Impacts of sediments yields and water quality on the Nairobi River basin ecosystem, Kenya

SHADRACK MULEI KITHIIA

Postgraduate Programme in Hydrology, Department of Geography and Environmental Studies, University of Nairobi, PO Box 30197-00100, Nairobi

skithiia@yahoo.com

Abstract This paper presents the results of a study on the effects and implications of sediment yields on water quality within the Nairobi River basin ecosystem. Sediments from water samples were obtained from the Ngong, Nairobi, and Mathare river sub-basins. The results indicate a seasonal variation/trend for suspended sediments in each basin, and a similar trend in water quality degradation. Annual suspended sediment flux estimates for the Ngong, Nairobi, and Mathare rivers are 1700, 6300 and 3000 tonnes, respectively. The results further indicate 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. 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 yields and water quality degradation. 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 yields had a significant effect on the Nairobi ecosystems in terms of water quality degradation. Strategies to control, and hence reduce water quality degradation, suggested as a result of this study, include removal of solid wastes from the river courses, protection of the river banks from construction activities, 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

INTRODUCTION

The Nairobi River sub-basin consists of three tributaries; namely the Nairobi, Ngong and Mathare rivers. These streams drain a greater part of the city of Nairobi in a southeast direction (Fig. 1). The city of Nairobi is the economic hub of the East African region and the capital of the Republic of Kenya. The city was established in the 1900s with a population of about 250 000 (Obudho, 1992) but has grown tremendously over the years and now is approx. 3.1 million (Kithiia, 1998).

Increased population has changed the land-use dynamics within the city and its environs. Land use changes from intensive agricultural systems in the upstream areas, to residential and industrial uses within metropolitan Nairobi (Kithiia, 1992, 1998, 2006a,b). The effect of various land uses on pollutants, sediment generation and water quality degradation is substantial, and worthy of investigation.

Increased sediment fluxes along the river profile contribute to increased water quality degradation as well as changes in 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 the trends in sediment loads and other pollutants on decreasing water quality status and the role of riparian vegetation (macrophytes) in water quality restoration for sustainable ecosystem use and habitat maintenance.

METHODS OF STUDY

The study involved water sampling at fixed points (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. The major land-use activity was used as the main contributing factor in

