Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.20, 2015

Assessment of the Impact of Urban Runoff from Migori Town on the Concentration Levels of Selected Heavy Metals in Migori River, Kenya

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Abstract
Water pollution and decreasing water quality is a major threat to water resources in urban set ups in the developing world. The key culprits include; agricultural runoff, untreated industrial and domestic wastewater, storm water and urban runoff. Migori is a rapidly growing city in Kenya with various land uses including crop and animal farming, industries, municipal markets, and commercial and residential set ups. The large volumes of urban runoffs generated in the town and its environs wash large pollutant loads into Migori River which is the main source of water in the region. This study investigated the effect of urban runoff from Migori town and its environs on the water quality of Migori River in terms of selected heavy metals. Water samples were collected from six established sampling stations along the river for six months (in wet and dry seasons). The water quality values were summarized as mean ± SE. Results indicated continued adverse impacts on the water quality of Migori River by urban runoffs. Water quality impairment in the river increased downstream – towards the town. Lead and nickel concentration levels are way above the WHO recommended guidelines for surface waters. Thus the river water poses serious risks to humans, animals and aquatic life. There is need for public awareness regarding the pollution problems and the consequences arising thereof in Migori River. There is also need for a study cataloguing the different chemicals used by different factories within Migori town. This will hopefully establish the definite sources of the heavy metals and nutrients and control their concentrations before they become too high and harmful to the ecosystem
Keywords: Urban run-off, Migori, water quality, pollution

1. Introduction

1.1 Background Information

Throughout the world history, water sources have been the centre of life, providing habitat and sustenance for animals and plants alike. Fresh water is a finite resource, essential for agriculture, industry and human existence. Without fresh water of adequate quantity and quality, sustainable development will not be possible. Water pollution and wasteful use of fresh water threaten development projects and make water treatment difficult in order to produce safe drinking water.

The increasing concern about pollution has been accompanied by more sensitive means of detecting pollutants and measuring their concentrations (Troeh *et al*, 1991). This increased sensitivity identifies pollutants that would have escaped unnoticed and raises the question of how much hazard such tiny amounts can cause. The pollution of the environment with toxic metals is a result of many human activities, such as mining and metallurgy, and the effects of these metals on the ecosystems are of large economic and public health significance (UNEP, 2005; UNEP and GEMS, 2006). The inadequacy of our conventional methods of river dumping is further exposed by the death of fishes and even deforestation of nearby trees on the shore, affecting human and animal lives (Oboh *et al.*, 2009). Therefore the study of the existing disposal methods, facilities, and attitudes on waste management is essential in order to make a positive impact on our environmental hygiene.

Rapid population growths, land development along river basins, urbanization and industrialization have subjected rivers to increased stress, giving rise to water pollution and environmental deterioration (Sumok, 2001). Surface water pollution issue has been one of the most serious problems in developing countries.

Water is the most valuable natural resource existing on our planet earth. Without this invaluable compound, the life on the earth would be non-existent. Although this fact is widely recognized, pollution of water resources is a common occurrence. In particular, potable water has become greatly affected, and in many instances has lost its original purpose. There are many sources of water pollution, but two main general categories exist: direct and indirect contaminant sources (IAWPRC, 1988). Direct sources include effluent outfalls from industries, refineries and wastewater treatment plants; whereas, indirect sources include contaminants that enter the water supply from soils/ground water systems and from the atmosphere via rain water and urban runoff. The study takes into consideration some selected heavy metals and nutrients, which come under inorganic. They are common contaminants and many of them are known to be toxic and carcinogenic.

Urban runoff is not simply clean rain that falls on the urban landscape and subsequently flows away. Rain falling upon a catchment collects pollutants from the air, road way surfaces, other catchment surfaces, and storm drains, and is thereafter transformed into a type wastewater (Chambers et al. 1997; Adams and Papa, 2000). Urban storm water runoff contains harmful pollutants from a variety of sources in the urban landscape which can adversely impact receiving waters (Martha et al, 2006). The quantity of these pollutants per unit area delivered to receiving waters tends to increase with the degree of development in urban areas, thus the impact (Morisawa, 1985).

