EFFECTS OF AGRICULTURAL NUTRIENTS INFLUX ON WATER QUALITY IN THIBA RIVER BASIN, A SUB-CATCHMENT OF TANA RIVER BASIN IN KIRINYAGA COUNTY, KENYA

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ABSTRACT

Excessive enrichment of waters with nutrients and the associated adverse biological effects leads to eutrophication, which is one of the major environmental problems across the world. Various studies have revealed the overuse of inorganic fertilizers to increase agricultural productivity in Kenya, which contributes to pollution of water bodies. In order to meet increasing demand for clean water, sustainable use and conservation of available water resources is therefore paramount. This study was done to find out effects of agricultural nutrient pollution in Thiba River, a sub- catchment of Tana River Basin, located in Kirinyaga County, Kenya. The study area was divided into four distinct agro-ecological zones based on different anthropogenic activities. Ecological survey design was used in the study. Sampling was done during the wet and dry season. Water samples were analyzed for temperature, transparency, pH, electrical conductivity (EC), dissolved oxygen (DO), biological oxygen demand (BOD), phosphates, nitrates, nitrites, ammonia and toxic microalgae. All parameters showed both spatial and temporal variations with statistically significant differences. Temperature of the river ranged from 14.57 ^{0}C to 28.08 ^{0}C due to climatic changes along the agro-ecological zones. The pH ranged from 7.02 to 8.51. The DO values decreased from the highlands to lowland within the range of 9.00 mg/l at the reference site to 5.43 mg/l at the most polluted site. EC ranged from 20.54 µScm^{-1} at the reference site during the wet season to 251.2 µScm^{-1} at the rice irrigation scheme site during the dry season. Water transparency ranged from 15cm to 81cm. This was low during the wet season and high during dry season. The highest values of BOD (3.49 mg/l) were recorded at the rice irrigation scheme during the wet season and the lowest (0.22 mg/l) at the forest edge reference site. The lowest levels of NH_4, P, NO2 and NO3 were recorded at the forest edge reference site at 1.088 µg/l, 1.177 µg/l, 0.217 µg/l and 0.148 µg/l respectively during the dry season while the highest values for the same nutrients were recorded at the rice irrigation site at 11.439 µg/l, 4.933 µg/l, 1.518 µg/l and 2.721 µg/l in the same order. There was a high peak of all nutrient levels at the rice irrigation scheme zone which was attributed to the extensive use of inorganic fertilizers. Dam water samples were analyzed for members of Cyanobacteria group of microalgae which are bio-indicators of eutrophic waters. Out of the seven members of this group that were identified four were toxic genera. These were *Nostoc, Oscillatoria, Anabaena* and *Microcystis.* During the wet season *Nostoc* had the highest population followed by *Oscillatoria* and *Anabaena.* No *Microcystis* was observed during the wet season. There was a steady increase of all the genera during the dry season with *Microcystis* making appearance. *Microcystis* and *Oscillatoria* had a very high correlation. This study concludes that various anthropogenic activities especially agriculture along the study site are the main factors of Thiba River pollution hence a major threat to human, livestock and aquatic organisms. Environmental protection laws should be enforced by the government.

Key words: Phytoplankton, Eutrophication, Nutrients, Cyanotoxins, Physico-chemical

INTRODUCTION

Agriculture is among the greatest contributor of non-point source pollution to water sources in various parts of the world where intensive agriculture occurs (Berka *et al*., 2001). Agricultural nonpoint sources and other anthropogenic inputs are important contributors of nutrients to the aquatic environment, especially nitrogen (N) and phosphorus (P) (Borbor-Cordova *et al*., 2006). Phosphorus found in fresh water bodies is mainly anthropological in origin with about 38% coming from agriculture. Excessive enrichment of waters with nutrients and the associated adverse biological effects leads to eutrophication, which is still one of the major environmental problems across the world water (Bøgestrand *et al*., 2005). Environmental consequences of nutrient pollution from agriculture may include the degradation of downstream water quality, the eutrophication of water bodies and elevated concentrations of nitrous oxide, a powerful greenhouse gas (Mozumder and Berrens., 2007). Pollution by nutrients affects the health of humans and aquatic organisms as well as increasing water treatment costs (USEPA, 2017).

Studies have revealed overuse of inorganic fertilizers to increase agricultural productivity in Kenya (Njuguna *et al*., 2017). This is evident in Kenyan inland lakes. For instance, the Kenyan side of Lake Victoria has the highest Biological Oxygen Demand, BOD (Peter *et al*., 2020). Large scale farming of cash crops has been identified as a major source of inorganic fertilizers that pollute water bodies in Kenya (Maghanga *et al*., 2013). Thiba River Basin, is part of the Tana River Basin. The water is used for domestic purposes and discharges into Kamburu Dam, one of the five hydroelectric power generation dams in Kenya. Economic activities along the lake and the rapidly growing population, have mounted environmental pressure on this source of freshwater in central Kenya (Muriuki *et al.,* 2016). According to (Heisler *et al*., 2008) there is a relationship between nutrient pollution and harmful algal blooms. Phosphorus in water is a major driver of eutrophication. Eutrophic water is characterized by harmful algal blooms formed mainly by members of cyanobacteria group or blue green algae. These produce several types of toxins that are collectively called cynotoxins. These toxins are contained within the cell walls but are released into the water after rupturing of the cell wall upon death and lysis of the alga. Some species are believed to release the toxins extracellularly into the water while still living (USEPA, 2017).

