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Temporal changes of sediment dynamics within the Nairobi River sub-basins between 1998–2006 time scale, Kenya

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Abstract: *Temporal changes of sediment dynamics within the Nairobi River sub-basins between 1998–2006 time scale, Kenya*. The city of Nairobi is the heart of both industrial production and the economic hub in Kenya and the Eastern Africa region. The city of Nairobi and its environs are drained by three streams, namely: Nairobi, Mathare and Ngong rivers. These streams drain areas of diverse land use activities. The land use changes in a spatial manner from the rich agricultural system through residential cum urban to industrial. The significance of these various land use systems to pollutants generation, pollution, sediment generation and hence water pollution and quality degradation is quite enormous and worth investigation. The land use changes in a spatial manner making the basin ideal for a temporal variation of sediments yields along the river profile and their impacts on the water quality status. This paper examines the results of study carried out within the basins in the years 1998–2006. The method of study involved water sampling and laboratory analysis to reveal the trends in sediment load increases downstream the investigated streams. Soil samples were also investigated to determine their relationship to soil erosion rates and sediment fluxes. The study attempts further to find the best sediment management strategies in reversing their increasing trends and restoring water quality within the basin.

Key words: quantity, quality, stream restoration, sedimentation.

INTRODUCTION

The city of Nairobi is the capital of Kenya and was established in the 1900's as the Headquarter of the Kenya-Uganda Railway (KUR). It is the centre of both administrative and economic functions and three tributaries of the Nairobi River run through the city; namely: Nairobi, Mathare and Ngong rivers. These streams drains the city in a south-east direction draining areas of diverse land use systems and collecting in them an enormous volume of pollutants, both dissolved and solid wastes. The amounts and volumes of these pollutants change over space and time within the drainage basin and its envions. The implication of this is increasing trends in water quality degradation in terms of dissolved load and suspended sediment loads (Kithiia 1992, 2006). With increasing trends in population growth from the initial population of 250,000 to over 2.1 million as at 1999 population census and predicted to reach a figure of over 3.5 million people as indicated in Table 1 (Republic of Kenya 1999, 2005); there has been increasing trends in water demands, infrastructure and waste generation. This coupled with a haphazard waste disposal strategy, sewer bursts and lack of proper waste management strategy has resulted to increasing trends in sediment load fluxes and water quality degradation. An investigation in the temporal changes of

TABLE 1. Nairobi population (1906–1999)

Year	Area [ha]	Population	% increase of Pop^n
1906	1 813	11 512	–
1928	2 537	29 864	159.4
1931	2 537	47 919	60.5
1936	2 537	49 600	3.5
1944	2 537	108 900	119.6
1948	8 315	118 976	9.3
1962	68 945	266 795	124.2
1969	68 945	509 286	90.8
1979	68 945	827 775	62.5
1989	68 945	1 324 570	60.5
1999	68 945	2 143 254	61.8
2005 (projected)	68 945	3 578 321	63.1

Source: Republic of Kenya, 1999; 2005. Population and Housing census, CBS and R.A. Obudho and G.O. Aduwo, (1992) Table 1:58.

sediment dynamics within the basin is worth investigation and gives an insight into the best control strategies applicable in the basin and the country in general.