Pollution is contamination that makes water unclean or impure. Water pollutants squander the resources that support life, and causes aesthetic, health and productivity problems. Water pollution and wasteful use of fresh water threaten development projects and make water treatment difficult in order to produce safe drinking water (Troeh *et al.*, 1991). Water pollution is a major problem in the global context. It is the leading worldwide cause of deaths and diseases (Pink, 2006; West, 2006). Quality of water is of paramount importance because of its role to human health, aquatic life, ecological integrity and sustainable economic growth (Ajibade, 2004). The control of water pollution is important not only for amenity and public health reasons but also because clean water for domestic, industrial and agricultural use is in short supply, even in comparatively wet countries such as United Kingdom (Mason, 1991).

2. Sources of Heavy Metals

River water is used to an increasing extent as drinking and irrigation water particularly in highly urbanized and industrialized areas. In addition to water pollution by nutrients or organic compounds, the heavy metal content in flowing waters has become one of the most important problems because of its toxic effect even in minor concentrations (Symder, 2001). The occurrence of heavy metals in aquatic system has also become a global phenomenon due to their carcinogenic and mutagenic nature (Mahiva *et al*., 2008). Various industries produce and discharge wastes containing different heavy metals into the environment. Thus, metal as a kind of resource is also becoming a serious environmental pollution, threatening human health and ecosystem.

Heavy metals can be present in industrial, municipal, and urban runoff, which can be harmful to humans and aquatic life. Increased urbanization and industrialization are to blame for an increased level of trace metals, especially heavy metals, in our waterways. Heavy metals are not biodegradable and tend to accumulate in living organisms, causing various diseases and disorders.

Roadways and automobiles now are considered to be one of the largest sources of heavy metals *(Conservation Currents, 2005).* Zinc, copper, and lead are three of the most common heavy metals released from road travel, accounting for at least 90% of the total metals in road runoff. Smaller amounts of many other metals, such as nickel and cadmium, are also found in road runoff and exhaust. About half of the zinc and copper contribution to the environment from urbanization is from automobiles. Nickel comes from paint and powder batteries processing units, fertilizers, food processing, fuel oil combustion, industrial waste, stainless steel cookware, tea and tobacco smoke. The source of copper is copper cookware, engine parts, brake emissions, copper pipes, fungicides, industrial emissions, insecticides and welding.

2.1 Effects of Heavy Metals

It has been established that dissolved heavy metals into the environment pose a serious health hazard (Volesky, 1999). Heavy metals are dangerous because they tend to bioaccumulate (Volesky, 1999). Compounds accumulate in living things when they are taken up and stored faster than they are metabolized or excreted. Heavy metals are toxic to aquatic organisms at very low concentrations. The contamination of water by toxic heavy metal ions is a worldwide environmental problem. The most common and harmful heavy metals are lead, copper, nickel, chromium and zinc. They are stable elements that cannot be metabolized by the body and get passed up in the food chain to human beings (Oboh *et al.*, 2009). Since even low concentrations of heavy metals can cause serious harm to aquatic systems, there is a need for controlling their emissions into the environment (Volesky, 1999). In humans, exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure. Various effects occur over a broad range of doses, with the developing foetus and infant being more sensitive than the adult. High levels of exposure may result in toxic biochemical effects in humans which in turn cause problems in the synthesis of haemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system, and acute or chronic damage to the nervous system (http://www.tip 2000.com/health/waterpollution.asp, 2000).

