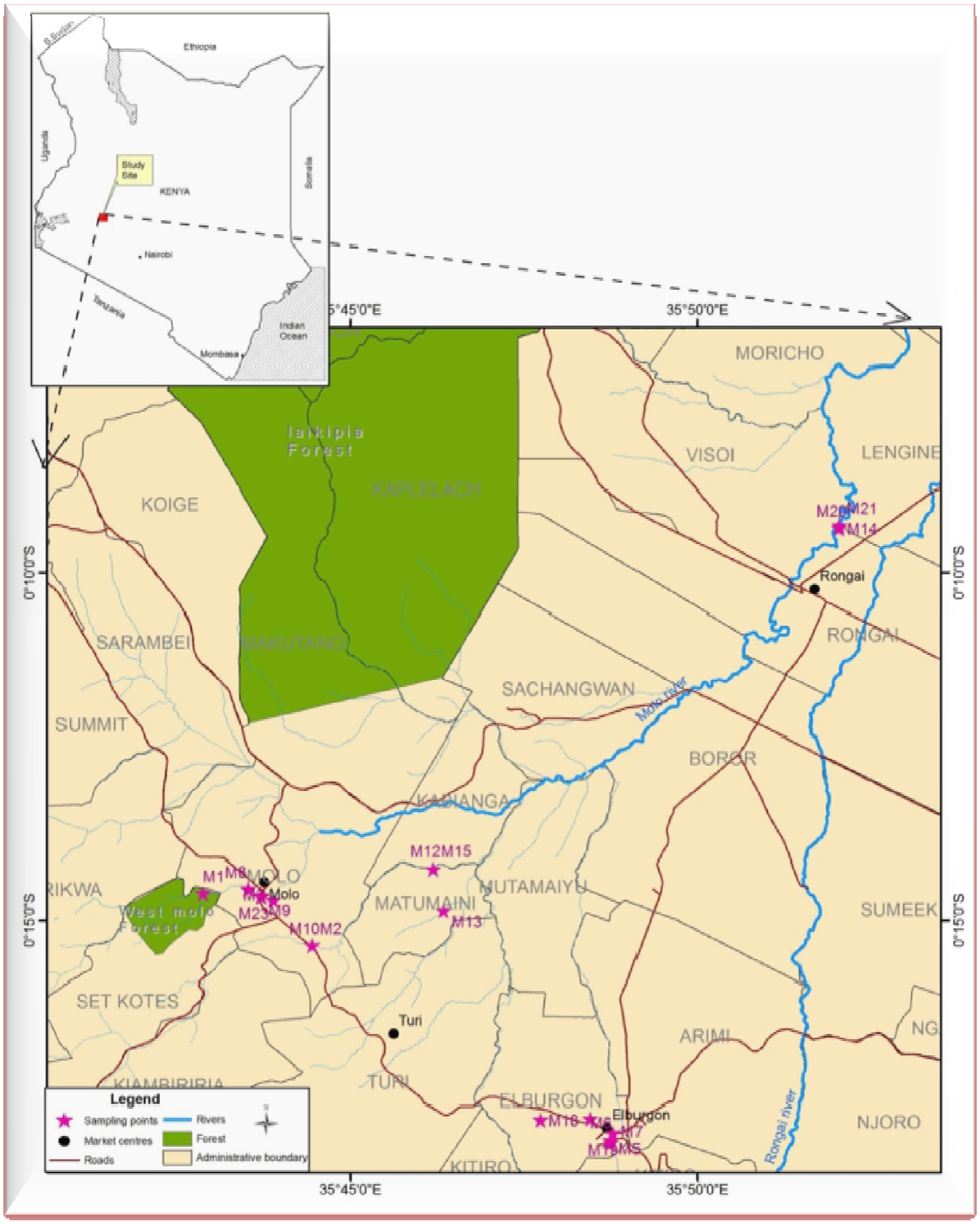

Figure 1: Location of the Molo River in Kenya and Molo River catchment.
Source: Modified from Survey of Kenya, 1972

Table 1: Sites, GPS points, altitude and description summary of sampling sites along tributaries of Molo River

