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Determination of physico-chemical quality of water in Kiamumbi Catchment, Kiambu County, Kenya

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Abstract

Water is an essential ingredient of our wellbeing and a healthy life. The quality of water is paramount for the existence of mankind. Water quality can be determined by the Physico-chemical parameters. The water quality of Kiamumbi Reservoir water project is of great importance because it is used for consumption by the population in the settlement area. This study aimed at analyzing the physical and chemical quality of water in Kiamumbi reservoir, the feeder river and water supplied to households during the wet and dry seasons. Portable pH meter (Jenways), Portable TDS meter 4076 (Jenways), Portable Ec meter (Jenways), and Portable turbidity meter were used after appropriate calibration. The mean pH ranged from 6.96 to 7.24. Total dissolved solids and turbidity levels were 137.7 mg/L and 8.04 NTU respectively. The mean electrical conductivity was 0.2 ms. Heavy metals were analysed using atomic absorption spectroscopy and the concentrations (ppm) were as follows; Zinc, 0.14, Chromium,0.57, cooper 0.06, calcium 1.3 , magnesium ,5.1, Manganese, 0.19, Cadmium 0.3, nickel, 0.25, lead, 0.4 and iron 0.5 . The concentrations of phosphate, sulphate and chloride in water was 12.92, 0.47 and 343.7 mg/L respectively. The heavy metals that were found to be present in concentration levels higher than the recommended standards (Kenya Beaurae of standards,2007, WHO, 2011) were Chromium, Lead, Iron, Nickel and Cadmium. Results of this study will form the baseline for monitoring and tracking changes in the presence and concentration of the pollutants and the water quality as a result of the reservoir's natural dynamics overtime or impact of anthropogenic activities on the reservoir and its water shed.

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Introduction

Water resources are of critical importance to both natural ecosystem and human development. The healthy aquatic ecosystem is dependent on the physico – chemical and biological characteristics (Venkatesharaju *et al.,* 2010). To assess these characteristics, monitoring of these parameters is essential to identify magnitude and source of any pollution load. These characteristics can identify certain condition for the ecology of living organisms and suggest appropriate conservation and management strategies (Srivastara *et al.*, 2009, Damotharan *et al.*, 2010; Prasanna and Ranjan, 2010).

Contamination of water bodies has increasingly become an issue of serious environmental concern. Clean water is a priceless and limited resource that man has began to treasure only recently after decades of pollution and waste (Smith, 2003). Contaminants such as bacteria, heavy metals, nitrates and salts have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, agricultural activities, industrial discharges and over-use of limited water resources (Singh and Mosley, 2005).

Kenya is classified as a water scarce country with only 647 cubic metres of renewable fresh water per capita. Globally a country is categorized as " Water Stressed" if its annual renewable fresh water supplies are between 1,000 and 1,700 cubic metres per capita per annum and "Water Scarce" if its renewable freshwater supplies are less than 1,000 cubic metres per capita per annum. (UN-Water/ WWAP/ 2006).

Surface and ground water resources in Kenya are increasingly becoming polluted. Water pollution occurs when pollutants are discharged directly or indirectly into water bodies leading to degradation. Continued consumption of polluted water may lead to serious impacts on human health.

Water quality in reservoirs is an important aspect of water resources management. It is a key catalyst for development and conservation because it determines the spatial- temporal dynamics of aquatic organisms and drives various water uses in aquatic ecosystems including reservoirs.

Reservoir water is rarely pure since it contains different kinds of dissolved and particulate matter including gases and solids. It is from this background that analysi of the quality of water in Kiamumbi catchment was necessary. This water is collected from the reservoir for treatment by Kiamumbi Water Trust and supplied to approximately 850 households in Kiamumbi Estate in Kiambu county for domestic use. Water for domestic use and especially for drinking should meet the set standards by World Health Organization (WHO). Therefore, based on this fact, investigating the water quality of Kiamumbi catchment to understand the pollutants therein, and to find out if these pollutants are reduced to acceptable levels after treatment for domestic use, was the main purpose of this study.