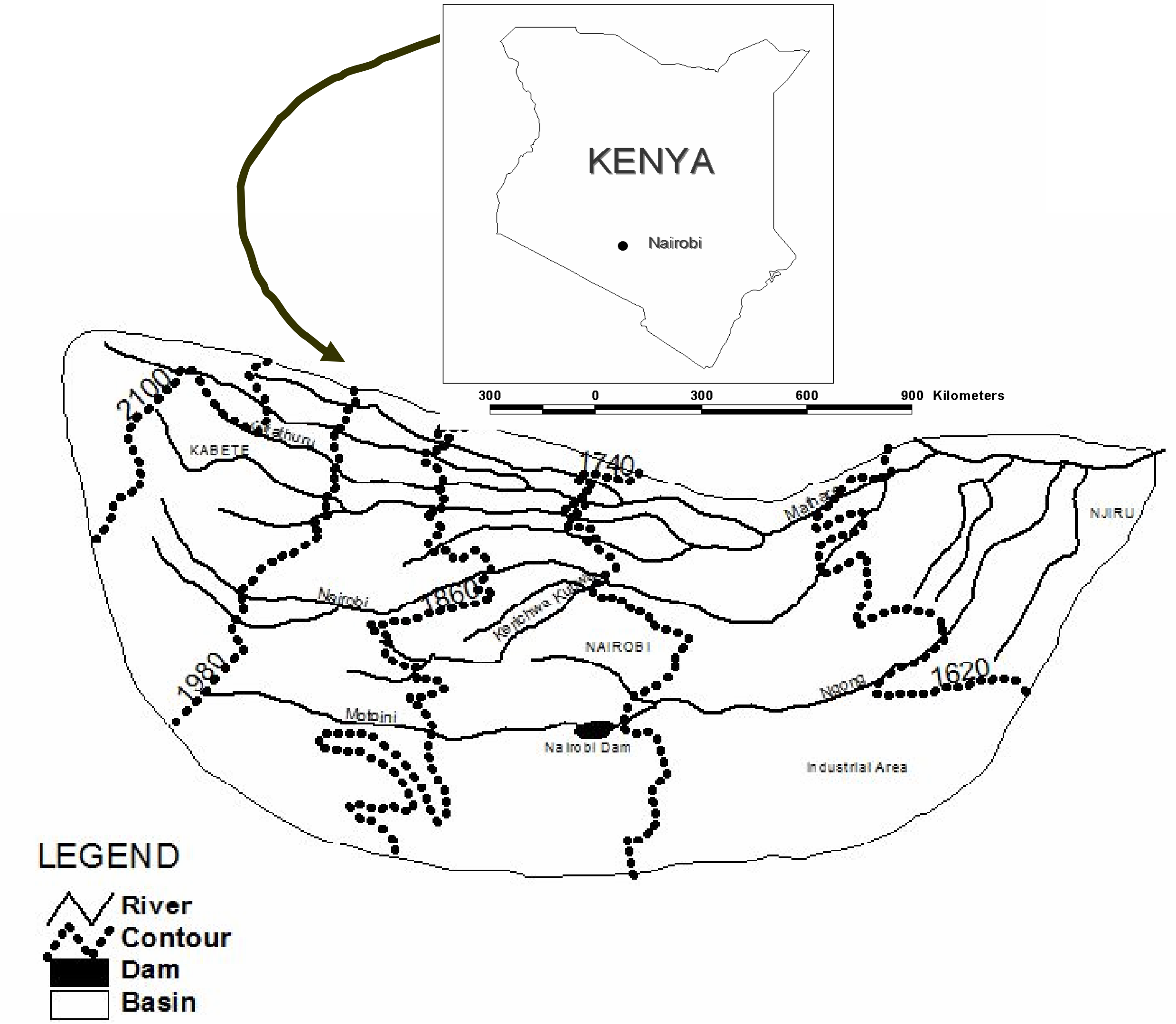

Fig. 1 Study area and Nairobi River sub-streams.

locating the sampling point(s). 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, 200 samples were collected within the period of study and analysed for 15 water quality parameters; that translates to a total of 3000 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 limit bias in the results obtained.

In addition, river discharges were determined by applying the velocity-cross-sectional area method (Linsley & Franzini 1979, Linsley *et al.*, 1988, Wilson, 1990). The river discharges (Q) were correlated with water quality parameters to determine trends in water quality degradation.

Plant tissues (macrophytes) were collected along 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 were an indication of

