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Climate Change and Natural Resource Use in Eastern Africa: Impacts, Adaptation and Mitigation

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Cover picture: Leopard Reed Frog (*Hyperolius viridiflavus pantherinus*) is a sub-species of frog that evolved from a lowland rainforest stock. This specimen was collected from the Mathews Range in Samburu, northern Kenya. Reduction in suitable habitats and climate change may lead to local extinctions (*picture courtesy of Peter Mwangi*).

Inside Photos: Nicholas Oguge

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THE IMPACTS OF SPORADIC EFFLUENT POLLUTION OF TIGONI DAM, KIAMBU DISTRICT, KENYA

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ABSTRACT

Water pollution arising from agricultural activities, municipal and industrial wastes is a major problem that affects living organisms in water bodies. Tigoni dam for example, often suffers from sporadic effluent pollutants originating from Limuru municipal council, Bata Shoe Company and other local industries. Around mid April 2009, heavy pollution occurred in the dam resulting in a massive scum and foaming whose sources and effects on the biota were unclear. This study therefore aimed at assessing the effects of this sporadic pollution on the water quality and biota. Physical (temperature, transparency) and chemical (Dissolved oxygen, pH, Total dissolved solutes, Conductivity) characteristics were measured, including selected anions, cations and heavy metals that may be released by the shoe company. Nutrient levels (Nitrates, Phosphates) were also measured. Relative abundance of the planktonic organisms and the macro-benthic invertebrates was also estimated. Results indicated low concentration of heavy metals in water column and high concentration in the sediments, increased relative abundance of cyanophytes, and reduced biodiversity of both zooplanktons and benthic invertebrates. There is need to control pollution within the basin so as to conserve biodiversity and usefulness of the dam to the community.

Key words: Pollution, biodiversity, Kenya.

INTRODUCTION

Many inland tropical aquatic systems are heavily polluted by agricultural effluents, domestic, municipal and industrial wastes (Nyakang'o, 2005). Pollution problems in East African countries started in early 1970's but became serious in early 1980's ((FAO, 1971; Alabaster, 1981). Abel (1996), for example, noted that the threat of pollution of African rivers, lakes and aquifers is increasing. These effects, particularly on the biota, are exuberated by the climatic changes. Boko *et al.* (2007) observed that upto 50% of Africa's total biodiversity is at risk due to reduced habitat and other human-induced pressures. Most aquatic organisms are under threat due to rapid deterioration of freshwater bodies (Abel, 1996; Dudgeon *et al.*, 2006; Collanes-Perira and Cowx, 2004).

Tannery sector has been termed as the basic skeleton on which leather industry depends on. However, the industry has been reported to pose major environmental threat to aquatic systems in the world (Khwaja, 2001). The industry uses various chemicals such as sodium sulphide, basic chromium, ammonium chloride and enzymes during soaking, tanning and post-tanning processes of hides and skins (Shabbir, 1995; Abdulrahman *et al.*, 2009). Affinity of chromium III to particulate phase has been reported to decrease its availability to planktons, but high concentration in sediments have detrimental effects on benthic invertebrates and ultimately to higher levels of aquatic food chain (Pawliskowski *et al.*, 2006). According to Leslie (1999), chromium causes sub-lethal toxicity and reduces the biodiversity of benthic invertebrates. Tannery wastewater has also been found to be highly toxic to filter feeders (Daphnia sp.) and bacteria (Coolman *et al.*, 2003; Talapatra and Banergee, 2005). Agriculture is a significant non-point source contributor to surface and groundwater pollution (Ignazi, 1993). It releases chemicals such as nitrogen, phosphorus and pesticide residues in surface and groundwater (FAO, 1996).

Excessive application of manure on the land, runoff from cattle, pig and poultry farms are common farming practices that leads to water pollution. Although this is controlled in many western countries, it constitutes a serious problem for water quality in much of the rest of the world.

