Volume 5 No.7, July 2015 ISSN 2224-3577
International Journal of Science and Technology

http://www.ejournalofsciences.org

Determination of Heavy Metals Pollutants in Sediments along the Banks of Athi River Machakos County, Kenya

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ABSTRACT

Athi River in Machakos County in Kenya is increasingly choking with pollutants from industrial and anthropogenic sources. This situation has occasioned spread of waterborne diseases, loss of sustainable livelihoods, loss of biodiversity, reduced availability of safe portable water and the insidious effects of heavy metal poisoning. This research set out to determine the heavy metals concentration in sediments from the banks of Athi River. Nine sediments ((S1 – S9)) were collected from targeted sites of Athi River banks, that is, at intervals of three kilometers. Flame atomic absorption spectrophotometer (FAAS) was used in the analysis of the concentration of Pb^{2+}, Cr^{2+}, Cu^{2+}, Cd^{2+} and Ni^{2+}. The results revealed that Pb was highest with a peak concentration 0.3513 ppm of followed by Cu and Cr with peak concentrations of 0.13866 ppm and 0.1329 ppm respectively. The high concentrations of Pb, Cu and Cr were attributed to the discharge of industrial waste and raw sewage to the river at specific points. These wastes are usually highly contaminated with various heavy metals. Ni and Cd were the lowest among all the heavy metal with concentrations of 0.01912 ppm and 0.01082 ppm respectively. The presence of Cd and Ni in sediments could also be attributed to the agricultural discharge as well as from spill of leaded petrol from transportation lorries. The study recommends that in order to improve the water quality and environment in the Athi River Basin, the National Environmental Program Agency (NEMA) should develop environmental management and planning systems. This entails the formulation of organizational structures, plans and resources for developing, implementing and maintaining policy for environmental protection. The agency should also come up with strategies and policies aimed to rehabilitate and restore the river.

Keywords: *Heavy Metals, Sediments, Pollution*

1. INTRODUCTION

Heavy metals are chemical elements with a specific gravity that is at least 5 times the specific gravity of water [10]; the specific gravity of water being 1 at 4°C (39°F). Some well-known toxic metallic elements with a specific gravity that is 5 or more times that of water are Cadmium, 8.65; Iron, 7.9; Lead, 11.34; and Mercury, 13.55 [6].

Heavy metals are indispensable for the support of daily life and even for sustaining life. For instance, copper, selenium and zinc are essential to maintain the metabolism of the human body [7]. However, the presence of high concentrations of heavy metals in the environment is of major apprehension because of their toxicity, bioaccumulation, and threat to human life and environment. Prolonged exposure to heavy metals such as cadmium, copper, lead, nickel and zinc can cause deleterious health effects in humans [11]. The primary sources of heavy metal pollution are industries and mining sites [5]. Atmospheric routes have also introduced large quantities of heavy metals to localized area [19].

Most of the industries which use raw materials containing heavy metals end up disposing their waste in rivers thus polluting them with heavy metals [3]. Such industries include smelting industries, hides and skins processing industries, soaps, detergents and perfume producing industries. Heavy metals in river waters lead to biotoxic effects to the aquatic animals in such rivers and also to the people who utilize water from such rivers [4]. Some health effects of heavy metals include diarrhea, stomatitis, tremor, hemoglobinuria, rust–red colour to stool, ataxia, paralysis, vomiting and convulsion, depression, renal dysfunction, cancer, teeth staining and Alzheimer's dementia among other many related effects [18].

Heavy metals are priority pollutants in rivers because of their environmental persistence, biogeochemical recycling and ecological risks [8]. Rivers are the major source of domestic and drinking water supply. Freshwater fish and invertebrates also

ISSN 2224-3577
International Journal of Science and Technology

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contribute towards recreation and food supply for locals and hence, bioaccumulation of heavy metals is a serious human health and environmental concern [2]. The presence of heavy metals in rivers as a result of their uses in modern society is matter of ever-growing concern to politicians, authorities and the public in the Kenya. The strategy for minimization of the effects of heavy metals in waste is partly to reduce today and future environmental and human exposure to the heavy metals in the waste, partly to reduce the content of heavy metals in products marketed [13].