MATERIALS AND METHODS

This study was carried out in Thiba River basin, in Kirinyaga County, Kenya. It lies between 0°34'23.43"S and 37°19'31.7"E (Fig. 1). The County has a total area of 1,478 square kilometers. The basin is characterized by intensive agricultural activities including large-scale cultivation of crops and the largest rice irrigation scheme in Kenya (Veldkamp., 2012). The river passes through the middle of the County and discharges into Kamburu

Dam.

Study Design and Selection of Sampling Stations

The method adopted in the study was ecological survey design. Data was collected and analyzed without manipulation. The study area was divided into four distinct agro ecological zones (Jaetzold *et al*., 1982). The first station was at the forest edge (Kimunye) and served as the reference point (Fig. 1). The second station was Kutus Bridge in the highlands. In this zone is grown tea and coffee as cash crops. There is also dairy farming and small-scale agriculture for subsistence. The third station was at Ndindiruku Bridge in the midlands zone. It is characterized by extensive rice irrigation and horticultural farming. The rest of the stations were located in Kamburu Dam in the lowlands. It is characterized by high temperatures and insufficient rainfall. This zone is dominated by free range livestock keeping and subsistence rain-fed farming of food crops that are tolerant to drought. The three dam stations were equally spaced from the River mouth to the point of exit from the Dam. Sampling was carried out for one year covering both the wet and the dry seasons.

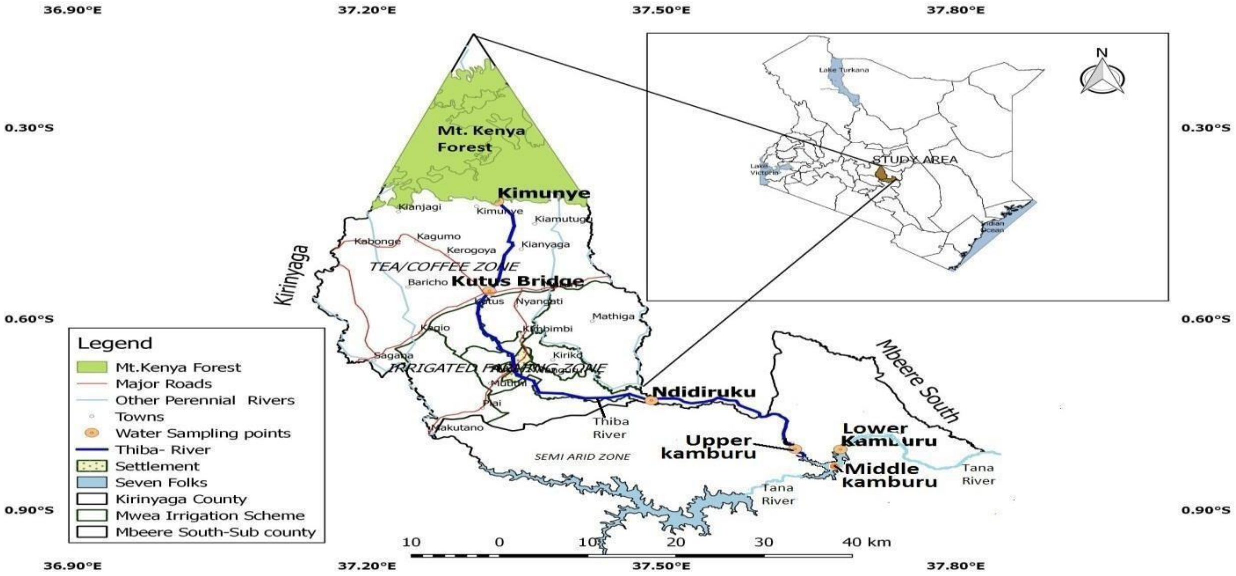

Figure 1: Map of the study site

Analysis of Water Samples

Water samples were collected according to Musselman and Robert (2012) in sterilized 250 ml plastic bottles and transported to the lab in an ice box at 4^0C. The physical-chemical parameters analyzed were temperature, transparency, pH, electrical conductivity, salinity, total dissolved solids and dissolved oxygen. These were recorded *in situ* using a digital meter model 605596-YSI-Proplus USA. Agricultural nutrients analyzed were Phosphates, Nitrates, Nitrites and Ammonia. These and BOD were done according to standard procedures as outlined Matsche and Kreuzinger, (2001) and APHA, (2012). Phytoplankton were collected by filtering 20lts of sample water through a 25µm mesh size cone shaped plankton net with a 50 ml concentrate bottle. Microalgae were examined under a phase contrast microscope using a bright field at a magnification of ×100 and ×400. Identification of the algae was done using keys based on standard morphological taxonomy (Stadtlander et al., 2013, Cilliers et al., 2021). Microalgae were counted using sedwick rafter chamber method. Data analysis was done using computer software SPSS version 22.0.

