ASSESSMENT OF HEAVY METALS CONTAMINANTS IN NKENYE STREAM IN MERU SOUTH, KENYA

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ABSTRACT

Access to portable water remains a major global concern due to its dimishing supply and increasing and competiting demand. Water scarcity is aggrevated by the increasing pollution from different sources. Nkenye stream in Meru South is depended upon source of water for domestic, agriculture and agricultural processing, Nonetheless, little attention has been accorded to ascertain the quality of its water despite of the stream being located in an urban area with high exposure to pollutants. Pressure on Nkenye wetlands ecosystem that habour Nkenye stream has seen major destruction of riparian leaving just few plant communities such as *Commelina banghalensis* whose water purification potential is not well known. A study was conducted to determine water quality of Nkenye stream. Samples were collected at designated locations using ecological survey method and taken to Chuka University for analysis. Macrophyte roots were cleaned and dried then powdered and digested using nitric acid. Sediment samples were dried, ground to pass a 2 mm non-metal sieve.The digested samples were diluted and analyzed using atomic absorption spectrometry model PG990 at Chuka University. The concentration of anions was determined by ion chromatography at Chuka University Chemistry laboratory. The results obtained from the field and laboratory were analyzed by General linear model (GLM) on Statistical analysis system (SAS) version 9.4 and significance means separated by Least significance difference (LSD) [alpha = 0.05]. The results showed that Nkenye stream is polluted with iron, copper and lead. However, the concentration of iron and copper were within the allowable concentrations for potable water by the World Health Organization while lead was slightly higher by 0.02 ppm. The results obtained were analyzed by General linear model (GLM) on Statistical analysis system (SAS) version 9.4 and significance means separated by Least significance difference (LSD) [alpha = 0.05]. The metals contaminants observed in the Nkenye stream water, sediments and root samples may be associated with discharge of wastes from Chuka town particularly wastes from car wash, garages and from farms that surround the stream and the wetland. Considerable amount of lead, copper and iron was observed in the root samples of *Commelina banghalensis.* This is an indication that *Commelina banghalensisfo* can be used can be used for the removal of contaminants from water. Local authorities should provide waste management disposal systems and policies that prohibit direct discharge of untreated effluents into the stream.

Keywords: Water quality, Heavy metals, Nkenye Stream, Meru South, Kenya

INTRODUCTION

Wetlands are areas where water is the primary factor controlling the environment and the associated plant and animal life, occurring where the water table is at or near the surface of the land, or where the land is covered by shallow water (Hammer & Bastian, 2020).). Wetlands can be classified as natural and artificial (constructed wetlands) (Yilma and Kim, 2003; Odum, 2016). Wetlands support highly diverse biological communities and provide extensive ecosystem services like heavy metal stabilization and phytoextraction (Bouchard *et al.,* 2007; Bassi *et al.*, 2014). Wetlands are the key in ecosystem processes such as, water purification due to its richness and in plant cover (Vymazal and Březinová, 2015; Odum, 2016).

Water contamination with heavy metals such as cadmium, chromium and copper at higher concentrations can lead to oxidative stress and growth inhibition in plants (Gill, 2014), Mercury, lead, cobalt, iron and nickel whose high concentration in the vegetative organs of most plants reaches toxicity at around 10-15 mg/l (Leguizamo *et al.,* 2017), While manganese and zinc which at high concentrations can cause muscular stiffness, loss of appetite, nausea and irritation (Meittei and Prasad, 2014) and arsenic pose a serious threat to humans due to their persistence, toxicity, non-destructible nature in the environment and their bioaccumulation in the food web (Fang *et al.*, 2014; Bortey-Sam *et al.*, 2015; Chopra and Pathak, 2015). The concentrations of chemical pollutants of Nkenye stream have been studied by (Ombaka *et al.*, 2013). Though chemical pollutants concentration was reported to be low (Ombaka *et al.,* 2013), However, little research has been done to evaluate the amount of chemicals load absorbed by macrophytes as a mean of improving water quality in this study area.

Waste water discharged into surface waters limits the availability of portable water for household and agricultural use. Sewage treatment systems such as activated sludge process, membrane bioreactors, and membrane separation have been used successfully for domestic waste water treatment in large cities (Li *et al.*, 2014). However, the installation and use of these treatment technologies is expensive complicating their use in rural set up (Chen *et al.,* 2014). Phytoremediation through Phytoextration and Phytostabilization is an effective, affordable and environmentally sustainable alternatives that can be used for sustainable sanitation and wastewater purification compared to conventional technologies (Sehar *et al.,* 2013; Ribadiya and Metha, 2014), Macrophytes; such as *Typha latifolia, Phragmites australis, Cyperus papyrus, Echinochloa pyramida*lis and *Typha dominguensis* have been reported to be key player and efficient in reducing water pathogen loads of wastewaters in wetlands (Boutilier *et al.*, 2010; Martin *et al.*, 2012; Abdel-Shafy and El-Khateeb, 2013; Giacoman-Vallejos *et al.,* 2015).

