Effects of Sediments Loads on Water Quality within the Nairobi River Basins, Kenya

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Abstract- **This paper presents the findings of a study carried out in the years 1998-2005 within the Nairobi River basins on the effects and implications of sediment loads on water quality. The study was motivated by the worrying trends in water quality degradation within the basin to be enable indentify possible mitigation strategies for the river basin. Sediments from river water samples were obtained from the Ngong, Nairobi, and Mathare river sub-basins. The results indicated a seasonal variation/trend for suspended sediments in each basin, and a similar trend in water quality degradation. Annual suspended sediment load flux estimates for the Ngong, Nairobi, and Mathare rivers are 1700, 6300 and 3000 tonnes, respectively. A close relationship between certain water quality parameters, such as total dissolved solids (TDS), conductivity, turbidity and colour, to increased water quality degradation, on a seasonal basis was demonstrated. Land-use changes per basin, including agricultural, residential, industrial and urban, were used to identify the most dominant type of land-use activity and its impact on sediment loads and reduction in water quality. Water pollution and pollutant levels varied with season and distance away from the city of Nairobi in the three sub-basins. The streams were found to be less chemically polluted away from the city due to dilution effects and self purification during the wet season. The results indicated that sediment loads had a significant effect on the Nairobi River basin's water in terms of water quality reduction. These appeared to significantly contribute to the pollution of the river and reduction in its water quality. This paper recommends the following water pollution control strategies, and hence reduce water quality reduction; removal of solid wastes from the river courses, protection of the river banks from construction activities, discourage people from dumping wastes into the river courses, relocation of the "*Jua-Kali*" garage and mechanics who operate near the river banks, as well as continuous monitoring to check on illegal dumping of wastes into the river as some of the Best Management Practices (BMPs) within the watershed, and the country in general.**

Keywords- Variability; Quality; Management; Aquatic Ecosystems; Stream Restoration

I. INTRODUCTION

The Nairobi River sub-basin consists of three tributaries; namely the Nairobi, Ngong and Mathare rivers. These rivers drain a greater part of the city of Nairobi in a southeast direction as indicated in Fig. 1 (Kithiia, 1992). The name "Nairobi" comes from the "*Maasai*" phrase *Enkare Nyirobi*, which translates to "the place of cool waters". It was founded in 1899 as a simple rail depot on the railway linking Mombasa to Uganda, the town quickly grew to become the capital of British East Africa in 1907 and eventually the capital of a free Kenyan republic in 1963.The city of Nairobi is the capital city of the republic of Kenya and the economic hub of the East African region. The city was established in the 1900s with a population of about 250,000 (Obudho, 1992) as a stop-over point and the Headquarters of the then Kenya-Uganda Railway workers (KUR) but has since grown tremendously over the years and now is approximately 3.1 million (Kithiia, 1998). The increased population has changed the land-use dynamics within the city and its environs. There is evidence of land use changes from intensive agricultural systems in the headwater areas, to residential and industrial uses within the metropolitan Nairobi city (Kithiia, 1992, 1998, 2006a, b). The results of these various land use changes on pollutants, sediment load generation and degradation in water quality are substantial, and hence worthy of investigation.

The increased sediment loads along the river profiles contribute significantly to increased water quality reduction as well as changes in the aesthetic enjoyment by the Nairobi city residents of the riverine ecosystems. Increased COD and BOD_5 levels, as well as increased coliform counts, imply reduced dissolved (DO) oxygen levels and less aesthetic enjoyment of the river system. This paper examines trends in sediment loads and other pollutants on decreasing water quality status and the role of riparian vegetation (macrophytes) and other water pollution control strategies in the restoration of river water quality for sustainable water use and environmental maintenance.

II. METHODS OF STUDY

The study adopted a standard method of water sampling at fixed points as indicated in Fig. 2. Water samples were collected using water samplers as specified by the American Public Health Association (APHA, 2001) criteria and procedures. Some water quality parameters were analysed in the field to avoid changes during transport. The sampling points were selected with respect to perceived land-use impacts within the streams investigated as indentified in the field. The prevailing land-use activity was used as the main contributing factor in locating the sampling point(s).