Tigoni dam is located in a high altitude area where major human activities such as farming and industrialisation are practised. Around mid April 2009, heavy pollution occurred in the dam resulting in a massive scum and foaming whose sources and effects on the biota were unclear. This study therefore aimed at assessing the effects of this sporadic pollution on the water quality and biota.

MATERIALS AND METHODS

Physical and chemical parameters (water temperature, pH, conductivity, total dissolved solutes and dissolved oxygen) were determined in situ using a Multi-Parameter Meter probe. Water transparency was measured using a Secchi disc by determining the average of points at which it disappears and re-appears when immersed in water.

Samples for nutrient analysis were collected using a Van Dorn water sampler and filtered through 0.45 µm filters. The filtrates were stored in iceboxes for transportation to the laboratory. Before analysis, sediment samples for total phosphorus determination were hydrolyzed with potassium persulphate followed by its determination by the molybdenum blue colorimetric method while nitrate (NO3--N) was determined using the sodium-salicylate method (APHA, 2000).

Major cations (Na^{+}, Ca^{2+}, K^{+} and Mg^{2+}), anions (HCO^{3-}, SO_4^{2-} and Cl^{-}) and selected heavy metals (Pb^{2+}, CU^{2+} and Cr^{3+}) were measured on two occasions to determine the pollution status of the dams. Major cations, anions and selected heavy metals were measured spectrophometrically using an atomic absorption spectrum (AAS) at the Mines and Geological Laboratory.

A standard filtration method was used to analyze the suspended sediment concentrations (APHA, 2000). The water samples were filtered through Whatman GF/C glass fiber filters. The filters have a nominal retention diameter of particles of 0.65µm. The concentration in milligram per litre (mg/l) was computed as the ratio of the weight of dry matter in the sample (mg) to the volume of the water-sediment mixture and volume of sample in litres.

Phytoplankton composition and abundance in the reservoir was analyzed by filtering water samples of known volumes using plankton net of 0.063 mm mesh. The filtrate were preserved in Lugol's iodine and transported to the laboratory for identification and enumeration under a compound microscope using appropriate keys (Wetzel and Likens, 1991).

Zooplanktons were sampled using a conical net of the Nansen type (0.25 m mouth diameter with a 60µm nitex net, then preserved in 4% formalin solution. They were then identified and counted under a compound microscope (Wetzel, 1991).

Samples of benthic sediments were collected using Ekman grab sampler, sieved and preserved in 70% alcohol for laboratory analysis. Counting and identification using appropriate keys was done in the laboratory.