The mechanism of macrophytes functioning in wastewater purification involves provisioning of surface area for attached microorganisms, pollutant uptake, enhancing filtration, and releasing oxygen; however, the role of the vegetation still requires quantification (Zhang *et al.,* 2009). The pathogenic microbial values recorded in Nkenye stream gave high bacteria load compared to recommended standards for drinking water based on WHO (Ombaka *et al.,* 2013). Wastes that are brought into the Nkenye stream from upstream comprises different organic and inorganic substances may settle at streambed and contaminate streams sediment (Ali *et al.,* 2019). Settling of pollutants as accumulated sediments chemicals that are toxic to biota and often contribute to aquatic biodiversity loss and ecosystem decline (Jeppe *et al.,* 2017). The continued contamination of sediments with heavy metals is an environmentally significant issue of concern with consequences on aquatic organisms and human health (Fernandes and Nayak, 2012; Staley *et al*., 2015). Sediments act as main pool of metals in aquatic environment (Zahra, 2014). Their quality indicate the status of water pollution. Due to the change in the aquatic environment it can pose serious ecological risks (Martin *et al*., 2015). The level of contamination in the sediments of any surface water strongly reflects water ecosystem health that might be a reflection of kind of wastes and effluent that are channeled in such water resources (Zhang *et al*., 2011). Many previous studies have also confirmed an increased contamination level of sediments in rivers and streams that provide water for the domestic use (Abuduwaili *et al.,* 2015; Chen *et al.,* 2016; Zhang *et al.,* 2016). These pollutants are stored in fine-grained sediments and complexed to organic matter and oxides (Bartoli *et al.,* 2012; Chen *et al*., 2016). Therefore, there is a need to evaluate many water bodies used for domestic water especially in areas surrounding emerging towns to determine their purity and find ways to purify polluted waters (Chen *et al*., 2016)

METHODOLOGY

Study Area

The study was conducted in Nkenye stream which is found in Chuka Municipality, Meru South within Tharaka Nithi County. The stream is approximately two and half kilometres and it is permanent. Macrophytes are sparsely distributed with *Commelina banghalensis* Tharaka Nithi county borders the Embu County to the South and South West, Meru County to the North and North East, Kirinyaga and Nyeri to the West and Kitui to the East and South East. The County lies between latitude 000 07’ and 000 26’ South and between longitudes 37º 19’ and 37º 46’ East. The highest altitude of the County is 5,200 m while the lowest is 600 m, Eastwards in Tharaka. The average annual rainfall is 717 mm. The high-altitude areas have reliable rainfall. The lower regions receive low, unreliable and poorly distributed rainfall. Temperatures in the highland areas range between 14ºC to 30ºC while those of the lowland area range between 22ºC to 36ºC. Major towns in Tharaka Nithi County include Chuka which is highly populated with 45,882 residents and Chogoria with a lower population of 33,378 residents (KNBS, 2010). The area accommodates diverse industries, hospitals, hotels, garages, schools and markets. Other major activities involve crops and livestock farming (GoK, 2018). A map of the study area is shown in Figure 3.

Research Design and Sample Collection

The study used ecological survey design both for water, sediments and macrophytes roots collection. Using belt transect of 1000 meters long, 20 sampling points were laid along the belt using quadrant (1x1m) where Macrophytes roots , sediments and water were collected for study to compare the pollutants reduction down Nkenye stream. During the study, data collected included: colour of water at each sampling point, nature of vegetation (floating, submerged and emerged, macrophyte diversity, water velocity (slow, medium and high speed), point pollution areas and their key sources. Samples collected include water, plants and sediments. These samples were carried to the laboratory for further study.