The density and distribution of the sampling points was based on the size of the river system and the prevailing land use systems within its proximity. The Nairobi River, which is the main stream in the basin, had six sampling points, followed by the Ngong and Mathare rivers with two sampling points each.

In total, 240 samples were collected within the period of study and analysed for 15 water quality parameters; that translates to a total of 3600 determinations. Laboratory analyses of the water samples were carried out to quantify sediment loads and water quality status along the river profiles. Total suspended sediment concentrations (TSS) were determined on replicate samples by gravimetric methods according to McGrave (1979) and Woodroffe (1985). The water samples were thoroughly shaken prior to sediment load concentration analysis to avoid bias in the results obtained.

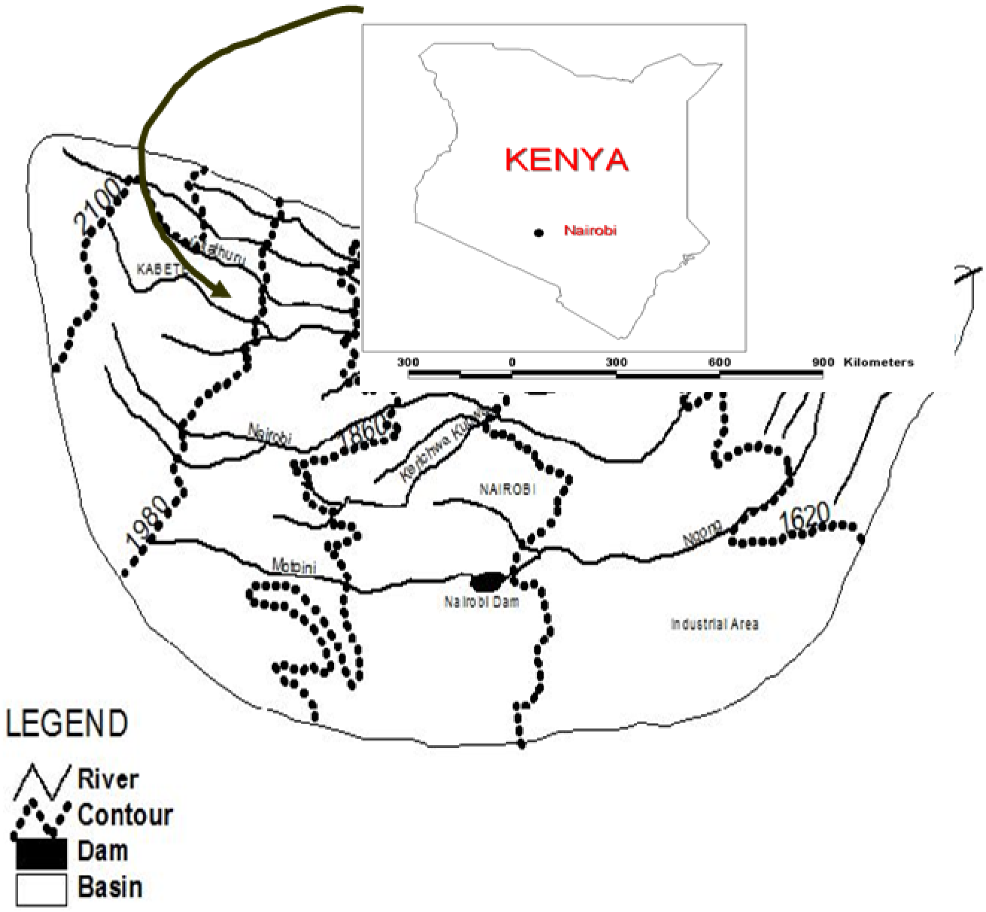
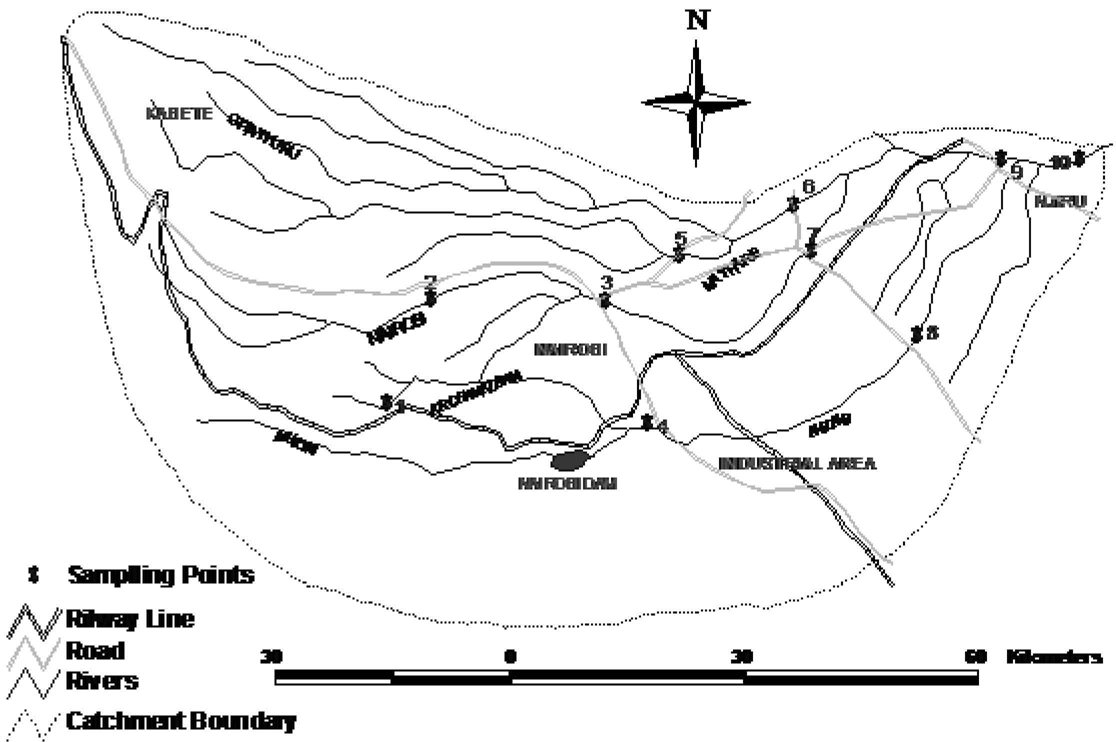


