SEASONAL VARIATION OF SURFACE WATER QUALITY IN THE NAIROBI RIVER SYSTEM

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Abstract
Most people living downstream of Kenya's capital use water from Nairobi River System. To evaluate surface water quality in Nairobi County, water samples were collected from ten different locations in Nairobi River System (NRS) during the dry and wet seasons. The total dissolved solids (TDS) and temperature were determined on site using a portable meter-EC 300A.Water turbidity was determined with the help of a portable turbidity meter (SGZ-B) while the concentration of trace metals (chromium, copper, iron, manganese, lead and zinc) was determined using an atomic absorption spectrophotometer. TDS increased from upstream to downstream. The most downstream end of NRS considered was at the Eastern bypass, where dry and wet seasons TDS was 3040 mg/l and 840 mg/l, respectively. For fresh water, the US EPA limits TDS at 500 mg/L, which was exceeded during both seasons. Normal water temperature was observed. Turbidity increased from upstream to downstream, reaching a maximum dry season value of 250 NTU at the Eastern bypass. Most heavy metals exceed the Kenya Bureau of Standards (KEBS) limits for domestic and agricultural water. With exception of iron, the concentration of metals was highest during the dry season. Ngong River had the highest concentration of lead (0.6-0.9 mg/l) and chromium (0.5-1.7 mg/l). Ngong and Nairobi tributaries had approximately the same levels of copper, manganese and iron. This study concludes that surface water in Nairobi has excessive levels of organic matter and heavy metals which are likely to affect the quality of Athi River, a major source of water in Machakos and Makueni Counties. It is recommended that deliberate efforts should be made to stop discharging untreated effluents into Nairobi River System as this can have serious effects on food safety and human health.

Key words: Nairobi River, wet and dry season, physico-chemical parameters, heavy metal

1.0 Introduction

Nairobi River System (NRS) comprises of three main tributaries, Ngong, Nairobi and Gitathuru, which discharge into the Athi River on the Eastern Side of the City of Nairobi. Nairobi River receives pollution from not only industrial and commercial sources in the city, but also from domestic sources. Broken or overloaded sewers are allowed to discharge into the river (Otieno 1995 or Okoth & Otieno, 2001). Pollution has rendered the River devoid of life and often produces smells and sights that are unpleasant and offensive (Otieno et al., 1997). Because the lower part of Athi River basin is semi-arid, Athi River remains the main source of water for domestic. Direct intake of such water without any form of treatment or the consumption of food produced using the water, can lead to health problems. (Swarup et al.,1997). Heavy metals are among the likely pollutants that may be found in polluted river water. Such substances can impact on the ecology of an area and affect human health (Singh & Agrawal, 2010 or Lone et al., 2008). Lead is highly poisonous heavy metal that targets the nervous system. Long-term exposure of adults can affect the functions of the nervous system (Schoeters et al.,2008). Zinc toxicity is commonly fatal. It causes a severe haemolytic anaemia, liver or kidney damage; vomiting and diarrhoea (Bothwell et al.,2003). Effects of long term exposure to copper causes liver and kidneys damage (Flemming & Trevors, 1989). Excessive Iron damages cells and can have significant effects including, coma, metabolic acidosis, shock, liver failure, coagulopathy, adult respiratory distress syndrome, long-term organ damage, and even death (Boukhalfa & Crumbliss, 2002).

This study evaluated the current levels of turbidity, dissolved solids and heavy metals at selected sites along the NRS which includes Ng'ong, Nairobi and Gitathuru tributaries.

2.0 Materials and Methods

The study involved sampling of River water along the Ngong, Nairobi and Gitathuru tributaries which constitute Nairobi River System, to determine the pollution levels of the basin. The physico-chemical parameters were determined in-situ whereas heavy metals tests were carried out to determine the pollution level of the Nairobi river system.