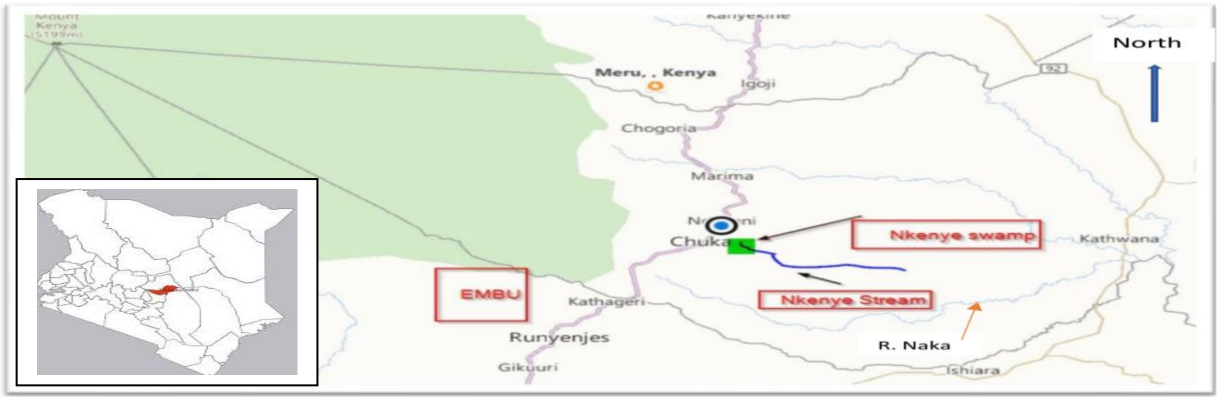

Figure 1: Map of study area
Source: National Atlas of Kenya, Topographic Sheets for Chuka (SA (SA372)

Water, Macrophytes and Sediment Collection

Water samples from the stream were collected in 1000 ml plastic bottles using grab method along the selected points within Nkenye stream. samples were collected during the dry season in the month of January, February and March in 2019. Water sampling is very important for the correct outcome of water analysis. Triplicate water samples were collected at each site. Triplicate sampling is more effective than duplicate sampling. A total of 20 water samples were collected for this study in triplicate totaling to 60 water samples. All the samples were appropriately labeled, stored in cool box for transport to the laboratory at Chuka University. Samples were stored at 4^{o}C prior to laboratory analysis. At every sample collection point established in section different plant species that form masses on the stream and on the wetlands that drains into the stream were collected in triplicate. Collected plants were packed in differentzip lock bags, marked appropriately, packed in cool box for transport to Chuka university where the samples were kept at 4^{o}C prior to laboratory analysis which was carried out one day after collection. At every sampling point established in section 3.2, approximately 220 g of soil sediments was scooped using sterile shovel. The sediment were packed in sterile ziplockbags, labeled, placed in a cool box, transported to the laboratory and stored at 4^{o}C prior to analysis.

Processing and Ion Determination

Macrophyte roots were cleaned and dried in an oven (Model Memmert UNB400; Chuka University) at 65 ^{o}C for 48 h, reduced in size and then powdered to pass through a 2 mm on-metal sieve. The powdered samples were further re-dried in an oven to obtain constant weight.1 g of the powdered sample was digested at 125^{o}C for 4 h using 10 ml concentrated nitric acid (HNO_3; trace metal grade). The mixture was then cooled to ambient temperature, filtered and diluted to 50 ml. The sediment samples were dried in an oven (Model Memmert UNB400; Chuka University) at 65 ^{o}C for 48 h then ground to pass a 2 mm on-metal sieve. The powdered samples were further re-dried in an oven to obtain constant weight.1 g of the powdered sample were digested at 125^{o}C for 4 h using 10 ml concentrated nitric acid (HNO_3; trace metal grade). The mixture was then cooled to ambient temperature, filtered and diluted to 50 ml.5 g of each water sample was acidified with 1 ml of concentrated nitric acid (HNO_3; trace metal grade$_{)}$. The acidified sample was then heated at 70^{o}C for 3 min, filtered with a 0.45µm filter syringe, diluted to a final volume of 100 ml and stored at 4^{o}C prior to analysis.

Standard solutions of the selected metal cations were prepared using respective analytical grade metal nitrates. The amount of the metal salt required was weighed accurately, dissolved and diluted with ultrapure water in a 1000 ml volumetric flask to prepare a 1000 ppm stock solution. The stock solution was serially diluted to prepare 1, 2, 3, 4 and 5 ppm working standards.The concentration of the selected metal cations in the water, macrophyte roots and sediments water was determined by atomic absorption spectrometry using a PG 990 Atomic Absorption Spectrophotometer at Chuka University. Samples were analyzed using the standard calibration method.