Fig. 1 Study area and Nairobi River sub-streams



1 – Kirichwa Kubwa D/S Kawangware
2 – Nairobi at Muthangari
3 – Nairobi at Museum
4 – Ngong at Langata Road Bridge
5 – Mathare at Thika Road Bridge
6 – Mathare at Outer Ring Road
7 – Nairobi at Outer Ring Road
8 – Ngong at Embakasi D/S Industrial Area
9 – Nairobi at Njiru 1
10 – Nairobi at Njiru 2 - Ruai

Fig. 2 Distribution of sampling points

In addition, river flow discharges were determined by applying the velocity-cross-sectional area method (Linsley & Franzini 1979, Linsley *et al*., 1988, Wilson, 1990). The river flow discharges (Q) were compared and correlated with water quality parameters to determine trends in water quality reduction within the investigated basins. Plant tissues (macrophytes) were collected along the aforementioned river profiles depending on species dominance determined by the presence/absence method. A plant tissue sample of about 100 g was cut into fine pieces and air dried in an oven at about 60°C. The sample was then transferred into a mortar and ground until it was free flowing (<1 mm); repeated inversion produced homogeneity. The mixture was then subjected to chemical analysis. The results obtained indicated the levels of dissolved metal ion uptake by the isolated vegetative tissue parts, and formed the basis for determining impacts of water quality changes (reduction) on environmental habitats of the river systems.