Economic and demographic growth in agricultural water sheds often leads to intensive land use and increased generation of point and non-point source pollutants. These pollutants, which include pathogens, nutrients, toxic contaminants and sediments are then transported by run-off to water bodies causing seriuos environmental effects. This is exactly what has been happening in Kiamumbi catchment where rampant construction of residential estates and increased farming activities along the catchment has been taking place hence necessitating the need for this study to find out the effects of increased population growth and extensive agriculture. In a study by Mwangi JK. *et al.,* (2006) on Assessment of the water quality status of Sasumua watershed, in Kenya which is about 80km from Kiamumbi catchment, the results of this study indicated that most of the physico-chemical water quality parameters were within the WHO and Kenya Bureau of Standards limits for drinking water and concluded that the water was suitable for domestic purposes. In the same study, conductivity and Total dissolved solids and other major ions varied from wet to dry seasons with elevated levels in the wet season. This conclusion motivated the reserchers to undertake this study in another area. This is because Kiamumbi catchment is prone to different sources of pollutants hence important to investigate if the water is fit for human consumption. Sasumua is in a rural area while Kiamumbi is in an urban geographical area a few kilometres from the city of Nairobi surrounded by other towns and residential estates hence the sources and quantities of pollutants may be very different from those in rural areas.

Materials and methods

Study area

This study was undertaken in Kiamumbi cathchment in the reservoir, feeder river and storage facility where water is stored after treatment. The reservoir is Located about 15 Km North of the capital city, Nairobi and about 4 Km from the Kamiti Maximum Prison. The geographical position of the reservoir is 1^0 10^1 40^{11}S, $36^0 53^1 3^{11}$E. The reservoir is fed by a River that flows through areas where agriculture is practiced either in large scale for example in coffee plantations and flower farms.

Sampling

The water samples for analysis were collected during the wet or rainy season in the month of June and during the dry season in the Month of September.A total of three samples were randomly collected along the feeder river from three sampling points at an interval of 2km upstream from the reservoir giving a total of nine (9) samples. There were four (4) sampling points in the reservoir from which three samples were collected from each giving a total of twelve (12) samples. Three samples were collected from the storage facility. A total of fourty eight samples were collected in the two seasons. The minimum sample size was 500mL. The samples were collected in plastic sampling bottles which were thoroughly cleaned by washing in non-ionized detergent rinsed with tap water, and soaked in 10% HNO3 for 24hrs and finally rinsed with non-ionized water prior to use. The bottles were rinsed with the water from each of the designated sampling points and then in-filled with water.

Materials

The Equipments that were used included Portable pH meter 3071 by Jenways, Portable TDS meter 4076 by Jenways,Portable Ec meter 4076 by Jenways and SGZ – B Portable turbidity meter. Heavy metals were analyzed using Atomic Absorption Spectroscopy (AAS) Equipment Model 220-GF (210 GVP).

Method

All the equipments were first calibrated appropriately. Total dissolved solids, pH, and Electrical conductivity were measured in the field from the collected samples. Turbidity was measured in the laboratory. The methods outlined in the standard methods for the examination of water and waste water (APHA, 1995) were followed for the analysis of all physico-chemical parameters, phosphates,sulphates and Chlorides. Standard stock solutions for each metal were prepared using respective analar grade reagents for each analyte which was dissolved in distilled water and from which dilutions calibration curves were prepared. The heavy metals that were analyzed using Atomic Absorption Spectroscopy included Zinc, Chromium, Copper,Calcium, Magnesium, Manganese, Cadmium,Nickel,Lead and Iron. Phosphate and sulphates were analysed using Nephelomentric method and Chloride using Spectrophotometry method.

Results and discussion

Water is a natural resource and is essential to sustain life. Safe drinking water remains inaccessible for about 1.1 billion people in the world and the hourly toll from biological contamination of drinking water is 400 deaths of children below the age five. Rivers are the most important sources of fresh water for man. Water quality problems have intensified overtime in response to increased growth and concentration of population and industrial centres.

Polluted water is an important vehicle for the spread of water related diseases with 1.8 million people, mostly children dying every year especially in developing countries. (WHO, 2004).