RESULTS

Analysis of Physico-chemical parameters

Analysis of variance (ANOVA) of the data showed highly significant differences of $p<0.01$ for all parameters in all sampling stations in spatial and temporal variations except DO. At Kutus Bridge DO did not show any significant difference in temporal variation at $p=0.39$. Machan'ga also did not show any significant difference in temporal variation of the same parameter at $p=0.59$. All the other sampling stations showed highly significant differences of $p<0.01$ for the parameter. For BOD there were highly significant differences of $p<0.01$ in both temporal and spatial variations for all the stations. There were highly significant differences of $p<0.01$ in both spatial and temporal variations for all the four agricultural nutrients in all the sampling stations.

The spatial temperature of the river ranged from 14.57 ^{0}C to 28.08 ^{0}C. The lowest temperature was recorded at the reference point near the forest edge during the dry season while the highest temperature was recorded at the middle of the dam during the wet season. There was a general increase in average temperatures from the forest zone towards the lowlands with the uppermost sampling point registering the coldest temperatures and the lower-most sampling points registering the warmest temperatures. The mean annual recordings were 14.57 ^{0} C at the forest edge, 18.6 ^{0} C at large-scale agriculture site, 22.72 ^{0} C at rice irrigation scheme site and a mean of 28.08 ^{0}C at the dam. The pH ranged from 7.02 at the reference site during the wet season to 8.51 at the dam during the dry season. The pH values increased as the river flowed from the highlands to the lowlands with the lowest values being recorded at the reference site and the highest at the upper part of Kamburu Dam. The pH values during wet season were 7.024, 7.490, 7.262, 7.87, 8.348 and 8.36 for Kimunye, Kutus Bridge, Ndindiruku Bridge, upper Kamburu, middle Kamburu and lower Kamburu respectively. The DO values showed both temporal and spatial variation within the sampling points (Fig. 2). The highest was recorded at the reference site (9.002 mg/l) during the wet season. The average values of DO decreased from the highland zone towards the lowlands zone. The annual same site averages were 8.587 mg/l, 7.840 mg/l and 6.403 mg/l for the reference point, large-scale agriculture point and rice irrigation scheme site, respectively. The annual averages within sampling points in the Dam were 7.357 mg/l, 7.416 mg/l and 7.718 mg/l for upper Kamburu, middle Kamburu and lower Kamburu Dam respectively. The average DO values for all Dam sites taken at different seasons showed that DO was lower during the wet season compared to the dry season

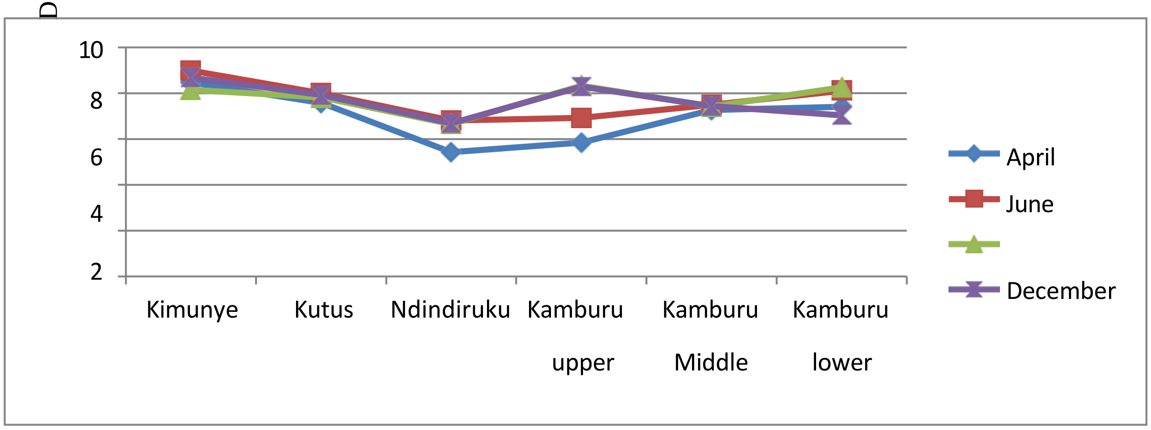

Figure 2: Spatial and temporal changes in DO values along the study site

There was wide temporal and spatial variation in Electrical Conductivity (EC) among the sites. The highest value was 251.2 µScm^{-1} recorded at the rice irrigation scheme site during the dry season while the lowest (20.54 µScm$^{-1)}$ was recorded at the reference site during the wet season (Fig. 3). The highest variation was 133.72 µScm^{-1} recorded between the dry and wet seasons at the irrigation scheme site of Ndindiruku. The lowest same site variation was 1.96 μScm^{-1} recorded at the reference site between the dry and wet seasons as well. The EC values also followed a similar pattern noted on other parameters of steady increase from upstream to downstream. Notably the increase was drastic at the rice irrigation site (Ndindiruku) during the dry season.