2.1 Sampling Points

Representative samples were obtained from the 10 sampling points (Figure 1), along the Ngong (NG), sampling were at Mater Hospital Junction (NG); Mukuru area (NG2); Enterprise road junction (NG3) and Outering road Junction (NG4). On Nairobi River water samples were collected at Globe Cinema round about (NA1); Eastleigh area (NA2); Dandora area (NA3) and Eastern by-pass junction (NA4). On Gitathuru River, the sampling points were at Kariobangi (G1) and Kasarani area (G2).

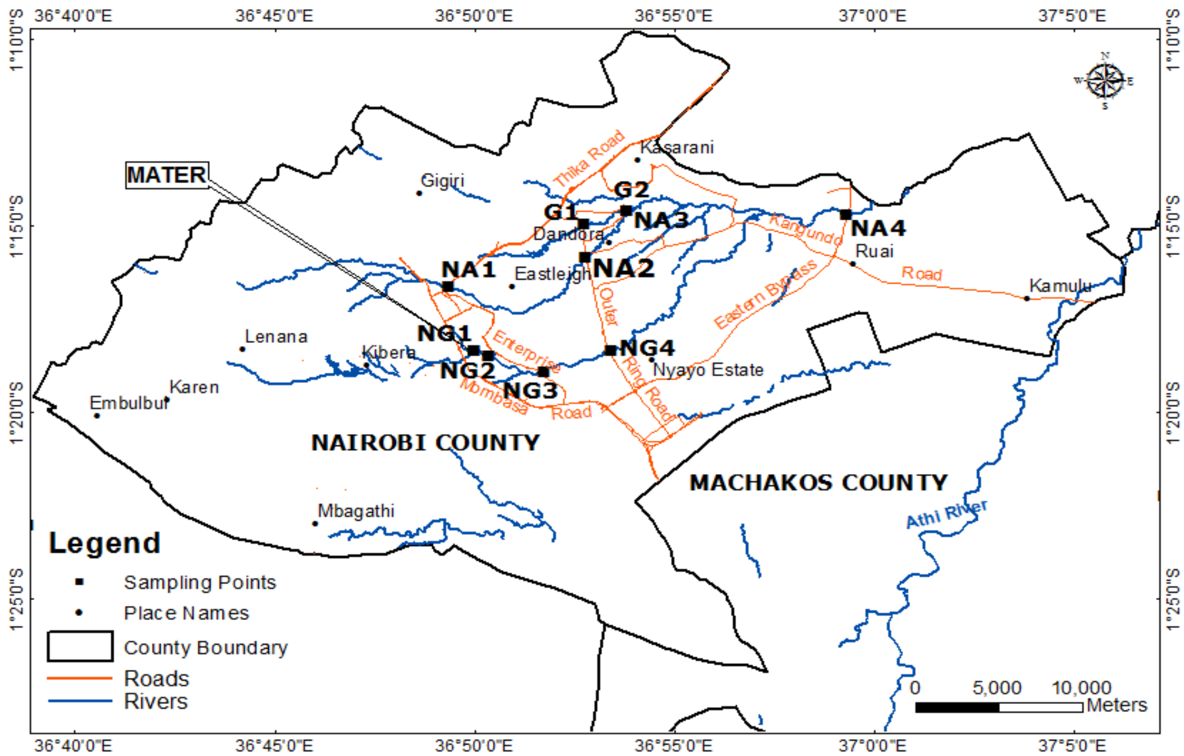


Figure.1: Sampling points at Gitathuru (G), Ngong (NG) and Nairobi (NA) River

2.2 Quality Assurance and Quality Control

All reagents (hydrochloric, HCl and nitric, HNO3 acids) used were of analytical grade. To avoid metal contamination, glassware were washed and rinsed with 10% HCL followed by distilled water to avoid metal contamination. Sample preparation and analysis were carried out using standard methods of analysis (APHA, 1998)

2.3 Sample Collection

Sampling was carried out in the month of February for the dry weather and April for the wet weather .Water samples were collected as grab samples in pre-cleaned containers in duplicates from all sites and treated with nitric acid (2%).The samples were stored in a cool box and transported to the laboratory. Acid digestion to release trace metals were conducted using an aquaregia (3:1, Nitric Acid (HNO_3): Hydrochloric acid (HCl) (APHA, 1998). A 100 ml of well-mixed, acid preserved sample was transferred to a 250 ml flask. A 10 ml aquaregia was added. The flask was placed on a hot plate and the solution cautiously evaporated without boiling to about 25 ml. The solution digested was then cooled, the wall of the flask and the watch glass were washed down with distilled water. The solution was then filtered using whattman filter paper No.42 to remove insoluble material that could clog the nebulizer, and the filtrate was stored in plastic bottles for AAS analysis.