Table 1. chloride concentration (mg/L) during wet and dry seasons.

Sampling points	Wet season	Dry Season
RS1	794	11
RS2	809	8.04
RS3	504	8.97
RSV	741	8.97
SF	544	7.9
STD	**250**	**250**

Certain natural phenomena such as heavy rainfall and underlying geology can result in water quality changes and deterioration. Heavy rains may result in soil erosion and subsequent high concentration of suspended solids in the water column. Surface run-off after rains can introduce suspended material containing organic, heavy metals and nutrients in a water body. Activities in the catchment can also result in introduction of unwanted materials in water. In this study a number of farming activities were found along the feeder river and these could result in the introduction of soil particles, insecticides and fertilizers during the rainy season.The findings of this study were as outlined hereafter.

Physical Parameters

The physical parameters that were analysed in this study were pH,Turbidity, Total dissolved solids and Electrical conductivity. The results of each parameter were as outlined below.

pH

Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. Careful attention to pH control is necessary at all stages of water treatment to ensure satisfactory water clarification and disinfection. For effective disinfection with chlorine, the pH should be less than 8, however, pH less than 7 is more likely to be corrosive. The optimum pH required will vary in different supplies according to the composition of the water and the nature of the construction materials used in the distribution system, but it is usually in the range 6.5 to 8.5 (WHO, 2011). In a study undertaken by Romulus Abila *et al.,* (2012) in shallow wells in Kitui town, Kenya, the pH was found to be between 5.7 to 6.6. In a study by Mwangi *et. al*, on Assessment of the water quality status of Sasumua water shed,Kenya, pH for most sampling points was found to be neautral (7.10). In this study, the pH was found to fall within the recommended levels(WHO,2011) during the wet and dry season as presented in figure 2. However, due to increased pollution during the wet season, pH levels were higher than in the dry season.This was well illustrated by the *t-test* results which showed a significance difference in pH levels during the wet and dry seasons (t_{cal} =3.884, p=0.05). However, the *t-test* results showed that there was no significance difference in the pH levels between the feeder river and the riservoir in both seasons.

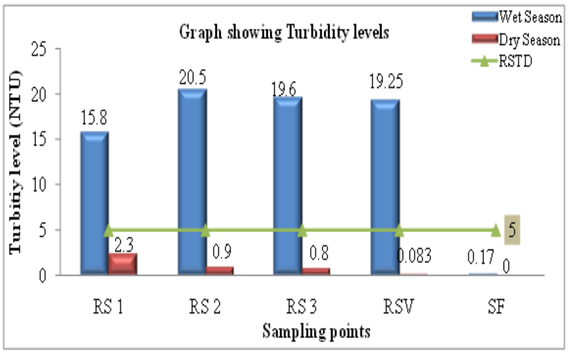

Fig. 1. Turbidity levels during the wet and dry seasons and the recommended standand levels.

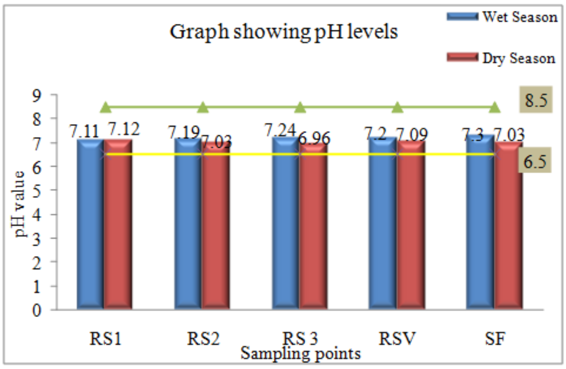

Fig. 1. pH level during wet and dry seasons.