Of major concern in Kenya is the Athi River. The river is increasingly choking with uncollected garbage; human waste from informal settlements; industrial waste in the form of gaseous emissions, liquid effluence and solids waste; agrochemicals, and other wastes especially petrochemicals and metals from microenterprises – the “Juakali”; and overflowing sewers. This situation has occasioned spread of waterborne diseases, loss of sustainable livelihoods, loss of biodiversity, reduced availability and access to safe potable water, and the insidious effects of toxic substances and heavy metal poisoning which affects human productivity [14]. Of major concern is the level of heavy metals in this river. Heavy metals enter the river when industrial and consumer waste, or even from the water run – off from the neighboring mining sites drains directly to the river [16]. These heavy metals have bio-accumulated in the river sediments to dangerous levels which pose precarious effects to human health, aquatic life and even the environment. The common polluting heavy metals are lead, cadmium, copper, chromium, nickel, selenium and mercury.

As an endeavor to clean this river and thus condense the hypothesized disparaging effects, there is need to initiate intense research to ascertain the type and magnitude of heavy metal pollution in this river and mainly in the sediments on the river banks. Consequently, this research set out to determine the heavy metal concentration in sediments from the banks of Athi river.

2. RESEARCH METHODOLOGY

The study will be done in Athi river in Machakos County in Kenya. Athi River forms part of athi-galana River which is the second longest river in Kenya (after the Tana River). It has a total length of 390 km, and drains a basin area of 70,000 km^2 [12].

This river has numerous uses not only to the habitats of areas around the river banks but also to the industrial sector. For these habitats, the river is useful as a source of water for agricultural irrigation, drinking water and for other such domestic uses. For industrial purpose, it is used as a major solvent for chemicals; it is also used as coolant especially in the smelter industries. It is used for large scale production of horticultural products [1]. The river flows through the Tsavo East National Park and attracts diverse wildlife, including hippopotamus and crocodiles.

The Athi River basin harbors two of the main urban and industrial and agricultural areas within and around Nairobi city. These are, Nairobi city on the upper catchment areas, which is the heart of industrial activities in Kenya. The second one is Malindi in the southeastern outlet of the basin [15]. In between, there are various economic activities, some of which are potential sources of pollutants. The upper catchment areas is extensively used for urban settlement, transport and industrial activities while in the southeastern parts is heavily used for agricultural production especially livestock keeping. The contribution of these land use activities to pollutants generation and hence water pollution and quality degradation is quite enormous.

Nine sampling sites in the Athi River ecosystem were selected (S1 – S9). Sediments were collected from targeted sites of Athi River banks, that is, at intervals of three kilometers. Five sediment samples were collected from each site with a 6.5 cm diameter a corer to a depth of about 15 centimeters and placed into distinct polythene bags and labeled according to the site of collection. These samples were kept in a deep freezer awaiting analysis.

A stock solution of 1000 mg/L containing Pb^{2+}, Cr^{2+}, Cu^{2+}, Cd^{2+} and Ni^{2+} were prepared. They were prepared by dissolving 1.59g, 3.05g,2.67g, 2.1g and 2.103g of $Pb(NO_3)_2$, $CrCl_2$, $CuCl_2$, $Cd(NO_3)_2$ and $Ni(NO_3)_2$, respectively. Standards of 0, 5, 10, 20, and 30 mg/L for each metal ion were prepared and their absorbance determined using AAS, from which calibration curve was plotted.

The sediment samples were dried in an oven at 80°C for 24 hours. The dried sediment samples were then ground using pestle and mortar till the desired fineness was achieved; this would be mainly to increase the surface area for extraction of the heavy metals from the sediment samples. The ground samples were then sieved using a sieve of mesh size 72 nm. 0.5 g of each dry sample was weighed and placed in a clean Kjedahl flask to which 10 ml of aqua – regia solution was added, that is, a mixture of concentrated $HNO_3$with concentrated HCl in the ration 1:3. The samples were then digested by electric digester with glass fume exhaust for a stretch of 2 – 3 hours. The solution was filtered using the normal filter papers(0.45 Whatman filter paper). Each of the resulting clear solution was diluted to 100 ml using distilled water in acid cleaned volumetric flasks. These solutions were ready for AAS analysis of heavy metals.

ISSN 2224-3577
International Journal of Science and Technology

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Flame atomic absorption spectrophotometer (FAAS) was used in the analysis of the concentration of Pb^{2+}, Cr^{2+}, Cu^{2+}, Cd^{2+} and Ni^{2+}. The concentrations of the metals were determined in triplicates.