2.4 Determination of Physical Chemical Properties

Total dissolved solids (TDS) and temperature were measured on site using portable TDS meter-EC 300A.While portable turbidity meter (SGZ-B) was used to determine the turbidity of the water.

2.5 Metal Analysis

The Content of heavy metals (Cr, Mn, Cu, Zn, Fe, and Pb) was analysed using the atomic absorption flame emission spectrophotometer (AA-6200 -Shimadzu). A series of standards were prepared for instrumental calibration by serial dilution of working solutions (100 mg/l) prepared from analytical grade stock solutions (1000 mg/l) from Sigma and Aldrich INC., USA.

3.0 Results

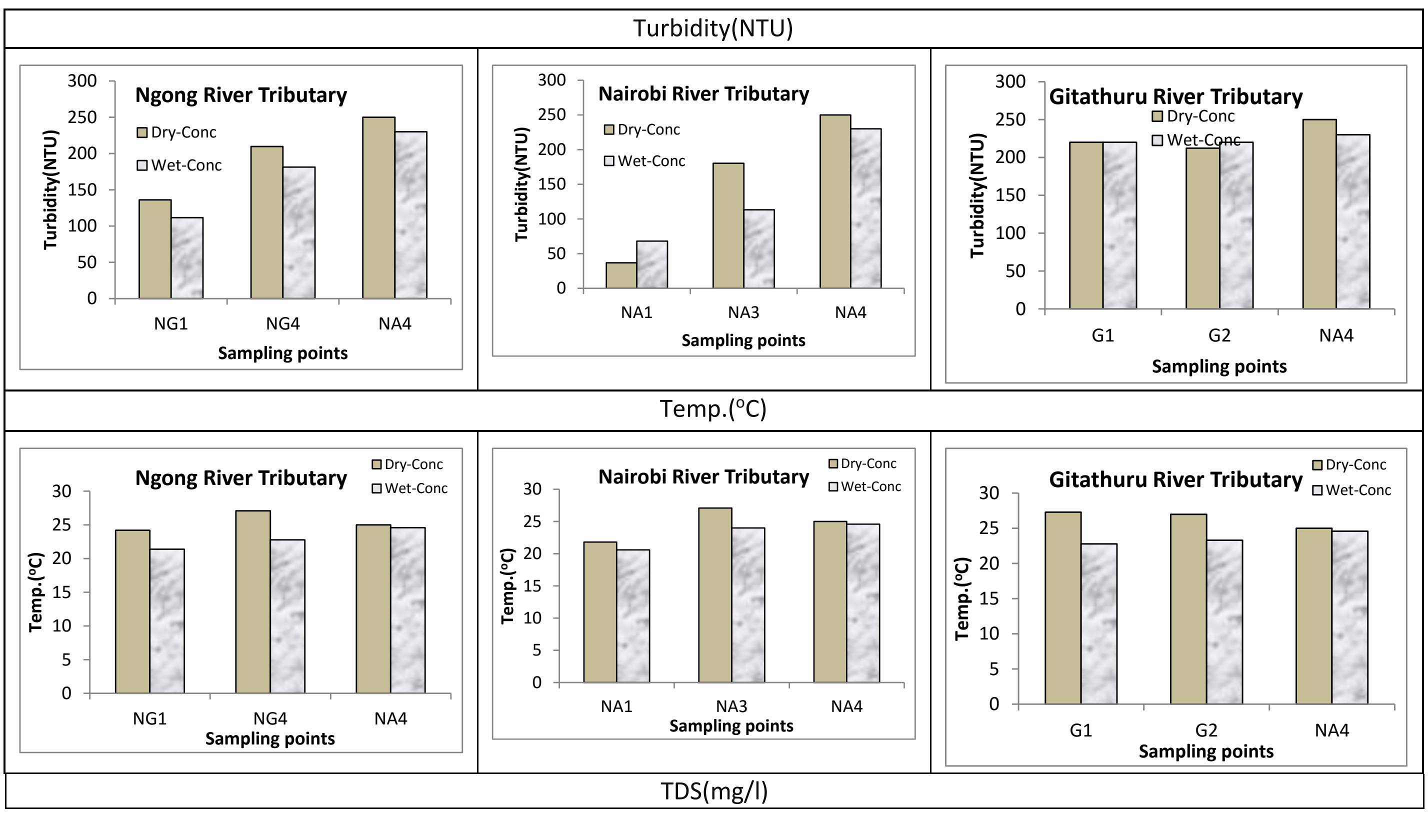
3.1 Physico-chemical Properties

3.1.1 Turbidity and Temperature of Surface Water

Gitathuru River tributary had higher turbidity than Ngong and Nairobi River tributaries in both the dry and wet season. In Ngong and Nairobi tributary the turbidity increased from upstream to the downstream end of River, but remained the same along Gitathuru river with the highest amount (250 NTU) occurring at Eastern by- pass junction(Fig.2). Temperature ranged from 24 and 27 ^oC in all the tributaries (Fig.2).

