Freshwater Contamination (Proceedings of Rabat Symposium S4, April-May 1997).
IAHS Publ. no. 243, 1997

Some problems of water quality degradation in the Nairobi River sub-basins in Kenya

SHADRACK MULEI KITHIIA
Department of Geography, College of Education and External Studies, University of Nairobi, PO Box 30197, Nairobi, Kenya

GEORGE S. ONGWENYI
Department of Geography, College of Humanities and Social Sciences, University of Nairobi, PO Box 30197, Nairobi, Kenya

Abstract This paper examines problems of water quality degradation with a special focus on the different land uses in the sub-basins of the Nairobi River, namely the Kamiti, Ngong and Kasarani Rivers. A study was carried out within these sub-basins for 8 months between October 1990 and May 1991 which covered the distinctive dry and rainy seasons of the country. In general, the deterioration of water quality in the study rivers was related to riparian land use. The response of ionic concentration to changing flow was also similar between the rivers, but was more pronounced for the Ngong River at Embakasi and for the main Nairobi River at Dandora slums than for the Kamiti and Kasarani Rivers, which reflected different riparian land-use activities. The deterioration in water quality within the study area suggests harmful effects to human health, especially as it relates to domestic uses of water. An evaluation of the water quality status for different land uses within the study area is recommended, especially for surface and groundwater resources. Effects on the human health aspects should also be considered. Proper land-water conservation policies should be incorporated within the management of water resources, which must include issues of water quality and pollutant sources not only in the study basin but also in the country as a whole.

INTRODUCTION

Ecologically, the study area lies within the agro-ecological zones II, III and IV which range from humid, through semi-humid to semiarid lands. However, land-use systems are highly influenced by rainfall patterns, topography and human activities. In general, the area has two distinctive land-use systems (Fig. 1), comprising agriculture, which is the main land use in the Kiambu district, and industry, which is the predominant land use in Nairobi city and its environs. The Kiambu district is close to Nairobi and the urban influence plays a major role in determining the intensity of land use.

Land use in Nairobi city is quite diverse and includes forest, grassland, agricultural practices (small-scale), residential, communications and industry. With the increase in industrial production and change in government policy in favour of industrial diversification (Republic of Kenya, 1986), there has been an increase in the number of industrial establishments and consequently of people employed. This has increased the number of housing units and area of residential land, and has increased the volume of domestic waste. A greater number of industrial establishments has also increased the effluent load discharged into the rivers passing through the city and has caused a serious deterioration in water quality.