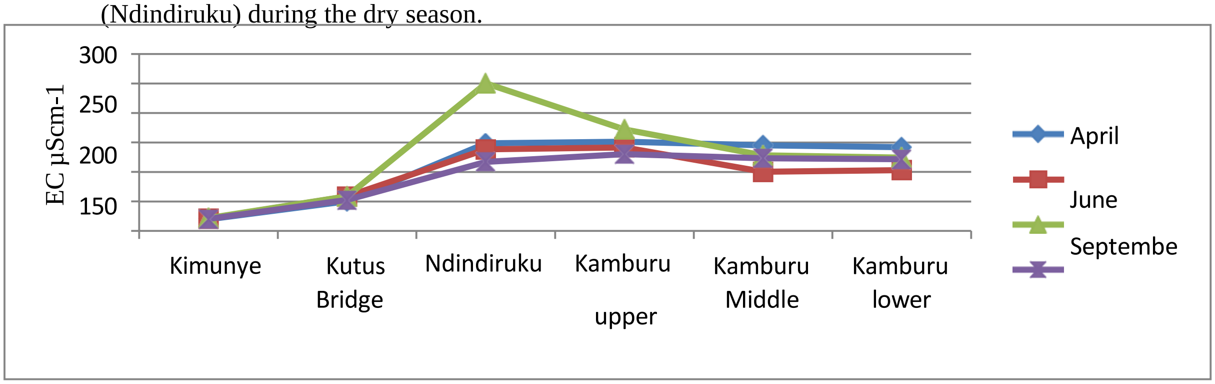

Figure 3. Spatial and temporal variations in EC values along the study site

Biological Oxygen Demand (BOD) showed a lot of spatial and temporal variations. The highest value of 3.49 mg/l ±0.192 was recorded at rice irrigation scheme area during the wet season. (Fig.4). The lowest BOD value was 0.22 mg/l ±0.10 recorded at the reference site during the wet season. Temporal variations of BOD were highest at the reference site. The lowest was in upper Kamburu. Unlike other parameters, BOD trends along the study site changed drastically between seasons. For instance, during the long rains, the BOD showed a downward trend from the forest edge through the large-scale agricultural area to the rice irrigation scheme with wide fluctuations at the dam. During the dry season the trend was reversed starting low at the forest edge and increasing downstream with wide fluctuations in the Dam. During the dry season BOD peaked at 3.49 mg/l ±0.192 in the rice irrigation area then took a downward trend downstream to 1.40 mg/l ±0.081at the lower end of the dam. BOD values were comparatively lower during the dry season except at upper Kamburu where the river discharged its water.

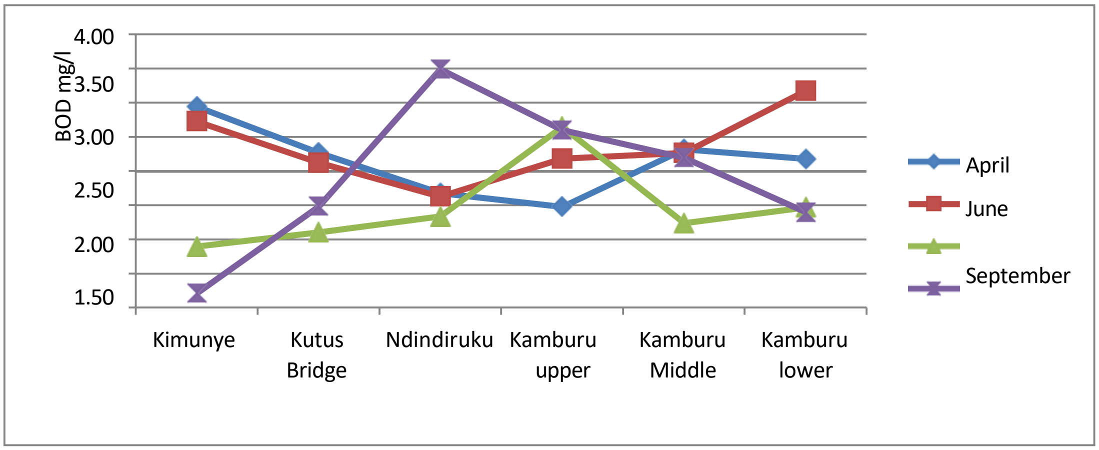

Figure 4. Spatial and temporal variation in BOD values along the study site

Correlation Analysis for Physico-Chemical Parameters

Correlation analysis showed that most of the parameters had similar correlation during both the wet season and dry seasons except for DO and pH that had negative correlation during the wet season (Table 1 and 2). DO showed negative correlation with all the parameters during the dry season but during the wet season it showed a strong correlation of 0.92 with water clarity. Water clarity and temperature were strongly correlated during the wet season at

0.86 but this became very weak during the dry season at 0.05. Water clarity and pH were also strongly correlated during the wet season at 0.902 but during the dry season the two become inversely correlated at −0.28. During the dry season the two become inversely correlated at −0.11. Water clarity and EC were also strongly correlated during the wet season but during the dry season the two became inversely correlated at −0.93. Ammonia and pH showed a weak

correlation of 0.42 which increased to 0.63 during the dry season. Water clarity and agricultural nutrients are inversely correlated during both wet and dry seasons.

