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Influence of land use practices on water physicochemical parameters and nutrients loading along the Mara River of East Africa

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Mara River originates from the Mau Forest and traverses through landscapes with varying activities. Over the years, Mara River Basin has witnessed population increase, accompanied with conversion of forestlands into agricultural farms, human settlements, industrial and tourist activities and development of urban centres. Land uses along riverine areas have influence on water quality and may affect health of surrounding ecosystems. The objective of this study was to investigate the influence of land use activities on the river water quality using samples collected along the river. A spring within the Mau Forest (Ainabsabet spring) and a stream emanating from forested land draining into the river after the mine site were controls. The samples were analyzed for water physicochemical parameters, which registered the following ranges of results; water pH (5.23 ± 0.01 to 8.04 ± 0.01), temperature (11.5 ± 0.06 to 23.73 ± 0.06°C), turbidity (65.77 ± 21.58 to 369.47 ± 15.69 NTU), dissolved oxygen (6.14 ± 1.55 to 8.18 ± 0.03 mg/l), total dissolved solids (45.22 ± 0.65 to 308.33 ± 2.08 mg/l), total soluble solids (6.33 ± 2.31 to 110.56 ± 1.50 mg/l), electrical conductivity (34.32 ± 0.45 to 252.00 ± 5.57 µS/cm), water nutrient loads; total nitrogen derivatives (223.57 ± 2.22 to 1630 ± 96.56 µg/l), total phosphates (42.32 ± 0.34 to 681.23 ± 68.8 µg/l) and silicates (up to 65.77 ± 0.65mg/l). Levels of most parameters increased ($p \leq 0.05$) downstream the river. Emarti site, close to large-scale maize farms, registered highest nutrient levels. Water from livestock and wildlife grazing areas (Tarime sites) that had gullies and bare soils, registered the highest levels of total soluble solids. The Kirumi wetland reduced ($p \leq 0.05$) nutrients concentrations entering Lake Victoria. Although land uses along the river contribute to nutrients loading into the water system, nutrient levels were within acceptable limits. There is need to conserve and protect the wetland and control activities along the Mara River, to mitigate future contamination of the Mara River which would pollute the Lake Victoria water.

Key words: Mara River basin, land use, water physicochemical parameters, nutrients loading.

INTRODUCTION

Increase in human settlement, agricultural activities, urban and industrial development in former forest lands cause a decline in water quality and ecological health of ecosystems (Johnson et al., 2001). The rise in human

populations increases diversity of their activities in fragile areas, which within river basins often reduce the river water quality (Hawkins et al., 1993). Major water pollution problems from agriculture have been reported in developed countries as, arising from intensified farming systems and use of agrochemicals (FAO, 1994). The increasing climatic stresses in developing countries also have led to changes in land use (Olesen and Bindi, 2002; Foley et al., 2005). These activities are being extended to developing countries. In East Africa, land use changes due to rapid urbanization and forests clearing to create room for agriculture and human settlement are the major stressors of streams and rivers (Kobingi et al., 2009). Water physicochemical parameters that is, water pH, temperature, dissolved oxygen (DO), turbidity, total suspended solids (TSS), total dissolved solids (TDS), water electrical conductivity (EC), concentrations of nitrates, nitrites, ammonium nitrogen, total nitrogen (TN), soluble reactive phosphorous (SRP) and total phosphorous (TP) are useful snapshots in evaluating water quality (APHA, 1980). The water bodies are home of different biodiversity which have optimal conditions that favour their existence (Ward and Tockner, 2001; Cardinale, 2011). Therefore adverse changes in ecosystem composition may lead to serious threats to biota (Dallas and Day, 2004). The evaluations of these parameters are necessary in water quality assessment.

The Mara River that forms the upper part of the Nile Basin is considered as one of the pristine rivers draining into Lake Victoria (Mati et al., 2005). Over recent years, the Mara River basin has undergone major land use/cover changes (Mango et al., 2010). The Mau Forests with savannah grasslands which used to be the sources of Mara River have been converted to human settlement and agricultural plantations such as Nyayo Tea Zones (Awiti et al., 2001). Other activities within the river basin include forestry, livestock keeping, fisheries, tourism, urban centres development, conservation areas and mining activities (Mango et al., 2010; Nyairo et al., 2015; Owuor et al., 2017). These activities decrease the environmental quality of the adjacent riverine lands as reservoirs, making them susceptible to pollution (Nyairo et al., 2015; Owuor et al., 2017). The Mara River water quality parameters were evaluated, to determine the need for policy intervention measures on livelihoods activities, in the area to mitigate water pollution and sustain aquatic ecosystem in the river and Lake Victoria.