Water samples was filtered using a 0.45 µm filter syringe and diluted with ultrapure water to a final volume of 1000 ml. Macrophyte root samples were dried in an oven at 65oC for 4 h. Then 2 g of the dried sample were placed in 200 ml of boiling ultrapure water for 5 min. The mixture was then cooled to ambient temperature, filtered; the filtrate was transferred into a 250 ml volumetric flask and diluted to the mark with ultrapure water. Sediment samples were dried in an oven (Model Memmert UNB400;

Chuka University) at 65oC overnight and ground into powder using an agar pestle and mortar. The 2 g of the powdered sample was placed in 200 ml of boiling ultrapure water for 5 min then cooled to ambient temperature. The sample was filtered and the filtrate transferred into a 250 ml volumetric flask. The sample was further diluted to the mark with ultrapure water as per Balcerzak and Janiszewska (2015).

Standard solutions of the nitrate and phosphate anions were prepared using analytical grade sodium salts. The required amount of the respective sodium salt was dissolved in ultrapure water to prepare 1000 ppm stock solutions. The stock solutions were then serial diluted to prepare working standards which was then mixed to prepare a multi-anionic standard solution. A certified multi-ion standard solution was also purchased from Sigma-Aldrich for comparative analysis. The concentration was determined by ion chromatography using UV 1800 model located at Chuka University Chemistry laboratory, after all the samples had been prepared 20 µl injection volume was used for all analyses. Each peak was manually identified and labeled as a specific anion and the concentration was computer generated. All reagents for use were of analytical grade acquired from sigma. Water purified in a Millipore Simplicity UV system prepared at Chuka University was used in all experiments. Standard solutions of fluoride, chloride, Nitrate (V), phosphate, and Sulphate anions (from Sigma) prepared from high purity sodium salts were used. Multi-anionic working solutions were prepared by mixing up single anion standards with appropriate dilution. Certified Multi-anion Standard Solution dedicated to IC (from Sigma) containing an aqueous mixture of, Cl^-, NO_3^-, PO_4^{3-}, and SO_4^{2-} (10 mg l–1 each of anions) was used for the evaluation of the accuracy of the chromatographic procedure applied. Sodium carbonate (Na_2CO_3) and sodium hydrogen carbonate ($NaHCO_3$) from Sigma was used for the preparation of the eluent (3.2 mmol l–1 Na_2CO_3 +1.0 mmol l^{-1} $NaHCO_3$).

RESULTS AND DISCUSSIONS

Concentration of Nutrients in Water, Plant Root and in Sediment

Concentration of Lead in Water, Plant Root and in Sediment

The concentration of lead in water samples were significantly different ($P<0.05$). The highest mean was at location 20 with mean of 2.87 ppm while the lowest mean for lead in water was location 5 and 10 with mean of 0.02 ppm. The difference between the highest mean and the lowest concentration of lead in water was 2.85 ppm. The overall mean of lead in water was 0.77 ppm. Seven out of the twenty water sample location sampled had means of lead in water higher than the overall mean (Table 1).

Table 1: Concentration of lead in plant root, sediment and water samples in ppm

Location	Lead in roots	Lead in sediment	Lead in water
20	11.63^{a}	93.50^{ba}	2.87^{a}
19	11.13^{a}	93.00^{ba}	1.74^{b}
18	8.00^{b}	65.0^{ebdacf}	1.53^{cb}
16	7.68^{cb}	79.43^{bdac}	1.68^{b}
14	7.23^{cb}	71.33^{ebdac}	0.57^{ed}
15	6.82^{cbd}	95.33^{a}	1.78^{b}
17	6.733^{cd}	80.47^{bac}	1.73^{b}
3	5.60^{ed}	34.53^{egf}	0.27^{ed}
13	$4.90f^{e}$	47.33^{edgcf}	0.40^{ed}
2	$4.17f^{g}$	20.33^{g}	0.23^{ed}
11	3.57^{g}	49.33^{ebdgcf}	0.71^{ced}
12	2.27^{h}	36.0^{edgf}	1.12^{ebd}
6	2.05^{h}	20.0^{g}	0.12^{e}
10	1.93^{ih}	47.0^{edgcf}	0.02^{e}
5	1.83^{ih}	23.0^{gf}	0.02^{e}
9	1.68^{ih}	47.67^{edgcf}	0.06^{e}
8	1.68^{ih}	35.33^{edgf}	0.14^{e}
4	1.18^{ihj}	17.47^{g}	0.17^{e}
1	0.76^{ij}	6.11^{g}	0.04^{e}
7	0.28^{j}	29.67^{egf}	0.17^{ed}
Mean	4.55	49.59	0.77
LSD(p<0.05)	0.67	23.58	0.51
CV	8.95	28.76	39.78

[a]Means followed by the same letters in columns are not significantly different at 5% probability level.