RESULTS

Study Area

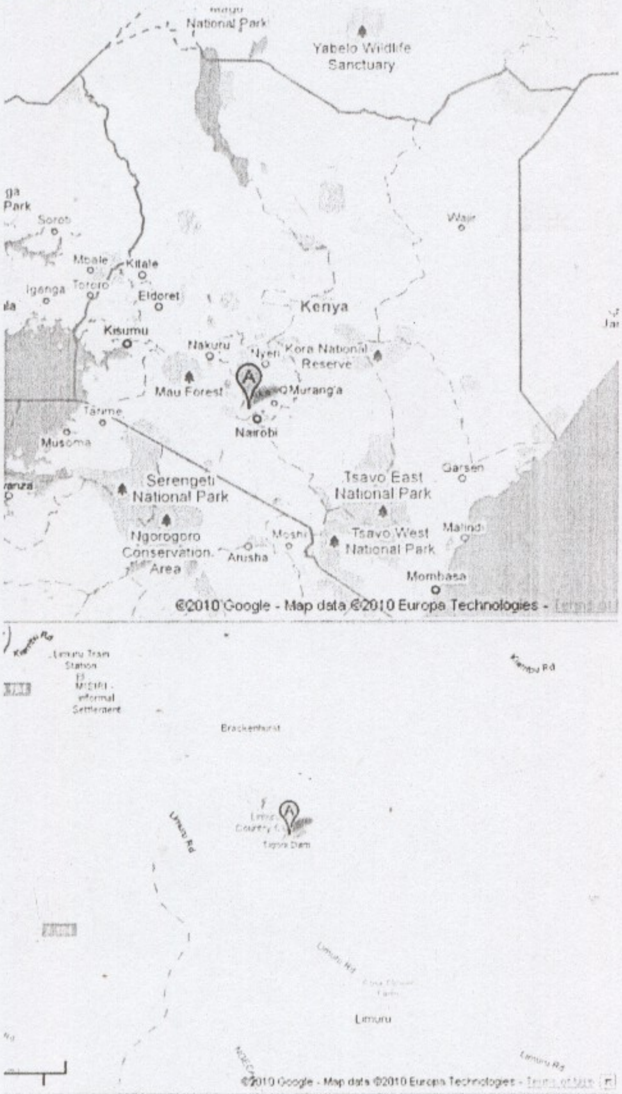

Figure 1: Location of Tigoni dam on Kenyan map and map of Tigoni area

Tigoni dam is located in Kiambu district (01°34'S and 36°4'E) and occurs 17 miles north of Nairobi at an altitude of 2100m above the sea level (a.s.l) as shown on figure 1. The colonial army constructed the dam during the 1939-1945 war and it currently provides farming water to the local farmers of Limuru division. Tigoni dam experiences wet climatic conditions due to its location on a high altitude. The banks of the dam are well protected by swath of macrophytes that extend up to 10m from the water edge. A dense vegetation of green leafy shrubs and a Eucalyptus plantation to the North Eastern side also surrounds the dam. Limuru town which is the home of Bata shoe company is located upstream of Ithanje river which is the main source of water to Tigoni dam. Effluents from the leather processing activities and sewage discharge from Limuru town are the major sources of pollution to the dam.

Water Quality

Differences in both physical and chemical characteristics of the water were observed after pollution of the dam as shown in the figure 2. Mean water transparency of the dam was 71± 1.09 cm before pollution and changed to 52.7 ± 18.94 cm after pollution although the reduction was not significant ($P>0.05$). The inlet of the dam recorded the lowest transparency of 15cm after pollution. The study revealed that transparency increased from the inlet towards the outlet after the contamination.

Mean depth of the dam recorded for the period preceding pollution was 2.8±1.52m and 3.0 ± 1.50m after pollution. However, there was no significant difference in the change of depth between the two periods ($P>0.05$). The shores of the dam recorded the lowest depths for the two periods while the highest depth of 6m was recorded towards the outlet after pollution.

The pH values recorded for the two study periods varied significantly ($P<0.05$) and all values were above the neutral as shown in table 1 and fig 2. Mean water pH before pollution was 8.2 ± 0.10 which increased after pollution to 8.8 ± 0.02 with the highest pH value being recorded at the inlet.

The study also recorded a significant change in Dissolved Oxygen (DO) concentration ($P<0.05$) for the periods before and after pollution. DO mean concentration of 7.1±0.19 mgl^{-1} was recorded before pollution that later increased after pollution to 8.4±0.26 mgl^{-1} after pollution. It was observed that DO concentration after pollution increased from the inlet towards the outlet.

Water conductivity and Total Dissolved Solutes (TDS) values recorded before and after pollution showed significant differences ($P<0.05$). Before pollution, a mean conductivity of 820 µScm-1 was recorded which increased to 910 ± 5.77 μScm^{-1} two weeks after pollution. Likewise, mean TDS increased from 540 mgl^{-1} to 605±2.89 mgl^{-1} after pollution. Both the values of conductivity and TDS were observed to increase from the inlet towards the outlet.

Changes in concentration of major cations that occurred in the dam following pollution are shown in figure 3.