MATERIAL AND METHODS

This study was conducted along Mara River, between longitudes 33°47'E and 35°47'E and latitudes 0°38'S and 1°52'S (Figure 1). The altitude of the basin ranges from 2,932 m above mean sea level (amsl) around Mau Escarpment to 1,134 m amsl around Lake Victoria. Water samples were collected in different areas along the Mara River (Table 1). The upstream of Ainabsabet Spring, within the Mau Forest, having least anthropogenic activities within its vicinity was used as control site 1. The Nyahenda stream emanating from forested land and draining into the river after the mine site was used as control site 2. Sampling points were selected based on dominant land use activities within the areas, accessibility and safety of the area (part of the area had wildlife on land or hippopotamus in the river).

Grab samples of surface water, were collected in three replicates of about 10 meters apart, along the Mara River area at each sampling site, using a clean beaker. The beaker was rinsed with the river water prior to each sample collection. Each sample was transferred into 500 ml plastic bottle, containing 0.2 g of $HgCl_2$ a preserving agent, and stored in an icebox before being transported to laboratory for analysis.

The water pH, temperature, turbidity, dissolved oxygen, and electrical conductivity were measured *in-situ* using a multi parameter-water quality meter (WQC-24-TOACOK). The total dissolved solids and total soluble solids were determined according to standard methods (APHA, 1989). For each sample, 20 ml was drawn and filtered through 0.45 µm GF/C filter paper using a filtering apparatus (Suction Pump P18990). The collecting beakers and filter papers had been dried in the oven at 90°C for 24 h and cooled to room temperature in desiccators and their weights were recorded before use. The collected residues were dried in the oven at 90°C for 8 h while the filtrate in the beaker were evaporated to dryness at the same temperature, then cooled in desiccators to room temperature before weighing.

TDS was calculated as:

(((B+S)-B) ×1000 ×1000) ÷ 20 ml

Where B = weight of beaker (gm), S = weight of sample (gm)

TSS was calculated as:

((F+R)-F) x 1000 x 1000÷ 20 ml

Where F= weight of filter (gm), R=weight of residue (gm).

Chemical analysis

Ammonium-nitrogen was determined by the indophenol blue photometric method (Koroleff, 1996). Accurately 17.5 g of phenol and 0.2 g of sodium nitroprusside were dissolved in Millipore milli Q water to a final volume of 500 ml (Reagent 1). Trisodiumcitrate-dihydrate (140 g) and 11 g of sodium hydroxide were dissolved in 300 ml of Millipore milli Q water. After complete dissolution, 20 ml of sodium hypochlorite was added followed by distilled water to a final volume of 500 ml (Reagent 2). Exactly 3 ml each of reagents 1 and 2 were added to 50 ml water, with vigorous shaking following addition of each reagent. Samples were then kept at room temperature for 24 h thereafter subjected to spectroscopic reading and the absorbance was read at 630 nm using a Genesys10s