The concentration of lead in sediment for different sampling location within Nkenye stream was significantly different ($P < 0.05$;). Significant differences between samples were detected for lead (F=44.555, $P < 0.001$) by Kariuki, Bates and Magana (2020) in their satudy of soil concentration of selected heavy metals in Chuka, where nkenye stream is located. The highest mean was at location 15 with mean of 95.33 ppm, while the lowest mean for lead in water was location 1 with mean of 6.11 ppm. The difference between the highest and lowest mean of lead concentration in sediment was 89.22 ppm. The overall mean of lead in water was 49.59 ppm. Seven out of the twenty sediment location sampled had means of lead higher than the overall mean (Table 1).

The concentration of lead in plant root for different sampling location within Nkenye stream was significantly different ($P < 0.05$). The highest mean of lead concentration in plant root was at location 15 which had the mean of 11.63 ppm followed by location 19 which had a mean concentration of 11.13 ppm. The lowest mean for lead in plant root was location 7 with concentration mean of 0.28 ppm. The difference between the highest mean and the lowest lead concentration in plant root was 11.35 ppm. The overall mean of lead in water was 4.55 ppm. Nine locations out of the twenty locations sampled for determination of concentration of lead in plant root had means higher than the overall mean (Table 1).

Concentration of Iron in Water, Root and Sediment

The concentration of iron in water samples from different locations in Nkenye stream was significantly different ($P < 0.05$). The highest mean of iron concentration was at location 19 which was followed by location 20 and location 16 with means of 14.44 ppm, 13.97 ppm and 12.82 ppm, respectively. The lowest mean for iron in water was observed from samples collected at location 1, location 4 and location 2 with means of 0.03 ppm, 0.07 ppm and 0.14 ppm, respectively. The difference between the highest mean and the lowest concentration of iron in water was 14.30 ppm. The overall mean of iron in water was 5.11 ppm. Eight out of the 20 water sample location sampled had means of iron in water higher than the overall mean (Table 2).

Table 2: Concentration of iron in plant root, sediment and water samples in ppm

Location	Iron in water	Iron in roots	Iron in sediment
19	14.44^{a}	44552^{b}	372827^{a}
20	13.97^{ba}	43513^{cbd}	366063^{a}
16	12.82^{bac}	27233^{fe}	289961^{b}
17	12.82^{bc}	30829^{e}	209913^{c}
18	11.85^{bc}	42593^{cbd}	353047^{b}
15	11.77^{c}	14437^{hg}	286733^{b}
14	8.80^{d}	16960^{g}	357830^{b}
13	6.72^{d}	20332^{fg}	325407^{b}
9	1.71^{e}	3483.33^{i}	36863^{d}
10	1.33^{e}	18587^{fg}	70390^{d}
12	1.33^{e}	11210^{hi}	259073^{b}
7	1.27^{e}	32482^{e}	27310^{d}
11	1.22^{e}	16910^{g}	74823^{d}
6	1.03^{e}	47467^{a}	58550^{d}
8	0.95^{e}	5936.67^{h}	52339^{d}
3	0.30^{e}	35197^{ced}	59697^{d}
5	0.27^{e}	14437^{hg}	52267^{d}
2	0.14^{e}	42972^{cbd}	61897^{d}
4	0.07^{e}	34253^{ed}	65500^{d}
1	0.03^{e}	8415^{hg}	106223^{d}
Mean	5.113	16.62	174335.7
LSD(p<0.05)	1.137	4.41	99192
CV	13.46	16.07	34.42

[a]Means followed by the same letters in columns are not significantly different at 5% probability level.

The concentration of iron in sediment for different sampling location within Nkenye stream was significantly different (p=0.05). The highest mean of iron in sediment was recorded at location 19 with mean of 372827 ppm followed by location 20, location 14 and location 13 with means of 366063 ppm, 357830 ppm and 325407 ppm respectively. The locations which recorded the lowest mean for iron in sediment was location 7 followed by location 9 and location 5 in that order with means of 27310 ppm, 36368 ppm and 52267 ppm respectively. The difference between the highest mean and the lowest mean of iron in sediment at Nkenye stream was 345517 ppm. Iron in sediment was 174335.70 ppm. Nine out of the twenty sediment location sampled had means of iron higher than the overall mean (Table 2).

