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Urbanization impact on the water resources with major Third World cities: A case study for Nairobi and its environs

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The expansion of low income urban dwellings (slums and shanty towns) and the high level of unplanned and poorly planned industrial developments have kept the rivers and drainage systems within the city of Nairobi and its environs under high levels of pollution.

Recent investigations of the surface waters around Nairobi indicate that rivers Ngong, Mathare, Nairobi and Rui Rwaka become heavily contaminated by heavy metals after flowing through both the industrial area and the low income urban centers. It is observed that both Nairobi and Mathare rivers become especially polluted after they flow through Majengo and Mathare slums respectively. The Ngong river on the other hand receives oily and toxic heavy metal discharges as it flows through the industrial area, while Rui Rwaka receives alcohol, heavy metals and offensive effluents from the breweries factory as it flows through the area of concern.

Chemical results of water samples collected from the Ngong River at the industrial area show high electrical conductivity and total dissolved solids (TDS) with high pH and temperature compared with the upper reaches of the river at Ngong Road. Mathare and Nairobi rivers have higher electrical conductivity, and dissolved solids (TDS) due to discharges into them as they pass through the Majengo and Mathare slums respectively. Rui Rwaka contains high total suspended solids (TSS) after receiving the offensive effluent discharges from the Breweries Factory. Water from these rivers is used for drinking and for other domestic purposes in those parts of the city and hence the exposure to water borne diseases.

Introduction

During the last few years, the number of diagnosed cases of typhoid, dysentery and cholera have increased tremendously in Nairobi. This phenomenon has caused concern both to the medical community and to the public at large, raising the question of the quality of the river waters in the city as a source for domestic use.

The outbreak of these diseases in the city can be linked to the state of the water system. A large section of the city's population which live in low income residential estates and slums do not have access to piped or treated water. Moreover, the estates do not have proper sanitation and sewage systems and therefore discharges are directed to the only available drainage system i. e. the rivers (Figure 1). These rivers in turn, are used as sources of water for the low income slum dwellers.

Physiography and hydrogeology

The physiography of the study area comprises of the Ngong hills in the south-west, the Kikuyu highlands and the Rift Valley flanks in the west and the Athi plains in the east. The maximum altitude of Nairobi is about 1,800 m in the west and it drops gently to about 1,500 m in the east. The rivers which flow through Nairobi originate from the eastern flanks of the Rift Valley and flow eastwards following the gentle tilt of the land (Givaerts, 1957, 1964). The major rivers are Ngong, Nairobi, Mathare and Rui Rwaka and they form a parallel drainage pattern, which exhibit youthful characteristics in their courses (Gaciri and Mailu, 1989).

The main rock types of the study area include alkaline lava and pyroclastic rocks which were extruded by fissure eruptions on the Rift Valley flanks during the Pliocene. The rock suites are represented by the Athi tuffs which are exposed in the north-east sector of

Figure 1 Map of Nairobi showing the main rivers and the slums where polluted water is consumed.

Figure 2 Map showing the extent of early lava flows in the Nairobi area (after Saggerson, 1991)

the city. The tuffs are overlain by Kandizi phonolite, the Limuru trachyte (Saggerson, 1967; 1991).

The natural surface flows of the area are in contact with the Athi tuffs, which generally overlie the Miocene Kapiti phonolites (Figure 2), the chemistry of the rocks and groundwater of the study area is discussed by Saggerson (1991).

Sampling and analytical procedures

Surface water sampling was carried out in 500 ml high density polythene bottles for a period of 5 months between 1994 and 1995. There were 30 sampling stations and two samples were collected from each station.

The sampling stations were set up in the upper reaches of the rivers in order to monitor the background characters of the water, the middle reaches in order to monitor specific sources of contamination and in the lower reaches in order to check the dilution effect due to self purification of the rivers.

Variables such as electrical conductivity, pH and water temperature were measured in the field. The pH of the water samples was maintained at pH 2 by adding nitric acid so as to prevent metabolic processes and adsorption within the samples. Dissolved calcium, iron, magnesium, cadmium, chromium, lead and zinc were analyzed by flame Atomic Absorption Spectrometry after filtering the samples. Dissolved sodium and potassium were analyzed by flame photometry using electro-selenium flame photometer. Total hardness, total dissolved solids, total suspended solids and biochemical oxygen demand (BOD) were determined by standard techniques as soon as the samples were brought to the laboratory.