3. RESULTS AND DISCUSSION

Heavy Metals in Sediments

i) Copper (Cu)

The mean concentration of copper in sediments from the nine sites is shown in figure 1. The peaks was observed in station 4(0.1581 mg/L) and 9(0.2475 mg/L), falling through to station 4 while the lowest concentration recorded in station 6(0.0607 mg/L). The possibility of the observed situation could be due to sediments acting as sinks and therefore adsorbing most of the settled copper in them resulting to the high concentration compared to the flowing water which becomes diluted as the river discharges downstream.

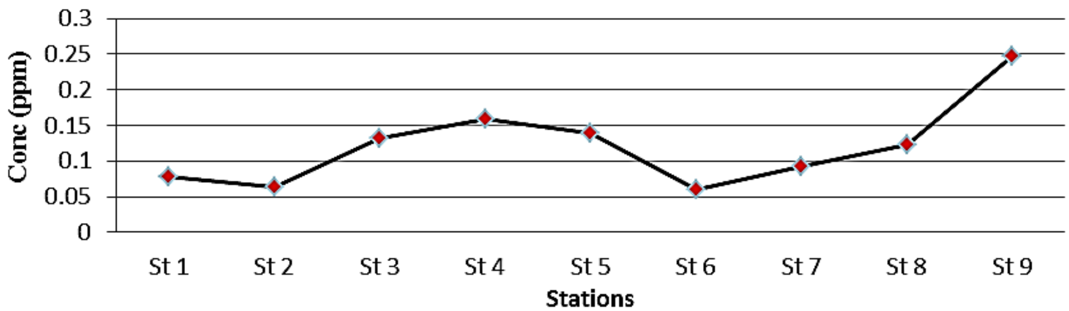

Figure 1: Variation of Copper concentrations in sediments in mg/L along Athi river.

ii) Lead (Pb)

Mean lead concentration in sediments varied very much for the first 5 stations (Figure 2). There was however no intense fluctuations from station 5(0.3513 mg/L) to station 9(0.2427 mg/L); with station 5 being the highest. This could be attributed to raw sewage discharge to the river at specific points in to the river. Also, dust which holds a huge amount of lead from the combustion of petrol in automobile cars led to increase Pb content [9]. Presence of dry cell battery manufacturing industry from catchment areas of the Athi River might probably responsible for high level of Pb. The water could be an influencing factor on the level of Pb in the sediments with other enhancing factor like pH since water acidity is known to influence the solubility and availability of metals.

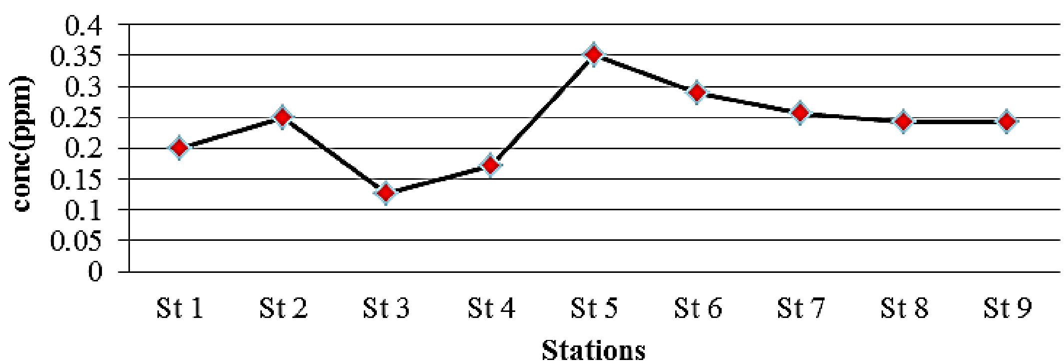

Figure 2: Variation of Lead concentrations in sediments in mg/L along Athi River

iii) Cadmium (Cd)

Generally, the mean concentration of cadmium was also high in sediment samples the peak value of this concentration being in station 5 (0.2402 mg/L). There was however variation in concentrations among the individual stations. The high level of Cd in the sediment was attributed to the deposition of this element from the water which is highly polluted. Sediments have been described as a sink or reservoir for pollutants in water [17].