	temps	*pH*	*D.O*	*E.C*	*TDS*	*Salinity*	*Water clarity*	*PO4*	*NO2*	*NO3*	*NH4*
temps	1.0000										
pH	0.8832	1.0000									
D.O	-0.4723	-0.053	1.0000								
E.C	0.9259	0.6557	-0.7523	1.0000							
TDS	0.8929	0.5938	-0.8075	0.9960	1.0000						
Salinity	0.8713	0.5660	-0.8425	0.9852	0.9953	1.0000					
Clarity	0.8698	0.9025	0.9295	-0.9943	-0.9560	-0.8963	1.0000				
PO4	0.5005	0.0519	-0.9556	0.7641	0.8132	0.8307	-0.985	1.0000			
NO2	0.6500	0.2686	-0.9749	0.8745	0.9131	0.9372	-0.951	0.9369	1.000		
NO3	0.6287	0.2078	-0.9548	0.8652	0.9026	0.9122	-0.998	0.9809	0.973	1.000	
NH4	0.7863	0.4241	-0.9001	0.9556	0.9760	0.9788	-0.997	0.9164	0.966	0.973	1.00

Table1. Pearson correlation matrix for physico-chemical parameters during the wet season

	temps	*pH*	*D.O*	*E.C*	*TDS*	*Salinity*	*Water clarity*	*PO4*	*NO2*	*NO3*	*NH4*
temps	1.0000										
pH	0.8279	1.0000									
D.O	-0.3149	0.1878	1.0000								
Conductivity	0.7775	0.5077	-0.5825	1.0000							
TDS	0.7583	0.4798	-0.5903	0.9992	1.0000						
Salinity	0.7591	0.4782	-0.5813	0.9979	0.9993	1.0000					
Water clarity	0.0543	-0.2812	-0.1177	-0.9336	-0.9240	-0.8536	1.0000				
PO4	0.5934	0.3512	-0.6166	0.9523	0.9563	0.9479	-0.9796	1.0000			
NO2	0.5598	0.4112	-0.4948	0.9270	0.9310	0.9272	-0.7054	0.9648	1.0000		
NO3	0.6964	0.3948	-0.6747	0.9558	0.9557	0.9451	-0.9433	0.9727	0.8899	1.0000	
NH4	0.7917	0.6358	-0.4564	0.9750	0.9686	0.9636	-0.8206	0.9405	0.9400	0.9314	1.00

Table 2. Pearson correlation matrix for physico-chemical parameters during the dry season

Analysis of Inorganic Nutrients

The nutrients had similar trends. The lowest levels of NH_4, P, NO_2 and NO_3 were recorded at the forest edge site at

1.088 mg/l, 1.177 mg/l, 0.217 mg/l and 0.148 mg/l respectively during the dry season. The highest values for the same nutrients were recorded at the rice irrigation site at 11.439 mg/l, 4.933 µg/l, 1.518 mg/l and 2.721 mg/l for NH_4, P, NO2 and NO3 respectively (Fig. 5 and 6). These levels remained high during the wet season but were slightly lower than those recorded on the same site during the dry season. There was a high peak of all nutrient levels in the rice irrigation site.

