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Experimental study on water pollution tendencies around Lobuliet, Khor bou and Luri streams in Juba, South Sudan

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Abstract

Urbanization and population demand for resources in Juba has led to pollution of aquatic ecosystems and deteriorated water quality. The streams water samples in Juba, central equatoria state, were collected in sterile 500ml plastic containers and instantaneously experimented. The pH, total solids, total dissolved solids, alkalinity and nitrate were used for evaluation. The results were then compared with standard permissible limits. The pH for Khor bou and Luri streams ranges from 6.1 to 6.7. Lobuliet stream showed abnormal pH value ranging from 9.7 to 9.9. Alkalinity ranges from 106.67 to 1060.33 mg/l. Total dissolved solids (TDS) ranges from 0.002mg/ml to 20.00mg/l. Statistical analysis using ANOVA indicated that TDS was insignificantly different ($p>0.05$) among the sites sampled. The nitrite level was low ranging from 0.04mg/l to 0.09mg/l. The cadmium and lead concentration ranges from 0.86mg/l to 1.92mg/l and 0.29mg/l to 0.95mg/l respectively. Analysis of variance showed the concentration of cadmium and lead were significantly different ($P<0.05$) among the sites sampled. Lobuliet stream had the highest concentration of heavy metals. The study concluded that pollution tendencies were attributed to the discharge of municipal and industrial effluent to the streams and if not properly tackled, may pose adverse impacts to the biogeochemical cycle.

Keywords: Pollution tendencies, Aquatic ecosystems, Streams, Municipal, Effluent, Biogeochemical cycle

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1. Introduction

Rivers and streams have always been important freshwater resources, along the banks of which civilizations still depend upon them. Rivers and streams play an important role in human development and are important natural potential sources of irrigation water. Pollution from industrial effluents finds their way into rivers and streams leading to a large scale deterioration of water quality. A key assessment criterion for the quality of water is the level of dissolved salts. Salts are present in rivers and streams in relatively small but significant amounts. Generally, metals enter aquatic ecosystem from a variety of sources, including: rocks and soils directly exposed to waters, dead and decomposing vegetation and animal matter, wet and dry fallout of atmospheric particulate matter and human activities, including the discharge of various treated and untreated wastes to the water body (Abo El Ella et al., 2005). Essential metals such as Cu, Zn and Fe have normal physiological regulatory functions (Hogstrand et al., 2001) but it may bio-accumulate and reach toxic levels. Increasing urbanization and population growth demands in Juba has led to deterioration of water quality. The streams pass through extensive tracts of low rain falls areas. These streams are also under environmental stress due to human encroachment, high macrophytic population and effluents from various sources. There are a number of discharge loading domestic wastewater and industrial effluents directly into those streams.

The hydro-chemical characteristics of water determine its usefulness for municipal, industrial and domestic water supplies (Casper et al, 2004). Rivers and streams serve as a sink and reservoir for a variety of environmental contaminants. Depending on the river-stream morphology and hydrological conditions, suspended particles with associated contaminants can settle along the water course and become part of the bottom sediments, often for many kilometers downstream from the chemical source (Vigano, 2003). Trace metals derived from natural inputs and anthropogenic emissions are ubiquitous in the global environment. According to the study by Wildi (2004), pollutions can manipulate the concentrations of trace metals if they are either adsorbed or become accessible to benthic organism.

One of the major problems that heavy metals cause with respect to their effects on aquatic organisms is their long biological half-life. Hence, since they are the most often observed micro pollutants, consistent methods have been formed for their removal and measurement (Wildi, 2004; Lanni et al., 2001: 43).