ISSN 2224-3577
International Journal of Science and Technology

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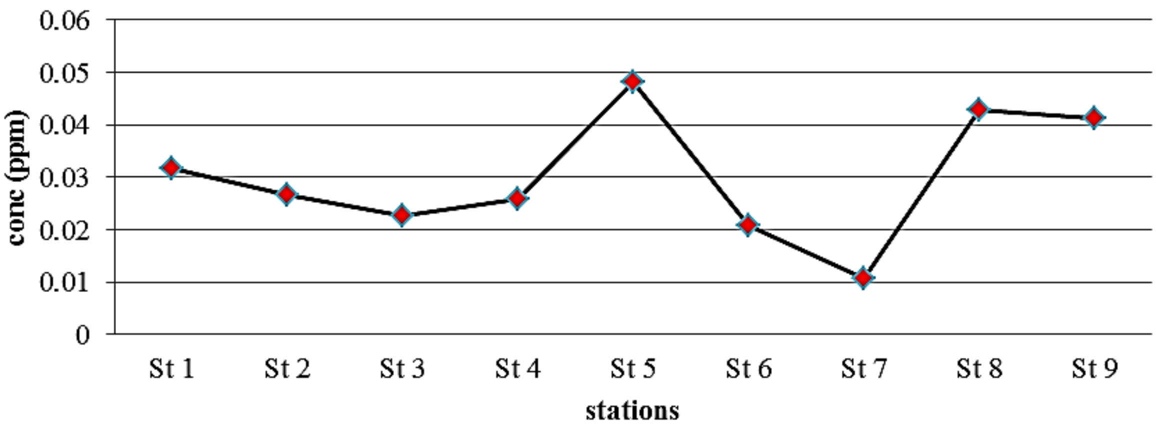

Figure 3: Variation of Cadmium concentrations in sediments in mg/L along Athi river

iv) Chromium (Cr)

The mean concentration for chromium in the sediments in the nine samples is shown in figure 4. The peak measurement was at station 3 and the lowest being at station 5. The high concentration of Cr can possibly be attributed to active discharge of this heavy metal from waste production from the nearby industries. The presence of Cd in sediments could also be attributed to the agricultural discharge as well as from spill of leaded petrol from transportation lorries. Apparently the Cr-containing chemicals used for skin tanning ends up in the environment the skin tunneling factory is located within two kilometers from the river.

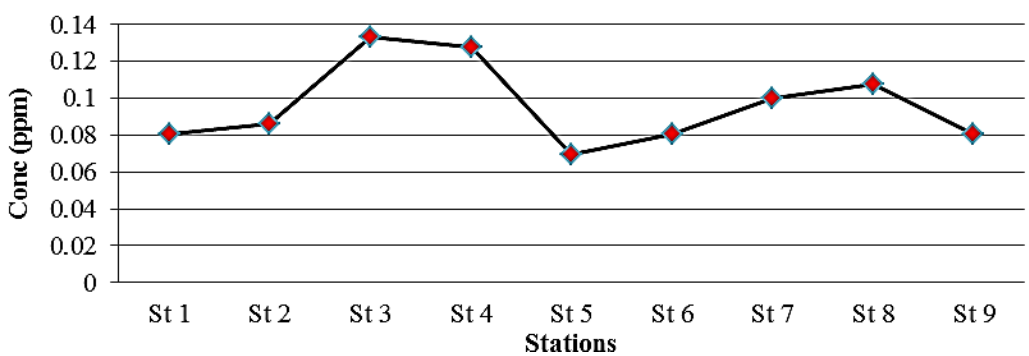

Figure 4: Variation of Chromium concentrations in sediments in mg/L

v) Nickel (Ni)

Mean Nickel concentration in the nine sediment samples is shown in figure 5. The highest concentration was recorded in station 1 and the lowest in station 7. Generally, the concentration of Ni was high in the samples. This could be attributed to the adsorption level of Ni by sediments as compared to the waters. Cadmium and Nickel are more adsorbed in sediment than in the flowing river water. The two elements have minimal rate of discharge compared to other metal ions. Their chemical and physical characteristics ions could be responsible for this observed phenomenon.