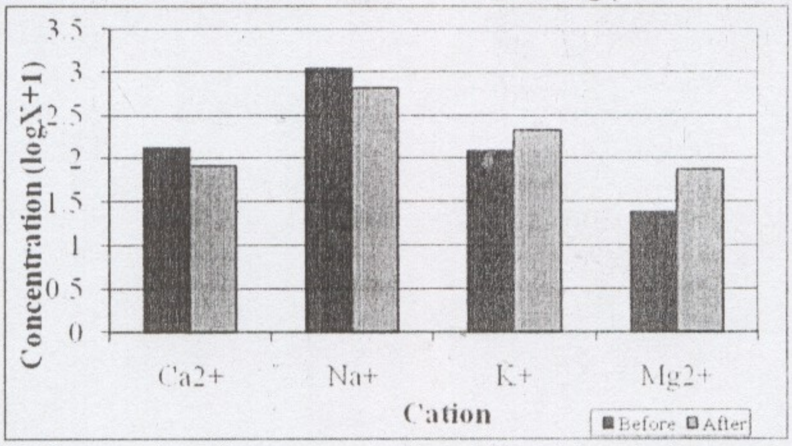

Figure 3: Changes in cations concentration of Tigoni dam before and after pollution

There was significant change ($P<0.05$) in concentration of calcium ion as a result of pollution of the dam. The concentration of calcium ions before pollution was 13.3±1.33 mgl^{-1} and decreased after pollution to 8.1±1.82 mgl^{-1}. Likewise, concentration of sodium before pollution was 106.6±1.99mgl^{-1} and later decreased significantly ($P<0.05$) after pollution to 63.6±16.09 mgl^{-1}. However, the concentration of both potassium and magnesium ions increased after pollution although the increase was not significant ($P>0.05$). The concentration of potassium ions changed from 12.2±0.28 mgl^{-1} to 20.7±7.65 mgl^{-1} while the concentration of magnesium ions changed from 2.4±0.03 mgl^{-1} to 7.4±2.97mgl^{-1}.

Insignificant changes ($P > 0.05$) occurred in ionic concentrations of the major anions after pollution as shown in figure 4. The Concentration of bicarbonate ions decreased from 53.6±0.41 mgl^{-1} to 29.1±11.49 mgl^{-1} after pollution. Concentration of sulphate ions on the other hand increased from 35.2±1.48 mgl^{-1} to 108.4±52.96 mgl^{-1}, while chloride ions increased from 160.7±6.17 mgl^{-1} to 163.1±49.79 mgl^{-1}. Water alkalinity recorded an increase from 44.0±1.15 mgl^{-1} to 95.6±38.22 mgl^{-1} after pollution.

The changes that occurred in the concentration of the heavy metal ions in the water column were not significant (fig. 4). Lead ions were not detected in the water before pollution. After pollution, a concentration of 0.03±0.06 mgl^{-1} was recorded. However, Copper ions were not detected in the water both before and after pollution. Chromium ions were not measured before pollution but after pollution, a concentration of 0.11±0.07 mgl^{-1} was recorded.

Study on nutrient ions showed that concentration of nitrate ions changed significantly ($P<0.05$) after pollution while the phosphate ions change was not significant ($P>0.05$).

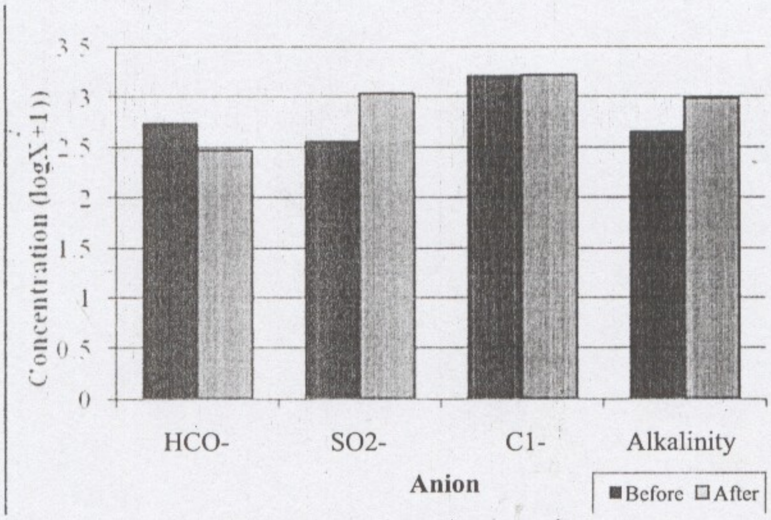

Figure 4: Changes in concentration of the major anions at Tigoni dam before and after pollution