Among the serious pollutants of the aquatic ecosystem, heavy metals are considered to be the most adverse pollutants due to their environmental toxicity and persistence (M.K.Jain, et al, 2011). Toxicity and ability to be incorporated into food chain (Li Ruzhong et al, 2010). The topic of heavy metal pollution in European Rivers has received the attention of many scientists. Much work to date has focused on more industrial parts of Europe such as the Rhine river of Germany and the Netherlands (Middle Koop, 2005; Brugmann, 1995). Others have documented the storage of heavy metals in the mined drainage of Europe (Coulhard and Macklin, 2003). The main objective of this paper is to assess the water pollution tendencies around the three streams of Lobuliet, Khor Bou and Luri resulting from discharge of municipal and industrial effluents to these streams and illustrate the distribution and levels of water contamination by heavy metals. The metals cadmium, chromium, copper, iron, lead, manganese and magnesium were sampled and analyzed because of their abundance and toxic effects in the environment.

2. Methodology

Three streams sites were chosen for sampling. They include Lobuliet streams, Khor Bou streams and Luri streams in Juba, Central Equatoria state. All the sites were visited and water samples were collected in sterile 500ml round bottom plastic containers and were immediately taken to laboratory. Analyses were carried out for pH, total alkalinity and acidity, total solids, dissolved and suspended solids, sulphate and nitrate. All analysis was done according to USEPA standard methods for analysis of water (APHA, 1995).

2.1.1. Total solids

An evaporating dish was dried in an oven, cooled and weighed. 100ml of water sample (well mixed) was measured and placed in a steam bath. Evaporation to dryness was carried out and the dish was cooled and weighed. Total residue in mg/ml was calculated as mass of solids in dish (mg) over volume of sample in litres.

2.1.2. Total dissolved solids

100mls of the filtered sample (using a pre-weighed filter paper) was transferred into a weighed evaporating dish. Evaporation to dryness was carried out on a steam bath. The dish was cooled and weighed. This was continuously done until a constant mass was obtained. The dissolved solid was calculated as mass of dissolved residue over volume of sample.

2.1.3. Total soluble solids

The filter paper from above was dried and weighed consistently until a constant mass was obtained. TSS in (mg/ml) was calculated as mass of filtered residue over volume of sample.

2.1.4. Acidity

Two drops of phenolphthalein indicator was added to 100mls of sample and mixed. This was titrated with 0.02N NaOH solution until a pink color was obtained. Acidity was calculated as volume of water sample multiplied by 1000.

2.1.5. Alkalinity

Two drops of phenolphthalein indicator was added to 100mls of sample and mixed. This gave a colorless mixture. A few drops of methyl orange were further added to the mixture and there was a change in color. Total alkalinity was calculated as volume of the titrated value multiplied by its normality and 50,000 over volume of water sample.

2.1.6. Sulphate and nitrate

Powder pillows specific for the compound being determined together with a data logging spectrophotometer HACH DR/2010 was used. These methods are USEPA accepted standard methods for the analysis of water (APHA, 1985).

2.1.7. pH

pH results were taken using a pH meter.

2.2. Determination of Metallic constituents in water samples

2.2.1. Digestion of water samples

The water was acidified at the time of collection with conc. HNO_3 by adding 5ml of acid/litre of samples. 100mls of water sample was transferred to a beaker and 5ml of HNO_3 was added to it. The solution was heated on a hot plate until the volume reduced to 15-20mls. The mixture was filtered. The sample pH was adjusted to pH 4 by drop wise addition of 5.0N NaOH standard solution. It was mixed and the pH checked. The sample was transferred to a 100ml volumetric flask and the volume made up to 100ml with deionized water. A reagent blank was carried through the process described above. It was then read with the AAS.

2.2.2. Analysis of metallic constituents in water sample

Usually cathode lamps specific for the metal being determined together with a spectrophotometer at the specific wavelength, the following metals were determined using Perkin Atomic Absorption spectrophotometer: Copper – 324.73 nm, Iron – 248.33nm, Cadmium – 228.80nm, Lead – 283.31nm, Magnesium – 285-21nm

2.2.3. Determination of lead

Different concentration of lead standard solution was first prepared into different test tubes. A cathode lead lamp was fitted into the spectrophotometer and the wave length adjusted to 283.31nm. The standard solutions were then aspirated by the spectrophotometer resulting in the absorbance reading and a graphical diagram showing absorbance and concentration being obtained. The sample mixture was then aspirated by the spectrophotometer. Analysis takes place and the concentration of lead was read on the screen. The same procedure was carried out for the remaining metal analysis in the water samples. The only difference is in the different wavelength used which was specific for each metal.