Turbidity

Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water. It may be caused by inorganic or organic matter or a combination of the two.Turbidity can be noticed by the naked eye above approximately 4 NTU. However, to ensure effectiveness of disinfection, turbidity should be no more than 1 NTU and preferably much lower. (WHO, 2011). In this study, turbidity levels were as presented in figure 1. The results showed that the turbidity levels were above the recommended levels in the river and the reservoir only during the wet season with a mean concentration of 18.8mg/L. The highest turbidity level was 20.5 mg/l recorded during the wet season. This is because during the rains, there is a lot of run – off that carries eroded soil resulting from poor farming methods, plant remains, oils and grease, sewage, animal waste, fertilizers among other organic and inorganic pollutants into the feeder river and the reservoir. The *t-test* results indicated that there was a significance difference in turbidity levels during the wet and dry season (t_{cal}*=3.720,p=0.06)*. However, during the dry season, there was a significance diffeence in levels of turbidity between the feeder river and the reservoir. This is an indication that, the substances that causes turbidity in the reservoir are deposited by the feeder river as it picks them on its course for example through erosion of the banks. Turbitidy levels at the storage facility in both wet and dry season was zero meaning that the treatment method was effective in lowering turbidity.

Total Dissolved Solids

The palatability of water with a TDS level less than about 600mg/l is generally considered to be good. Drinking water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000mg/l (WHO, 2011). The results of this study were as presented in figure 3. The TDS levels were found to be below the recommended levels for drinking water in all sampling points in both dry and wet season. However, the highest level was 217.3 recorded in the storage facility during the wet season. This is because during the rainy season, the management increases the amount of chemicals used for water treatment like chlorine,soda and alum and they are transferred to the storage facility in residual form.There was no significance difference in TDS levels between the wet and dry season. However, there was a significance difference in the TDS levels between the feeder river and the reservoir where during the wet season (t_{cal}*=3.63,p=0.002)* and during the dry season (t_{cal}*=4.72,p=0.0.)* The *t=test* results were a clear indication that high quantity of total dissolved solids in the reservoir are deposited by the feeder river. Therefore if the sources of the solids are controlled along the river regime, the reservoir will not have high amount of TDS.

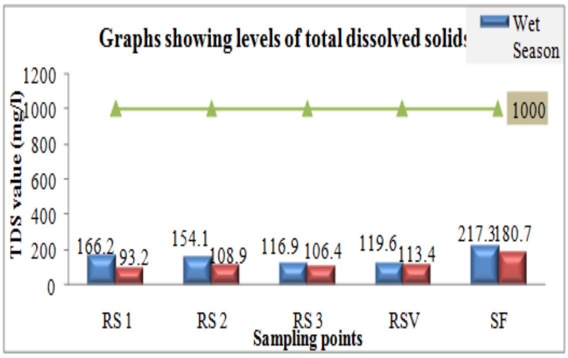

Fig. 3. Total Dissolved solids during wet and dry seasons.

Electrical Conductivity

Electrical conductivity is a measure of the ability of water to pass an electric current. Conductivity in water is affected by the presence of inorganic dissolved solids such as Chloride, nitrate, sulphate and phosphate (ions that carry a negative charge) or sodium, magnesium, calcium, iron and aluminium cations (ions that carry a positive charge). The levels of electrical conductivity recorded that were recorded in this study in all sampling points were as presented in figure 4. The highest conductivity was 0.3ms measured at the storage facility during the wet season, while the lowest was 0.03ms recorded at the third sampling point in the river during the dry season. The *t-test* results showed that there was no significance difference in conductivity between the wet and dry season (t_{cal}=1.455, p=0.184). *There was a significance difference in conductivity during the dry between the feeder river and the reservoir (t-$_{cal}$ = 3.888, p = 0.001)* while there was no significance difference during the wet season(t_{cal} = 0.4, p = 0.001).

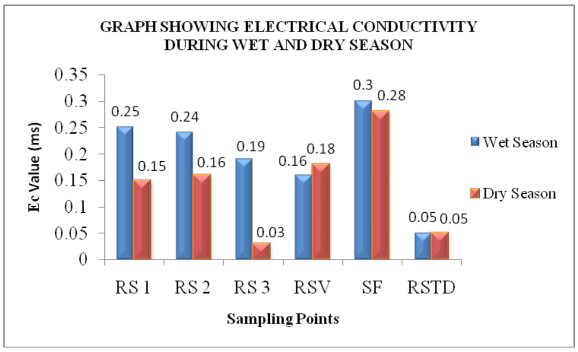

Fig. 4. *Electrical conductivity during wet and dry seasons.*

Heavy Metals

Heavy metals have been used as indices of pollution because of their high toxicity to human and aquatic life (Omoigberale and Ogbeibu, 2015). A total of ten heavy metals were analysed. Five of the heavy metals that were found to be above the recommended levels in the feeder river, reservoir and the storage facility in both wet and dry season were Cadmium, Chromium, Lead, Nickel and Iron. The heavy metals that were found to be present but below the recommended levels were Calcium, Copper, Magnesium, Manganese and Zinc. The results of the heavy metals whose concentration was above the recommended levels were as discussed below.