Site	GPS Points	Altitude (m)	Description of land use pattern or major concern
M1	36M 0802171 UTM 9973055	2501	Forest area/upstream limited agriculture/ 'Undisturbed' (West Molo Forest).
M2	36M 0805099 UTM 9971661	2777	Forest area/Limited agriculture/grazing area/ 'Undisturbed' (West Molo Forest).
M3	36M 0804048 UTM 9972872	2459	Town Centre/Suburban areas/abstraction point/Molo Police
M4	36M 0813308 UTM 9965509	2435	Agricultural area/ abstraction point: Before Jerald Flower farm
M5	36M 0813107 UTM 9966428	2424	Agricultural area/horticulture/ abstraction point: After Jerald Flower farm
M6	36M 0813102 UTM 9966508	2431	Saw milling/agricultural/Suburban/abstraction point: Before Eel hotel
M7	36M 0813168 UTM 9966690	2417	Service Industry/Suburban/Urban Centre/point of discharge/after Eel hotel
M8	36M 0803380 UTM 9973173	2463	Wet land/Suburban area/ abstraction point/ Before KB Ltd wetland
M9	36M 0803729 UTM 9972993	2505	Town Centre/Suburban areas/ abstraction point /KBL Industry-main stream
M10	36M 0805099 UTM 9971657	2486	Near town Centre/market and a water abstraction point/ Munju River
M11	36M 0812559 UTM 9967076	2415	Agricultural/Town Centre/abstraction/point of discharge from Tim sales
M12	36M 0808346 UTM 9973701	2362	Confluence/Mau summit-Gathage-Matumaini River/abstraction/agricultural area
M13	36M 0808624 UTM 9972594	2323	Agricultural area/horticulture/abstraction point/Matumaini flower farm upstream
M14	36M 0819213 UTM 9982746	1855	Agricultural area/horticulture/ abstraction point/PP Flora flower farm
M15	36M 0808346 UTM 9973702	2341	Quarrying/Agricultural area/Abstraction/Matumaini-Gathage River Quarrying
M16	36M 0803382 UTM 9973175	2471	Agricultural/Suburban/Town Centre/abstraction/effluents from Tim sales
M17	36M 0803735 UTM 9972968	2461	Agricultural/suburban/Town Centre/abstraction/after KBL malting discharge I
M18	36M 0812256 UTM 9967055	2435	Timber industry/Town Centre/agricultural area/ abstraction/ Sokoro Tim sales
M19	36M 0813174 UTM 9966697	2410	Agricultural/Suburban/Town Centre/abstraction/effluents: Mt Elgon furniture
M20	36M 0819213 UTM 9982746	1855	Agricultural/Suburban/Flower farming/abstraction/effluents PP flower farm
M21	36M 0819218 UTM 9982814	1867	Agricultural/Settlement area/Town Centre/abstraction/effluents PP flower farm
M22	36M 0803726 UTM 9972963	2468	Agricultural/Suburban/Town Centre/abstraction/KBL malting industry II
M23	36M 0803735 UTM 9972967	2460	Agricultural/Suburban/Town Centre/abstraction/KBL malting discharge II

Description of Sampling Sites along Molo River Ecological System

Descriptions of the research sites are presented in Table 1. All sampling points except M1, M2 were water abstraction locations. Point denoted as M1 is located upstream; the area is forested and has limited agricultural activity (West Molo Forest Figure 1 above). The regional forest department has allowed controlled food crops cultivation to permit people to nurture tree seedlings introduced to enhance the forest cover. This activity may, however, be a cause for high nutrients levels recorded at the sites TN registered 5.27±1.3 mgL^{-1} for the rainy season, while dry season recorded 12.5±1.3 mgL^{-1} and 14.92±9.9 mgL^{-1} for morning and afternoon sampling respectively. Value for afternoon sampling seemed to be higher than morning, an observation recurrent for most sites. Site M2 had few human activities, however, grazing animals were observed along the river. The site with most activity was observed at M12; it is a confluence of three rivers (Mau summit-Gathage-Matumaini River) and is located at Jolly farm Bridge, Sacha-Ag'wan area. Observed activity in the site was water abstraction and washing of linen. Other sites which seem to have great disturbance are designated M7, M9, M11, M16, M17, M22 and M23. The site shown as M7 near a service industry (i.e. hotels, and dispensaries), is located in the town center where effluence is from residential/urbancenter, intensive agriculture and dumping of solid waste.

Site designated M11 represent timber industry; it is located within the periphery of Molo Town. The point is impacted by the industry which discharges inadequately treated waste into the stream. Dry season sampling recorded high TN of 65.53±0.5 mgL^{-1} and 62.27±0.3 mgL^{-1} for morning and afternoon respectively. Rainy season recorded 33.24±2.1 mgL^{-1} in the morning and 9.85±9.8 mgL^{-1} afternoon. Conductivity for the dry season was high and ranged from366±0.7 µS/cm to 368.5±0.4 µS/cm and TDS of 244.12±5.8 mgL^{-1} and 245.79±1.6 mgL^{-1}, for morning and afternoon sampling respectively. Rainy season recorded conductivity of 561±42 µS/cm and TDS of 374.6±2.2 mgL^{-1} and 559.5±6.4 mgL^{-1} for morning and afternoon respectively. The high levels of TN, conductivity and TDS indicate perturbations from the timber industry and human activities from the adjacent areas. Sites denoted M9, M22 and M23 are located at the discharge point of a beverage producing industry, discharge point II. TN at site M9 in dry season ranged 39.69±13.4 mgL^{-1} and 85.06±1.2 mgL^{-1} for morning and afternoon sampling. The range for M23 was 109.36±09 mgL^{-1} which was high compared to other sites. Human activities at the site seem to influence significantly the TN levels. Waste high in Nitrogen content is discharged into the river at this point; this may be the cause of elevated TN levels at M23 and M9.