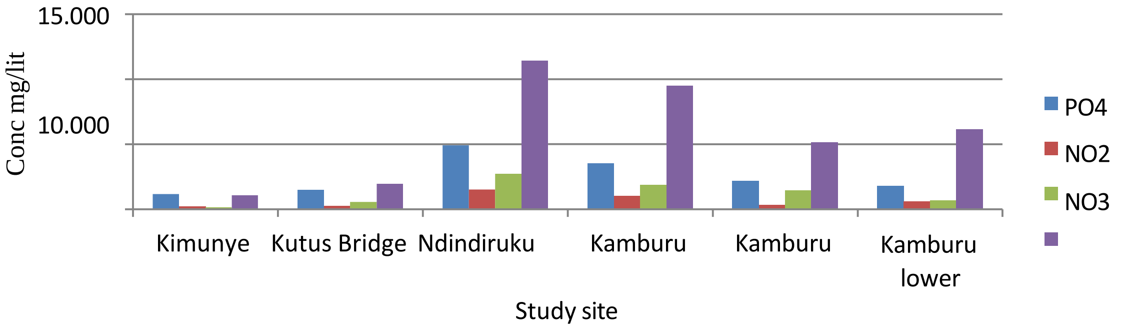

Figure 5: Inorganic Nutrient levels along the study site during the dry season

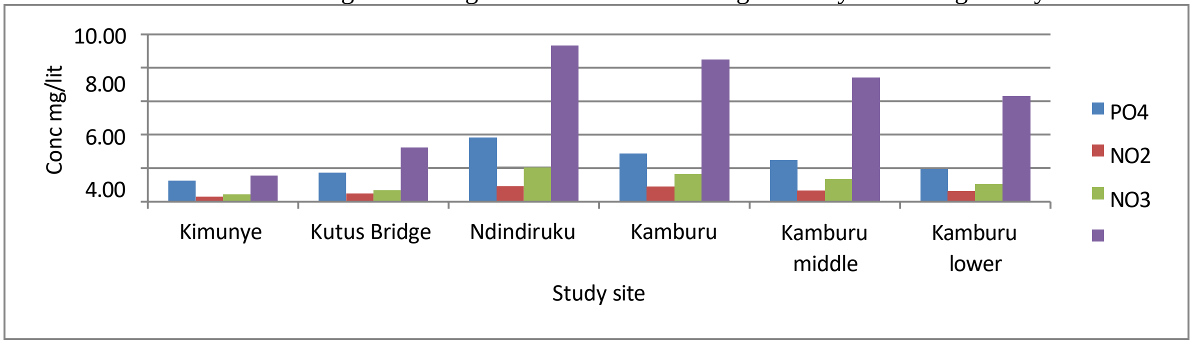

Figure 6: Inorganic Nutrient levels along the study site during the wet season

Characterization of microalgae from Kamburu Dam

Analysis of microalgae present in the water samples revealed a total of thirty two genera. Most of the microalgae were from Chlorophyta (12 genera), Ochrophyta (8 genera), Cyanobacteria (7 genera), Charophyta (3 genera) and Euglenozoa (2 genera). This study focused on the division of Cyanobacteria or blue green algae because it has toxic species that pollute water bodies and form harmful algal blooms. These produce cyanotoxins that are a health hazard to both humans and animals and therefore their presence is a water quality problem. Out of the seven genera in this division, four were found to be toxin producing species. These were *Microcystis*, *Anabaena*, *Nostoc* and *Oscillatoria* (Fig. 7). The population of these microalgae varied greatly between seasons. During the wet season the highest population belonged to *Nostoc* (950) followed by *Oscillatoria* (200), *Anabaena* (450) and none for *Microcystis*. During the dry season the population increased to 2,500, 1,050, 1,600 and 600 for *Nostoc*, *Oscillatoria*, *Anabaena* and *Microcystis* respectively. Generally the population of microalgae was lower during the wet season with no *Microcystis* being observed but increased considerably during the dry season.

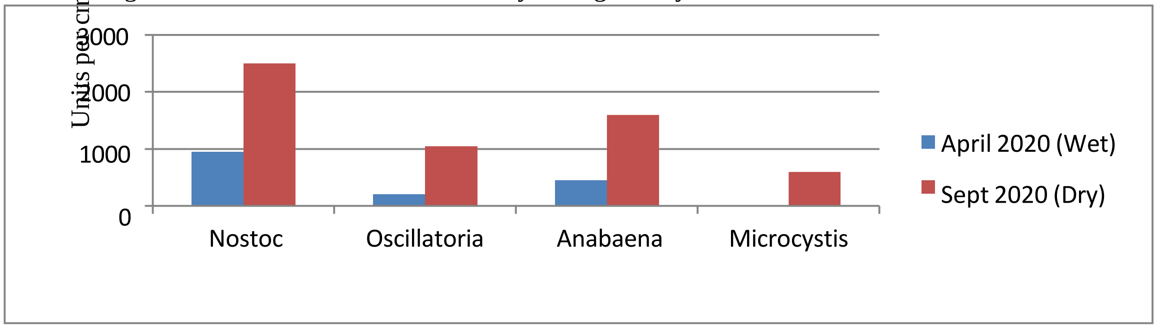

Figure 7: Seasonal variations in abundance of toxic algae in Kamburu Dam

On correlation analysis *Anabaena* and *Nostoc* were negatively correlated while *Microcystis* and *Oscillatoria* had a very high correlation with each other. In one of the samples *Oscillatoria* was observed to grow inside a colony of *Microcystis*. There was also a strong correlation between the microalgae and the four agricultural nutrients. For instance, there was a strong correlation between *Nostoc*, PO_4 and NH_4. For *Oscillatoria* and *Microcystis* the strongest correlation was with NO_2.

Table 3. Correlation analysis for toxic algae and nutrients within study

site

	Nostoc	*Anaebaena*	*Oscillatoria*	*Microcystis*	*PO4*	*NO2*	*NO3*	*NH4*
Nostoc	1							
Anaebaena	-0.04	1.00						
Oscillatoria	0.31	0.54	1.00					
Microcystis	0.28	0.48	1.00	1.00				
PO4	0.78	0.55	0.75	0.71	1.00			
NO2	0.63	0.22	0.90	0.90	0.81	1.00		
NO3	0.65	0.72	0.51	0.45	0.91	0.50	1.00	
NH4	0.72	0.30	0.87	0.86	0.90	0.98	0.64	1.00

DISCUSSION AND CONCLUSION

The temperature range of 13.6 ^{0}C – 28.84^{0}C recorded in the study site was notably wider compared to other tropical water bodies but falls within the normal range. Water reservoirs in central Kenya showed a mean range of 21.6 ^{0}C – 24.3 ^{0}C (Kitur, 2009). The wide temperature range recorded in this study is attributed to the geographically wide study area that cuts across several different ecological zones with the coldest temperatures being recorded at the forest edge. The results are comparable to those recorded in a study on Molo River, Kenya that found the range to be 14.02 ^{0}C - 31.5 ^{0}C (Chebet et al., 2020). In Nigeria it was found that surface temperatures for main rivers ranged from 22.6 ^{0}C – 31.0 ^{0}C which is much higher (Ajibade *et al*., 2008). The reference site is at the highest altitude (1,831.2 meters) and had the lowest annual average temperatures while lowermost site at 1,011.3 meters had the highest annual average temperatures. Water temperatures therefore reflected those of the air across climatic zones.