III. RESULTS AND DISCUSSION

The study found out that land use changed from predominantly agricultural in the upper reaches (headwater areas) to predominantly urban in the middle reaches of the basin. This change, as a result of the increase in impervious surfaces, reduced infiltration rates and increased flooding as well as fluvial discharge during storm events (Kithiia, 1997, 1998, 2006, 2008). This in addition implied more sediment load conveyance by the river flow discharges during storm events. Table I illustrates the mean values for various water quality parameters at different sampling points within the river sub-basins. The general effect of the changes in land-use activities in the three sub-basins, led to increases in a variety of water quality parameters, in a downstream direction as demonstrated by Table II.

On the other hand, increasing river discharge could have a diluting effect on various water quality pollutants and, hence, cause a decrease in water quality degradation. However, on a seasonal basis, the overall effect of increasing discharge led to increasing pollutant concentrations and increasing water quality degradation as indicated in Table I. A close comparison between discharge profiles with water quality profiles in the three sub-basins revealed that increases in discharge for the Nairobi River between the Outering and Njiru 2 sampling points had a similar trend and pattern for water quality parameters as shown in Figs. 3 and 4. Fig. 4 further illustrates that increased discharge rates results in increased water quality degradation. However, increased discharge had a diluting effect on certain water quality parameters such as total dissolved solids (TDS) and conductivity, which reflect the concentrations of dissolved ions in water as illustrated for the Ngong River at the Embakasi sampling point in Fig. 5.

TABLE I MEAN MEASURED VALUES OF PHYSICAL AND CHEMICAL WATER QUALITY PARAMETERS AT SAMPLING POINTS

		Mean Concentrations				
Sample Site	**River**	**Q ($m^3 s^{-1}$)**	**TSS ($mg L^{-1}$)**	**Cond. ($\mu S cm^{-1}$)**	**TDS ($mg L^{-1}$)**	**Turb. (NTU)**
Muthangari	Nairobi	0.772	158	392	240	69
Museum	Nairobi	1.376	129	398	244	69
Outering Rd	Nairobi	2.14	256	565	291	66
Njiru 1	Nairobi	5.083	199	510	311	68
Njiru 2 (10)	Nairobi	5.341	96	475	299	29
Thika Rd	Mathare	0.738	161	352	216	35
Outering Rd	Mathare	1.371	251	527	350	85
Kibera Slums	Ngong	0.11	33	233	88	134
Langata Rd	Ngong	0.305	59	599	59	42
Embakasi	Ngong	0.949	180	612	174	71

Source: Field data 1999-2002; COND: electric conductivity, TDS: total dissolved solids, TSS: total suspended sediments, TUR: turbidity.

TABLE II MEAN CONCENTRATIONS OF METAL IONS AT VARIOUS SAMPLING POINTS AND RIVERS

		Mean Concentrations of Metal Ions in mg L^{-1}							
Site	**River**	**Pb**	**Zn**	**Cu**	**Fe**	**Mg**	**Na**	**Cl**	**Ca**
Muthangari	Nairobi	0.01	<0.01	<0.01	0.3	6.4	43	54	18
Museum	Nairobi	0.02	<0.01	0.01	0.7	6.4	45	56	19
Outering Rd	Nairobi	0.05	0.01	0.04	2.0	8.4	59	47	18
Thika Rd	Mathare	<0.01	<0.01	0.01	0.4	6.8	40	40	17
Outering Rd	Mathare	0.01	0.01	0.02	1.6	9.6	46	39	20
Langata Rd	Ngong	0.05	<0.01	0.01	1.1	8.6	59	52	28
Embakasi	Ngong	0.07	0.02	0.15	1.3	7.8	70	46	24
Njiru 1	Nairobi	0.04	0.02	0.18	1.4	7.2	47	40	17
Njiru 2 (10)	Nairobi	0.03	0.03	0.20	1.2	4.4	42	29	16
Donyo Sabuk	Athi (Middle)	<0.01	<0.01	<0.01	0.3	4.4	29	8	10
Malindi	Athi/Sabaki (Coast)	ND	ND	ND	ND	29.1	120	19	21