Water Quality Analysis

Cooler box filled with ice cubes was used to transport samples to Animal Science laboratoryat Egerton University for analyses. Samples were transported within 24 hours after sampling.All the chemical parameters were determined by spectrophotometry using spectrophotometer Model LW V-200-RS following standard APHA 2005 method**.** Unstable parameters; Dissolved Oxygen (DO_2), and Hydrogen potential (pH) were measured *in-situ* using *Wisenschafflich-Technische Werkstätten* (WTW) meters and probes. Water temperature (T ºC), Total Dissolved Solids (TDS) and, conductivity were measured using pen type DIST 3 MODEL.

Data Collection

Samples for water quality tests were taken randomly using scatter of both across and along the stream at each sampling site. Composite surface water was collected in the middle of the river and stored in clean polyethylene bottles that had been pre-washed with HNO_3 and thoroughly rinsed with deionized water. Water samples were stored below 4ºC in the laboratory before chemical analysis of total nitrogen (TN), total phosphorus (TP), nitrate-nitrogen (NO_3-N), and ammonium-nitrogen (NH_4-N).All sampling sites were geo-referenced and coded using GPS gadget.

Data on human activities was collected using an observation schedule and was analyzed using descriptive statistics. The frequency of occurrence was recorded, pictorial plates comprising of live human activities were used to enhance the information.

Data Analysis

The data on human activities was analyzed using descriptive statistics. The frequency of occurrence was recorded and percentages computed as a total of the total observed human activities during the period of studies, pictorial plates comprising of live human activities were used to charaterize actual activities. Analysis of variance (ANOVA) was used to analyze mean concentrations of various physical-chemical parameters and various sampling occasions. One-way ANOVA was used to determine variations in mean concentrations of parameters at various sampling sites. The results were presented as the mean and standard deviation (Mean ± SD). Least significant difference (LSD) test at 5% significance level was adopted to evaluate the differences among the means of all the measures during the observation period.

Results and Discussion

Human activities at site denoted M1 and M2 was only water abstraction except for some farming activity at the forested area. Abstraction of water was highest in the following site (in ascending order) M12> M22> M23> M13> M17. Total recorded observation of water abstraction was 1567 and the highest observation was made at site denoted as M12 which is a confluence of three streams. On average a total of 74 abstractions could have been observed on every site during the sampling period. Water abstraction was almost uniform for all the sampling points for all sampling seasons and had an average of 57 observations except for M12, M22, and M23 which had 245 and 120 observations respectively.

The trends for ‘Animals watered at the river’ was in the following pattern starting from the least to the most observed during sampling events, sites M21>M10>M12> M15> M20> M8>M14> M7> M19. More animals were watered at the river during the dry season than the rainy season**.** Site M21 recorded 512 animals and site denoted as M10 recorded 138 animals.

Observed agricultural activities include intensive farming extending to the river bank, along the riparian buffer zone. Food crops were predominant however cash crops were planted and included maize plantation. Intensive farming was mainly horticultural and floriculture. More than four flower farms were observed in the study area, located at sites denoted as M4, M13, M20 and M21. Washing carrots/potatoes/vegetables was characteristic to sampling points near horticultural farms or sub-urban areas this was observed at sites denoted as M9, M10, M12, M17, M22 and M23 recording a total of 135 observations during the dry and rainy season sampling. The trend followed the following pattern starting from the most to the least observed agricultural activities, M17> M9> M12> M23> M22> M21. The remaining sites recorded the same agricultural activities of 12 observations during the study period. On average 24 different agricultural activities could have been observed at every site during the study period.

Observed Industrial and Suburban activities included, Showering at the river, and washing linen. 'Children playing in the river' category recorded 86 and 100 observations in the morning and afternoon respectively at the site denoted M13, the least was at the site denoted M16 which recorded 2 persons. The point with the highest 'damping of waste/saw dust along the river' was observed at the site denoted M5 with 10 observations. Vehicle/cars/motorbike washing was predominant at site denoted M3, the site is located at the town Centre.

Highest human activity for all categories were at the site denoted as M12 and accounted 890 observations. The order of this observation in ascending order for seven sites was M12>M13>M3>M15>M10>M5>M20. On average, in this category there would have been 231 observations for every single site during the study period.

DO values in the present study between and within the sites ranged from 0.33 ± 0.07 to 13±3.5 mgL^{-1}, with an overall mean concentration of 6.38 mgL^{-1} which is suitable for aquatic life. Concentration levels of DO below 5.0 mgL^{-1} adversely affect aquatic life (Sinha and Biswas, 2011). All the sites were above 5.0 mgL^{-1} except for M10, M11, M15, M16, M18, M19, M20, M22, and M23. The sites are located at an abstraction site at Munju, near Timber industry, near quarry, near dump site, near flower farm and beverage industry respectively.

The findings also indicate that at 95% confidence level, there are significant differences between and within the sites (p=0.0001). The probable reason for low Dissolved oxygen in some sites may be as a result of the decomposing organic matter, dissolved gases, industrial waste, mineral waste and agricultural runoff (Srivastava *et al.*, 2011; Addo *et al.*, 2013). Others also have reported similar values of DO for river water bodies (Karikari *et al.*, 2007; Jayalakshmi *et al.*, 2011; Addo *et. al.*, 2013).