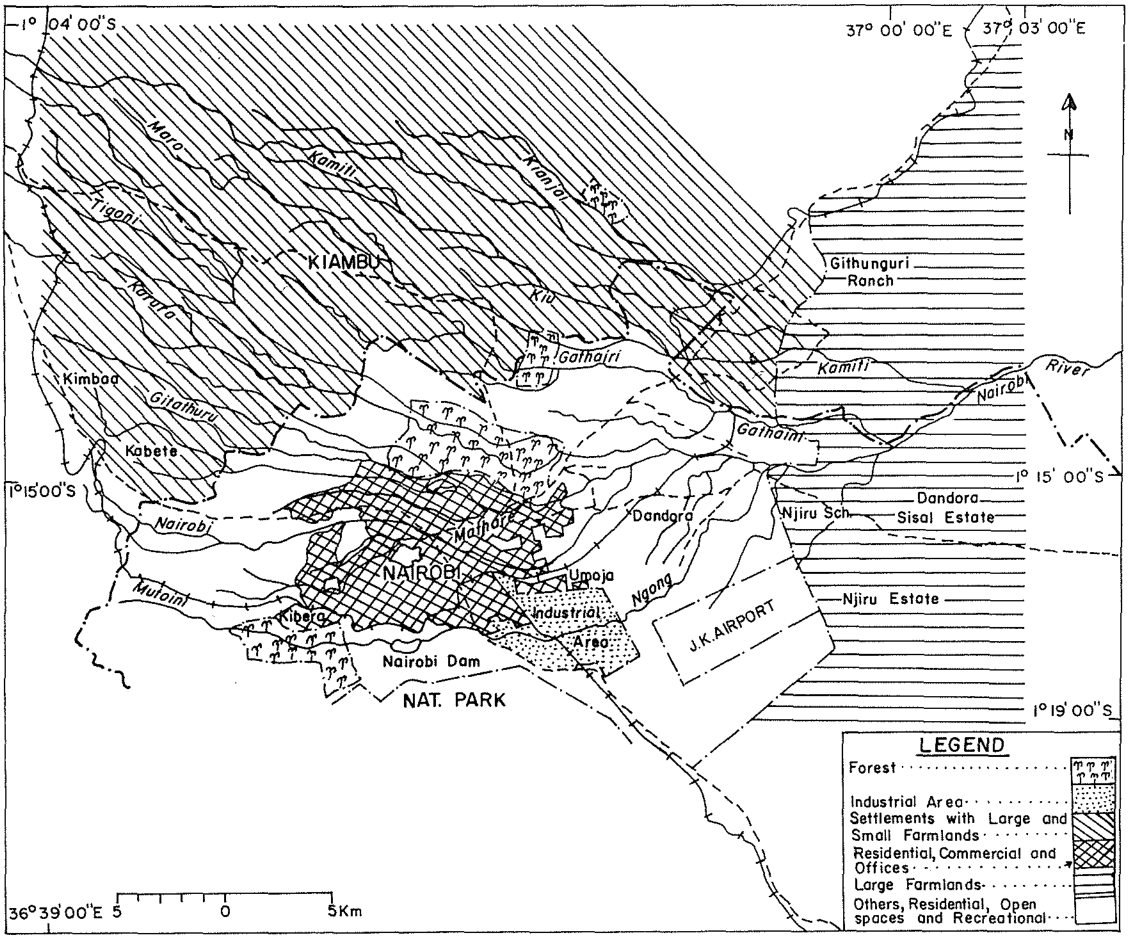

Fig. 1 Land-use systems in the study area.

WATER QUANTITY AND QUALITY STATUS OF THE STUDY BASINS

While the amount of water available in a drainage basin normally remains relatively static, the demand for water often rises with changing human activities. The latter include a wide spectrum from changes in the basic way of living to changes in the technology employed to exploit natural resources (Dunne & Leopold, 1978; Kithiia, 1992). Water pollution often arises as a consequence, and not only does a low quality supply result, but there may also be a major reduction in its quantity.

The sources of water for Nairobi River sub-basins are the Ondiri springs, the Kabete and Karura forests, the Ngong hills, and all the streams which join downstream of Nairobi to form the main Athi River (Fig. 2). The total quantity of water in these streams is 23.6 $m^3\ s^{-1}$ which is equivalent to $36.7 \times 10^6\ m^3\ year^{-1}$. This amount of water, however, is less than the discharge of waste water from both industry and domestic use in the city.