Source: Field data (1999–2002), ND – not detected

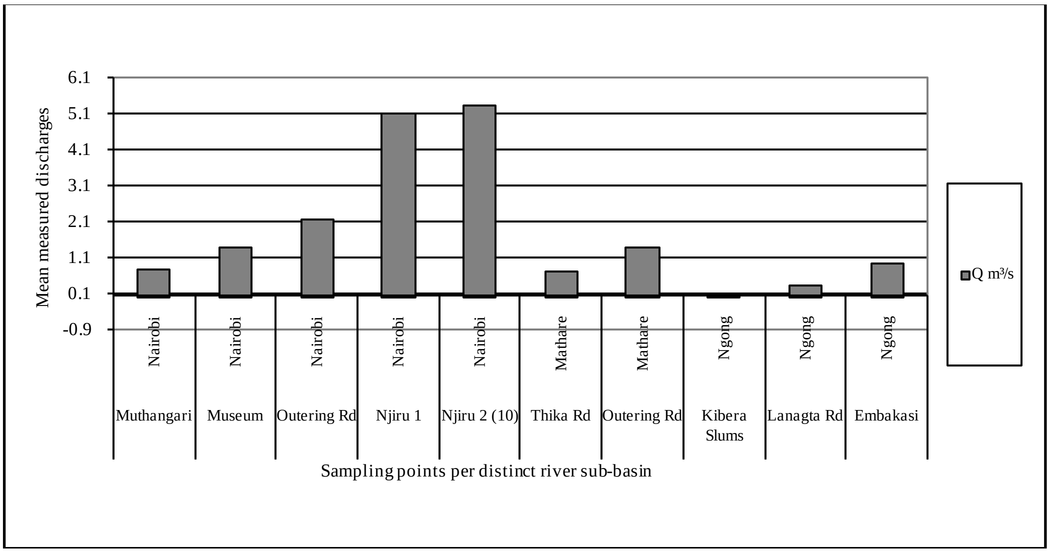


Fig. 3 Variations in river discharge (Q) along each of the river sub-basins

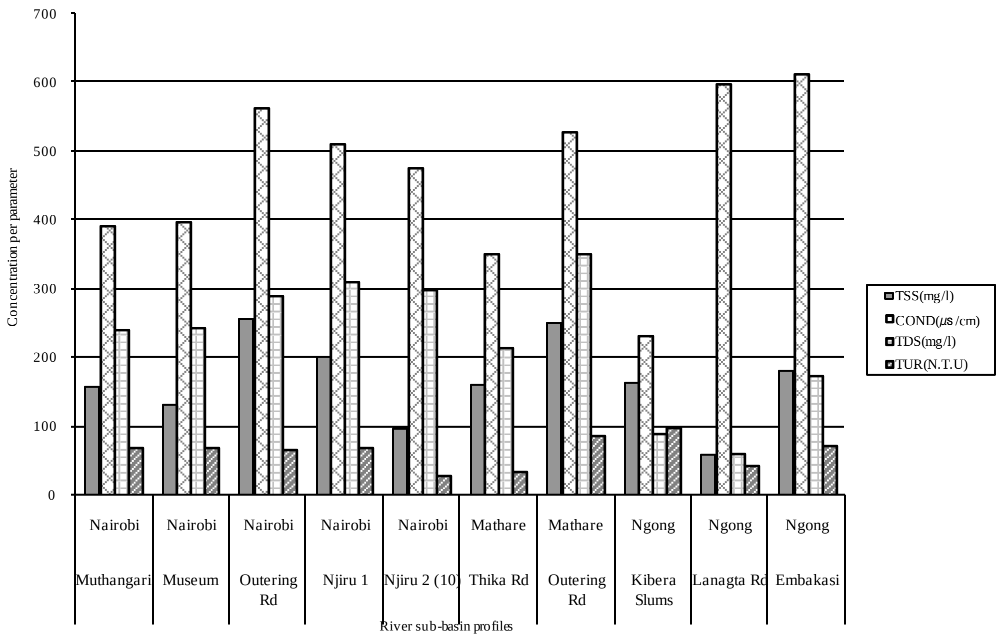


Fig. 4 Downstream variation of some physical water quality parameters

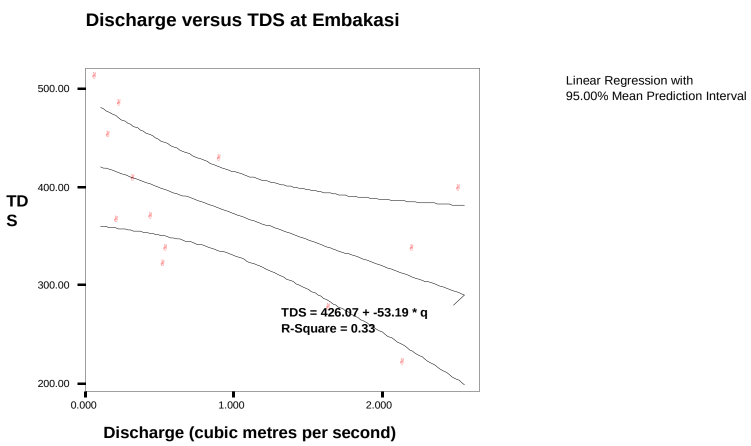


Fig. 5 Regression line between Total dissolved solids and discharge

IV. CONCLUSIONS

The study revealed that storm water can effectively clean up the rivers during the rainy season, since water can conventionally easily be treated if physically polluted. This can be achieved through systems of engineering ponds to trap the sediments, or the use of conventional treatment methods such as flocculation, filtration, and sedimentation. In addition, construction of engineering waterfalls along the river courses may prove useful in improving the oxygen content and aeration of the river waters. Goldyn *et al*. (2001) identified overland flow as an effective method of decreasing the loads of nutrients and other pollutants discharged to surface waters. Macrophytes also were found to be quite useful in reducing water quality degradation because they trapped sediment, and due to their uptake of several dissolved heavy metal ions such as Zn, Cu, Pb, Cd, Cr and Ni. The concentrations of these elements were found to vary in different plant tissues and species. The most significant plant species included, in order of their metal uptake, *Sphaeranthus napirae*, *Pennisetum purpuream*, *Commelina benghalensis* and *Xanthium pungens*. Thus, if these plant species can be left to grow along the riparian sections of the rivers, they can prove quite useful in the restoration of the water quality status within the basins.

V. RECOMMENDATIONS