The mean EC values was significantly different from each other at 95% confidence level (p=0.0001) and ranged between 108 to 613.63 µS/cm at site M1 and M18 respectively, however the ranges are within the prescribed limit set by WHO for drinking purposes (Sankpal and Naikwade, 2012). Other Studies elsewhere have shown EC values to be in the ranges of 225 to 3350 µS/cm (Jayalakshmi *et al.*, 2011), 2130 µS/cm (Inoti *et al.,* 2012) which are higher than the findings of Molo River.

pH values vary from a minimum of 7.07± 0.03 and a maximum of 7.80± 0.19. But, the statistical analysis showed that there was no significant difference between the Corrected Total numbers of 87 sites (p=0.1510). This may indicate that impurities from different sites affecting the quality of Molo River may be similar.

Naturally water bodies show changes in temperature daily and seasonally due to different activities that can contribute to changes in surface water temperature. Water temperature obtained during the sampling period for all sites were significantly different (p=0.0021) at 95% confidence level. Generally, the river temperature varied from 15.89± 1.35^0C upstream of M1 to 24.063± 1.78^0C downstream of M23 and is considered lower compared to WHO maximum permissible limit (WHO, 2008). Thus, temperature of Molo River is likely suitable for aquatic lives. This result is similar to other studies reported within a range of 18.72 ± 1.35°C to 23.84 ± 1.78°C (Ftsum *et al.,* 2015), 19.01 to 23.93°C (Okweye, 2013) and 19.5 to 21°C (Patil *et al*., 2012).

Average values for TDS at 21 sites varies from a low of 73.62 mgL^{-1} to a high of 402.42 mgL^{-1} and the difference were highly significant at p=0.0001. Higher TDS can be toxic to aquatic life through increases in salinity or changes in the composition of the water. Primary sources for higher TDS in the river water might be due to agricultural runoff, discharge of domestic waste from the urban centers and other human activities like washing of different vehicles at and around the river (Annalakshmi and Amsath, 2012). Jayalakshmi *et al.* (2011) also reported TDS values (221 to 3534 mgL^{-1}) for river water.

Table 2: Least Squares Means for sites for Physical-Chemical Parameters

Site	NO_2	NO_3	NH_4	TN	TP	SRP	DO	EC	pH	T°C	TDS
M1	3.128^{c}	1.63^{d}	7.038^{b}	18.93^{de}	5.478^{c}	2.11^{a}	7.11^{bcdefg}	108^{g}	7.47^{abcde}	15.89^{e}	73.62^{g}
M3	5.905^{c}	4.52^{bcd}	2.885^{b}	30.55^{cde}	7.458^{bc}	18.66^{a}	6.10^{efgh}	288.5^{c}	7.49^{abcde}	19.33^{bcd}	198.91^{c}
M4	5.042^{c}	4.20^{bcd}	6.405^{b}	7.80^{e}	1.610^{c}	1.80^{a}	8.98^{abcd}	157^{efg}	7.64^{abcd}	17.68^{bcde}	105.8^{efg}
M5	7.193^{bc}	11.64^{bc}	1.990^{b}	55.28^{ab}	3.076^{c}	24.04^{a}	9.51^{abc}	196de	7.68^{abc}	18.8b^{cde}	140.82^{d}
M6	3.603^{c}	3.02^{d}	7.288^{b}	17.96^{de}	2.980^{c}	10.09^{a}	9.66^{ab}	190.63^{def}	7.61^{abcd}	16.63^{cde}	126.2^{def}
M7	6.360^{bc}	2.09^{d}	1.745^{b}	15.99^{de}	3.585^{c}	5.54^{a}	10.41^{a}	195.38^{de}	7.70^{abc}	16.56^{de}	129.8^{def}
M8	9.148^{bc}	2.25^{d}	17.733^{b}	20.01^{de}	15.608^{abc}	21.68^{a}	9.01^{abcd}	185.75^{def}	7.69^{abc}	17.06^{bcde}	122.8^{def}
M9	6.053^{c}	4.15^{cd}	16.085^{b}	28.98^{de}	25.875^{a}	24.82^{a}	7.24^{bcdefg}	191.75^{de}	7.681^{abc}	16.31^{de}	127.6^{def}
M10	6.143^{c}	3.05^{d}	15.310^{b}	11.14^{e}	4.253^{c}	7.92^{a}	5.73^{efgh}	212.63^{d}	7.58^{abcde}	18.24^{bcde}	140.81^{d}
M11	5.573^{c}	1.72^{d}	4.624^{b}	39.19^{bcd}	7.058^{bc}	20.27^{a}	3.46^{h}	463.75^{b}	7.46^{abcde}	19.938^{b}	309.9^{b}
M12	3.513^{c}	2.11^{d}	5.928^{b}	11.42^{e}	9.423^{bc}	21.73^{a}	7.39^{bcdef}	151.96^{efg}	7.73^{ab}	17.38^{bcde}	102.3^{efg}
M13	4.390^{c}	1.63^{d}	8.565^{b}	7.35^{e}	9.843^{abc}	4.97^{a}	6.85^{cdefg}	142.13^{gf}	7.57^{abcde}	19.85^{b}	100.14^{fg}
M14	3.463^{c}	1.27^{d}	9.850^{b}	27.41^{de}	4.380^{c}	28.50^{a}	8.41^{abcde}	149.56^{efg}	7.63^{abcd}	17.56^{bcde}	99.74^{fg}
M15	6.045^{c}	1.26^{d}	2.093^{b}	10.26^{e}	22.985^{ab}	16.46^{a}	4.88^{fgh}	184.5^{def}	7.20^{bcde}	17.2^{bcde}	120.6^{def}
M16	9.035^{bc}	2.02^{d}	13.365^{b}	39.40 ^{bcd}	8.288^{bc}	26.40^{a}	3.48^{h}	197de	7.07^{e}	19.73^{bc}	110.02^{de}
M17	15.298^{b}	1.52^{d}	16.140^{b}	65.71^{a}	6.763^{c}	20.79^{a}	6.70^{defg}	177.63^{def}	7.14^{de}	18.03^{bcde}	134.72^{de}
M18	25.120^{a}	3.18^{d}	48.555^{a}	75.54^{a}	11.903^{abc}	9.18^{a}	0.33^{i}	613.63^{a}	7.18^{cde}	19.69^{bc}	402.42^{a}
M19	9.565^{bc}	3.06^{d}	50.130^{a}	59.71^{ab}	2.269^{c}	12.50^{a}	0.58^{i}	153.5^{efg}	7.18^{cde}	19.713^{bc}	402.42^{a}
M20	4.683^{c}	3.29^{d}	1.655^{b}	8.17 ^{e}	2.858^{c}	25.32^{a}	5.53^{fgh}	153.95^{efg}	7.53^{abcde}	18.19^{bcde}	102.8^{efg}
M21	5.888^{c}	23.75^{a}	6.023^{b}	26.02^{de}	26.040^{a}	28.99^{a}	9.75^{ab}	284^{c}	7.49^{abcde}	18.19^{bcde}	198.28^{c}
M22	4.075^{c}	3.83^{cd}	3.885^{b}	53.52^{abc}	3.053^{c}	28.67^{a}	4.75^{fgh}	286.75^{c}	7.80^{a}	18.31^{bcde}	198.28^{c}
M23	3.138^{c}	12.29^{b}	3.385^{b}	56.38^{ab}	3.188^{c}	5.48^{a}	4.68^{gh}	300.2^{c}	7.80^{a}	24.063^{a}	201.45^{c}