2.2.4. Determination of Anions

2.2.4.1. Sulphate

A clean sample was filled to the 25ml mark with the test sample. The entire content of one HACH sulphate reagent powder pillow was added and the mixture swirled to mix. The sample was allowed to stay for 6

minutes in order that the full color might develop. The prepared sample was placed in the cell holder and the absorbance read.

2.2.4.2. Nitrite

A clean sample was filled to the 25ml mark with the test sample. The entire content of one HACH reagent powder pillow was emptied into the water sample in the cell. The mixture was shaken vigorously and left for 5 minutes. The mixture was placed into the cell holder and the nitrite value read.

3. Results

Table 1. pH results in water samples

Location	pH readings			Average pH
Khor bou stream	6.6	6.1	6.4	6.4 ± 0.25
Luri stream	6.4	6.7	6.4	6.5 ± 0.25
Lobuliet stream	9.9	9.8	9.9	9.7 ± 0.06
p				>0.05

Table 2. Acidity and Alkalinity levels in water samples (mg/ml)

Location	Acidity (mg/ml)	Alkalinity (mg/ml)
Khor bou stream	10.83 ± 0.76	128.67 ± 11.85
Luri stream	21.00 ± 1.00	106.67 ± 5.77
Lobuliet stream	0.00 ± 0.00	1060.33 ± 30.00
p	>0.05	

Table 3. Total solid concentration in water samples (mg/ml)

Location	Total solids concentrations			Average TS (mg/ml)
Khor bou stream	19.70	19.70	53.00	34.00 ± 23.55
Luri stream	13.60	16.30	13.00	15.00 ± 1.76
Lobuliet stream	0.0027	0.002	0.003	0.003 ± 0.05
p				>0.05

Table 4. Levels of total dissolved solids in water sample (mg/ml)

Location	Total dissolved solids			Average TDS (mg/ml)
Khor bou stream	17.70	21.20	22.30	20.00 ± 2.74
Luri stream	10.80	13.20	11.00	12.00 ± 1.33
Lobuliet stream	0.002	0.0025	0.0026	0.002 ± 0.003
p				>0.05

Table 5. Total soluble solids in water samples (mg.ml)

Location	Total soluble solids			Average TSS
Khor bou stream	0.81	0.79	0.73	0.78 ± 0.04
Luri stream	0.71	0.71	1.49	1.10 ± 0.45
Lobuliet stream	0.17	0.14	1.49	0.16 ± 0.04
p				>0.05

Table 6. Concentration of Sulphate in water samples (mg/ml)

Location	Average sulphate concentration
Khor bou stream	700.00 ± 0,01
Luri stream	420.00 ± 0.03
Lobuliet stream	240.41 ± 0.34
p	>0.05

Table 7: Concentration of Nitrite in water samples (mg/ml)

Location	Average Nitrite concentration
Khor bou stream	0.09 ± 0.01
Luri stream	0.04 ± 0.01
Lobuliet stream	0.04 ± 0.01
p	>0.05

Table 8. Concentration of heavy metals in water samples

Location	Magnesium	Iron	Cadmium	Lead	Magnesium	Chromium	Copper
	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Maximum Contaminant Level (MCL)	0.02	10.00	0.01	0.05	0.02	0.05	0.01
P	<0.05	<0.05	<0.05	<0.0	<0.05	<0.05	<0.05
Khor Bou	2.29 ± 0.01	6.18 ± 0.04	1.92 ± 0.02	0.95 ± 0.02	0.58 ± 0.02	0.01 ± 0.02	0.35 ± 0.02
Luri	2.05 ± 0.0	10.86 ± 0.04	0.86 ± 0.01	0.48 ± 0.07	0.60 ± 0.01	0.04 ± 0.04	0.38 ± 0.04
Lobuliet	2.05 ± 0.02	13.52 ± 0.04	1.13 ± 0.01	0.29 ± 0.04	0.60 ± 0.04	0.04 ± 0.04	0.38 ± 0.04