The concentration of iron in plant root for sampling location within Nkenye stream was significantly different (*P* < 0.05). The highest mean of iron concentration in plant root was at location 6 which had the mean 47467 ppm followed by location 19 which had a mean concentration of 44552 ppm and location 20 with mean iron concentration of 43513 ppm. The lowest mean for iron in plant root was location 9 which had mean concentration of 3483.33 ppm and was followed with plant sample from location 8 with mean of 5936.67 ppm and location 1 with mean of 8415.00 ppm. The difference between the highest mean and the lowest iron concentration in plant root was 44836.67 ppm. The overall mean of iron in water was 25590.72 ppm. Ten locations out of the twenty locations sampled for determination of concentration of iron in plant root had means higher than the overall mean (Table 2).

Concentration of Copper in Water, Plant Root and in Sediment

The copper concentration in water samples from different locations in Nkenye stream was significantly different (*P* < 0.05). The highest mean of copper concentration was at location 20 which was followed by sample from location 19 and location 16 with means of 2.97 ppm, 2.90 ppm and 2.53 ppm, respectively. The lowest mean for copper in water was observed from samples collected at location 9, location 10 and location 3 which recorded means of 0.00 ppm. The overall mean of copper in water was 0.99 ppm. Seven locations out of the twenty water sample locations sampled had means of copper in water higher than the overall mean (Table 3).

Table 3: Concentration of iron in plant root, sediment and water samples in ppm

Location	Copper in water	Copper in roots	Copper in sediment
20	2.967^{a}	15.167^{a}	137.00^{a}
19	2.900^{a}	11.962^{abc}	117.00^{b}
16	2.533^{ba}	10.180^{bcd}	85.333^{cd}
18	2.133^{bc}	13.200^{ab}	96.667^{bc}
15	1.750^{c}	10.920^{abcd}	90.333^{bc}
17	1.667^{cd}	11.233^{abcd}	62.333^{de}
13	1.00^{de}	8.433^{g}	54.667^{fe}
14	0.977^{deh}	9.700^{bdec}	325407^{b}
12	0.800^{feh}	11.233^{abcd}	57.00^{ef}
7	0.700^{fgeh}	4.100^{ijh}	34.33^{fg}
8	0.633^{fgeh}	5.533^{efghij}	42.00^{efg}
5	0.500^{fgeh}	5.196^{efghij}	39.667^{efg}
1	0.290^{fgeh}	2.300^{j}	31.00^{fg}
2	0.283^{fgeh}	47467^{a}	21.333^{g}
6	0.267^{fgh}	4.933^{fghij}	55.333^{fe}
4	0.240^{fg}	3.780^{ijh}	49.333^{ef}
11	0.200^{fg}	9.033^{bcdef}	52.33^{ef}
3	0.00^{g}	2.800^{ij}	33.667^{fg}
10	0.00^{g}	6.967^{defghi}	45.00^{efg}
9	0.00^{g}	7.600^{defgh}	52.00^{ef}
Mean	0.992	7.986	60.900
LSD(p<0.05)	0.7312	2.3124	27.136
CV	44.597	17.286	26.957

[a]Means followed by the same letters in columns are not significantly different at 5% probability level.

The concentration of copper in sediment for different sampling location within Nkenye stream was significantly different (*P* < 0.05). The highest mean of copper in sediment was recorded at location 20 with mean of 137 ppm followed by location 19, location 18 and location 15 with means of 117.00 ppm, 96.67 ppm and 90.33 ppm, respectively. The locations which recorded the lowest mean for copper in sediment was location 2 followed by location 1 and location 3 in that order with means of 21.33 ppm, 31.00 ppm and 33.67

ppm, respectively. The difference between the highest and lowest mean of copper at Nkenye stream was 115.67 ppm. The overall mean of copper was 60.90 ppm. Seven locations out of the twenty sediment locations sampled had means of copper higher than the overall mean (Table 3).

The concentration of copper in plant root for different sampling location within Nkenye stream was significantly different ($P < 0.05$). The highest mean of copper concentration in plant root was recorded at location 20 which had the mean 15.17 ppm followed by location 18 which had a mean concentration of 13.20 ppm and location 19 with mean copper concentration of 11.92 ppm. The lowest mean for copper in plant root was location 1 which had mean concentration of 2.30 ppm and was followed with plant sample from location 3 with mean of 2.80 ppm and location 4 with mean of 3.78 ppm. The difference between the highest mean and the lowest copper concentration in plant root was 12.96 ppm. The overall mean of copper in water was 7.99 ppm with a coefficient variance (CV) of 17.28 ppm. Ten locations out of the twenty locations sampled for determination of concentration of copper in plant root had means higher than the overall mean (Table 3).