Some studies suggest that there may be a loss of up to 2 IQ points for a rise in blood lead levels from 10 to 20μg/dl in young children (http://en.wikipedia.org/wiki/Lead_poisoning). Long term exposure to nickel can cause decreased body weight, heart and liver damage, and skin irritation (Bishop, 2002). Nickel is an ‘‘intermediate metal that forms less stable complexes, mostly by weaker ionic bonding (Schiewer and Volesky, 2000). Copper is an essential substance to human life, but in high doses it can cause anemia, liver and kidney damage, and stomach and intestinal irritation. People with Wilson's disease are at greater risk for health effects from overexposure to copper.

3. Study area

Migori River passes through Migori town, which is situated in Western part of Kenya, Nyanza Province (Fig. 1.1). The town is 63 km south of Kisii town and 22 km north of the Tanzanian border. The region, with a population of 82,000 people, is not served with adequate piped water. Most of the residents depend on the raw water from the river. The town is also poorly served with sewerage system, making most of the wastes from residential areas to find their way into the river through run off.

Migori town is a major agricultural growing area and is situated on both sides of Migori River. The flow of the river is from South-East to North-West direction across the town. Rainfall is in two seasons, like most parts of Kenya, and the highest rainfall is between the months of March and May. The second season (short rains) is between the months of September and November.