3.1.2 Dissolved Solids

Along all the tributaries, TDS increased from upstream to downstream (Fig. 2).At the upstream end of each tributary, the difference between dry season and wet season was insignificant. However at the downstream end, the levels of TDS were slightly higher during the dry season.



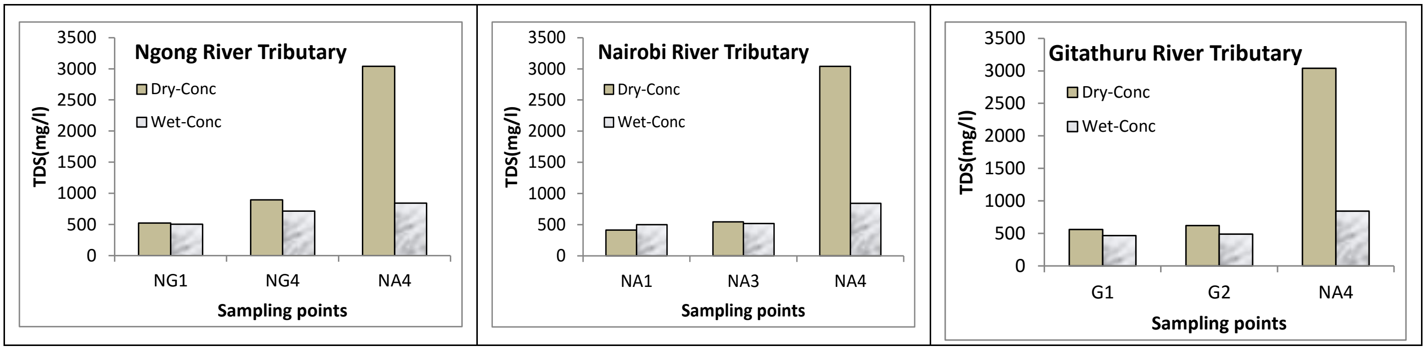


Figure 2: Turbidity, temperature and total Dissolved solids for Nairobi surface water

3.2 Heavy Metal Content of Surface Water in Nairobi River

Heavy metals in water can cause detrimental effects to the aquatic, terrestrial and human life. Therefore, Kenya has formulated some standards for acceptable levels of these metals in drinking water. Other than Zinc which did not exceed the recommended value of 5 mg/L in drinking water and 2 mg/L in irrigation water (Table 1) the metals studies exceeded those limits. Unless otherwise stated, this paper uses the Kenya Water Quality Standards (KEBS, 2007). Zinc levels remained the same during dry and wet weather conditions, and did not vary spatially from the upstream to the downstream ends of the three tributaries.