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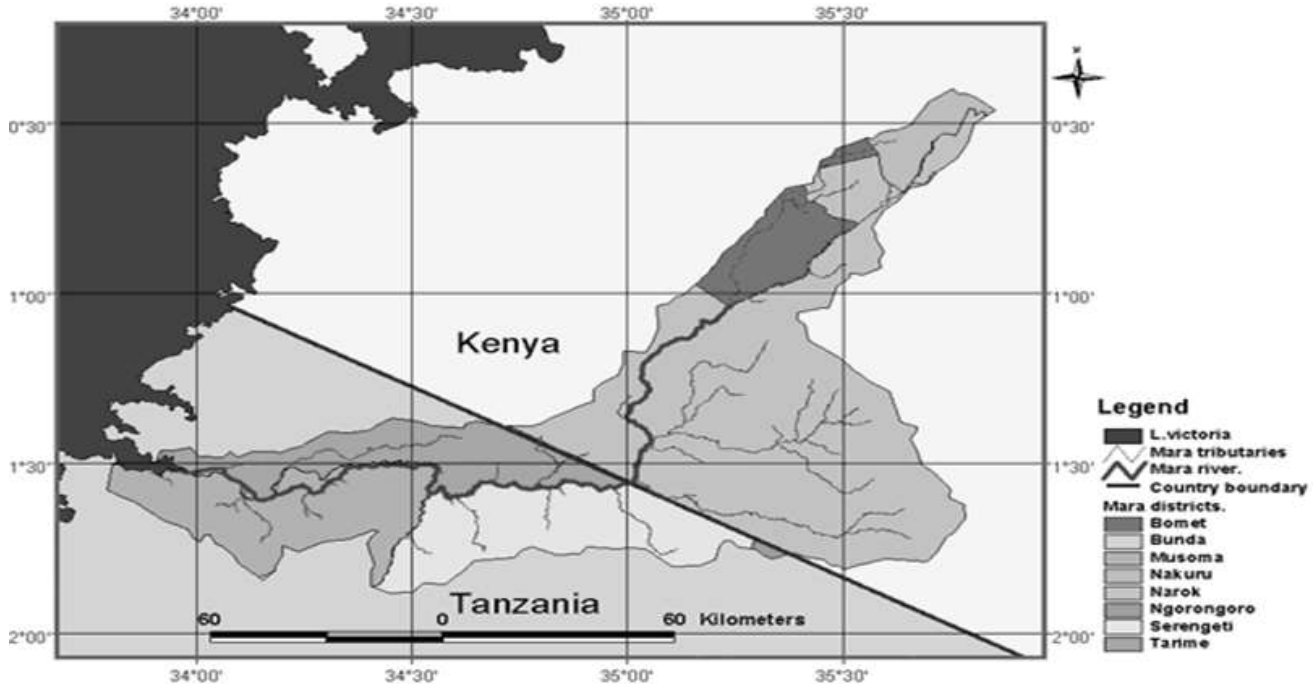

Figure 1. Map of the Mara River Basin (http://nowater-nolife.org/watersheds/Mara/Map .Accessed on 25th June 2013).

UV-Vis Spectrophotometer. The concentration of ammonium nitrogen was quantified using calibration curve prepared from a sub stock solution of 10 mg NH_4-N from anhydrous ammonium chloride (NH_4Cl) (Analar (AR)).

The levels of nitrite, nitrate and total nitrogen were determined using standard methods (Wetzel, 1991). For nitrites, 25 ml of each filtered water sample was added with 1 ml of sulphanilamide followed by vigorous shaking and standing for 5 min, before addition of further 1 ml N-I-napthylethylene diamine dihydrochloride. Absorbance of the solutions was then read against distilled water as a blank at 543 nm using a Genesys 10s UV-Vis Spectrophotometer. Nitrite concentration was quantified using a calibration curve prepared from a sub stock solution of 1000 µg NO_3-N/l from potassium nitrate (Analar).

Nitrates levels were determined as nitrites by, first passing the water sample through a copper cadmium column to reduce the nitrates to nitrites (Wetzel, 1991). The first 25 ml of each sample were discarded and the final 25 ml was analyzed as described for nitrite determination. The levels of total nitrogen (TN) were determined using the unfiltered sample which involved the addition of sulphanilamide and N-1-napthylethylene diamine dihydrochloride (Wetzel, 1991). The samples were digested for 3 h in an autoclave steam sterilizer at 93 to 120°C, using Electric Model no.25x. The samples were allowed to cool, and then passed through copper cadmium column and the absorbance read as described in the nitrite analysis.

Soluble reactive phosphorus (SRP) was determined by the ascorbic acid reduction method (Murphy and Riley, 1962). A mixed reagent of ammonium molybdate, sulphuric acid, ascorbic acid and potassium antimonyl titrate in the ratio of 2:4:2:1 respectively was prepared. Unfiltered samples (50 ml) was added to 5 ml mixed reagent and within 3 h, the extinction of the solutions were measured using a Genesys 10s UV-Vis spectrophotometer at a wavelength of 885 nm. The soluble reactive phosphorous concentration was quantified using calibration curve prepared from a sub stock solution of 1mg PO_4^-P/l which was prepared from potassium dihydrogen phosphate (KH_2PO_4) (Analar (AR). Total phosphorous was determined using the ascorbic acid reduction method (Murphy and Riley, 1962). Unfiltered samples (50 ml) was added to 5 ml of the mixed reagent, followed by digestion in an autoclave pressure steam sterilizer at 90 to 120°C of Electric Model no.25x for 2 h. The solutions were allowed to cool and absorbance read at 885 nm (Genesys 10s UV-Vis Spectrophotometer). The levels were quantified using a calibration curve from a sub stock solution of potassium dihydrogen phosphate (KH2PO4).