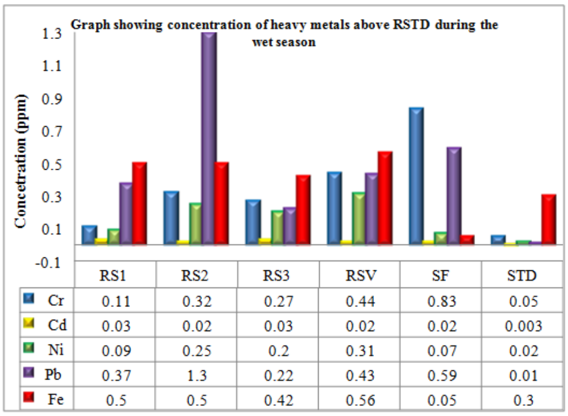

Fig. 5. Concentration of heavy metals above RSTD during the wet season.

Chromium

Chromium is widely used in a variety of industries like electroplating, tanning, manufacture of paints and pigments and fungicides(WHO, 1999, 2011). In this study the mean concentration of Chromium was found to be above the recommended levels of 0.05ppm (WHO,2011). The highest concentration level was recorded at the storage facility (0.83ppm) and lowest at the first sampling point in the river six kilometres upstream from the reservoir (0.11ppm) during the wet season. During the dry season, the highest mean concentration was in the storage facility (1.4ppm) and lowest at the first sampling point in the river (0.3ppm). This is an indication that there was low chromium pollution in the river course and the reservoir. The high concentration levels in the storage facility can be linked to long term accumulation after transfer from the reservoir because the treatment method is not effective in removal of heavy metals. The *t-test* results showed that there was no significance difference in the concentration of chromium in the river and the reservoir and also between the wet and dry season.

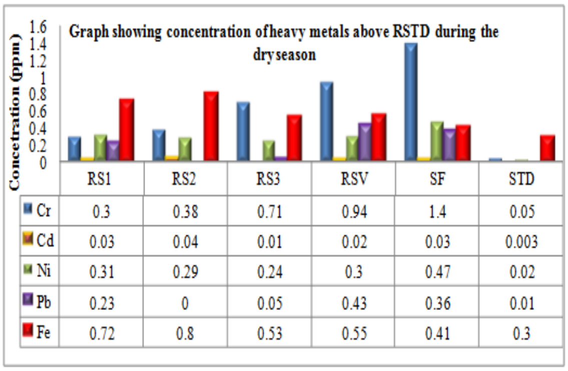

Fig. 6. Concentration of heavy metals above RSTD during the wet season.

Cadmium

Cadmium is used in the steel industry and in plastics. Cadmium compounds are widely used in batteries. Cadmium is released to the environment in waste water and diffuse pollution is caused by contamination from fertilizers produced from phosphate ores and local air pollution. Contamination in drinking water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings (WHO, 2011). In this study, the concentration of Cadmium was found to be above 0.003ppm the recommended levels for drinking water. (WHO, 2011). The highest mean concentration of cadmium was 0.03ppm at the first and third sampling points of the feeder river and the lowest mean concentration was 0.02ppm in the second sampling point in the river and it was the same in the reservoir and storage facility during the wet season. During the dry season, the highest mean concentration of cadmium was 0.04ppm at the second sampling point in the river and the lowest mean concentration was 0.01ppm at the third sampling point of the river. The *t-test* results indicated that there was no significance difference in concentration of cadmium in the feeder river and the reservoir and also during the two seasons. This most likely source is run-off contaminated with fertilizers produced from phosphate ores. This indicates that the sources of chromium in the reservoir and the river are the same and the treatment method does not reduce the levels of cadmium.