Table 1: Kenyan standards for permissible levels of heavy metals in water (KEBS, 2007)

Water use	Lead (mg/L)	Zinc (mg/L)	Copper (mg/L)	Iron (mg/L	Manganese (mg/L	Chromium (mg/L)
Drinking	0.05	5	0.1	0.3	0.1	0.05
Irrigation	5	2	0.05	1	------	1.5

3.2.1 Lead

The mean concentration of Lead in surface water in Ngong River (0.6-0.9 mg/L) was slightly higher than in the Nairobi River (0.6 mg/L) and Gitathuru River (0.5-0.6 mg/L) (Figure 4). This is probably because in the City of Nairobi the industrial area is located along the Ngong River tributary. Possible sources of Lead in the water would be industrial wastes, used lead acid batteries, solder, alloys, cable sheathing, pigments, rust inhibitors and plastic stabilizers (Akan et al., 2010). All these sources of heavy metals are present in Nairobi's industrial area.

In the three tributaries, the drinking water standard of 0.05 mg/L was exceeded (KEBS, 2007). However, the lead level was safe for agricultural use. At all sampling points, the concentration of lead did not significantly change between the dry and wet seasons, meaning that the contribution of runoff to lead concentration was insignificant.

Lead is non-essential element in the human body and excess levels can damage human kidneys, the liver and the nervous system; blood vessels and cognitive impairment in children (Sharma & Pervez, 2003; Kaur, 2012)

3.2.2 Chromium

As was the case with lead, the concentration of chromium in surface water in Ngong River (0.5-1.7 mg/L) was slightly higher than in the Nairobi River (0.1-0.5 mg/L) and Gitathuru River (0.1-0.2 mg/L) (Fig.3). In the three tributaries, the drinking water standard of 0.05 g/L was exceeded. In Ngong River the levels of chromium exceeded the limits for irrigation water (1.5 mg/L), but in Nairobi and Gitathuru tributaries the upper limit for irrigation was not exceeded. It is apparent that the industries located along the Ngong River tributary may be contributing significant amounts of chromium. High chromium concentration in the River tributaries may be related to river dumping of solid waste containing dyes, pigments, glues, tannery waste, and wood preserving materials (Alloway, 1995). Chromium and its compounds are known to cause cancer of the lung, nasal cavity and suspected to cause cancer of the stomach and larynx (ATSDR, 2000 or Barchi et al, 2002).