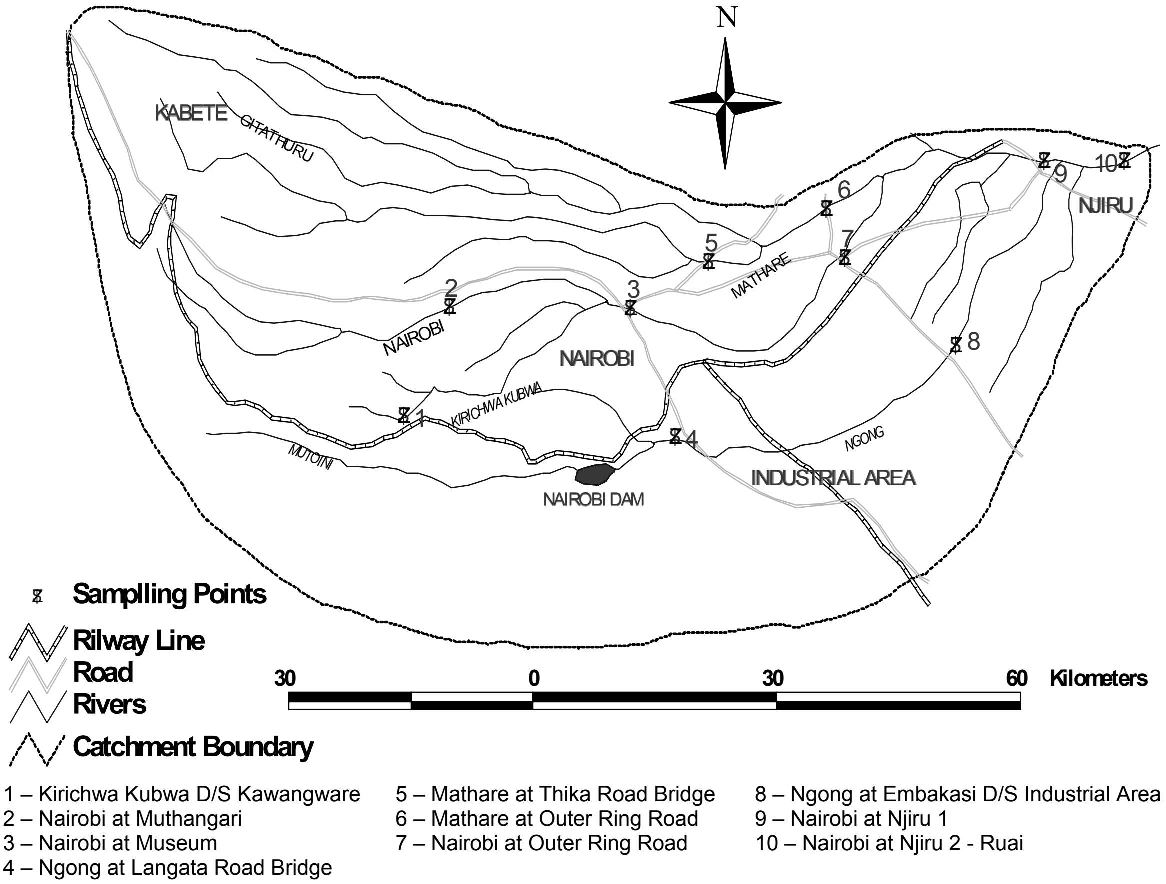

Fig. 2 Distribution of sampling points.

metal uptake by the isolated vegetative tissue parts, and formed the basis for determining impacts of water quality changes on the ecosystem and environmental habitats of the river systems.

RESULTS AND DISCUSSION

Land use changed from predominantly agricultural in the upper reaches 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). Table 1 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 (Table 2).

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. 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.

Figure 4 further illustrates the fact that increased discharge 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 (Fig. 5).

Table 1 Mean measured values of physical and chemical water quality parameters at sampling points.

Sample site	River	Mean concentrations 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 2 Mean concentrations of metal ions at various sampling points and rivers.

Site	River	Mean concentrations of metal ions in $mg L^{-1}$ 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

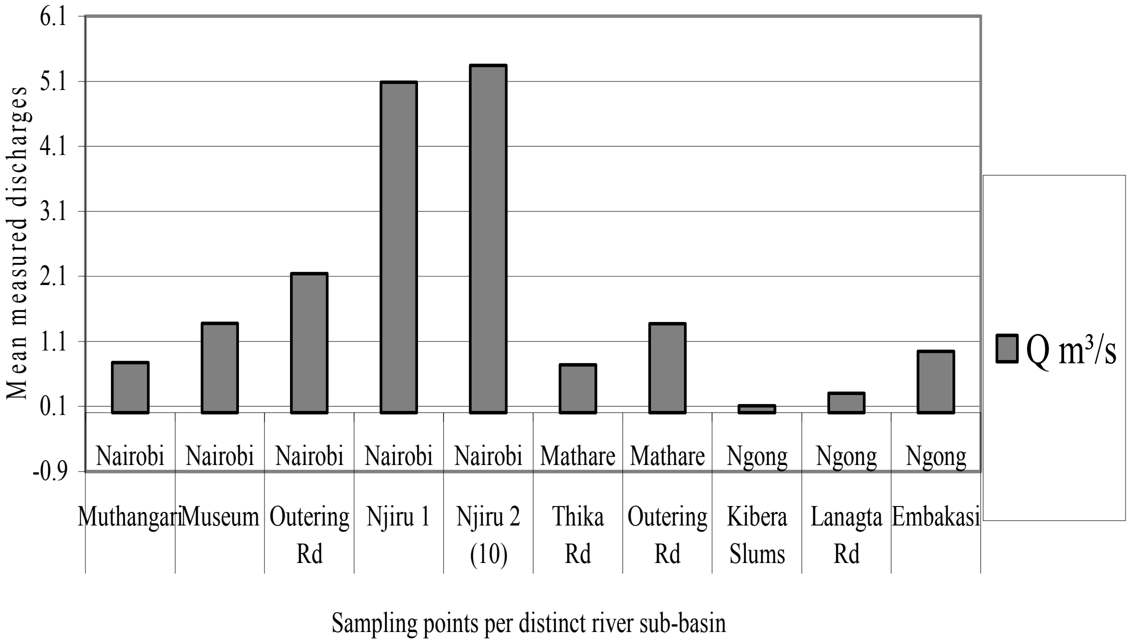

Fig. 3 Variations in river discharge (Q) along each of the river sub-basins.