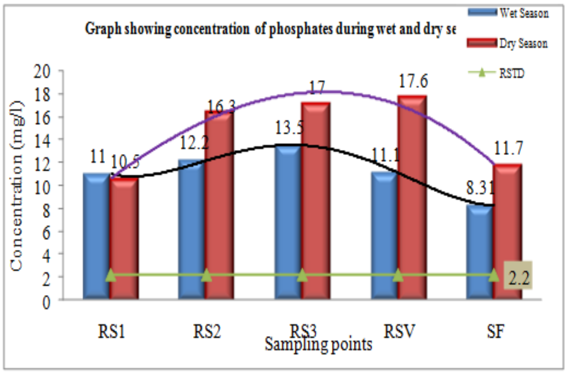

Fig. 7. Phosphates concentration during wet and dry seasons.

Iron

The mean concentration of Iron was found to be above the recommended levels of 0.3ppm (WHO,2011). During the wet season, the highest mean concentration was 0.56ppm at the reservoir and the lowest was 0.05ppm at the storage facility. During the dry season, the highest concentration was 0.8ppm at the second sampling point in the river while the lowest was 0.41ppm at the storage facility. This is an indication that the treatment method aid in reduction of iron concentration though not effective to reduce it to recommented standards. The *t-test* results indicated that there was no significance difference in the concentration of iron in the feeder river and the reservoir and also in both wet and dry season. This is because the sources remain the same and this may actually mean that a lot of iron is not deposited into the reservoir by the river.

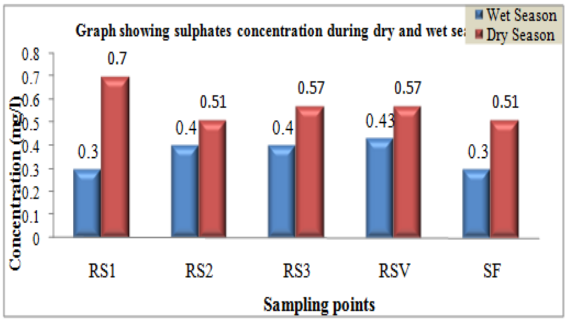

Fig. 8. Sulphates concentration during wet and dry seasons.

Lead

Lead is used principally in the production of Lead-acid batteries, solder and alloys. The presence of Lead is primarily from corrosive water effects on household plumbing systems containing Lead in pipes, solder, fittings or the service connections at homes (WHO, 2011). After domestic use of lead contaminated water and subsequent disposal, Lead finds its way into water bodies through run-off and leaching. Run – off from and through small businesses like garages and workshops all over the catchment can be a good source of Lead into the surface water in Kiamumbi catchment. The mean concentration levels were found to be above 0.01ppm which is the WHO recommended level. During the wet season the highest mean concentration level was 1.3ppm at the second sampling point in the river and the lowest mean concentration was 0.22ppm at the third sampling point in the river. During the dry season, the highest mean concentration was 0.36 at the storage facility and the lowest was 0 at the second sampling point in the feeder river. The *t-test* results showed that there was no significance difference in the concentration levels of Lead in both dry and wet season(t_{cal}=1.779, p=0.113) and also between the feeder river and the reservoir in the wet season (t_{cal}=1.373, p=0.186) and dry season (t_{cal}=1.780, p=0.091). This was an indication that there are similar sources of Lead during the two seasons that finds its way into the surface waters. The statistical test showed that Lead in the reservoir is not deposited by the feeder river but as a result of contaminated run-off.

Nickel

Nickel is used mainly in the production of stainless steel, nickel alloys and in batteries. It can also occur naturally in ground water(WHO, 2011). In this study, the concenration levels were found to be above 0.02ppm which is the WHO recommended level. The highest mean concentration level was 1.3ppm during the wet season at the second sampling point in the river and the lowest mean concentration was 0.22ppm at the third sampling point in the feeder river. During the dry season, the highest mean concentration was 0.36ppm at the storage facility and at the second sampling point in the feeder river there was no detectable concentration. The *t-test* results showed that there was no significance difference in the concentration of Nickel between the wet and dry season and also between the feeder river and the reservoir.