Means with the same letter within the column are not significantly different

Observed Human Activities along Molo River Ecological System

The findings for the characteristics of anthropogenic activities along river Molo system are presented in Tables 3 to 6. These are categorized as Table 3 'abstraction of water', Table 4 'domestic animals and related activities', Table 5 'Agricultural activities' and Table 6 'Industrial and residential activities'. The figures represent percentages.

Table 3: Abstraction of water

Categories	Dry Season	Wet Season	Before site	After site
Women fetching water ≤20 liters	11.9%	11%	12.8%	11.7%
Fetching water using bicycle > 50 liters	3%	1.82%	3.52%	3.56%
Fetching water using donkey > 50 liters	1.5%	0.9	2.2%	2.4%
Fetching water using motorbike >50 liters	3.0%	1.8%	3.5%	3.6%
Children fetching water 20&5 liters container	4.1%	1%	3.3%	5.04%
Children fetching water 30 liters/wheelbarrow	0.2	0.3%	0.1%	0.2%
Abstraction of water using motorized pipe	0.01%	0.07%	0.07%	0
Fetching water using vehicle >100 liters	0.4%	0.3%	0.3%	0.3%
Total	24.07%	20.5%	27.41	26.8%

Table 3 shows categories of observed water abstraction. Women fetching water using 20 liters container was the highest occurrence recording 11.9% and 11% for dry and rainy season respectively. They carried water using plastic containers by supporting it on their head or back by means of a rope contrary to the United Nations Millennium Declaration Goals (MDGs) and Kenya vision 2030. Another observation was children fetching water by use of donkeys, fetching water by use of wheelbarrows, vehicles, motorbike, bicycles and use of motorized pipes. Use of motorized pipe to abstract water directly from any water body is prohibited by the Water Act (Kenyan water policy) unless with the provision of a license from the relevant authority.

Table 4: Domestic Animals and Related Activities

Categories	Dry Season	Wet Season	Before site	After site
Watering domesticated animals	12.49%	15.6%	10.1%	10.1%
Cattle, Goats, Donkeys &sheep grazing	12.8%	12.5%	14.6%	11.9%
Soil erosion-trapping from animals	1.4%	1.4%	1.4%	1%
Total	26.69%	26.1%	26.1	23%

Table 4 shows observation on domestic animals and related activities. More animals were watered at the river during dry season recording 12.49% than rainy season which had 15.6%. Total observed grazing domestic animals (cattle, goats, sheep and donkeys) along the stream was 53.1%. Major concerns were soil erosion observed especially in the impacted sites at the watering points. The sites had deep crater-like depressions measuring more than 21 m^2 and more than 1.4 meter in depth, with a steep gradient towards the river. The depressions seem to widen during the rainy season because of over flooding.