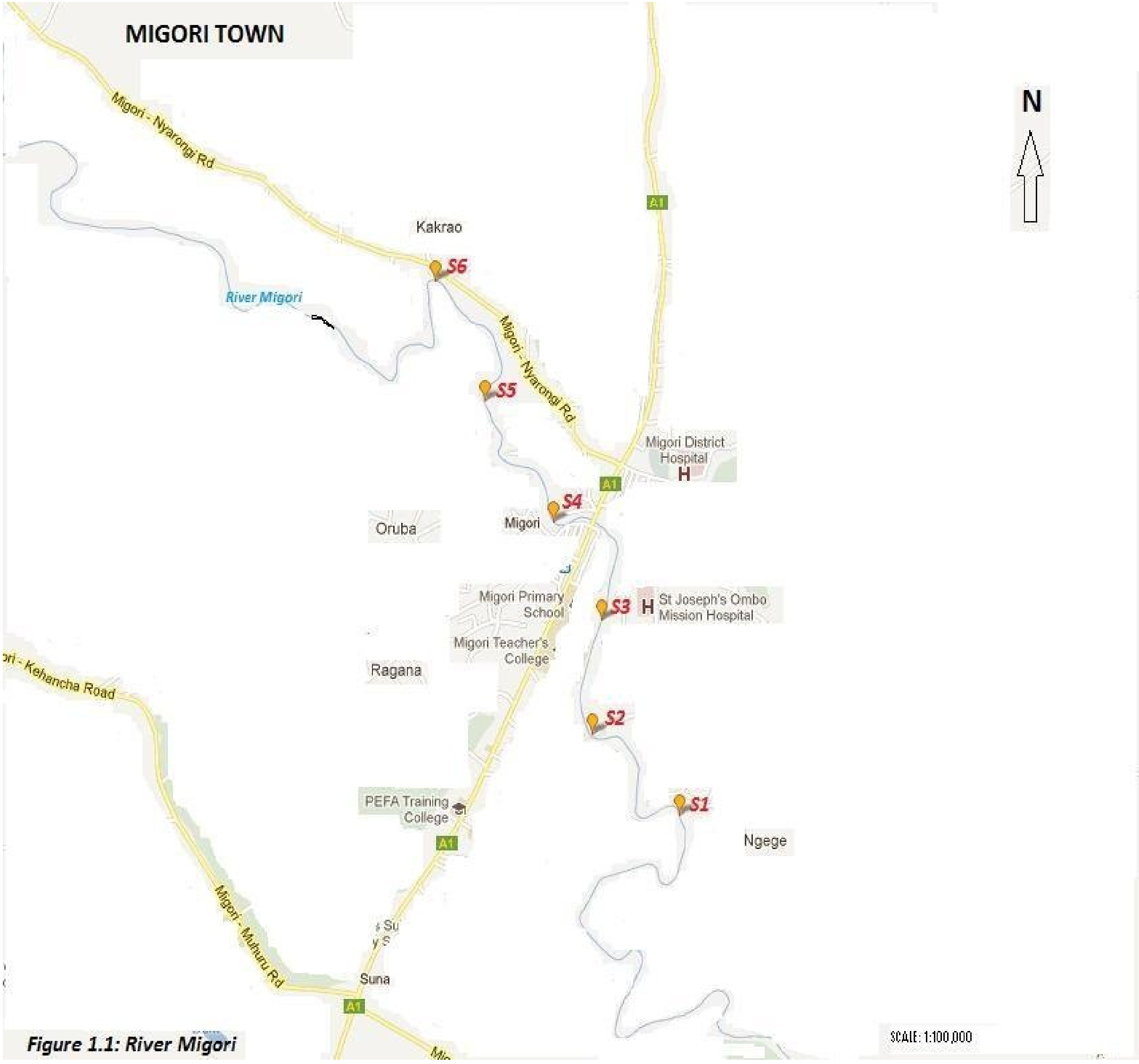

Figure 1.1: River Migori

4. Materials and Methods

4.1 Materials

The sampling bottles and glassware were cleaned according to the recommended methods (APHA, 1995). All of the chemicals used throughout the experiments were high quality analytical reagents. Distilled water was used in all dilutions and standard preparation; All containers were washed up with hot nitric acid and then rinsed with distilled water before using in the experiments. All glass beakers and containers were kept and stored in 1.0 mol/L HNO_3 to eliminate any possible contamination.

4.2 Sampling

Six sampling stations were established, three upstream and three downstream of Migori town. The stations were designated S1, S2, S3, S4, S5 and S6 starting from the farthest upstream (S1) to the lowest downstream (S6), at intervals of 2 km apart (Figure 1.1). Samples were collected monthly from each station December 2013 to May 2014. This included samples collected in dry season (December 2014 to February 2015) and wet season (March to May 2015). The samples were collected midstream, in duplicates, using plastic sampling bottles. The samples were transported to the laboratory in ice-cool boxes and were analyzed within 12 hours of sampling.

4.3 Experimental Procedures

The acidified samples (100 ml), after filtration with preconditioned plastic Millipore filter unit equipped with a 0.45µm filter, were digested with concentrated HNO_3 to concentrate and convert metals free metal ions. The solutions were then determined for Pb, Zn, Ni, and Cu levels using Perkin Elmer Analyst 400 Atomic Absorption Spectrophotometer (AAS).