Nutrients

Two nutrients, that is phosphate and sulphate were analyzed. The results were as discussed below.

Phosphate

In this study, there was a sharp increase in phosphates concentration between the first and the second sampling point along the river. This is the point where there are huge coffee plantations and extensive farming activities along the catchment. These activities reduces as one moves downstream but due to accumulated collection of phosphates by the river and deposition through run-off direct into the reservoir, the level of phosphates was high at the reservoir than along the river in both seasons. The level gradually reduces in the storage facility but it should be noted that even after treatment of the water, the concentration levels were beyond the recommended standard. This was attributed to the ineffectiveness of the treatment method. The *t-test* indicated that there was no significance difference in the concentration levels between the wet and dry season and also between the feeder river and the reservoir during the wet season. However, there was a significance difference between concentration in the feeder river and the reservoir during the dry season(t_{cal}=3.448, p=0.003)

Sulphate

Sulphates are used in the production of fertilizers, chemicals, dyes, glass, paper, soaps, textiles, fungicides, insecticides, astringents and emetics.rocessing. Sulphate is also used in the mining, wood pulp, metal and planting industries, in sewage treatment and in leather processing. Aluminium sulphate (alum) is used as a sedimentation agent in the treatment of drinking – water. The findings of this study showed that the concentration levels of sulphates were below the recommended levels of 400mg/L(KEBS, 2007). The highest mean concentration recorded was 0.57mg/L. The results of the *t-test* showed that there was a significance difference between the concentration of sulphates between the wet season and dry season t_{cal}=4.653, p=0.002). This was an indication that the sulphates finds their way into the water bodies through run-off though at low quantities.Also some sulphate in the storage facility may be residual from use of alum in excess during the wet season during treatment of the water. There was no significance difference the levels of sulphates between the feeder river and the reservoir and therefore the trace amount of sulphates are not deposited into the reservoir by the feeder river.

Chloride

Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban run – off containing salts and saline intrusion. Excessive chloride concentration increase rates of corrosion of metals in the distribution system, depending on the alkalinity of the water. This can lead to increased concentrations of metals in the supply (WHO, 2011).

In a study undertaken by Romulus Abila *et al.,* (2012), in shallow wells in Kitui town, Kenya, the concentration of chloride was found to be between 9.92 mg/l to 127.74 mg/l. In this study, the highest recorded mean concentration of chrolide was 809 mg/L in the wet season and the lowest recorded mean level was 7.9mg/L during the dry season. The chloride concentration was found to be beyond the recommended levels(WHO, 2011) during the wet season in all sampling points and below the recommended levels during the dry season in all the sampling points. The *t-test* results showed that there was a significance difference in concentration of Chloride between the wet and dry season ($t_{cal}=10.403, p=0.0$). This was an indication that there are high quantities of Chloride in the catchment during the wet season and this is mainly introduced by the run-off. However, there was no significance difference between the concentration of Chloride between the feeder river and the reservoir. Therefore, the sources of chloride in the river and the reservoir are the same.

Conclusion

This study aimed at finding out the quality of water in Kiamumbi catchment by analyzing the Physical and chemical quality of the water. The results of this study strongly suggested that the physico-chemical quality of water in Kiamumbi catchment is not good because some of the analyzed parameters were found to be above the levels recommended by WHO for drinking water even after treatment. This poses serious public health concerns to unsuspecting water users.

Recommendation

It is recommended that the management of the water project do regular analysis and monitoring of the water quality within the catchment. To safeguard the health of the consumers of the water, there is need to improve the water treatment method to ensure that the concentration of the heavy metals, phosphates and chlorides and other elements are lowered to below acceptable levels. It is also important to create awareness among the land owners within the catchment to adopt good land use practices that do not contribute to pollution of the catchment. It is also important to do analysis of the quality of the water at the taps in the households to find out whether there is additional pollution during distribution and also find out if there are treatment methods applied by the users before consumption and how effective they are.

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