The pH range of the study site was 7.024-8.5 A study on Molo River in Kenya found the range to be higher at 7.90 – 9.66 (Chebet et al., 2020). The pH was lower during wet season compared to the dry season. This trend is similar to that observed in Asa inland lake, Nigeria that ranged between 7.3 to 8.1(Araoye, 2009). This is attributed to increase in chemical pollutants that make water more acidic during the rains. There was higher pH in the dam than in the river. This increase is attributed to higher algal growth in the dam due to accumulation of nutrients and more favourable conditions for algal growth. Carbon dioxide exists as weak carbonic acid in water. Photosynthetic activity by algae in the Dam extracts CO_2 from the water making it more basic. This is why pH is higher in the Dam than in the river where algae growth is less. According to Osman and Kloas, (2010) most fresh water bodies have a pH range of 6.0- 8.0. A pH range of 6.5- 8.5 is considered safe for both humans and animals (EPA, 2002).

The DO is an important parameter for measuring water quality because it indicates the ability of a water body to support aquatic life. The amount of DO is influenced by temperature. Cold water holds more oxygen than warm water (Taseli, 2006). This is why the levels of DO are higher at the reference site where temperatures are low. Secondly at higher altitudes land gradient is steeper compared to the lowlands where it is gentle. Water flow is therefore faster in the highlands. There is more mixing of water with air more so with many rapids and cataracts created by the rocky bed that is characteristic of high altitude rivers. According to Robert *et al*., (2019) gas transfer velocity in rivers varies spatially and is usually higher in rapids and lower in quiescent sections of the river. The ideal DO range for fresh water aquatic life is 6.5 mg/l – 8.0 mg/l hence the value of 5.43 mg/l recorded at the rice irrigation site is too low for aquatic life. This is the section of the river where agricultural activities were highest and pollution was highest. Rice processing in the study area produce large amounts of organic wastes. With no proper systems of disposal these eventually end up in the river through runoff. Aerobic microbial decomposition of these wastes depletes O_2 from the water and accounts for the abnormally low DO on this site. Improvement of DO levels in the Dam is attributed to photosynthetic activity of microalgae that consumes CO_2 and releases O_2 into the water.

Electrical Conductivity indicates the amount of dissolved substances in the water that releases ions. EC values in the showed a very drastic change increasing sharply downstream from 20.54 µScm at the reference site to 251.20 µScm at the rice irrigation site. This is considerably high compared to the range of Masinga Dam within the same basin whose range was narrower at 89.70 µScm – 168.83 µScm (Nzeve, 2015). The range for the study area is lower compared to that of Lake Naivasha which seems much more polluted at 270 µScm – 305 µScm (Mwamburi, 2013). The value of EC is dependent on the concentration of ions and temperature. The sharp increase of EC downstream is attributed to increase of ion releasing pollutants especially inorganic fertilizers from irrigation farming. The EC values increased steadily downstream to peak sharply at the irrigation site, a clear indication of increased water pollution at this area.

The BOD is one of the most important and widely used parameter for characterizing the organic pollution of water. It is indicates the amount of oxygen required by aerobic microorganisms to degrade the organic matter in the water to carbon dioxide and water (Sulivan *et al*., 2013). Sources of organic matter are natural decaying of plants and animals as well as anthropogenic activities such as agricultural runoff, urban runoff and industrial wastewater discharge. Occurrence of these pollutants in high levels may result in the aerobic microorganisms using all the oxygen in the water for their degradation creating anaerobic conditions that kill aquatic life and cause bad odours (Gary, 1999). The

wide variation in BOD recorded was as a result of both natural and anthropogenic causes. The sharp BOD raise at the irrigation site and upper Kamburu is attributed to pollution of the river by organic wastes from both agricultural and urban settlements. The BOD values recorded at the reference forest site during the rains is predominantly from natural origin. According to (Tatiana *et al*., 2016) large amount of dead plant material decomposing on the forest floor generates large amounts of water soluble organic substances such as humic and fulvic acids. These find their way to rivers and lakes through surface runoff and leaching during the rains where they cause large changes in BOD (James *et al*., 2014). According to Joaquim, (2010) BOD less than 4 mg/l is considered to be reasonably clean. BOD was highest at the irrigation site due to increased pollution