Table 5: Agricultural activities

Categories	Dry Season	Wet Season	Before site	After site
Poor farming methods: farming along river bank	2.3%	3.1%	3.1%	2.6%
Run-offs:-horticultural farms &surrounding	0.6%	1.4%	1.7%	1.3%
washing carrots/potatoes (vegetables)	1.1%	1.0%	0.9%	1.1%
Arrow roots planted along the stream	0.2%	0.2%	0.2%	0.2%
Farming activity upstream/flower farm	0.2%	0.2%	0.2%	0.2%
Total	3.1%	5.9%	6.1%	5.4%

Table 5 represents observed agricultural activities which include intensive farming extending to the river bank, along with the riparian-buffer-zone. Dry season recorded the highest occurrence 2.3%. Common food cropping system along the river includes maize, beans, vegetable, potatoes, tomatoes and carrots. Increase sub-urban population means increased demands for these products especially during the dry season since tropical agriculture is mostly rain fed except for the recent development of floriculture/intensive farming.

Table 6: Industrial and Residential activities

Categories	Dry Season	Wet Season	Before site	After site
People crossing river/motorbikes	19.3%	19.9%	19.2%	20%
Children playing in the river	6.6%	6.3%	6.67%	7.2%
Women washing linen	4.4%	4.4%	2.2%	4.4%
Washing vehicle/cars/motorbike	5.0%	3.7%	5.0%	5.2%
Man showering in the river	1.3%	1.7%	0.8%	1.6%
Sand harvesting, quarrying along river	0.16%	0.2%	0.16%	0.16%
Solid waste along river:- urban/residential	1.4%	1.3%	1.4%	1.3%
Sewage:-residential directed to river	1.3%	30 (1.2%)	1.3%	1.1%
Poor management of solid waste	1.2%	1.1%	1.1%	1%
Septic tanks leaks/hotels/residential areas	0.6%	0.5%	0.6%	0.5%
Urban/Residential along riparian area	1.2%	0.9%	1.4%	1.2%
Total	42.5%	41.2%	39.8%	43.6%

Table 6 represents industrial and residential activities observed in Molo river ecological system. There were 19.3% people crossing the river using motor vehicles, motor bikes or on foot during the dry season sampling, wet season sampling had the least 19.9% compared to other sampling sessions. Children playing in the river were observed to be 12.9% for all seasons. Sand harvesting and quarrying was observed to be 0.16%. Septic tanks leaks, sewage-solid waste discharged into the river system was observed and accounted 4%.

Discussion

Use of motorized pipe to abstract water directly especially during drought conditions can cause decreased river flow. Observed intensive farming (Flower farms, horticulture and various cropping systems), sewage and solid waste discharge from the residential area upstream may cause elevated phosphates as observed during the study, for example, mean TP recorded 44.8±3.9 mgL^{-1} and 43±0.9 mgL^{-1} for morning and afternoon sampling at site denoted M15 located at Quarry near Matumaini area. Detergents used for cleaning contain phosphate compounds as active ingredients which can also increase phosphate levels. The activities can cause direct effects on the physical-chemical characteristics of the river.

Frequent crossing of the river, on the other hand, may increase oil and related hydrocarbons contamination through spillages, in addition to interference with the sub-stratum of the river and aquatic organism. Hydrocarbons contamination through spillages contributes to oxygen demand and nutrient loading which promotes the growth of toxic algae and other aquatic plants. Washing of clothes and watering of animals is bound to raise turbidity, TDS, nutrients loads and increase soil erosion, especially in the watering points. Watering points for domestic animals had deep crater-like depressions measuring more than 21 m^2 and more than 1.4 meter in depth, with a steep gradient towards the river. The depressions seem to widen during the rainy season because of over flooding. Livestock drops their waste into the river water as they are being watered causing contamination through increased nutrients loads affecting the physical-chemical composition of water. Water may attain unwanted odours making it unsuitable to the transient consumer.

Growing of food and vegetable cropping systems along the riparian area utilizingriverwater for irrigation seems the only option to meet the demand. Flower farming is becoming popular and a growing industry in the study area, more than four flower farms was observed, one is located at site signified M4, another at the point denoted M13 located in the middle reaches and others at sites denoted M20 and M21 representing a flower farm. There was observed the use of Organochlorine pesticides (OCPs) in the study sites. These compounds are capable of persisting in the environment, transporting between phase media and accumulating to high levels, implying that they could pose a risk of causing adverse effects to human health and the environment. Most OCPs are designated as persistent organic pollutants (POPs). In a study carried in uplands and urban areas of Taiwan, it was estimated that over two million kilogrammes of OCPs were released into the environment annually in that period via volatility, soil erosion and agricultural runoff (Doong *et al.*, 2002). Mean ± sd TP for M20 representing a flower farm in Rongai Town downstream was 49.2±6.7 mgL^{-1} and 52.8±6.4 mgL^{-1} in dry season for morning and afternoon sampling.