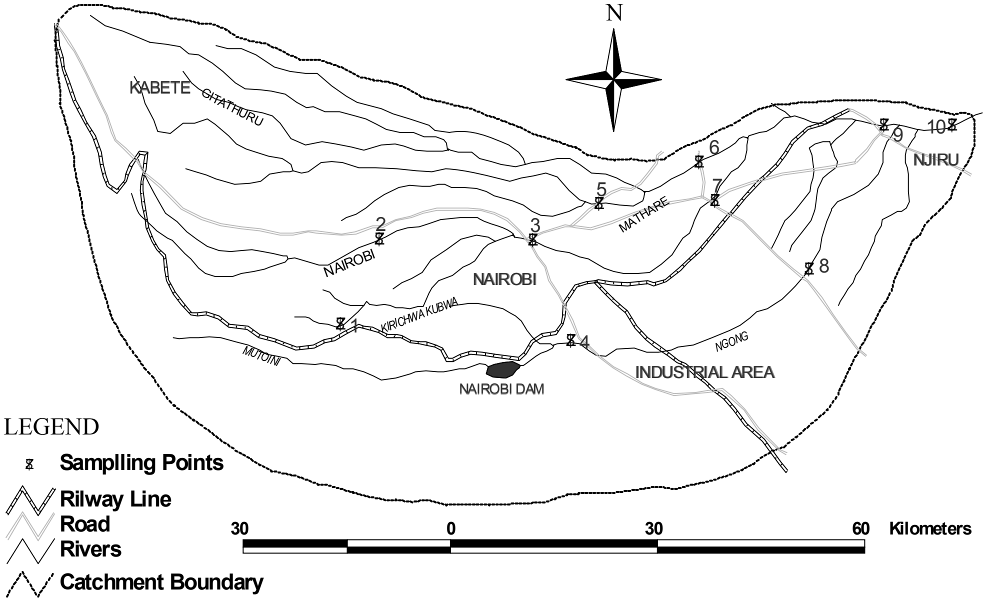
STUDY METHODS

Water samples were drawn from designated water sampling points within the sub-basins investigated as indicated in Figure 1. The samples were analysed for in situ water quality parameters and the rest were pre-treated prior to transportation to the central laboratory facilities at the Ministry of Water and Irrigation for sediment load analysis and quantification (Kithiia 2006). During the 1998–2000 period, water samples were collected in a frequency of one month and this was increased to a frequency of once per two weeks from 2000–2008 in the sampling points. A total of 6 sampling points were used and the number increased downstream the streams investigated. A total of 50 samples were drawn from each sampling point translating to a total 300 number of samples as well as water quality parameters. This was used to reveal the trends in suspended loads along each of the river profiles and the over-all trends in sediment loads changes over the entire basin investigated.

RESULTS AND DISCUSSION

Table 2 gives the results and trends in sediment load fluxes within the streams investigated over the period of study. Generally, there was an increasing trend in sediment load running in a downstream trend. Low sediment load values were recorded in the headwater areas. This tended to change in a downstream scenario as the river tributaries join to form the main river system.

Table 3 indicates the changing trends in total suspended load within the three Nairobi River tributaries, namely: Nairobi, Mathare and Ngong rivers. The results indicated an increasing trend in suspended sediment loads downstream each of the three river system and through the



SAMPLING POINTS

1. Kirichwa Kubwa D/S Kawangware
2. Nairobi at Muthangari
3. Nairobi at Museum (RGS 3AA22)
4. Ngong at Langata Road Bridge
5. Mathare at Thika Road Bridge (3BB 10)
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

FIGURE 1. Water Sampling Points in Nairobi River sub-basins
Source: Researcher (1998–2008) & MOWD (1997).

TABLE 2. Rating equation of suspended load and its volume of some selected streams in the Athi river drainage basin

Code	River	River profile section	Suspended load	
			Mean [ppm]	Annual [$t \cdot yr^{-1}$]
3AA04	Mbagathi	Upper drainage area (Headwaters)	193	4 456
3BAA22	Nairobi		57	2 231
3BB10	Riara		118	1 474
3CB05	Ndarugu		202	29 356
BDA02	Athi (Twake Conf.)	Middle reaches	153	131 089
3F02	Athi (Tsavo)		549	753 627
3HA12	Athi (L. falls-mouth)	Lower reaches	859	2 057 487

Source: Adapted from NWMP, 1992 report Vol. 1, Table 2.31.

TABLE 3. Concentration of Total Suspended Sediments (TSS) In the Nairobi river Sub-basins in tones per year

Sampling stations	Main river	TSS Values t year^{-1}
Langata rd Bridge	Ngong	188.02
Embakasi rd Bridge		1733.15
Thika rd Bridge	Mathare	1194.54
Outering rd Bridge		2986.63
Muthangari	Nairobi	1001.02
Museum		1611.15
Outering road		6317.20
Njiru 1 after Mathare Confluence		12520.17
Njiru 2 All streams joined		5166.23

Source: Field data (1998–2008).

city of Nairobi. In addition, there was a seasonal change in suspended sediment loads in the streams, being high during the wet season and low in the dry season as well as along the river profiles. The implication of increasing sediment loads into the rivers in the physical contamination of the water resources as illustrated by Ongwenyi (1979), Kithiia (1992), Ongwenyi, et al. (1997), Kithiia and Ongwenyi (1997), Okoth and Otieno (2000), Mavuti (2003) and Kithiia 2006 a and b studies within the same basin and streams investigated. The increasing sediment loads are also associated to changes in land use systems within the study area. The area is basically characterized with agricultural activities in the upper catchment areas (headwaters) to industrial and residential land use systems in the city.

In addition, the Total Suspended Solids (TSS) and Total Dissolved Solids (TDS) were found to vary widely from one river basin to another and also within each specific individual sub-streams. This correlated well with river discharges and was in accordance with the seasons of measurement. Ngong River at Embakasi sampling point yielded suspended solids during the peak flows of the tune of 1640 t·year^{-1} and total dissolved solids at the tune of 3750 t·year^{-1} respectively and during the low flows at 1360 t·year^{-1} and 3600 t·year^{-1} (Kithiia 2006).

CONCLUSIONS

The study revealed an increasing trend in sediment load fluxes downstream the sub-streams investigated. The measured TSS for Nairobi River ranged between 95.5–255.7 mg·l^{-1}, Mathare River 161–251.2 mg·l^{-1} and Ngong River 239.7–310.9 mg·l^{-1}. This correlated well with the increasing water quality degradation within the investigated streams. Increasing trends in water quality deterioration within the streams call for quick and appropriate measures to check the rate and to abate the eminent problems of disease out-breaks especially those related to water. The water in these streams has also lost its aesthetic appeal enjoyed in the early 1900's when the city of Nairobi was established as the Headquarters of then Kenya-Uganda Railway (KUR) and therefore, this requires multi-displinary efforts to reverse the trend.