Silicates were analyzed according to a standard procedure (Wetzel, 1991). Each filtered sample (25 ml) was added to 5 ml of 0.25 M HCl, followed by swirling, 5 ml of 5% ammonium molybdate was then added with further swirling, thereafter 5 ml of 1% disodium EDTA was added followed by vigorous swirling. After 5 minutes, 10 ml of 17% sodium sulphite was added in each sample solution and these were allowed to stand for 30 min. The sample solutions were introduced to Genesy 10s UV-Vis spectrophotometer and the absorbance read at 700 nm. The silicates concentrations were quantified using calibration curve from a stock solution of 100mg SiO_2/l prepared from (AR) sodium hexafluorosilicate (Na_2SiF_6) (Analar (AR).

Data analysis

The data were subjected to a one-way analysis of variance using Statistical Analysis System (SAS) version 9.2 SAS Inc, 2002. The standard deviations were calculated using Microsoft excel programme.

RESULTS AND DISCUSSIONS

The results from 10 sites along Mara River Basin are presented in Tables 2 and 3. The World Health

Table 1. Sample sites, sampling coordinates land use and riverside characteristics.

Name	Sampling coordinates		Land use and riverside characteristics within the sampling site
Ainabsabet	0.658°S	35.544°E	Dense forested tress, thick grasslands and shrubs
Emarti site	1.043 °S	35.240°E	Large scale wheat and maize farming
Ngerende 1	1.109°S	35.166°E	Wildlife conservation-pools of hippopotamus upstream of the sampling point, isolated shrubs and trees within the river bank
Ngerende 2	1.137°S	35.142°E	Wildlife conservation- tourist lodges (Ngerende Campsites), game animals (Zebras, Gazelle, Hippos, Crocodiles, buffalos).
Old Mara Bridge	1.246°S	35.032°E	Isolated pockets of tall grasses, wildlife browsers and livestock (Maasai cattle and sheep).
New Mara Bridge	1.529°S	35.021°E	Wildlife Conservation, evidence of intense browsing. Presence of trenches and gullies used as paths by game animals assessing drinking water points
Tarime before mines	1.616°S	34.531°E	Pockets of human settlement, livestock, human domestic activities, excavated heaps of soils neighbouring the mining industries.
After mine	1.510°S	34.465°E	Sand harvesting, human settlement, small scale maize and banana farming
Nyahenda stream	1.476°S	34.414°E	It's a stream of clear water draining into the main Mara River. Emanating from a small forested land upstream, thick grasslands/shrubs.
Kirumi wetland	1.493°S	34.258°E	Fishing activities, pockets of human settlement, the water mass covered by aquatic vegetation(wetland)

Organization (WHO, 2004) and National Environmental Management Agency (NEMA, 2006) standards for comparison are presented in Tables 4 and 5, respectively. The water pH at Ainabsabet Spring (Control Site 1) was 5.4 ± 0.01 while in areas after the Tarime mine site was 8.04 ± 0.01. The result shows there was a significant ($p \leq 0.05$) increase of pH downstream. Abundance of organic acids due to natural decomposition of organic matter tends to increase water acidity (Chapman, 1996; Watanabe et al., 2006; Reuss and Johnson, 2012). The low pH at Ainabsabet Spring might be a result of no human habitation or anthropogenic activity hence attributed to the abundance of decomposition of leaves, twigs and natural weathering processes due to high rainfall in the site.

The areas adjacent to Tarime Mine site recorded the highest pH compared to all sites in the study area. Similar, high pH adjacent to to mining site had been observed in Western United States where, use of cyanide in leaching gold ores contributed significantly to the increase of water pH (Vladmir and Robert, 2006). Despite the observed increase, all sites in the study area along the river registered pH levels that were within the standard limits surface water of 6.5 to 9.2 (WHO., 2011) and 6.5 to 8.5 (NEMA., 2006). The pH results of this study were within the same range with another studies whereby the results from Mara River water ranged between 4.8 and 7.6 (Glows, 2005) and that of Mara River tributaries ranged from 5.7 to 7.4 (Nyairo et al., 2015).