The concentration of nitrate ions in water before pollution was 1.0±0.05 mgl^{-1} and declined to a point whereby no nitrate ions were recorded. However, the concentration of phosphate ions increased from 8.4±1.45 mgl^{-1} to 79.6±43.99 mgl^{-1} after pollution. The changes that occurred are shown in figure 5.

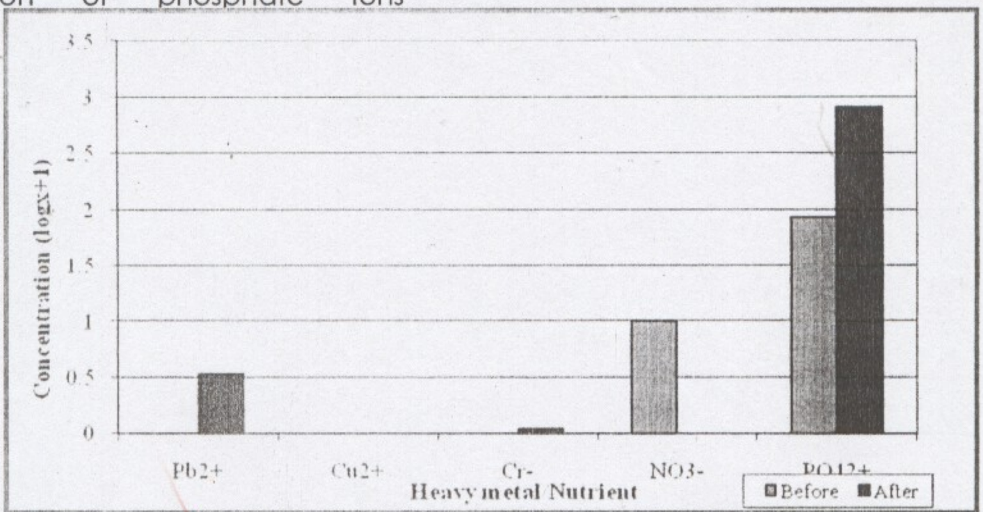

Figure 5: Concentrations of different ions on sediment after pollution of Tigoni dam

Analysis on sediments showed that calcium, sodium, chromium, lead and phosphate ions were highly concentrated at the inlet (table 2).

However, potassium and magnesium ions occurred in high concentration both at the inlet and the outlet of the dam. Manganese ions occurred in high concentration at the centre of the dam while copper ions occurred in high concentration at the outlet.

Biotic Community

Tigoni dam exhibited high phytoplankton production but lower species diversity. Before pollution, blue green algae constituted about 54%, diatoms 34% and desmids 10% of the total algae community. After pollution (May 2009), the situation changed significantly, with the blue green algae forming an algal bloom consisting mainly of *Microcystis aeruginosa* (22%) and *Oscillatoria* (39%). The common *phytoplanktons* before pollution were *Microcystis, Navicula, Scynechocystis, Coscinodiscus* and *pediastrum* and *Oscillatoria, Microcystis,* *Spirulina, Navicula* and *Euglena* after the pollution of the dam.