RECOMMENDATIONS

As was evident in the study, land use changes and activities had profound effects on sediment fluxes and water quality. There is need to review the existing land use policy in the country to protect against encroachment of land use activities into the watershed areas. This will encourage land management control and conservation measures as well as riparian use of water resources in the headwater areas and along the river profiles of the three sub streams investigated.

In the headwater and middle reaches, construction of benches on the steep slopes would effectively reduce soil detachment and velocity of runoff. This will increase rates of infiltration and immensely reduce sediment loads in the downstream river courses. This will include use of well designed, constructed and maintained terraces to control runoff and soil losses and thereby reduce the amounts of sediments conveyed by the river water. Encourage people to avoid cutting down trees but rather plant more trees. This will reduce soil erosion and sediment load generated during the rains by increasing the soil cover.

Population settlement should also be well planned to discourage people from settling on steeper slopes, which tends to increase the rates of sediment delivery and runoff. While implementing the Best Water and Soil management Practices (BMP's) in the catchment will also be necessary to include the protection of water catchment areas through afforestation, revegetation, natural regeneration and legal measures.

REFERENCES

G.O.K; Kenya, Republic of, 1999: Population and Housing census, CBS, Government printer, Nairobi, Kenya.

G.O.K; Kenya, Republic of, 2005: Projected Population and Housing census, CBS, Government printer, Nairobi, Kenya.

KITHIIA S.M., 1992: Effects of Industries and Other land-use systems on the water quality within the Nairobi river sub-catchments, Kenya. M.Sc. Thesis, University of Nairobi, Nairobi, Kenya.

KITHIIA S.M., ONGWENYI S.O., 1997: Some Problems of Water Quality degradation in the Nairobi River sub-basins in Kenya. In: *Freshwater Contamination* (*proceedings of Rabat Symposium S4*, April 1997). IAHS Publ. No 243, 1997.

KITHIIA S.M., 1997: Land use changes and their effects on sediment transport and soil erosion within the Athi river drainage basin, Kenya. In: *Human Impact on Erosion and Sedimentation* (*proceedings of Rabat Symposium S6*, April 1997). IAHS Publ. No 245, 1997, 145–150.

KITHIIA S.M., 2006: The Effects of land-use types on the Hydrology and water quality of the upper-Athi River Basin, Kenya. Ph D. Thesis, University of Nairobi, Nairobi, Kenya.

OKOTH P.E., OTIENO P. (eds) 2000: Technical report of the Nairobi River basin project – Africa Water Network, UNEP.

ONGWENYI G.S., 1979: Water Resources and the Environment in Kenya: Seminar of Environment Engineering, University of Nairobi.

ONGWENYI G.S., KITHIIA S.M., DENGA F.O., ABWAO P., 1993: An overview of soil erosion and sedimentation problems in Kenya. Proceedings of the 4th joint IAMAP-IAHS assembly in Yokohama, Japan, July 11–23, 1993.

Streszczenie: *Zmiany okresowe dynamiki osadów dennych w latach 1998–2006 rzeki Nairobi i jej dopływów*. Miasto Nairobi jest centrum produkcji przemysłowej i centrum ekonomicznym Kenii oraz wschodniego regionu Afryki. Miasto Nairobi i jego otoczenie jest odwadniane przez trzy następujące strumienie: Nairobi, Mathare i Ngong. Te

strumienie odwadniają obszary o różnym użytkowaniu i działalności. Użytkowanie terenu zmienia się w sposób przestrzenny od bogatego systemu rolnego poprzez miejski mieszkaniowy do przemysłowego. Znaczenie tych różnych systemów użytkowania terenu było bardzo istotne i warte badań z punktu widzenia tworzenia zanieczyszczeń, zanieczyszczenia i generacji rumowiska a tym samym zanieczyszczenia wody oraz degradacji jakości. Zmiany przestrzenne użytkowania terenu czynią zlewnie idealnymi dla czasowych zmian przyrostu ilości rumowiska wzdłuż profilu rzeki i ich wpływu na stan jakości. W referacie przedstawiono wyniki badań przeprowadzonych w zlewniach w latach 1998–2006. Metoda badań obejmowała pobór próbek wody i analizę laboratoryjną w celu określenia trendów zwiększenia ilości rumowiska w badanych strumieniach, w ich odcinkach dolnych. Próbki rumowiska były także badane w celu określenia ich zależności od wielkości erozji i strumieni rumowiska. Badania mają na celu znalezienie najlepszych strategii gospodarowania rumowiskiem w celu odwrócenia ich trendów wzrostowych i przywrócenia jakości wody w zlewni.

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