This study indicates that declining water quality in the Nairobi River basins requires much more attention from policymakers than is currently the case. Stormwater, and macrophyte cover along the banks of the Nairobi River basin, can substantially improve water quality as a result of dilution (stormwater) and ionic adsorption (macrophytes). Both can be quite useful in water quality restoration projects in the basin.

There is a need for community participation in the clean up exercises so that people may better appreciate the need for a safer and cleaner Nairobi River basin. This will allow Nairobi city residents to better appreciate other clean-up projects that will help achieve the goals of both water quality restoration and ecosystem maintenance within the sub-basins investigated. This also should involve a continuous environmental education for all stakeholders.

The riparian areas of the river should be legally by protected to ensure no encroachments into the river banks by land use activities that pollute and degrade the water quality. The government may try to impose land use zoning laws or implement NEMA regulations as applied to land use activities near water courses.

Environmental Education (EE) should be made compulsory for those businesses operating close to river systems to avoid dumping of wastes into the river waters.

Close monitoring of the water quality status near some of the industries as well as water sampling should be made a priority by the government agencies charged with the responsibility of controlling water pollution. Where possible sampling can be done at night when some of the industries are notorious in dumping their wastes into the river systems.

The government may further consider the implementation of the polluters-pay principle in ensuring sustainable and quality environment for its citizens and especially more to the Nairobi city residents.

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