Concentration of Phosphate in Water, Plant Root and in Sediment

The phosphate concentrations in water samples from different locations in Nkenye stream were significantly different ($P < 0.05$). The highest mean of phosphate concentration was at location 19 which was followed by sample from location 20 and location 17 with means of 24.80 g/L, 21.03g/L and 12.58 g/L respectively. The lowest mean for phosphate in water was observed from samples collected at location 12, location 7 and location 4 which recorded means of 0.15 g/L, 0.20 g/L, 0.40 g/L. The overall mean of phosphate in water was 5.34 g/L. Seven locations out of the twenty water samples location sampled had means of phosphate in water higher than the overall mean (Table 4).

Table 4: Concentration of phosphate in plant root, sediment and water samples in g/L

Location	Phosphate in water	Phosphate in sediment	Phosphate in roots
19	24.8033[a]	38.47[a]	8.0[ba]
20	21.0333[ab]	48.63[b]	7.4[bac]
17	12.5833[bc]	16.8[ed]	4.57[bedc]
18	6.8667[cd]	29.30[c]	5.03[bdc]
10	5.7677[cd]	15.93[edf]	2.0[fed]
14	5.0333[cd]	13.77[egdf]	2.60[fed]
13	5.0000[cd]	12.0[hegdfi]	4.0[edc]
9	4.8000[cd]	13.67[hegdf]	1.13[fe]
6	4.6333[cd]	8.15[hgfi]	1.53[fed]
8	3.6667[cd]	9.97[hegdfi]	1.70[fed]
5	3.4000[cd]	12.37[hegdf]	2.93[fed]
11	3.0000[cd]	31.43[cb]	3.43[fed]
2	2.0833[cd]	9.00[hegfi]	8.60[a]
3	1.3333[d]	17.57[d]	1.60[fed]
15	0.7833[d]	5.97[hgi]	1.60[fed]
1	0.7000[d]	8.8333[a]	8.83[a]
16	0.4667[d]	3.93[i]	0.33[f]
4	0.4000[d]	15.20[edf]	2.27[fed]
7	0.2000d	13.17[hegdf]	2.67[fed]
12	0.15 [d]	5.13[hi]	2.15[fed]
Mean	5.34	16.62	3.62
LSD(p<0.05)	5.92	4.41	1.87
CV	67.16	16.07	31.28

[a]Means followed by the same letters in columns are not significantly different at 5% probability level.

The concentration of phosphate in sediment for different sampling location within Nkenye stream was significantly different ($P < 0.05$). The highest mean of phosphate in sediment was recorded at location 20 with mean of 48.63 g/L followed by location 19, location 11 and location 18 with means of 48.63 g/L, 38.47 g/L and 31.43 g/L and 29.30 g/L, respectively. The locations which recorded the lowest mean for phosphate in sediment was location 16 followed by location 12 and location 15 in that order with means of 3.93 g/L 5.13 g/L and 5.57g/L respectively. The difference between the highest mean and the lowest mean of phosphate in sediment at Nkenye stream was 44.70 g/L. The overall mean of phosphate in sediment was 16.62 g/L. Six locations out of the twenty sediment locations sampled had means of phosphate higher than the overall mean (Table 4).

The concentration of phosphate in plant root for different sampling location within Nkenye stream was significantly different ($P < 0.05$). The highest mean of phosphate concentration in plant root was recorded at location 1 which had the mean 8.83 g/L followed by location 2 which had a mean concentration of 8.60 g/L and location 19 with mean phosphate concentration of 8.00 g/L. The lowest mean for phosphate in plant root was location 16 which had mean concentration of 0.33 g/L and was followed with plant sample from location 9 with mean of 1.33 g/L and location 6 with mean of 1.53 g/L. The difference between the highest mean and the lowest phosphate concentration in plant root was 8.50 g/L. The overall mean of phosphate in root was 3.62 g/L with a coefficient variance (CV) of 31.27 g/L. Seven locations out of the twenty locations sampled for determination of concentration of phosphate in plant root had means higher than the overall mean (Table 4).

Concentration of Nitrate in Water, Plant Root and in Sediment

The concentrations of nitrate in water samples were significantly different ($P < 0.05$). The highest mean of nitrate concentration was recorded at location 4 with mean of 32.63 g/l followed by location 8 and 7 with means of 29.63 g/L, and 23.53 g/L respectively. The lowest mean for nitrate in water was location 6 and location 1 with mean of 5.27 g/L and 5.97 g/L, respectively. The difference between the highest mean and the lowest concentration of nitrate in water was 27.39 g/L. The overall mean of nitrate in water was 14.54 ppm. Seven out of the twenty water sample location sampled had means of nitrate in water higher than the overall mean (Table 5).