(EMCA 2006, The Kenyan Environmental protection framework) section 72 (1) on water pollution prohibits any person, to discharge or applies any poison, toxic, other pollutants or permits any person to dump or discharge such matter into the aquatic environment in contravention of water pollution control standards established under this part. A breach to this shall be guilty of an offence and liable to imprisonment for a term not exceeding two years or to a fine not exceeding one million shillings or to both such imprisonment and fine. The Act gives guidelines on how industrial effluents shall be discharged or other pollutants originating from any trade and issuance of effluent discharge license. There observed negligence in the observance of EMCA and execution of directives enshrined in the policy.

Quarrying was observed at M15 located in the middle reaches. Quarrying can contribute harmful heavy metals to the natural environment. Aquatic plants (e.g. algae) are known to accumulate heavy metals. The input of heavy metals in surface waters has a particular concern due to their toxic nature. Sediments are regarded as ultimate sink and indicator of changes in the water column as well as the influence of anthropogenic activities in air and watersheds (Ramesh *et al.*, 1990). Heavy metals of anthropogenic origin enter into the rivers as inorganic complexes or hydrated ions, which are easily adsorbed on the surface of sediment particles and constitute the labile fraction (Vukovic *et al*., 2014). Environmental and ecosystem variables such as turbulence, water pH, redox potential, seasonal flooding, and storms cause periodic remobilization of contaminated surface and thereby making the bottom sediments a potential source (Osakwe *et al.*, 2014). Heavy metals in solution are highly reactive, hence their trace level concentrations. Studies have shown that 30–98 % of heavy metals in rivers are transported in sediment-associated forms (Wang *et al.*, 2011). Metals entering the river through natural processes such as weathering, erosion, and dissolution of water-soluble salts constitute the background level, but those added through anthropogenic activities substantially enhance the concentrations in sediment (Rzetala *et al.*, 2015). Being non-biodegradable, metals accumulate in sediments and in biota a process called bioaccumulation and bio-multiplication, across the food chain leading to long-term ecosystem level effect. Some of the metals such as Pb and Cd are nonessential and are harmful even at very low concentrations (Pehlivan *et al.*, 2009).

Conclusion

Water abstraction/watering of domestic animals were significant during the sampling period. Both extensive and intensive farming was rife in the upper and lower stretches and was impacting negatively the flow of the river. Extensive livestock production was characteristic in the lower reaches; major concerns are soil erosion especially in the impacted sites which are used as watering points. Flower and horticultural farming are a growing industry in the study area, more than four flower farms were observed. There is need to develop a stringent monitoring plan for the activity or total sanction of such activities along the river ecological system because of observed impacts from such activity in the study area. Sites considered as point-source pollution were found to be receiving effluents from residential and agricultural manufacturing industries. Observed non-point source pollution was nonspecific but may have originated from croplands, pasturelands (rangelands), forests and other rural lands. Discreet sources of pollution include discharge points from service industries, urban runoff, timber manufacturers, beverage producing industries, effluence from flower farms and quarry activities. Selected sampling points near settlement areas had intense interference as compared to sampling points relatively distant from settlement areas. Preventing pollution through legislated and controlled human activities is among the most cost-effective means of increasing water supplies this is an integral aim of this study. These results can be utilized to mitigate effects of human activities and resulting pollutants on Molo River system.

Acknowledgements

The authors wish to acknowledge the support received from National Council of science and Technology (NCST), Kenya and Graduate School, Egerton University for their favorable consideration to fund this paper. I express my sincere appreciation to Animal science Department-Egerton University for allowing me the time to pursue this study, tuition waiver which they granted me and the support received from the Department of Environmental Science-Egerton University.

References

Addo, M.A., Darko, E. O., Gordon, C. and Nyarko, B. J. B. (2013). Water quality analysis and human health risk assessment of groundwater from open-wells in the vicinity of a cement factory at Akporkloe, Southeastern Ghana. *e-Journal of Science & Technology*, 8(4): 15-30.

Annalakshmi, G. and Amsath, A. (2012). An assessment of water quality of river Cauvery and its tributaries Arasalar with reference to physico-chemical parameters at Tanjore DT, Tamilnadu, India. *International Journal of Applied Biology and Pharmaceutical Technology*, 3(1): 269-279.

Arimoro, F.O. (2009). Impact of Rubber Effluent Discharges on the Water Quality and Macro-invertebrate Community Assemblages in a Forest Stream in Niger Delta. *Chemosphere,* 77: 440-449 http://dx. doi. org/10. 1016/j. chemosphere. 2009. 06. 031

Baykal B., Tanik B.A. and Gonecn I.E. (2000). Water Quality in drinking water reservoirs of a magacity, Istabul. *Environmental Management*, 26(6): 607-14

Doong. R.A., Sun, Y.C., Liao, P.L., Peng, C.K. and Wu, S.C. (2002). Distribution and fate of organochlorine pesticide residues in sediments from the selected rivers in Taiwan. *Chemosphere*, 48: 237-246.