The dissolved oxygen (DO) concentration along the Mara River water ranged from 6.14 ± 1.55 mg/l at the wetland to 7.94 ± 0.01 mg/l before the mine and 7.56 ± 0.10 mg/l after the mine site (Table 4). Nyahenda Stream (Control Site 2) which was off the main river registered DO level of 8.18 ± 0.03 mg/l. The data from this site of unpolluted water was not used to evaluate the land use effects, but to determine changes in water quality downstream entering the main river. Cold flowing water generally has more oxygen with many particles of moderate plants compared to stagnant and slow flowing water (Wetzel, 1983). At Ainabsabet Spring (control site 1), the water was slow flowing with pockets of natural decaying vegetative matter on the surface. This caused an increase in oxygen demand by decomposer species and possibly leading to the observed decrease of dissolved oxygen. However, the decrease was within acceptable standard limits (WHO., 2011, Williamson et al., 1998). In an earlier study, the DO levels ranged from 0.49 mg/l before draining into the Kirumi wetland to 7.35 mg/l at the Mara mines sites (Glows, 2005). With exception of the wetland, all the DO levels were above the recommended guideline set by the

Table 2. *In-situ* water physicochemical parameters at different sites along the Mara River.

Names	pH	DO (mg/l)	EC (µS/cm)	Turbidity (NTU)	Temperature (°C)
Ainabsabet Spring	5.23±0.01	6.45±0.01	34.32±0.45	98.45±1.15	11.53±0.06
Emarti site	7.48±0.01	7.28±0.05	67.00±0.01	160.37±29.21	18.83±0.15
Ngerende 1	7.53±0.06	7.62±0.38	66.30±5.03	143.17±48.97	19.73±0.32
Ngerende 2	7.56±0.02	7.53±0.09	65.00±2.65	109.87±1.86	19.70±0.1
Old Mara	7.47±0.01	7.28 ±0.05	67.00±0.01	176.20±28.19	18.83±0.06
New Mara	7.27±0.01	6.92±0.15	81.00±3.60	280.97±2.54	23.73±0.06
Before mine	7.75±0.01	7.94±0.01	108.00±6.08	364.17±29.56	23.50±0.29
After mine	8.04±0.01	7.56±0.10	112.00±3.0	369.47±15.69	23.03±0.15
Nyahenda Stream	7.47±0.06	8.18±0.03	42.33±0.6	90.55±0.90	18.07±0.12
Kirumi(Wetlands)	7.58±0.12	6.14±1.55	252.00±5.57	65.77±21.58	23.26±0.13
CV (%)	0.68	6.98	3.91	12.61	0.73
LSD, (p ≤ 0.05)	0.08	0.87	5.97	39.92	0.25

SE = Standard error.

Table 3. Total dissolved solids and total suspended solids in water at different sites, along the Mara River.

Site name	TDS(mg/l)	TSS(mg/l)
Ainabsabet Spring. (Control Site1)	45.22 ±0.65	9.22±0.13
Emarti site	129.33 ± 4.04	6.33±2.31
Ngerende 1	183.33 ± 4.93	41.67±1.15
Ngerende 2	180.68 ±1.15	42.00±2
Old Mara bridge	183.68 ±1.15	73.33±2.89
New Mara bridge	106.67 ±10.4	11.67±2.89
Tarime-(Before Mines)	193.24 ± 0.17	107.33±0.19
Tarime-(After Mines)	221.33 ±12.66	110.56±1.50
Nyahenda Stream(Control Site 2)	59.00±1	9.33 ±1.15
Kirumi(Wetlands)	308.33±2.08	24.67±1.53
CV (%)	3.50	4.18
LSD (P≤0.05)	9.60	3.11

SE= standard error.

Tanzania Government for surface water, suitable for fisheries and domestic use of 6 mg/l (Bitala, 2008). But the levels were within acceptable standards and guidelines (NEMA, 2006, WHO, 2011), demonstrating sustainability of dissolved oxygen concentration in Mara River. The DO levels at the wetland were slightly above 6 mg/l. The low level could be due to the biological activities taking placewithin the wetland (Wetzel, 1983, Gagnon et al., 2007, Kadlec and Reddy, 2001).