Table 5: Concentration of nitrates in plant root, sediment and water samples in ppm

Location	Nitrate in roots	Nitrate in sediment	Nitrate in water
20	8.27^{a}	96.67^{a}	17.67^{abc}
18	8.13^{a}	78.33^{cd}	17.47^{abc}
17	7.43^{ba}	89.33^{ab}	14.20^{abc}
19	7.03^{bac}	87.00^{abc}	18.00^{abc}
10	6.73^{bdac}	44.67^{jik}	15.40^{abc}
12	5.43^{bdec}	45.33^{jik}	14.12^{abc}
07	5.43^{bdce}	44.00^{jik}	23.53^{abc}
14	4.53^{fdec}	79.33^{abc}	13.00^{abc}
16	4.40^{fdec}	75.67^{ed}	11.83^{abc}
15	4.40^{fdec}	67.00^{ef}	11.02^{bc}
04	4.37^{fdec}	43.00^{jik}	32.63^{a}
09	4.23^{fheg}	36.00^{k}	11.97^{abc}
13	3.87^{fheg}	51.00^{ghi}	11.37^{abc}
08	3.10^{fheg}	39.33^{jk}	29.68^{ab}
02	3.07^{fheg}	51.33^{ghi}	7.33^{c}
06	2.47^{fhg}	46.67^{jik}	5.27^{c}
03	2.40^{fhg}	61.33^{gf}	8.17^{c}
05	2.10^{fhg}	52.67^{ghi}	6.30^{c}
01	1.67^{hg}	56.67^{fgh}	5.97^{c}
11	1.27^{h}	39.67^{jk}	15.80^{abc}
Mean	4.52	59.40	14.54
LSD(p<0.05)	0.56	10.36	21.497
CV	19.23	9.97	89.47

[a]Means followed by the same letters in columns are not significantly different at 5% probability level.

The concentration of nitrate in sediment for different sampling location within Nkenye stream was significantly different ($P < 0.05$). The highest mean of nitrate in sediment was at location 20 with mean of 96.67 g/L, followed by location 17 with mean of 89.37 g/L followed by location 19 with mean of 87.00 g/L. location 18had mean of 78.33 g/L, location 16 had mean of 75.67 g/L and location 15 had mean of 67.67 g/L. The lowest mean for nitrate in sediment sample was recorded at location 9 with mean of 36.00g/L followed by sample from location 8 with mean of 39.33 g/L and at location 11 with mean of 39.67 g/L. The difference between the highest mean and the lowest mean of lead concentration in sediment was 42.33g/L. The overall mean of nitrate in water was 59.40g/L. Four out of the 20 sediment location sampled had means of nitrate higher than the overall mean (Table 5).

The concentrations of nitrate in roots were significantly different ($P < 0.05$). The highest mean was at location 20 with mean of 8.267 g/L followed by location 18 and 17 with means of 8.13 g/L, and 7.43 g/L respectively. The lowest mean for nitrate in root was location 11 and location 1 with mean of 1.27 g/L and 1.67 g/L respectively. The difference between the highest mean and the lowest concentration of nitrate in root was 7.00 g/L. The overall mean of nitrate in root was 4.52 g/L. Eight out of the twenty root sample location sampled had means of nitrate in roots higher than the overall mean (Table 5).

CONCLUSION AND RECOMMENDATIONS

Metal pollutants were significantly different from location to location of sampling. However, their concentrations were within the WHO standards for drinking water. The metals contaminants observed in the Nkenye stream water, sediments and macrophytes roots may be associated with discharge of wastes from Chuka town particularly wastes from car wash, garages and from farms (agrochemicals) that surrounds the stream and wet land. Due to fluctuation in the concentration of chemical pollutants observed, there is need for regular and proper monitoring of the stream to safeguard the integrity of Nkenye stream and the lives of people who draw water from it.

Nitrates had the highest mean concentrations compared to other phosphates and indication that nitrates pollutants that are drained into Nkenye stream are in high amount. The high levels of lead, copper and iron were observed in the sediment samples from Nkenye is of major concern, as these may be dismounted from the streams sediment by turbulence and carried along the river at the point where water is drawn thus a health hazard. For this reason. The county government should impose policies that outlaw cultivation along the stream or any activity that endangers the riparian zones of Nkenye stream.

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