Volume 5 No.7, July 2015 ISSN 2224-3577
International Journal of Science and Technology

http://www.ejournalofsciences.org

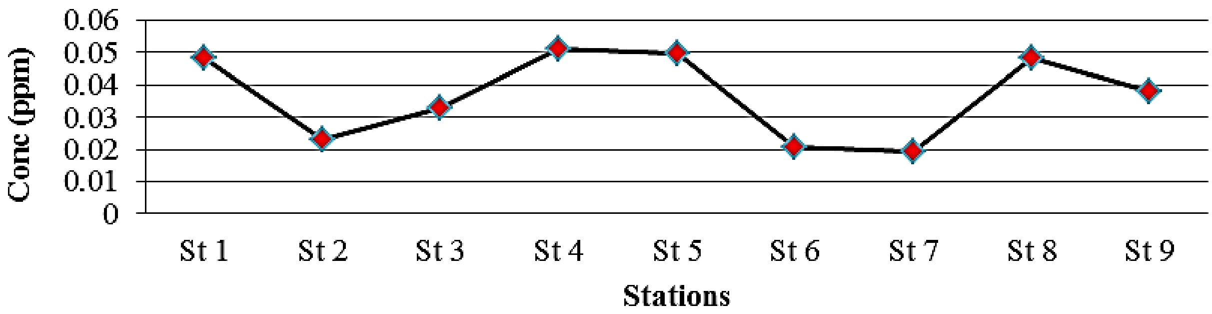

Figure 5: Variation of Nickel concentrations in sediment in mg/L

Comparison of the concentration of the heavy metals is shown in figure 6. The comparison of the five tested heavy metals revealed that lead and chromium had the highest concentrations while cadmium had the least.

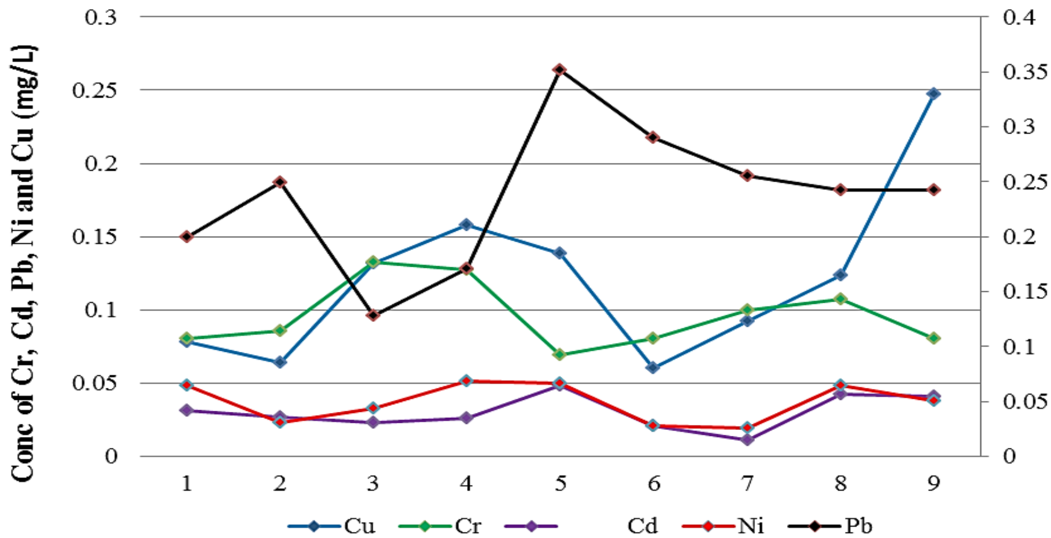

Figure 6: Comparative line graph showing the variation of all the tested heavy metals on sediments in mg/L along the river

4. CONCLUSION

The investigation heavy metal pollutants in sediments from Athi river banks revealed that Pb was highest with a peak concentration 0.3513 ppm of followed by Cu then Cr with peak concentrations of 0.13866 ppm and 0.1329 ppm respectively. Ni and Cd were the lowest among all the heavy metal with concentrations of 0.01912 ppm and 0.01082 ppm respectively.

Recommendations

To improve the water quality and environment in the Athi River Basin, the National Environmental Program Agency (NEMA) should initiate the following strategies:

1. Develop environmental management and planning systems. This entails the formulation of organizational structures, plans and resources for developing, implementing and maintaining policy for environmental protection.
2. Come up with strategies and policies aimed to rehabilitate and restore the river.
3. Develop and implement seasonal water quantity and quality measuring protocols.
4. Sustain public awareness of, and participation in, environmental issues directly affecting the Athi River Basin.
5. The concentration of heavy metals and other physicochemical parameters such as pH, YDS, COD, BOD and TSS should be conducted.

6. The government should embark on regular by monitoring activities of streams and rivers to ensure the safety of its human population and the environment.
7. It is recommended that further periodic research should be done to continuously monitor these indicators of pollution.

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