The electrical conductivity of water along the Mara River ranged from 34.32 ± 0.45 to 252.00 ± 5.57 µS/cm (Table 2). There was significant (p≤0.05) increase of electrical conductivity downstream of Ainabsabet Spring water (control site 1). Nyahenda Stream water (control site 2) showed a significant (p≤0.05) low electrical conductivity. Farm inputs that avail ions into surface water are primary causes of increased electrical conductivity within agricultural lands (Williamson, 2001). The high electrical conductivity registered at Emarti site might have resulted from farm inputs via surface runoff and leaching into the river. Livestock herding that was evident before the mining site also contributed to soil erosion, enhancing the ionic inputs into the water. Mining operations accelerate the chemical oxidation processes of the earth crust, releasing acids, metals and sulphates into surface and ground water (Lupankwa et al., 2004). Along the Mara River, the most significant input of ions was the mining activities as demonstrated by higher conductivity registered downstream the mine site. All the electrical conductivity levels were within acceptable standard limits of 400µS/cm in surface water (WHO, 2011). The anthropogenic activities within the Mara River basin were therefore not releasing excessive ions into the river water system.

Table 4. National Environment Management Authority (NEMA)-permissible quality standard limits for domestic and surface water.

Parameter	Domestic water	Surface water
pH (Fresh water)	6.5 - 8.5	6.5-8.5
pH in Marine waters	No set guideline	5.0 -9.0
Dissolved oxygen	Above 6 mg/l	Above 6 mg/l
Total Suspended solids	30 mg/l	30 mg/l
Total Dissolved Solids	1200 mg/l	1200 mg/l
Ec (water conductivity)	No set guideline	400 µS/cm
Turbidity	Below 10NTU	300 NTU
Nitrate (NO_{3-})	10 mg/l	10 mg/l
Ammoniacal- N (NH^{4+}.)	0.5 mg/l	0.5 mg/l
Nitrite (NO_{2-})	3 mg/l	3 mg/l
Dissolved Iron	0.3 mg/l	10 mg/l

(NEMA., 2006).

Table 5. World Health Organization (WHO)-permissible quality standard limits for domestic and surface water.

Parameter	Domestic water	Surface water
pH (Fresh water)	Below 8.0	6.5-9.2
pH in Marine waters	No set guideline	5.0 -9.0
Dissolved oxygen	No set guide	Above 6 mg/l
Total Suspended solids	5 mg/L	30 mg/l
Total Dissolved Solids	500 mg/l	1200 mg/l
Ec (water conductivity)	No set guideline	400 µS/cm
Turbidity	10NTU	300 NTU
Nitrate (NO_3^-)	3 mg/l	10 mg/l
Ammoniacal- N (NH^{4+}.)	No set guideline	Below 0.2 mg/l
Nitrite (NO_2^-)	0.05 mg/l	0.05-0.01 mg/l
Silicates	No set guide	100 mg/l.

(WHO, 1984; WHO, 1996; WHO, 2004; WHO, 2011).

Water turbidity along the Mara River ranged from 65.77 ± 21.58 NTU at Kirumi wetland to 369.47 ± 15.69 NTU after the gold mine site (Table 2). Apart from Kirumi wetland, all sites sampled registered higher turbidity ($p \leq 0.05$) compared to Ainabsabet Spring (control site 1). Normally, high turbidity results are from surface runoffs and from both non-point and point sources. The poor soil conservation practice is one entry source of sediment loads into surface water (Bugenyi and Balirwa, 2003). The increase in turbidity downstream along the Mara River might be a result of sediment loading resulting from diversified land use practices. The mining activities were major contributors of turbidity along Mara River, but other contributors included land tillage from agricultural farms, livestock herding and wildlife descending to drinking water points. The Ngerende sites showed a predominant land use of game conservancy with higher water turbidity. The turbidity levels after the mine site exceeded the standard limits of 10 NTU for drinking water and 300 NTU for domestic use and some aquatic life forms (WHO., 2011). This higher level of turbidity than accepted level might pose health risk to consumers of water. The Kirumi wetland and downstream, showed a reduced turbidity to acceptable level, before water was discharged into Lake Victoria. The water temperature of Mara River ranged between 11.53 ± 0.06°C to 23.73 ± 0.06°C (Table 2). All sites recorded significantly ($p \leq 0.05$) higher temperatures than Ainabsabet Spring (control site 1). The temperatures in all sites in the study were below NEMA upper limit of 35°C for natural surface water (NEMA, 2006).