Table 2: Shows concentration of major cations and anions in sediments (mgl-1) from the inlet to the outlet

Parameter	Inlet	Centre	Outlet
Ca^{2+}	2768	1549	692
Na^{+}	1076	879	332
K^{+}	1494	911	1316
Mg^{2+}	650	437	676
Cu^{2+}	12.4	6.8	18.4
Pb^{2+}	1132	172.6	568
Cr	47.4	42.6	34
Mn	106.3	209.2	115
PO_4^{2-}	64.6	34.4	6.2

Zooplankton community of Tigoni dam was dominated by rotifers and mainly of *Branchionus* sp. which constituted about 50%. In November 2008 (before pollution), the species of rotifers found in the dam were *Keratella* and *Polyratha* which constituted less than 4% of the total rotifer population. Copepods mainly *Cyclop* sp. had a relative abundance of about 24% and *Daphnia Pulex* had a relative abundance of about 18%.in may 2009 after pollution, there was an increase in the relative abundances of the rotifers and copepods. However, relative abundance of the *Daphnia* decreased and one rotifer species lost.

Benthic invertebrate community of the dam comprised of *Oligochaetes, Odonatans* and *Dipterans*. In November 2008, *Oligochaetes* constituted about 75% of the macro-invertebrate community with *Chironomid* larva constituting about 25% and *Odonata* less than 1%. After pollution (May 2009), *Oligochaete* population increased greatly to about 94% with *Chironomids* constituting only 6% of the macro-invertebrate community as summarized in table 5 and figure 6.

Table 5: Relative abundance of different orders of Benthic macro-invertebrates both before and after pollution

Before pollution (Nov-08)			After pollution (May-09)	
Order	Counts (m^2)	Relative abundance (%)	Counts	Relative abundance (%)
Diptera	996	24.7	1,797	6.1
Odonata	29	0.7		0
Oligocheata	3,016	74.6	27,831	93.9
Total	4,041	100	29,628	100

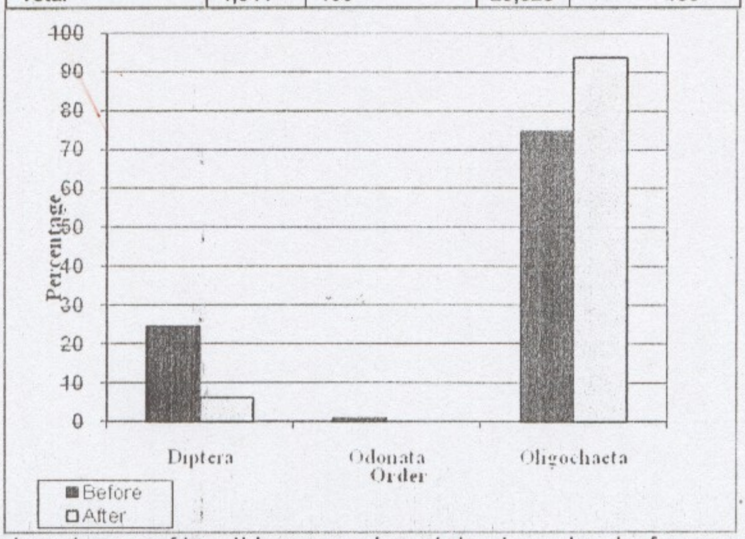

Figure 6: Relative abundance of benthic macro-invertebrate orders before and after pollution of Tigoni dam in percentage

DISCUSSION

Changes in physical characteristics measured in the dam after the emission of effluents were not significant. There was a slight increase in water depth which was attributed to the rains experienced in the area between December 2008 and March 2009. On the other hand, a decrease in transparency after pollution was noted. This was caused by deposits of organic substances which stimulated growth of algae causing algal bloom. Low transparencies have been associated with low primary productivity since light penetration into the water is reduced.

Significant increase in pH and dissolved oxygen was recorded during the study. The increase in oxygen might have been caused by strong waves and oxygen liberated by the process of photosynthesis since the measurements were done at midday. Increase in pH might have been caused by reduced carbon atoms due to uptake of carbon dioxide by algae during the process of photosynthesis. However, the reverse is expected to occur at night. Organisms respire at night; a process that requires oxygen and liberates carbon dioxides. These process decreases oxygen concentration and increases the pH as carbon dioxide gas is given out. The breakdown of organic matter by bacteria might worsen the situation since they too require oxygen for respiration.