3.2.3 Copper

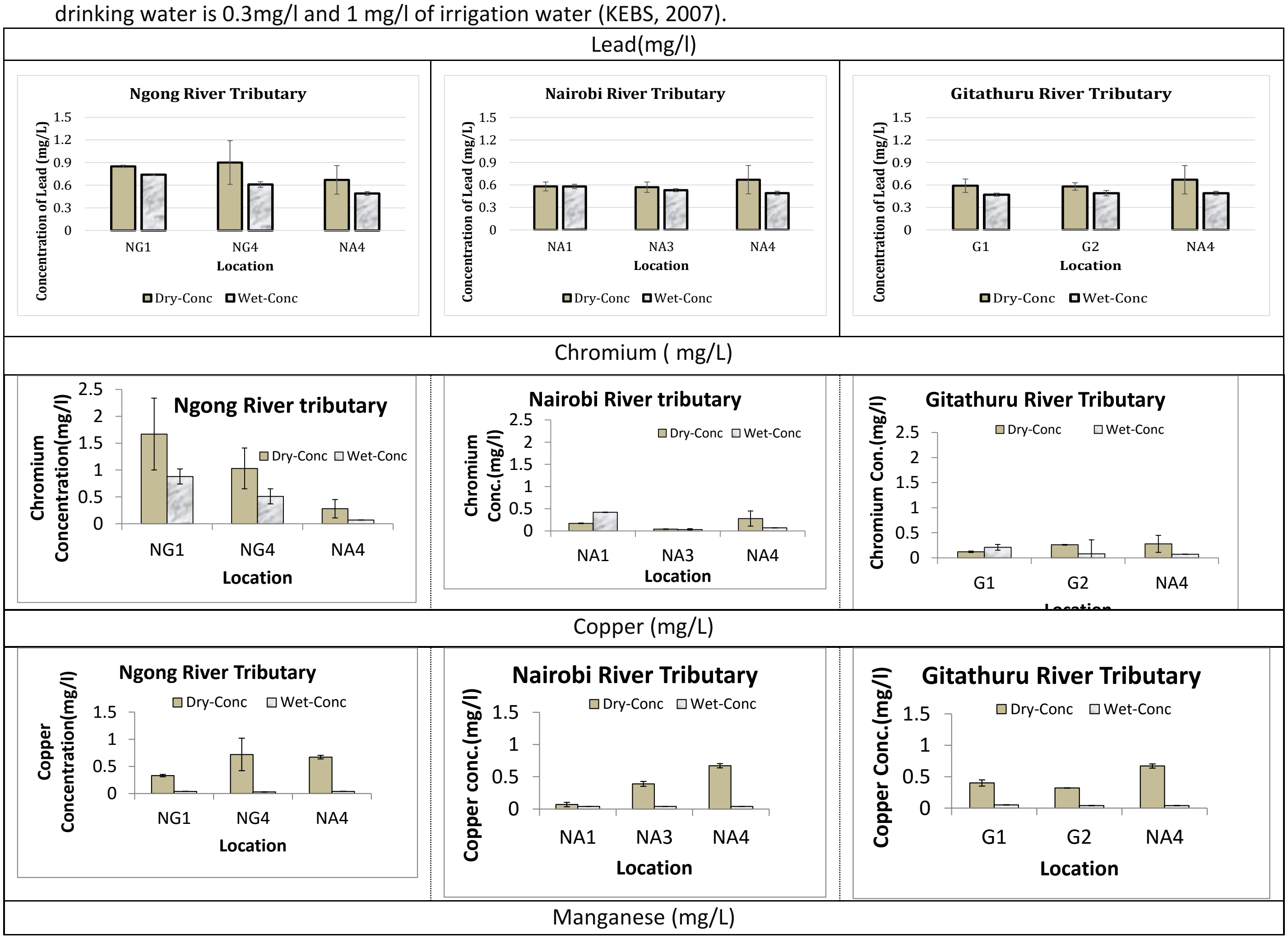
Dry season copper levels were significantly higher than wet season levels. In Ngong and Nairobi River tributaries, the concentration of copper tended to increase from upstream to the downstream end. In Gitathuru, the concentration of copper seemed not to vary from upstream to downstream. The highest mean concentration of copper (about 0.7 mg/l) was recorded during the dry season while during the wet season the concentration tended to just meet the safe drinking water quality standard for copper 0.1 mg/L (Fig.3).

3.2.4 Manganese

The concentration of Manganese in the three tributaries varied between 5 and 6 mg/L, during the dry weather, and between 1 and 3 mg/L during the wet weather (Fig.3). The lower concentration during wet weather was probably due to dilution. The concentration of manganese did not vary from upstream to the downstream end of the river. In the three tributaries, the concentration of Mn was nearly the same and at all sampling stations the concentration of Mn exceeded the recommended levels for drinking (0.1 mg/L) and irrigation (0.2 mg/L) purposes. Expired dry cell batteries are a major source of manganese in river water (Ziemacki et al., 1989). Industries located along the river could also be another source of this pollutant.

3.2.5 Iron

As was the case with manganese, the concentration of iron did not vary from one tributary to another. The concentration of iron was significantly higher during the wet season (18 to 20 mg/l) than during the dry season (10 to 15 mg/l). Others have also found the concentration of iron in surface water to be higher in wet season (Dan et al, 2014). This could be as a result of storm run-off from the surrounding areas. The recommended level of iron in drinking water is 0.3mg/l and 1 mg/l of irrigation water (KEBS, 2007).