4.4 Data Analysis

The results were corrected according to recovery rates. Data was subjected to linear analysis using Microsoft Excel, EuraChem and SAS software packages. Quality assurance and quality control procedures for the laboratory included analysis of duplicates, and blanks.

5. Results and discussion

Table 4.1 shows the mean concentration levels of Ni^{2+}, Pb^{2+}, Zn^{2+} and Cu^{2+} during wet and dry seasons, with their standard deviations (±SD); while figures 1 to 4 show the variations of metal ions in the six sampling sites during wet and dry seasons.

Table 4.1: Concentrations of metal ions in river (mg/L) –wet and dry seasons

	Cu		**Zn**		**Pb**		**Ni**	
Site	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**	**Wet**	**Dry**
S1	0.050 ±0.030	0.080 ±0.010	0.120 ±0.020	0.090 ±0.006	0.005 ±0.001	0.005 ±0.001	0.030 ±0.005	0.030 ±0.006
S2	0.110 ±0.010	0.150 ±0.006	0.180 ±0.010	0.160 ±0.005	0.010 ±0.007	0.010 ±0.00	0.060 ±0.006	0.030 ±0.005
S3	0.260 ±0.020	0.190 ±0.010	0.230 ±0.009	0.200 ±0.006	0.050 ±0.010	0.04 0 ±0.010	0.070 ±0.015	0.040 ±0.011
S4	0.280 ±0.020	0.250 ±0.010	0.270 ±0.017	0.210 ±0.011	0.060 ±0.006	0.050 ±0.006	0.070 ±0.006	0.050 ±0.010
S5	0.270 ±0.010	0.250 ±0.006	0.24 0 ±0.010	0.200 ±0.050	0.060 ±0.005	0.04 ±0.005	0.060 ±0.015	0.050 ±0.006
S6	0.250 ±0.010	0.230 ±0.010	0.230 ±0.006	0.180 ±0.050	0.050 ±0.006	0.030 ±0.006	0.050 ±0.011	0.040 ±0.010
WHO Guide	1.0		5.0		0.01		0.02	