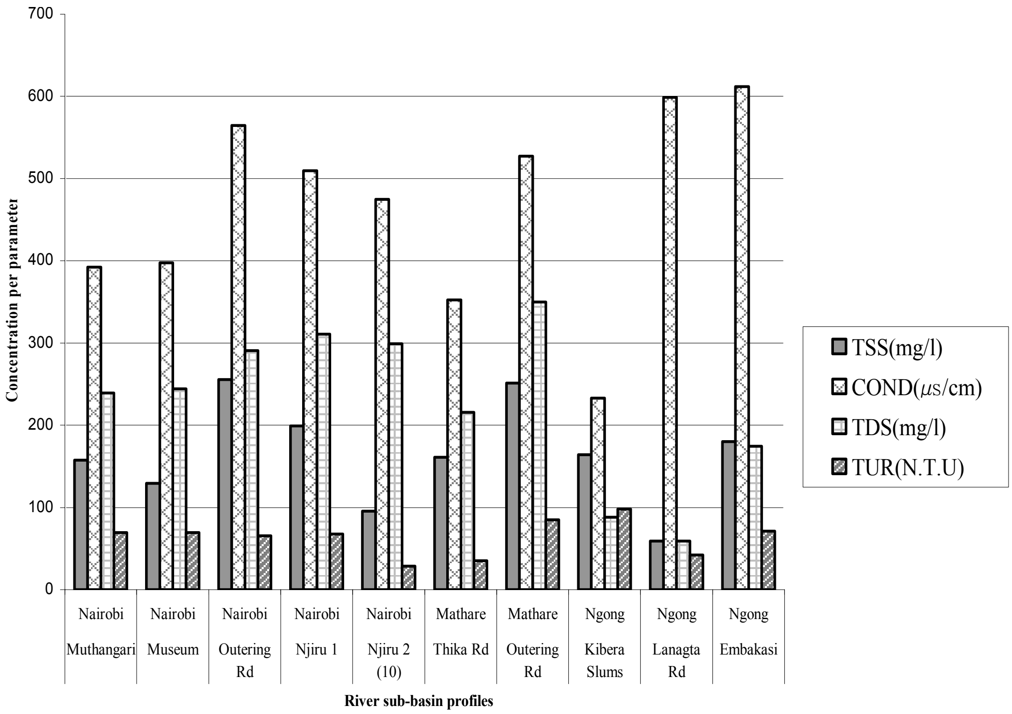

Fig. 4 Downstream variation of some physical water quality parameters.

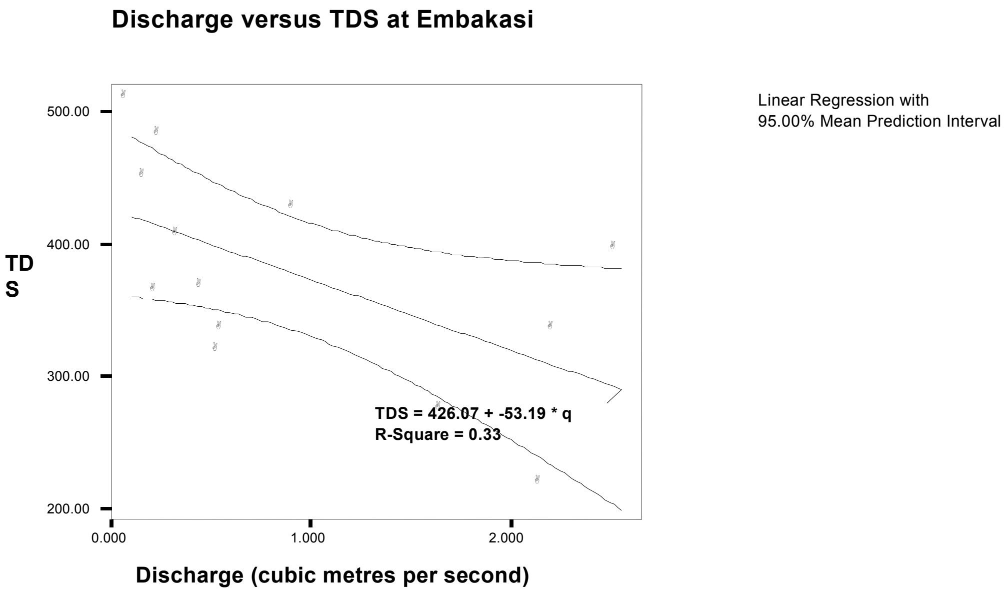

Fig. 5 Regression line between Total dissolved solids and discharge.

CONCLUSIONS

The study found that stormwater can clean up the rivers during the rainy season, since water can 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 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, were *Sphaeranthus napirae*, *Pennisetum purpuream*, *Commelina benghalensis* and *Xanthium pungens*.

RECOMMENDATIONS

This study indicates that declining water quality in the Nairobi River basin 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 continuous environmental education for all stakeholders.

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