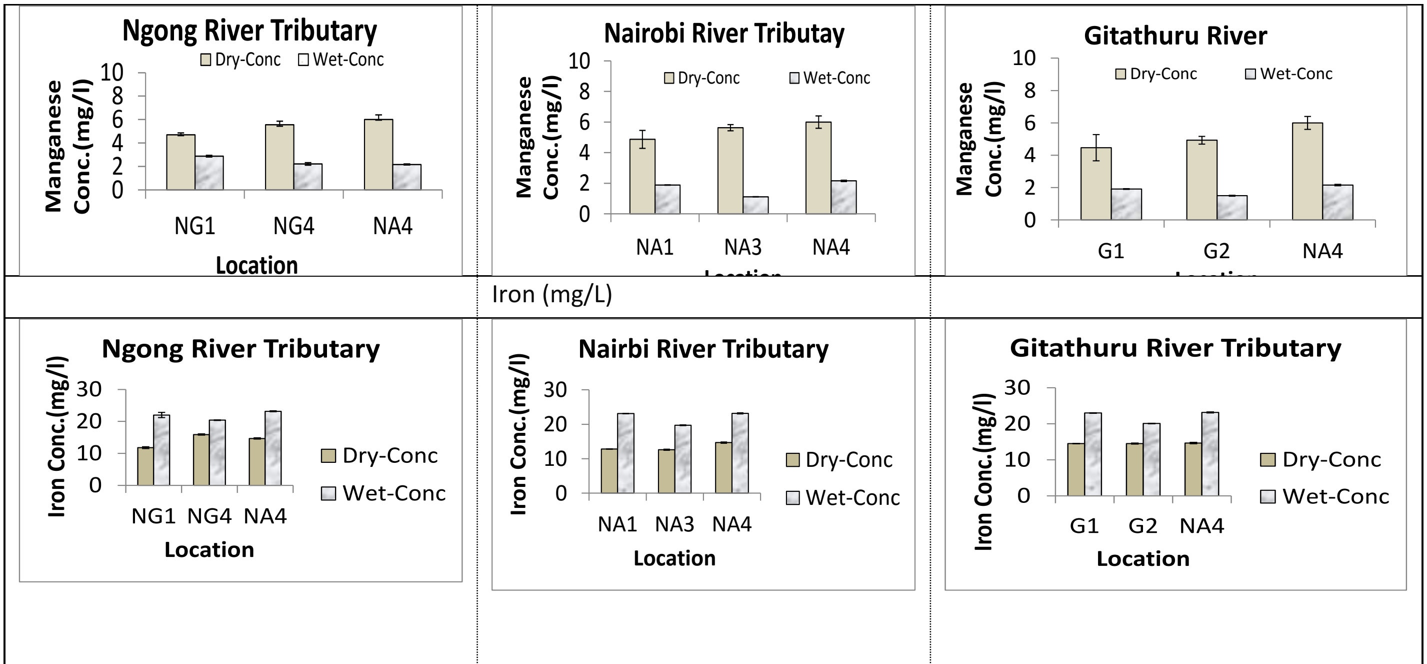


Figure 3:Heavy metal seasonal and spatial variation in Nairobi River Surface water

4.0 Discussions

4.1 Turbidity and Temperature

Turbidity is attributed to the source of runoff and is a measure of the organic matter in water. High turbidity affects the aquatic life and water aesthetics. Temperature Variation affects the amount of dissolved oxygen. The maximum solubility of oxygen in water at 1 atm. pressure (standard air pressure at sea level) ranges from about 15 mg/L at 0ºC to 8 mg/L at 30ºC—that is, ice-cold water can hold twice as much dissolved oxygen as warm water (Wetzel, 2001). Increase in Surface water temperature decreases the amount of the dissolved oxygen.