Effluent deposition into the dam also led to significant increase in conductivity and total dissolved solutes (TDS). This is because the pollutants contained dissolved ions that were carried into the dam as water run-off from the agricultural farms, Limuru town and its associated industries. Chromium and sulphate ions were detected in high concentration after pollution in the dam. Both chromium and sulphate ions are associated with chemicals used by leather industries. Nutrient ions such as phosphates and also sulphates originate from agricultural farms. High concentration of these ions in water indicates that fertilizers and animal wastes find their way into the dam due to poor agricultural practises. Lead and copper deposits are associated with chemicals used as pesticides in agricultural farms.

Relative abundance of blue green algae in the dam was generally high; however, it increased significantly after pollution. Blue green algae have been known to prefer water with low nitrogen content and rich in phosphates. Eutrophication condition in water bodies has been linked with over-stimulation of aquatic ecosystem leading to reduced quality of water (Daniel *et al*., 1994; Sharpley *et al*., 1994). As algae dominate and turn the water green, the growth of other water plants is suppressed; these die first, disrupting the food chain. Death of invertebrates and fish follow on, and their dead remains in turn lead to excess bacterial activity during decomposition, reducing oxygen levels still further. Increase in abundance of algae favoured rotifers of genus *Branchionus* and copepods of genus *Cyclops* whose relative abundances increased. However, the relative abundances of *Daphnia* and *Polyratha* decreased, while *Keratella* totally disappeared. Studies by Coolman *et al*. (2003) and Talapatra and Banergee (2005) reported decline of *Daphnia* species as result of pollution by chromium.

Concentration of chemical ions was quite high in the sediments of the reservoir. This is attributed to the accumulation of ions over time. The concentration of ions such as sodium, calcium, potassium, phosphates, magnesium and chromium was high at the inlet and tended to decrease towards the outlet. This shows that the main entry point of these ions into the dam was the river. Copper and lead ions on the other hand accumulated more at the outlet and the inlet. High concentration of heavy metals in the sediments led to increase in abundance of pollution tolerant Oligochaetes while the population of Dipterans decreased tremendously and Odonatans disappeared from the ecosystem. Benthic organisms have physiological tolerance limits to both physical and chemical changes in water (Bechara, 1996). The decline in the biodiversity of aquatic organisms in ecosystems is strongly linked to water pollution. Studies by Leslie (1999), Coolman *et al*., 2003, Talapatra and Banergee, 2005 support these results.

Water that sustains rich fauna and flora is more likely to be useful, and less likely to be a hazard to human health (Abel, 1996). Hence there is a need to conserve our aquatic resources by employing good agricultural practises in our farms and treating or using environmentally friendly methods of wastes disposal. Farming along the banks of Ithanje River should be discouraged and sound agricultural methods be adopted by the farmers. Runoff mitigation measures such as infiltration basins, bioretention systems, constructed wetlands and retention basins need should be used to protect the dam (Menlo, 2003; Trenton, 2004).

REFERENCES

Abdulrahman, F. I; Akan, J. C; Ayodele, J. T and Ogugbuaja. (2009). "Impact of tannery and textile effluents on chemical characteristics of Challawa river, Kano state, Nigeria". *Australian journal of basic and applied sciences* Vol. 3, pp 1933-1947.

Abel, P. D. (1996). Water pollution biology; Second edition. Taylor and Francis Ltd.

American Public Health Association (APHA), (1992), Standard Methods for the Examination of Water, Sewage and Wastewater. (17th Ed). APHA, New York, pp 1550.

Bechara, T. A. (1996). "The relative importance of water quality, sediment composition and floating vegetation in explaining the macrobenthic community structure of flood plain lakes", *Hydrobiologia, Dordrecht*, Vol. 333, pp 95-109.