Ainabsabet Spring (control site 1) registered the lowest TDS (45.22 ± 0.65 mg/l) level closely followed by Nyahenda Stream (control site 2) (59.00 ± 1mg/l) (Table 3). Low total dissolved solids are often characteristic of forested rivers (Chapman and Chapman, 2003). Both control sites were emanating from forested riverbanks,

which probably filtered dissolved solids before discharging to downstream. All sites sampled had higher ($p \leq 0.05$) TDS than control sites. The Kirumi wetland site recorded the highest level of TDS (308.33 ± 2.08 mg/l). The increased TDS levels downstream might be a result of soluble salts from land use practices such as agricultural and mining activities, and vegetative destruction due to over grazing. The wetlands usually have high TDS retention (Tanner et al., 1998). These activities enhance availability and entry of salts through surface runoff and leaching into the river. The pattern was similar to that of electrical conductivity. Despite the observed increase of TDS in Kirumu wetland, the values were within acceptable limit of 1200 mg/l (WHO., 2011), thus may not have considerable effects on water quality to the Mara River water users.

The highest TSS level of 110 ± 1.50 mg/l was recorded from streams passing through the mining site while the lowest TSS level of 6.33 ± 2.31 mg/l recorded around Emarti site which had large wheat and maize farming within its vicinity (Table 3). The large-scale wheat and maize farming around Emarti site area were therefore not contributing to the influx of TSS. The levels of TSS at Emarti site were not significantly different from that at Ainabsabet Spring (control site 1) which was recorded to be 9.22 ± 0.13 mg/l. Insufficient soil conservation practices in agricultural regions increase TSS values (Nightingale and Bianchi, 1980; Bugenyi and Balirwa, 2003).

The soil conservation practices in the study area were adequate to contain the TSS at low levels in the water. Increase in TSS levels along the Mara River was higher in mining sites than agricultural areas. The Mara River water recorded high level of TSS exceeding the 5 mg/l permissible limits (WHO., 2011) while Kirumi wetland recorded TSS level of 24.67 ± 1.53 mg/l before the water drained into Lake Victoria which was below the 30 mg/l permissible limit (NEMA., 2006).

The dominant derivatives of the inorganic nitrogen along the Mara River was the nitrate nitrogen (NO_3^--N) followed by the ammonium nitrogen (NH_4^+-N) and then the nitrite nitrogen (NO_2^--N). The highest NO_3^--N level of 243.65 ± 5.26 µg/l was at Emarti site, which was the nearest site to large-scale agricultural plantations. The farming activities might be the main source of these nutrients. Similar result had been observed on the lower portion of the Mara River in Tanzania where high concentrations of NO_3^- and $P0_4^3$ were originating from the nearby agricultural soils (Kihampa and Wenaty, 2013). Within the Nyando River Basin of Kenya, agricultural land use was the major contributing factor in variations of water quality particularly the nutrients levels (Raburu et al., 2002).

Livestock and wildlife animals increased nitrates levels in adjacent waters (McCartney, 2010). Similar rise in the inorganic derivatives was registered at the Ngerende Site, which was near the section inhabited by hippopotamus and crocodiles. Aquatic vegetation utilizes phosphate and nitrates as nutrients thereby lowering their concentrations in ecosystem (Belke, 2007). This explained the observed low levels of nitrates (3.16 ± 0.20 µg/l) and soluble reactive phosphates (5.53 ± 1.22 µg/l) at Karimi wetland. All the nutrients levels (Tables 4 and 5) in the Mara River water were within acceptable limits with permissible level of total nitrogen of 19 mg/l (NEMA, 2006; WHO, 2011).

SRP and total phosphorous (TP) levels are presented in Table 6. The SRP levels were highest around the Ngerende sites, which were inhabited by a pool of hippopotamus and crocodiles upstream during the sampling period. A previous study (McCartney, 2010), recorded high SRP levels along the Mara River at the New Mara Bridge. This was attributed to the presence of large herds and livestock wastes within the area. Other than the natural phosphate, human and animal excreta are some of the most important sources of phosphate inputs into surface water (Golterman, 1993). Along the Mara River, both wildlife animals and livestock were sources of nutrient loadings particularly phosphorous in water. However the total phosphorous levels in surface water fell within the permissible WHO limit of 10 mg/l (WHO, 1984).