Results

The biochemical oxygen demand (BOD) of Nairobi rivers is considerably higher than the internationally accepted values (Table 1). In the discharge points where the effluents enter the rivers the BOD at times reaches a maximum of 2,700 mg per liter during the dry season. The BOD values however decrease significantly during the wet season due to dilution of effluents by rain waters (Johnalagadda et al., 1989). The Total Cation Concentration (TCC) and the Total Dissolved Solids (TDS) reached maximum levels (Figure 3) during the driest month of January and dropped to the minimum levels during the wetter month of March. The Total Suspended Solids reached minimum levels in January and maximum levels in March (Figure 3). The temperature of water in the rivers of the study area is normally between 17.1 and 22.1 °C. However, it was observed that the temperature increases by about 2 °C at Rui Rwaka river near the Breweries factory and at Ngong river near the Nairobi Industrial area. This is due to the influx of warm breweries and industrial effluents. There was no notable changes in temperature either in Ngong, Nairobi and Mathare rivers.

The pH of the waters of all the rivers was generally between 7.0 and 7.5. However, the pH of Nairobi, Mathare and Ngong rivers dropped to about 6.5 during the rainy season. The samples collected from the Kenya Breweries at Rui Rwaka give a pH of about 5.5, almost throughout the year. The dissolved heavy metals except for lead, cadmium and chromium are within the acceptable international levels for domestic water (Table 1). However, heavy metals in natural waters can also exist in colloidal and suspended forms (Chapman and Kimstach, 1992; Davies, 1993). The colloidal binding of pollutants in their sediment phases diminishes their toxic properties to organisms (Spitzzy and Leenheer, 1991). However, the rivers of the study area flow through gentle river channels whose banks are covered by vegetation and therefore colloidal and sediment binding are minimal. The waters of all the rivers had undetectable levels of dissolved copper except during the dry season when the detected

Figure 3 Graph showing the mean TDS, TSS and Total Cations for rivers in Nairobi area (after Masibo, 1993).

Table 1 Some selected hydrochemical data for surface waters of Nairobi city (Modified from T. C. Davies, 1993).

Parameter	Range	Arith. mean	International average for fresh water	Maximum permissible level in drinking water	Jonnalagadda et. al., 1989
pH	5.5-9.5	7.6	6.5-8.5(R)	6.5-8.5(R)	7.00-7.5R
EC ($\mu\text{S}/\text{cm}$)	70-4420	526	10-1000(R)	—	—
Hardness ($\text{mg l}^{-1} \text{ CaCO}_3$)	20-48	32	—	500	—
TDS (mg l^{-1})	105-390	205	< 100	1000	180-1890R
TSS (mg l^{-1})	1-46	22	150	—	80-2760R
BOD (mg l^{-1})	5-990	177	2.0	3.0	2700
COD (mg l^{-1})	8-1088	194	<200	—	6520
Cd ($\mu\text{g l}^{-1}$)	1-4	2	.001	5	8-19R
Cr ($\mu\text{g l}^{-1}$)	1-265	20	.1	50	14-239R
Cu ($\mu\text{g l}^{-1}$)	1-57	10	1.4	1000	15-530R
Fe ($\mu\text{g l}^{-1}$)	400-2500	883	50	300	100-12650R
Mn ($\mu\text{g l}^{-1}$)	1-2976	442	10	100	80-4750
Pb ($\mu\text{g l}^{-1}$)	1-26	7	.04	50	80-1990R
Zn ($\mu\text{g l}^{-1}$)	10-163	56	.2	5000	30-118R

R = Range

Sources: WHO, 1984 (a); CCREM, 1987; CEC, 1980; Sayre, 1988; Meybeck, 1988; Schiller and Boyle, 1985, 1987; Meybeck and Helmer, 1989; Chapman and Kimstach, 1992 and Jonnalagadda et al., 1989

maximum was about 28 ppm. Dissolved manganese varied between 80 and 4,750 ppm, which is within the acceptable international levels (Table 1). Dissolved zinc concentrations in the water of all the rivers in the study area varies from 30 to 118 ppm. The concentrations however increase during the dry month of January. The zinc concentrations rose to 480 ppm both in the Ngong at the Industrial area and in Rui Rwaka at breweries during the dry season. Enhanced amounts of lead (80-1990 ppm), cadmium (8-19 ppm) and chromium (14-239 ppm) beyond the internationally accepted levels were observed in the points where discharge water from industrial concerns enters into the Nairobi and Rui Rwaka rivers. It was also observed that dissolved lead, cadmium and chromium increased at points where sanitary waters and sewage discharges entered into rivers.

