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 city. The tuffs are overlain by Kandizi phonolite, the Limuru tachyte (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 electroselenium 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 Tosal 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 Rur 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 (Spitzy 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...
ing pathogen in the contaminated waters of Nairobi streams are the research on water borne diseases, the most common dysentery caus-

Waweru (personal communication) who has carried out extensive (Masibo, 1993; Jonnalagadda, et al., 1989).

problems especially water borne diseases such as typhoid and cholera from the discharge points, this leads to a variety of hygienic prob-

Within the Industrial area, the sewage discharge points in Nairobi respectively. High values of TDS, TSS and electrical conductivity

activities such as sewage from residential areas, chemicals from industrial wastes and urban storm water. These pollution loads make

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

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 damps should be made a priority by the City Public Health Planning Department.

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Range</th>
<th>Arithmetic mean</th>
<th>International average for fresh water</th>
<th>Maximum permissible level in drinking water</th>
<th>Jonnalagadda et al., 1989</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>5.5-9.5</td>
<td>7.6</td>
<td>6.5-8.5</td>
<td>6.5-8.5</td>
<td>7.00-7.50</td>
</tr>
<tr>
<td>EC (µs/cm)</td>
<td>70-4420</td>
<td>526</td>
<td>10-1000</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Hardness (mg/l CaCO₃)</td>
<td>20-48</td>
<td>32</td>
<td>–</td>
<td>500</td>
<td>–</td>
</tr>
<tr>
<td>TDS (mg/l)</td>
<td>105-390</td>
<td>205</td>
<td>&lt;100</td>
<td>1000</td>
<td>180-1890</td>
</tr>
<tr>
<td>TSS (mg/l)</td>
<td>1-46</td>
<td>22</td>
<td>150</td>
<td>–</td>
<td>80-2760</td>
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<tr>
<td>BOD (mg/l)</td>
<td>5-990</td>
<td>177</td>
<td>2.0</td>
<td>3.0</td>
<td>2700</td>
</tr>
<tr>
<td>COD (mg/l)</td>
<td>8-1088</td>
<td>194</td>
<td>&lt;200</td>
<td>–</td>
<td>6520</td>
</tr>
<tr>
<td>Cd (µg/l)</td>
<td>1-4</td>
<td>2</td>
<td>.001</td>
<td>5</td>
<td>8-19</td>
</tr>
<tr>
<td>Cr (µg/l)</td>
<td>1-265</td>
<td>20</td>
<td>.1</td>
<td>50</td>
<td>14-2390</td>
</tr>
<tr>
<td>Cu (µg/l)</td>
<td>1-57</td>
<td>10</td>
<td>1.4</td>
<td>1000</td>
<td>15-5300</td>
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<tr>
<td>Fe (µg/l)</td>
<td>400-2500</td>
<td>883</td>
<td>50</td>
<td>300</td>
<td>100-12650</td>
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<tr>
<td>Mn (µg/l)</td>
<td>1-1296</td>
<td>442</td>
<td>10</td>
<td>100</td>
<td>80-4750</td>
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<tr>
<td>Pb (µg/l)</td>
<td>1-26</td>
<td>7</td>
<td>.04</td>
<td>50</td>
<td>80-1990</td>
</tr>
<tr>
<td>Zn (µg/l)</td>
<td>10-163</td>
<td>56</td>
<td>2</td>
<td>5000</td>
<td>30-118</td>
</tr>
</tbody>
</table>

R = Range

Sources:

References

CCREM (Canadian Council of Resource and Environment Ministers), 1987, Canadian Water Quality Guidelines: Environment Canada, Ottawa, p. 120.


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