4.2 Total Dissolved Solids

A total dissolved solid (TDS) is the term used to describe the in organic salts and small amounts of organic matter present in solution in water. The principal constituents are usually calcium, magnesium, sodium and potassium; and carbonate, hydrogen carbonate, chloride, sulphate, and nitrate anions (WHO, 1996). High levels of evaporation during the dry season

increase the concentration of ions in the surface water and hence high levels of TDS during the dry season. In the study very high amount of total dissolved solids were observed at the Eastern by- pass area. The increase was attributed to the addition of sewage, industrial or urban and agricultural run-off wastewater along the course of the river, resulting to addition of ions such as chlorides phosphates, nitrates and the like. High TDS in drinking water can have adverse effect to human health such as cancer (Burton & Cornhill, 1977), coronary heart disease (Schroeder, 1960), arteriosclerotic heart disease (Schroeder, 1966), and cardiovascular disease (Craun & McGabe, 1975). This study concludes that surface water in Nairobi has excessive levels of organic matter (associated with turbidity). The high TDS is likely associated also with the presence of heavy metals.

4.3 Heavy Metal Content of Surface Water in Nairobi River

There were significant seasonal differences in heavy metal concentrations in Nairobi surface water. Among the factors contributing to these differences include dilution which occurs following rainfall events as well as washing of pollutants resulting in enhanced pollutant levels in run-off (Rai, 2008; Olatunde & Oladele, 2012; Mondol et al, 2011; Nwabueze & Oghenevwairhe, 2012).

The concentration levels of most of the metals studied with an exception of zinc exceeded the Kenyan standards of drinking and irrigation water, along all the Nairobi River tributaries. This is attributed to industries waste, high traffic and other solid waste disposals (Sorme & Lagerkvist, 2002 or USEPA., 1992).Studies carried out along Nairobi river tributary indicated that the mean concentration of copper, zinc and iron were below detectable limits according to (Budambula & Mwachiro, 2005).Whereas, (Kithia & Ongwenyi, 1997) reported that the mean concentration of Copper and Zinc as 0.1 mg/L and 0.2 mg/L respectively.

One of the major factors of human exposure to metals through the food chain is the soil-to-plant transfer (Lacatusu et al.,1996). The Nairobi River is used by some of the urban population for irrigation of vegetables and other crops (Githuku, 2009). Other studies revealed that food crops grown on untreated wastewater have excessively high concentration of heavy metals (Chealteau, 2007).Prolonged consumption of vegetables and crops with heavy metals are detrimental to human health. The rise of occurrence of non- communicable diseases such as cancer is attributed to such pollutants (Ward et al., 1995 or Turkdogan et al., 2003). Heavy metals pollutants are non-biodegradable and hence their effect may not only be to the urban population, but also by the rural communities' down-stream. Small concentrations of heavy metals even in portions as negligible as parts per billion (ppb), act as biological poisons (Okoronkwo et al.,2005).Based on the results obtained, the Nairobi River was found to be contaminated with heavy metals. The water is not safe for domestic and irrigation (Table 1). We conclude that NRS has excess amounts of heavy metals which are likely to affect the quality of Athi River, a major source of water in Machakos and Makueni Counties.

4.0 Conclusion

(i). Nairobi River water is not safe for domestic utility. Total dissolved solids and turbidity were found to be higher than KEBS and US EPA standards.

(ii). Among the heavy metal studied only zinc and copper were found to be within the recommended levels for drinking water and only zinc for irrigation water.

(iii). Ngong River had the highest concentration of lead (0.6-0.9 mg/l) and chromium (0.5-1.7 mg/l). Ngong and Nairobi tributaries had approximately the same levels of copper, manganese and iron. High heavy metal levels may be associated with industrial activities along Ngong and Nairobi River tributaries.

(iv). Seasonal variations may be attributed to dilution from rainfall. For all the heavy metals studied except Iron, high concentrations were found to occur during the dry season. The increase of iron in the river water during the wet season could be attributed to probability of presence of soils rich in iron in the storm water.

5.0 Recommendation

It is recommended that deliberate efforts should be made to stop discharging untreated effluents into Nairobi River System as this can have serious effects on food safety and human health.

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