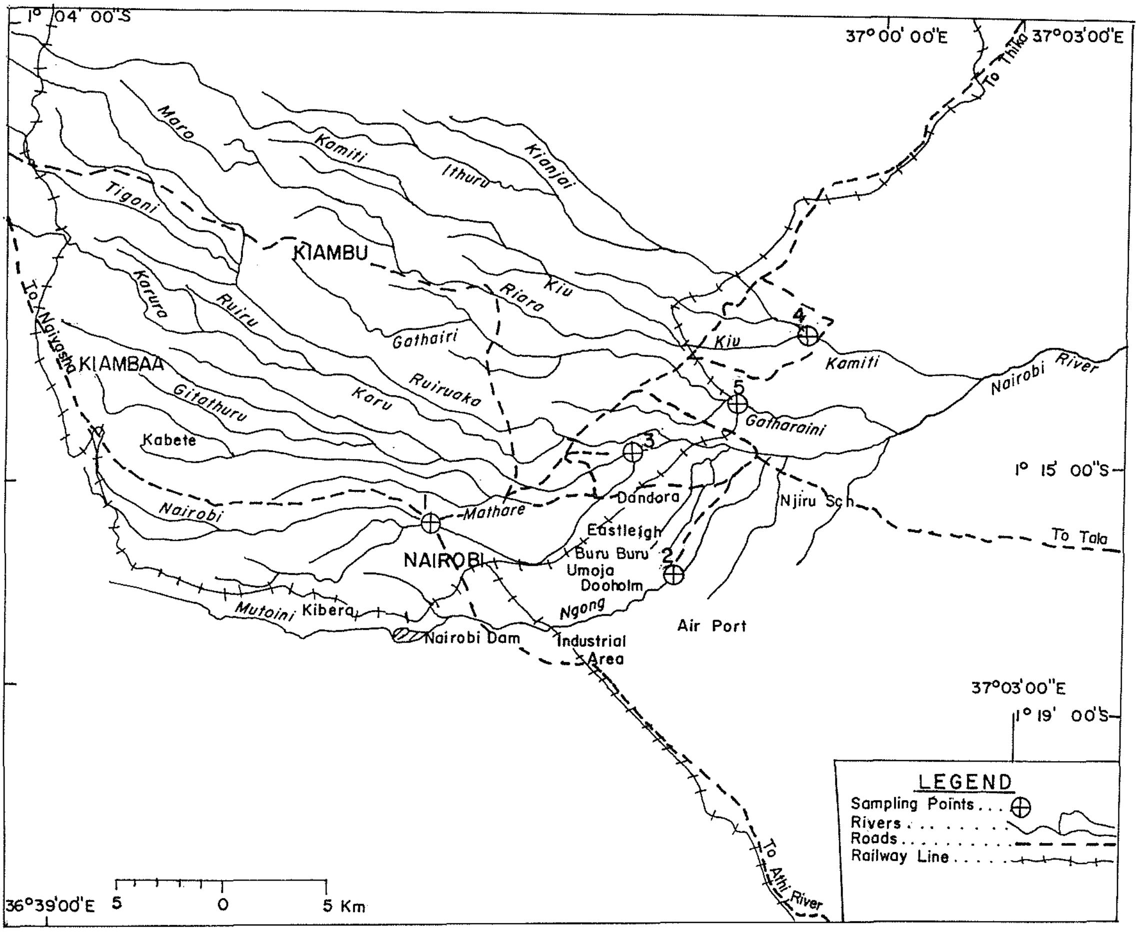

Fig. 2 Sampling sites on the study rivers.

Trends in water use and demand are often a guide to the availability of water in terms of both quantity and quality. In many instances, an increase in water demand and use is directly proportional to a deterioration in water quality. The amount of waste discharged tends to increase with rising water demand, although the relationship depends in detail on the amount of water and the specific use involved. The amount of water in a river depends on the type and number of water abstraction facilities along the course, the number of tributaries, amount of rainfall and distribution, soil type, temperature and the shape of the drainage basin, as well as the population structure. The nature and extent of human activity, be it industrial, agricultural or both, will in turn determine the magnitude and nature of pollution and the water quality status of the water course.

Clearly, in order to avoid the dangerous consequences of serious water pollution, there is a need to properly understand the amount of water required and the volume of effluents to be discharged by any development projects planned for a drainage basin.

RESULTS

Land-use effects on water quality

A range of water quality parameters were investigated for areas under agricultural and industrial land uses. The measured concentrations were compared with the recommended WHO and Kenyan guidelines for drinking water quality in order to identify problems of water pollution.