Eaton A.D, American Public Health Association, American Water Works Association, (2005). Standard Methods for Examination of Water and Wastewater. English: 21st edition. (American Public Health Association Inc. Washington D.C., U.S.A.: APHA-AWWA-WEF)

Inoti, K.J., Fanuel, K., George, O. and Paul, O. (2012). Assessment of heavy metal concentrations in urban grown vegetables in Thika Town, Kenya. *African Journal of Food Science*, 6(3): 41-46.

Jayalakshmi, V., Lakshmi, N. and Singara Charya, M.A. (2011). Assessment of physicochemical parameters of water and waste waters in and around Vijayawada. *International journal of research Pharmaceutical and Biomedical Sciences*, 2(3): 1040-1046.

Karikari, A.Y., Bernasko, J.K. and Bosque-Hamilton, E.K.A. (2007). An assessment of water quality of Angaw River in southeastern coastal plains of Ghana. *West African Journal of Applied Ecology*, 11(1): pp 77-87.

Mwangi W. and Olson G. Gabriel, Baseline survey for the campaign to save Molo River. *Report by Network for Eco-Farming in Africa and Maendeleo Endelevu Action Program. 2008, pp. 8-32.https://necofakenya.files.wordpress.com/.*

Ogbogu, S.S. and Olaide, S.A. (2002). Effects of Sewage Oxidation Pond Effluent on Macro-invertebrate Communities of a Tropical Forest Stream, Nigeria. *Journal of Aquatic Science.* 17: 22-27. http://dx.doi.org/10.4314/jas.v17i1.19906.

Okweye, P.S. (2013). Seasonal Variation in physico-chemical parameters and Heavy Metals Assessment in Surface Water of North Alabama. *Research Journal of Chemistry and Environment*, 17(7): 68-115.Ftsum Gebreyohannes, Abraha Gebrekidan, Amanual Hadera and Samuael Estifanos (2015). Investigations of Physico-Chemical Parameters and its Pollution Implications of Elala River, Mekelle, Tigray, Ethiopia. *Momona Ethiopian Journal of Science* Vol. 7(2): 240-257, 2015.

Osakwe J.O. and Adowei, P, Jnr M.H. (2014). Evaluation of heavy metal species in bottom sediments from Imo River system, Southeastern Nigeria*. Res J Chem Sci* 4(6): pp. 23–30.

Osakwe, J.O., Adowei P., Jnr M.H. (2014). Evaluation of heavy metal species in bottom sediments from Imo River system, Southeastern Nigeria. *Res. J. Chem. Sci.,* 4(6): 23–30.

Patil, P.N., Sawant, D.V. and Deshmukh, R.N. (2012). Physico-chemical parameters for testing of water–A review. *International Journal of Environmental Sciences*, 3(3): 1194-1207.

Pehlivan, E., Ozkan, A.M, Dinc¸ S. and Parlayici, S. (2009). Adsorption of Cu^2 and Pb^2 ion on Dolomite powder. *J. Hazard Mater.,* 167(13): 1044–1049.

Ramesh, R., Subramanian, V. and Grieken, R.V. (1990). Heavy metal distribution in sediments ofKrishna River basin. *Environ. Geol. Water Sci.,* 15: 207–216.

Republic of Kenya; the Environmental Management and Coordination (EMCA) Act. Regulations, 2006. Legal Notice NO 120*. Kenya Gazette Supplement No 68, 69th September 2006.*http://faolex.fao.org/docs/pdf/ken84962. Pdf.

Republic of Kenya; the Water Act, 2002, No. 8 of 2002. http://faolex.fao.org/docs/pdf/ken37553-a.pdf

Rzetala, M.A. (2015). Assessment of toxic metal contamination of bottom sediments in water bodies in urban areas. *Soil Sediment Contamination International Journal,* 24(1): 49–63.

Sankpal, S.T and Naikwade, P.V. (2012). Physico chemical analysis of effluent discharge of fish processing industries in Ratnagiri

India. *Bioscience Discovery*, 3(1): 107-111.

Srivastava. A., Kr. R., Gupta. V., Agarwal. G., Srivastava. S., Singh. I. (2011). Water Quality Assessment of Ramganga River at Moradabad by Physico-Chemical Parameters Analysis. *VSRD-TNTJ*, 2(3): 119-127.

Vukovic, D, Stankovic, S.J., Vukovic, Z. and Jankoviv, K. (2014). Transport and storage of heavy metals in the Sava River Basin in Serbia. *J. Serbian.Chem. Soc.,* 79(3): 379–387.

Wang, X. (2001). Integrating water-quality management and land-use planning in a watershed context. *Journal of Environmental Management;* 61: 25-36.

Wang, Y., Yang, Z., Shen, Z., Tang, Z., Niu, J. and Gao, F. (2011). Assessment of heavy metals in sediments from a typical catchment of the Yangtze River, China. *Environ. Monit. Assess.* 172(1–4): 407–417.

Wenwei,, R., Yang, Z., John, M., Bruce, A., Watt, W. E., Jiakuan, C., Hok-Lin L. (2003). Urbanization, Land use, and water Quality in Shanghai 1947-1996. *Environmental International* (ELSEVIER) 29: 649-659.