Discussion and conclusions

The main contaminants of the rivers around Nairobi City are organic in origin and result from point sources such as waste disposal sites or urban run-off effluents.

The highest values of BOD, TDS, TSS and electrical conductivity were recorded at effluent discharge points in Ngong river within the Industrial area, the sewage discharge points in Nairobi and Mathare rivers at the sprawling slums of Majengo and Mathare respectively. High values of TDS, TSS and electrical conductivity drastically impairs the quality of water in the rivers and considering that the water is used for domestic consumption in the lower reaches from the discharge points, this leads to a variety of hygienic problems especially water borne diseases such as typhoid and cholera (Masibo, 1993; Jonnalagadda, et al., 1989).

According to a well known Nairobi medical practitioner, Dr. Waweru (personal communication) who has carried out extensive research on water borne diseases, the most common dysentery causing pathogen in the contaminated waters of Nairobi streams are the *Entamoeba histolytica* and the *Shigella dysenteriae*, the latter of

which causes dysentery in human beings. The faeces of the sick contain the organism and therefore when it enters into the stream waters through unplanned open sewage channels, other consumers of the affected water suffer from dysentery. About 120 cases which form about 18% of the slums infected population, are diagnosed and treated every week in a relatively small city clinic. *Entamoeba histolytica*, is characterized by clinical pathological intestinal manifestations and the sufferer from its consumption through drinking contaminated water, develops acute dysentery. Another common pathogen in the contaminated water, especially in the slums, is *Salmonella typhosa*. The pathogen causes typhoid fever to the consumer of contaminated water and about 87 cases which is only about 38% of the skin infected population, are diagnosed and treated every week in a city clinic. The protozoan *Giardia labria*, which is another common pathogen in the untreated water, consumed by slum dwellers, inhabits in the sufferer's small intestines and it causes acute diarrhea.

The water quality data from Nairobi rivers indicate that the dissolved heavy metals content are within the international accepted levels (Table 1). However, higher levels of heavy metal ions cadmium, chromium and lead were observed at industrial area where they were caused by discharges from industries. Once cadmium enters into the environment, it is ingested by human being through food and water. Consumers of high cadmium content water and food may suffer from hypertension, arteriosclerosis and reduced ability of kidneys to reabsorb water (Emmerson, 1970). Normal intake of chromium at harmless levels is used with the hormone insulin to promote glucose utilization. Higher levels however, are known to cause skin lesions and gastrointestinal ulcers (Smith and Ailean, 1975). Consumption of excess lead through drinking water increases it beyond the required levels in the blood stream where it is stored in tissues and disrupts both enzyme systems and neurological processes. In blood lead interferes with the synthesis of hemoglobin causing anemia. Lead deposits also interfere with normal kidney function (Waldbott, 1973).

A good management policy prevents environmental degradation and maintains proper aesthetic standards. This is achieved through hygienic, efficient collection, transportation and disposal of solid wastes (UNEP, 1987).

Nairobi generates a lot of industrial, commercial and domestic wastes. The inefficiency in collection and disposal of the wastes causes them to remain in rotting piles for long periods in the dumping sites. This leads to the proliferation of insects and rodents which are disease vectors in the refuse piles. Heat and humidity accelerate the decomposition of refuse giving rise to foul smell and ideal sites for the disease vectors. During the rainy seasons, surface run-off carries refuse piles to rivers through storm sewers contributing to direct water pollution.

Most water pollution problems of Nairobi are caused by human activities such as sewage from residential areas, chemicals from industrial wastes and urban storm water. These pollution loads make water unfit to drink and consequently enforcement of regulations governing the way industries dispose of their wastes, the city council deals with sewage lines and refuse pile dumps should be made a priority by the City Public Health Planning Department.

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