4. Discussions

4.1. pH change

As per the WHO standards (WHO, 1996), pH for aquatic life is in the range of 6.5 – 8.5. An abnormal value is a warning that the water needs further evaluation. Water with a pH beyond the normal value causes discrepancy in nutrition and may sometimes contain toxic element. In this study, pH for Khor Bou and Luri stream ranged from 6.1 – 6.7. For Lobuliet stream, pH value ranged from 9.7 to 9.9. This is an abnormal range. This is apparent with the absence of aquatic life.

4.2. Alkalinity change

Total alkalinity in natural water is generally impacted by the hydrolysis of carbonates, bicarbonates, phosphate and nitrates. Total alkalinity of stream waters is closely related to the nature of subsurface formations. Lower values of alkalinity indicate all anions and cations are not concentrated. Higher values of alkalinity causes problem like corrosion in water pipe. Alkalinity in this study ranges from 106.67-1,060.33 mg/mg.

4.3. Total solids

Total solids (TS) refer to any minerals salts, metals, cations or anions dissolved in water. TDS is a measure of the solid materials dissolved in the river water. This includes salts, some organic materials and a wide range of other things from nutrients to toxic materials. Concentration of total dissolved solids that are too high or too low may limit growth and lead to the death of many aquatic life forms (CPCB, 2000). In the present study, TDS ranged from a minimum of 0.00mg/ml at Lobuliet stream to a maximum of 20.00mg/ml at Khor Bou stream. Statistical analysis using ANOVA indicate that TDS was not significantly different ($p > 0.05$) among the sites sampled.

4.4. Anions

An excess of sulphate in river water is taken as an index of pollution. Desirable recommended limit for sulphate is 250mg/l (WHO 1996). Sewage water, industrial and agricultural effluents have increased sulphate ion. Sulphate values ranged from 240.41mg/ml to 700.00mg/ml. Common sources of nitrite contamination include fertilizers, animal wastes, septic tanks, municipal sewage treatment systems and decaying plant debris. However the nitrite level was quite low ranging from 0.04mg/ml to 0.09mg/ml.

4.5. Heavy metals in waters

From the results presented in Table 8, Cadmium concentration range from 0.86mg/ml – 1.92mg/ml. Analysis of variance results showed that the concentration of cadmium were significantly different ($P < 0.05$) among the various sampling sites. This observation suggests that the distribution of cadmium depends on the

sources of pollution in the river. Cadmium is of no use to the biological processes and can be harmful to aquatic life. It also has the ability to concentrate along the food chain. The result of lead showed that lead concentration ranged from 0.29mg/ml to 0.95mg/L. Analysis of variance results showed that the concentrations of lead were significantly different ($P < 0.05$) among the various sampling sites. The relatively elevated levels recorded in this study were higher than the maximum contaminant level (MCL) of 0.05mg/L. Lead is easily distributed in the aquatic ecosystem through surface runoffs or overflow during flood. From the result chromium concentration ranged from 0.01mg/ml to 0.04mg/ml. Analysis of variance results showed that the concentrations of chromium were significantly different ($p < 0.05$) among the various sampling sites. The observed levels tend to be higher than those recorded in other rivers (Middlekoop, 2000). The environmental mobile elements are arranged in the order $Fe > Mg > Cd > Pb > Mn > Cu > Cr$ from the samples collected and Lobuliet stream showed the highest concentration of heavy metals.

5. Conclusions

The result obtained in this study indicates that Lobuliet stream; Khor Bou and Luri streams are highly polluted. This is evident from the high levels of Pb, Cr and Cadmium recorded. The result showed that with continuous discharge of wastewater, pollution of the sampled rivers with high Cd, Pb and Cu is likely to have adverse impacts on the environment.

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