All sites along the Mara River recorded an increase of silicates from the control sites, while the Kirumi wetland site recorded highest concentrations (Table 6). Studies elsewhere show that mining activities and dust were inseparable and the main dust component was silica (Ogola et al., 2001). The increase in silicates levels downstream mining sites were attributed to the mining activities. Vegetative destruction due to mining activities, which result in heaps of sandy soil within the mining sites, accelerates routes of silica dust into the Mara River water. The silicates levels in Kirumi wetland water were above the standard limits of 1 to 30 mg/l in surface water. Therefore, Mara River can be noted as one of the sources of silicate pollution in Lake Victoria. However the silicate concentration in the Mara River water was within acceptable limit of 100 mg/l in surface water (WHO., 2011). The Kirumi wetland reduced ($p \leq 0.05$) all the nutrients concentrations other than the silicates. The wetland is therefore a purification site used in reducing and controlling pollutants nutrients from entering Lake Victoria.

Conclusion

The anthropogenic activities in and around the Mara River Basin have been changing the physiochemical parameters of the river. Despite the changes of water quality, the levels of the physiochemical properties recorded were within acceptable quality standards (NEMA, 2006; WHO, 2011).The Kirumi wetland reduces the nutrients levels hence mitigating pollutant loads from upstream from entering into Lake Victoria. The anthropogenic activities within the Mara River basin

Table 6. Nutrients concentrations in water at different sites along the Mara River.

Site name	Silicates (mg/l)	NO_3^- (µg/l)	NO_2^- (µg/l)	$NH4^+$(µg/)l	SRP (µg/l)	TN (µg/l)	*TP (µg/l)*
Ainabsabet Spring (Control Site 1)	Nd	111.97±1.50	3.20 ±0.1	56.57 ±0.91	32.95 ±1.37	923.24 ±5.77	52.00 ±0.01
Emarti Site	29.50± 1.70	243.65±5.26	15.58±3.96	15.26 ±4.18	78.40 ±1.48	1515.67±7.63	581.00±25.35
Ngerende 1	30.00± 0.00	142.97±2.17	32.03±1.05	30.33 ±0.58	122.68±0.58	1209.33±3.06	479.33±15.14
Ngerende 2	30.33± 0.58	141.73±2.06	33.06±0.96	30.43 ±0.81	123.33±0.58	1206.33±1.53	483.67±4.72
Old Mara Bridge	29.02± 2.89	149.14±6.49	30.50±0.81	31.95 ±1.92	79.46 ±1.94	1309.33±61.85	681.23±68.8
New Mara Bridge	28.83± 1.31	145.36±3.11	13.83±2.81	15.48 ±2.68	69.10 ±1.73	1630.00±96.56	373.47±8.66
Tarime (Before Mines)	26.08± 0.10	41.41 ±2.05	21.73±6.35	24.23 ±1.97	46.38 ±2.28	1285.13±4.39	456.00±2
Tarime(After Mines)	32.50± 3.83	8.08 ±2.35	8.07 ±1.79	13.15 ±0.27	17.78 ±2.92	1093.40±24.48	505.33±3.05
Nyahenda Stream (Control Site 2)	21.47± 0.33	5.37 ±0.30	0.10 ±0.01	5.73 ±0.46	6.13 ±0.42	223.57 ±2.22	42.32 ±0.34
Kirumi(Wetlands)	65.80± 0.65	3.16 ±0.20	0.37 ±0.46	8.18 ±0.57	5.53 ±1.22	442.07 ±5.25	95.19 ±2.50
CV (%)	5.76	3.19	16.70	8.06	2.82	4.70	6.38
LSD (p≤0.05)	2.88	5.39	4.51	3.17	2.78	86.69	40.76

Nd = not detected, SE = Standard error.

needed to be control with appropriate policy strategies to mitigate water pollution in future. In addition, the Mara River water quality needs periodical monitoring and evaluation, to determine any possible adverse increase of physiochemical downstream. The Mara River basin should have land use planning and strategies to discourage inhabitants from land tilling, up to the banks of the river in order to conserve the bank vegetation to reduce erosion and sediment loading in the Mara River. The Kirumi wetland should be conserved and integrate the wise use aspect, due to its significance in the reducing of nutrients concentration entering the Lake Victoria.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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