Figures 1 to 4 show the variations of metal ions in the six sampling sites during wet and dry seasons.

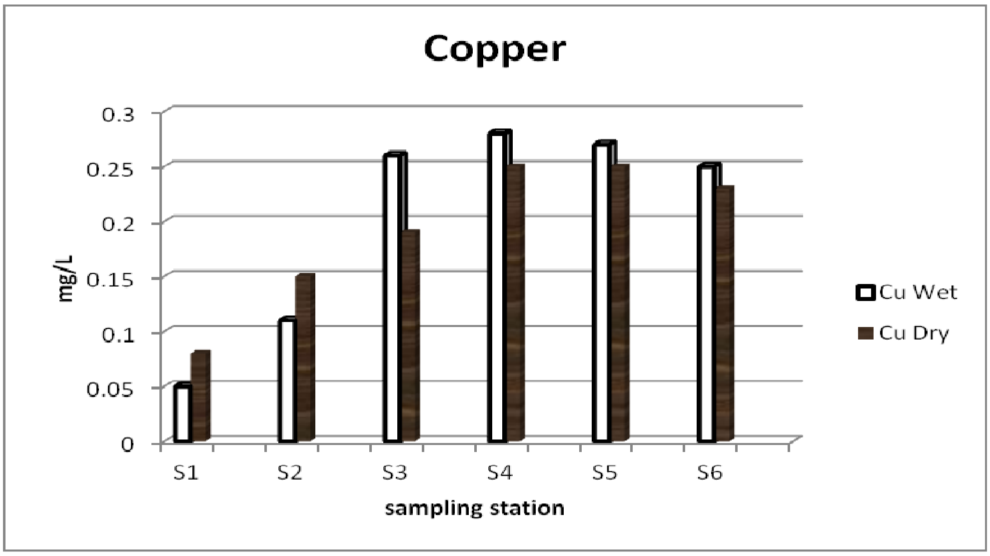

Figure 1

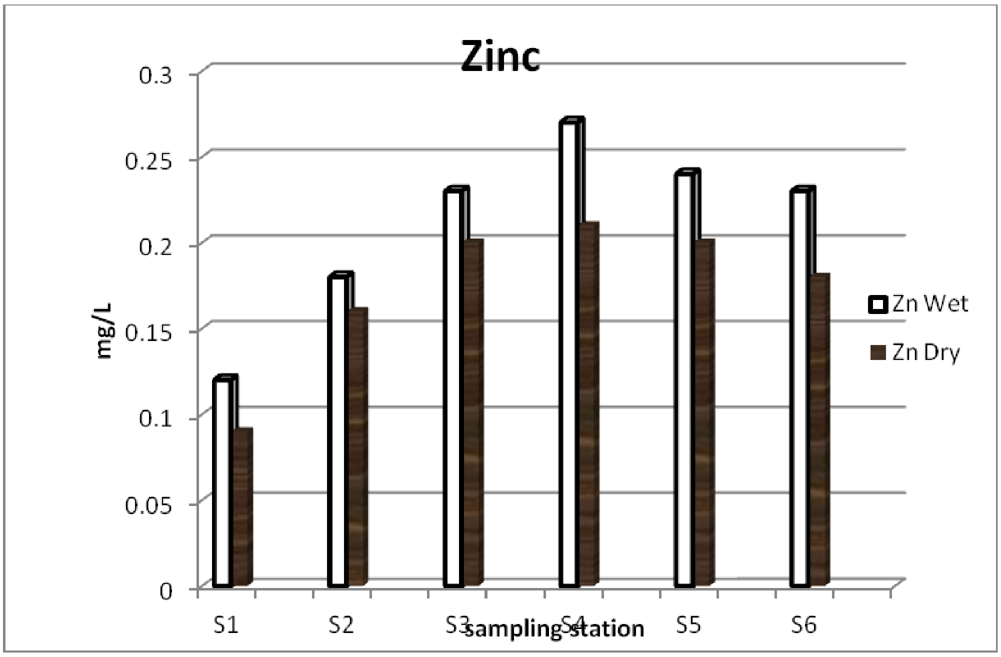

Figure 2

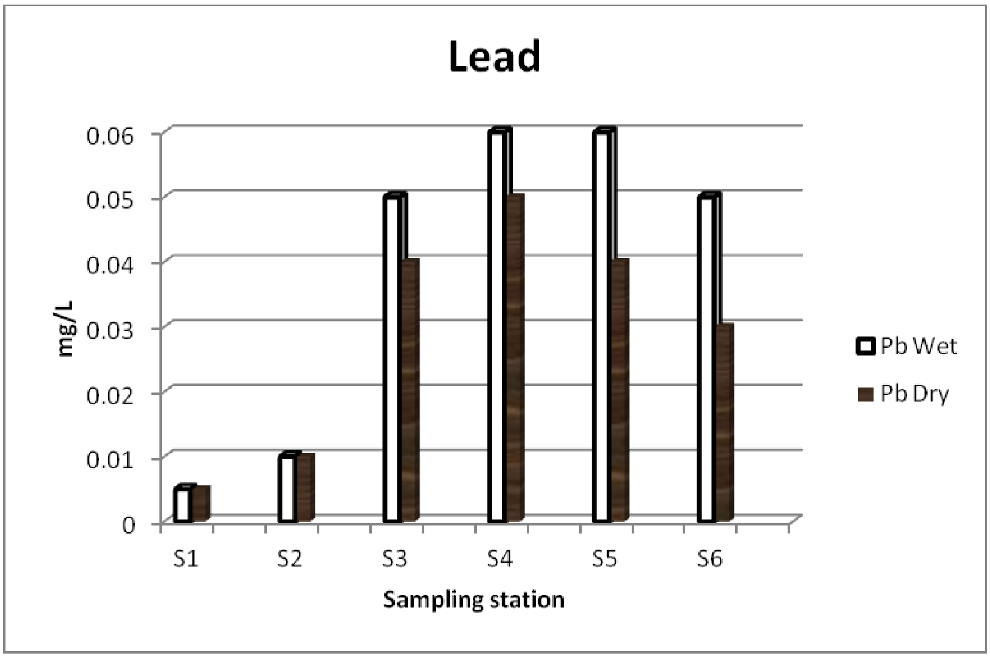

Figure 3

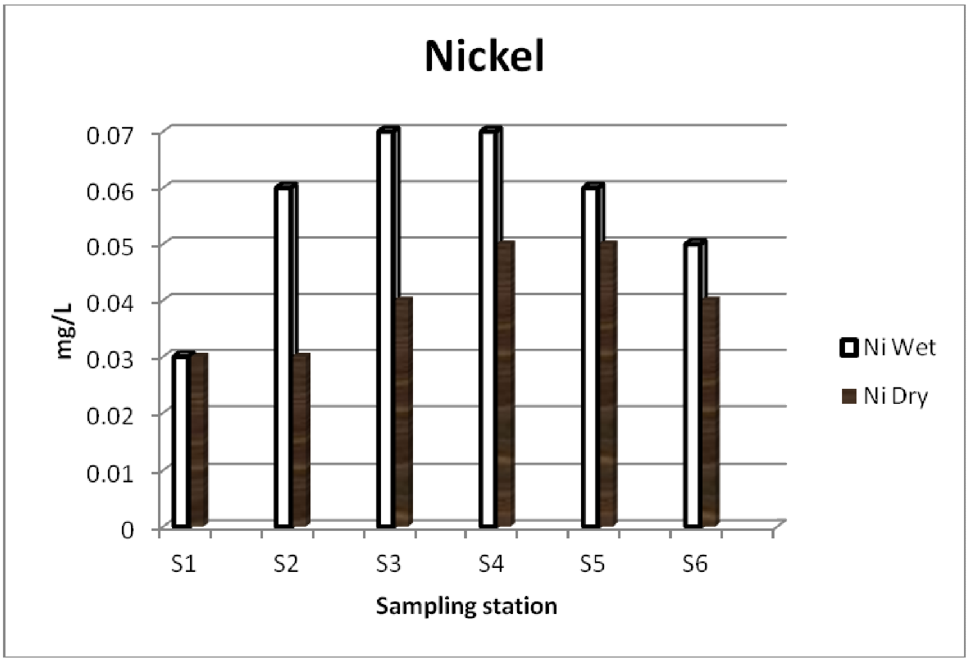

Figure 4

Concentration levels of Cu^{2+} ions varied from 0.02 to 0.29 mg/L and from 0.07 to 0.26 mg/L in wet season and dry season respectively. Concentration levels of Zn^{2+} ions varied from 0.10 to 0.28 mg/L and from 0.09 to 0.22 mg/L in wet season and dry season respectively. Lead (Pb^{2+}) ions levels varied from 0.01 to 0.07 mg/L and from 0.01 to 0.04 mg/L in wet season and dry season respectively. While that of Ni^{2+} ions varied from 0.02 to 0.08 mg/L and from 0.02 to 0.06 mg/L in wet season and dry season respectively.

The general trend shows that metal cconcentrations is lowest in site S1 which is upstream of Migori town and highest in S4 in the middle of the town. There is then a slight decrease as one moves downstream indicating some level of self purification of the river. Generally it was observed that concentration levels are higher during wet season than in dry season. This is likely due to runoff from town both from commercial and residential areas. According to the figures from WHO water quality standards guidelines, lead and nickel concentration levels is above the allowed limit (WHO 2000). However copper and zinc are within the allowed range.

6. Conclusions

Water quality deterioration within Migori River was found to increase with increase in runoff discharge in the wet seasons. The study revealed that runoff discharge and concentration of water pollutants had relationship. Storm water run-off was found to be washing up and transporting solid wastes; chemical industrial pollutants; waste water from residential and commercial areas, agricultural farms, food processing plants and others into Migori River. Lead and nickel concentration levels are way above the WHO recommended guidelines for surface waters. Thus the river water poses serious risks to humans, animals and aquatic life.

6.1 Recommendations

There is need for public awareness regarding the pollution problems and the consequences arising thereof in Migori River investigated and the entire basin. Generally, there is need for an integrated Environmental Education (EE) programme within the basin focusing on the need for people living within Migori and its environs to appreciate a cleaner environment. Integrated water resources management (IWRM) approach would be very key in addressing the problem of water quality degradation within Migori and its environs. The approach will involve all Government Ministries, water resources stakeholders and the participation of the local communities in understanding the implication of declining water quality status and the need to guard against polluting the resources. This will ensure potable water resources and continued safe supply of clean water to the people.

Continuous monitoring programs consisting of standardized sampling and runoff measurement should be put in place for the river to provide reliable and enough data for implementing sustainable management measures.

There is need for a study cataloguing the different chemicals used by different factories within Migori town. This will hopefully establish the definite sources of the heavy metals and nutrients and control their concentrations before they become too high and harmful to the ecosystem

Acknowledgement
The author is very grateful for the assistance of the laboratory staff from Eldoret Water and Sanitation Company. Much thanks to Ms. Dorothy and Mr. Kizito who assisted during the preparation and analysis of samples.

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