Blackman, A. (2005). Adoption of clean leather-tanning in Mexico.

Boko M, Niang I, Nyong A, Vogel C, Githeko A, Medany M, Osman-Elasha B, Tabo R and Yanda P. (2007). "Climate Change 2007: Impacts, Adaptation and Vulnerability", Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Parry M L, Canziani O F, Palutikof J P, van der Linden P J and Hanson C E (eds). Cambridge University Press. Cambridge UK. pp. 433 – 467.

Calamari, D. (1985). "Review of the state of aquatic pollution of west and central African inland waters", FAO. Rome, *CIFA Occasional paper no. 12*.

Collares-Pereira, M. J. and Cowx, I. G. (2004). "The role of catchment scale environmental management in fresh water fish conservation", *Wiley Interscience Journal*, Vol. 11pp 30 - 312.

Coolman, K; Gajardo, M; Nieto, J; Bornhardt, G and Vidal, G. (2003). Tannery wastewater characterization and toxicity of *Daphnia* sp. *Environmental toxicology journal* pp 18: 45.

Food and Agricultural Organization of United Nations (FAO). (1996). Control of water pollution from Agriculture. Natural resources management and Environment department, FAO irrigation and drainage papers- 55.

Food and Agricultural Organization of United Nation (FAO), (1971). Report on survey of inland water pollution in Uganda, Kenya, Zambia and Tanzania based on the work of A. E. Thorslund. *FAO regular programme* Rep. 11, pp 12.

Ignazi, J.C. 1993. "Improving nitrogen management in irrigated, intensely cultivated areas: the approach in France", In: *Prevention of Water Pollution by Agriculture and Related Activities.* Proceedings of the FAO Expert Consultation, Santiago, Chile, 20-23 Oct. 1992. Water Report 1. FAO, Rome. pp 247-261.

Nyakang'o, J., (2005). Major environmental pollution problems in Kenya: training on cleaner technologies for sustainable chemistry, CairoEgypt, April 4th – 6th 2005.

Pawlisz, A. V; Kent, R. A; Schneider, U. A and Jefferson, C. (1996). Canadian water quality guidelines for chromium. *Wiley international journal,* Vol.12, pp 123-183.

Khwaja, A.R; Singh, R and Tandon, S. N. (2001). "Monitoring of Ganga water and sediments vis-avis tannery pollution at Kanpur (India)": A case study. Environmental monitoring and assessment Vol. 68, pp 19-35.

Leslie, H. A;Pavluk, T. I; De Vaate, B.J and Kraak, M. H.S. (1999). "Triad assessment of the chromium contamination on the benthic macroinvertebrates in the Chusovaya". *Arch. Environ. Contam. Toxicol,* **Vol**. 37, pp 182.

Menlo Park, C. A. (2003). "Storm water Best Management Practice (BMP) Handbooks", Storm water Quality Association, Carlifornia.

Pawlikowski, M; Szalinska, E; Wardas, M and Dominik, J. (2006). "A preliminary investigation from the upper Dunajec River, Poland", *Polish journal of environmental studies,* Vol. 15 No 6, pp 885-894.

Shabbir, K. (1995). Leather industry in Pakistan and Gulf economist. Pp 69

Talapatra, C. N. and Banergee, S. K. (2005). "Acute toxicity study of heavy metal chromium and tannery effluent water in flea, daphnia magma straus by bioassay method", *Asian journal of water, Environment and pollution,* Vol. 2, pp 33-37.

Trenton, N. J. (2004). "New Jersey Storm water Best Management Practices Manual." New Jersey.

Wetzel, R. A. and Likens, G. E. (1991). " Limnological analysis", (2nd Ed), Spriger-Verlag. pp 391

UFCCC, (2007). "Climate change: Impacts, vulnarabilities and adaptation in developing countries", Climate change secretariat (UNFCCC), Bonn, Germany Pp 17, 28, 51 1nd 54.