The concentrations of chloride, fluoride, manganese and heavy metals were measured in the Ngong River at Embakasi downstream of the Nairobi industrial complex, in the Nairobi River at Museum, in the Kamiti River at Kamiti, in the Kasarani River at Kasarani and in the Nairobi River downstream the city centre at Dandora. Results (Table 1) reveal that most metal concentrations exceed those recommended by the Republic of Kenya (1985) and by the WHO (1984) (Table 2), and clearly show the strong polluting effect of industries discharging to these rivers, which is particularly marked for the Ngong river at Embakasi Bridge. There appears to be an increasing trend of industrial pollution along the river courses which presents a potential danger to the people who use water for drinking purposes downstream of the specified sampling stations.

The study also revealed variations of concentrations related to changing river discharge in the two seasons investigated. Problems relating to physical water quality parameters were more significant during the peak flows than in the periods of low flows. Thus, during the period of peak flows, water is highly polluted, has a high

Table 1 Mean concentrations of chemical parameters in the study rivers.

Parameter ($mg\ l^{-1}$)	River and sampling site: Nairobi at Museum	Kamiti at Kamiti	Kasarani at Kasarani	Nairobi at Dandora	Ngong at Embakasi
Pb	-	0.1	0.1	0.1	0.1
Zn	-	-	0.4	0.1	0.1
Cu	-	-	-	0.1	0.1
Hg	-	-	-	0.02	0.3
Al	1.6	2.8	2.1	2.5	1.65
Mn	0.4	0.4	1.01	1.0	1.6
Fe	1.5	2.7	2.7	3.0	1.2
Na	43.7	18.9	168.0	55.0	112.8
Mg	6.1	3.1	4.8	7.4	8.4
Cl	54.6	14.6	106.0	35.0	64.6
Fl	-	-	-	-	1.84

Table 2 Concentration limits for chemical substances in drinking water after WHO (1984) and Republic of Kenya (1985).

Substance	Upper limit of concentration ($mg\ l^{-1}$)
Zinc as Zn	5.0
Fluoride as Fl	1.5
Copper as Cu	1.0
Iron as Fe	0.3
Aluminium as Al	0.1
Manganese as Mn	0.1
Lead as Pb	0.05
Mercury (total as Hg)	0.001

content of suspended solids, and is highly coloured, although conductivity is low reflecting the dilution of total dissolved solids concentration. During the period of low flows, the water was not highly polluted with respect to physical parameters, but there was a significant increase in the soluble inorganic constituents including the metallic ions, which were present at higher concentrations than during peak flows.

Table 1 also reveals that the concentration of potentially polluting substances varies in the different sub-basins depending on the type of land use that is present. Thus, the Ngong River at Embakasi exhibited high values for most of polluting substances studied, including manganese, lead and mercury, as a result of the industrial activity upstream of this station. The water in the river is therefore of low quality for domestic use, and the measured mean concentration values exceed the stipulated Kenyan standards and WHO guidelines for drinking water (Table 2). The effects of this on human health has not yet reached a critical condition since no incidents have been reported so far, but the water is generally highly polluted and of low quality.

The relationship between ionic concentration and discharge varied from one sub-basin to another. The slope of the concentration-flow relationship was steepest for the Ngong River, followed by the Nairobi River at Dandora, the Kamiti River and the Kasarani River and the Nairobi River at Museum. The different response of ionic concentrations to changes in flow reflects the nature and volume of pollutant discharges which affect different sub-basins.

Agricultural pollution and water quality deterioration

By increasing suspended solids, turbidity and colour, nitrates and phosphates from fertilizer application, and animal wastes, agricultural activity causes deterioration in both the hygienic and aesthetic aspects of water quality. Health problems rarely result, but agricultural pollution leads to increased treatment costs and a reduction in the aesthetic enjoyment of the water resources (Kithiia, 1992).