Ammonia exists in water as unionized ammonia (NH_3) or as ionized ammonia (NH_4^+). The proportion of these two forms of Ammonia in water is dependent on pH. The unionized ammonia is the toxic form and is dependent on temperature (Forrest, 2005). Ammonia in levels above 0.53 mg/ are considered toxic to fresh water organisms. Excessive and continuous input of nitrogen contaminants into rivers is the fundamental reason for high concentration of ammonia in rivers (Zhang *et al*., 2007). Very high levels of Ammonia were recorded at the rice irrigation site and downstream stations during both wet and dry seasons peaking at 11.439 µg/l at the irrigation site. The high levels are due to the intensive agricultural activities and use of fertilizers (Du *et al*., 2017). In the current study the high ammonia levels are attributed to widespread use of Diammonium Phosphate fertilizer (DAP) in irrigation agriculture. The decline in ammonia levels downstream is attributed to microbial activities by denitrifying bacteria taking place in the water being part of the nitrogen cycle.

Nitrates and Nitrites occur naturally as part of the Nitrogen cycle. The transformation of nitrite to nitrate is affected by temperature (Lizhi *et al*., 2016). Being unstable NO_2^- is more reactive and has serious health consequences in both humans and animals and therefore creates water quality problems. At high levels it creates nitrite toxicity which causes fish mortalities and blue baby syndrome in humans (Tilak *et al*., 2007). Nitrites can also react with amines and amides in human bodies to form highly carcinogenic N-nitroso compounds (Parvizishad *et al*., 2017). Nitrates and Nitrites are discharged into water bodies mainly through surface runoff and leaching (Larry *et al*., 2002). Nitrate ions (NO_3^-) are loosely bound in soil and being water soluble they are easily carried by surface runoff and also leached into ground water during the rains (Larry *et al*., 2002).

Sources of phosphates in water are mainly non-point such as erosion and sedimentation, decomposition of naturally occurring minerals, atmospheric deposition and agricultural runoff (USEPA, 2017). Phosphorus may also be from point sources where industrial and organic wastes such as sewage are discharged into rivers. Phosphorus is critical in supporting aquatic life but is a major driver of eutrophication when in excess (Hossain *et al*., 2006). Temporal and spatial distribution of phosphates followed a similar pattern to that of nitrates although comparatively higher in quantities. Similar findings were reported by Adesuyi *et al*., (2015) in a study of Nwaja Creek, Nigeria. This strongly suggests that the phosphates and nitrates have common origin chiefly inorganic fertilizers from irrigation agriculture practiced around the study site.

Algae are good indicators of pollution owing to their wide temporal and spatial distribution, rapid reproduction rates and short life cycles (Wan, 2010). Algae species are specific and well correlated with particular types of pollution. Cyanobacteria which are toxic grow well in organically polluted water and their absence is an indicator of clean water (Bulent *et al*., 2013). *Oscillatoria* is tolerant to organic pollution and is a good indicator of organically polluted water. Excessive growth of toxic algae is largely caused by nutrient pollution particularly N and P (Donald *et al*., 2002). In high densities cyanobacteria are an undesirable component of fresh water ecosystems because they produce cyanotoxins that disrupt food webs by killing aquatic organisms (Karl, 2012). *Microcystis, Anabaena, Nostoc* and *Oscillatoria* produce microcystin and cyanopeptolin which are neurotoxins and hepatotoxins (Havens, 2008). Cases of cyanotoxin poisoning have been reported in Kenya. In 1999, about 30,000 flamingoes died in Lake Bogoria, Kenya from cyanotoxin poisoning (Krienitz *et al.,* 2004). In addition, mass mortalities of fish along the Kenyan coast have been attributed to harmful algal blooms (Linet and Kiteresi, 2013). The presence of four toxic genera in Kamburu Dam is a matter of concern that requires immediate action to control nutrient pollution in Thiba River Basin.The increase in algal populations during the dry season is attributed to increased sunshine, warmer water temperatures and increased light penetration as a result of settling down of the suspended particulate matter all of which are favourable to algae growth (Chokchai *et al*., 2011). During the rains water transparency is reduced and light penetration low due to increased turbidity mainly from soil particles from a degraded catchment. This curtails photosynthetic activity hence the low algae population during the wet season.

CONCLUSION AND RECOMMENDATIONS

This study concludes that various anthropogenic activities especially agriculture along the study site is the main factor contributing to water pollution hence a threat to human, livestock and aquatic organisms. Values in physico-chemical properties varied along the site during both the wet and dry season while those of nutrients increased steadily from upstream to downstream. Major area of concern was at the rice irrigation scheme where high level of nutrient pollution was recorded rendering the site unsuitable for aquaculture. Pollution of Thiba River by agricultural nutrients from the irrigation scheme is responsible for the rapid growth of microalgae in Kamburu Dam. This poses an environmental threat to the reservoir if left uncontrolled. Another concern is the abundance of toxic microalgae in the dam that if left unchecked could make the Dam eutrophic and eventually an ecological disaster. To cub this trend, environmental protection laws in the County with particular emphases to water pollution should be strictly enforced. This would create a sustainable water resource that can be used for aquaculture for income generation and increased food security. Influx of nutrients into rivers can be controlled by using irrigation outflows to irrigate other food crops instead of directing it back to the river.

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