The application of chemicals through agricultural production in the Nairobi river sub-basins was the main subject of the study. The substances investigated were pesticides, which are applied to control crop pests and diseases. Pesticides are considered to be very toxic in water, even in small concentrations, and they render the water harmful for human consumption.

The pesticides used in the study area include "Dithane M45", "Ambush", "Malathion", "Ridomil", copper sulphate and DDT, and both soil and water samples were tested for these substances. DDT and "Malathion" were detected in soil samples from the upstream reaches of the Gitathuru and Kamiti Rivers (Table 3). These and other pesticide residues were not detected in the lower reaches of these streams, nor in the Ruaka, Riara, and Gatara Rivers and the main Nairobi River. The presence of DDT residues in the soil reflects its persistence as an organochloride

Table 3 Pesticide residues in soil samples.

Pesticide	Type	Residue (mg kg^{-1})	Sampling site
DDT	Organochloride	0.0678	Giathuru upstream
"Malathion"	Organophosphate	0.178	Kamiti upstream

Table 4 Pesticide residues in water.

Sampling site	Pesticide	Residue (mg l^{-1})
Gatara River	DDT	0.086
Gitathuru River	"Ambush"	0.0948
Gitathuru River	"Malathion"	0.14
Ruaka River	"Ambush"	0.255
Ruaka River	"Malathion"	0.63
Riara River	"Ambush"	0.074

pesticide, while the presence of "Malathion" reflects the relatively high frequency of application.

Table 4 indicates that levels of pesticide residues in water varied widely in the study rivers. This variation may be attributed to differences in the amounts of pesticide used and in the intensity of cultivation in terms of land under cultivation per plot. Generally the presence of trace amounts of pesticide residues in water contributed to water pollution and quality deterioration, and measured concentrations were well in excess of the WHO and Kenyan standards for drinking water quality. For example, DDT was detected at a concentration of 0.086 $\mu g\ l^{-1}$ in the Gatara River, and "Malathion" at concentrations of 0.14 and 0.63 $\mu g\ l^{-1}$ in the Gitathuru and Ruaka Rivers, respectively. The absence of guidelines and/or quality standards for drinking water for most pesticides and herbicides in use in the country makes it complicated to assess the risk to water users from this source of pollution.

RECOMMENDATIONS

Water in most of the Nairobi River sub-basins was found to be highly polluted. Thus, urgent remedial measures are required in order to avert serious problems within these sub-basins. The measures required are:

(a) Pesticide application, including the amounts, rates and types, should be monitored by a group of advisory personnel from the Ministry of Agriculture.

(b) Disposal of domestic wastes should be confined to those drainage/sewage channels with very limited leakages.

(c) Urban garbage dumping sites should be located away from river banks and residential areas, because these are major sources of organic pollutants.

(d) Use of waste lagoons should be confined to those dry areas in the sub-basins with a low water table in order to avoid groundwater contamination.

(e) The management and control of water pollution should use an integrated approach involving interdisciplinary resource management committees to oversee and evaluate water resources, exploitation methods and conservation practices and thereby reduce environmental degradation.

(f) Management of environmental pollution requires sound legislation policies and a close monitoring of the environmental degradation, which is lacking in the study area. This knowledge is important in setting up an environmental assessment centre where all the necessary information regarding environmental pollution can be passed onto the communities.

REFERENCES

Dunne, T. & Leopold, L. B. (1978) *Water in Environmental Planning*. W. H. Freeman Co., San Francisco.

Kithiia, S. M. (1992) Effects of industries and other land use systems on the water quality within the Nairobi river sub-catchments, Kenya. MSc Thesis, Nairobi Univ., Kenya.

Republic of Kenya (1985) Kenya standards for drinking water quality. *Kenya Bureau of Standards (KBS), Standard no. KS 05-459.*

Republic of Kenya (1986) Economic management for renewed growth. *Sessional Paper no. 1.*

WHO (1984) *Guidelines for Drinking Water Quality*, vol. 1. *Recommendations.*