

Water Quality Degradation Trends in Kenya over the Last Decade

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“Once the water is polluted, life is polluted; once the water is exhausted, civilization is exhausted; once the water disappears, the human being disappears; protecting the water resources is protecting the human being”.
Mingjun, J. (2010).

1. Introduction

Water is described as both a chemical substance vital to life on earth and a means for navigation. Water, is a commodity that is consumed, and carrier of other substances or properties, such as heat, disease vectors, pollutants and energy (Jordaan *et al.* 1993). But, whereas the total quantity of water on earth remains constant, its quality changes in both time and space. The problem of water quality was articulated by Jordaan *et al.* (1993) as causing a great strain on water supply systems, especially in cities along river courses. Similarly, in 1985, at the midpoint of the international water supply and sanitation decade, it was pointed out that although 870 million people lived in urban areas of the developing world, roughly 1.6 million were rural inhabitants and approximately 22% of the urban group was lacking water supply service and 40% were without sanitation. The population represented 64% and about 85% as lacking water supply and sanitation services to the rural population, respectively (Jordaan, *et al.* 1993). In essence, the rural inhabitants are faced with a great threat of using low quality water compared to the urban counterparts. This explains the existent problem of water quality degradation not only in the urban areas but also in the rural areas.

The problem of water pollution and quality degradation in the developing countries is increasingly becoming a threat to the natural water resources. This phenomenon is attributed to the increasing quest of these countries to attain industrialization status and diversification of the national development goals and Kenya is no exception to this phenomenon (Kithiia, S.M & Khroda, G.O, 2011).

Kenya is described as a water scarce country, and yet future projections show that per capita available water currently at 650m³/year, will likely drop to 359m³/year by 2020, as a result of population growth. This figure is far much below the global accepted value of 1000m³

year⁻¹ per capita level. Urgent action is therefore needed to increase the capacity of the water sector to improve the availability and accessibility of clean and safe drinking water (GoK, 2007). Many Kenyans especially in the rural areas have limited access to quality water. They walk for long distances in search of this precious commodity and use it raw and untreated from rivers, lakes and dams. The untreated water is not only turbid, but also contain disease causing bacteria and in some cases chemicals. The problem is further compounded by the seasonal fluctuations of water availability which is more correlated to the seasonal patterns of rainfall in most parts of the country.

“Water is essential to sustain life and a satisfactory (adequate, safe and accessible) supply must be available to all. Improving access to safe drinking water can result in tangible benefits to health. Every effort should be made to achieve a drinking water quality as safe as practicable”. (W.H. O; **Guidelines for Drinking Water Quality, 1991, 1997**).

In addition, water resources in Kenya are under pressure from agricultural chemicals (fertilizers and herbicides) and urban and industrial wastes, as well as from use for hydroelectric power. Thus, increase in demand for water resources for various uses is likely to cause many constraints and lead to the pollution of the available water resources. Water pollution from urban and industrial wastes poses another environmental problem. Kenya has 20.2 cubic kilometers of renewable water resources with 76% being used in farming activity and 4% used for industrial purposes. Only about 42% of the residents in rural areas and 88% of city dwellers have pure drinking water. The situation is much worse in the informal settlements in the urban areas due to lack of proper sanitation and sewerage system. These settlements are located near or on top of the rivers courses draining the city of Nairobi and contribute significant pollutants amounts and water quality degradation.

In addition, water resources in Kenya are increasingly being polluted by organic, inorganic and microbial matter (Kithiia, 1992 & 1997). The impact of pollution on water resources is manifested by water of poor quality which gives rise to water toxicity to mammals and aquatic life; loss of aesthetic value by becoming unsuitable for recreational activities, high cost of water supply as polluted water is expensive to treat, eutrophication, deoxygenation, acid rain and habitat modification. This is evident in the urban centers and more in the city of Nairobi.

Kenyan urban population which has been growing at a rate of 8% per annum is now more than 27% of the country's total population as described in the state of the Environment report of 2003 (NEMA, 2004). In addition, generation of solid, liquid and gaseous wastes has been increasing at the same level as industrial development and the diversification of consumption patterns. The report by NEMA (2004) indicates that per capita waste generation ranges between 0.29 and 0.66 kg day⁻¹ within the urban areas of the country, and that of the municipal waste generated in the urban centres is 21% emanating from industrial areas and 61% from residential areas.

The city of Nairobi is the heart of industrial production in Kenya and the commercial hub of the East African Community (EAC). It is drained by three tributaries of the Nairobi River, namely; Ngong, Nairobi and Mathare rivers. These rivers collect most of the wastes generated in the city and its waters are heavily polluted by solid, liquid and organic wastes. The polluted water has a strong impact on human beings and other living organisms and the environment in general. Nairobi River has acted as a major depository of waste from

both domestic and industrial sources. The riparian reserves of the three main rivers are marked with numerous informal settlements without adequate sewerage and sanitation services and hence discharge their raw sewage into the rivers; and most industries find it cheaper to discharge their effluents into the rivers without any satisfactory treatment (UPIU, 2009). There is therefore, a need to find strategic ways and methods of reducing pollution levels and manage the water quality status within the basin. This is the basis of the investigations explored in the present paper.

2. Background information – Water quality issues in Kenya

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 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 (Kithiia, S.M & Ongwenyi, S.O. 1997).

Water quality degradation problem is not a new phenomenon in Kenya. Initial research reports on the problem in the country dates back in the 1950's. In Kenya, the problem of water quality degradation was first exposed in the MOWD (1976 a&b) containing case studies of three rivers; Nzoia, the Nyando and Kerio. These reports contain the chemical characteristics of water shortly before and after establishment of factories along their courses. Nzoia River which drains into Lake Victoria carries the effluents discharged from Pan Africa Paper Mill in Webuye upstream and from Mumias Sugar Factory downstream; Nyando which also discharges its waters into Lake Victoria receives Molasses from Sugar Factories, Chemilil and Muhoroni. Kerio River drains the Kerio Valley with intermittent flow into Lake Turkana. This is now periodically polluted by effluents from fluorspar factory established three decades ago. All these three reports are a clear indication of the effects of industrial growth on the quality of water courses and their effluents are a major contributing factor to water quality degradation at the extreme vicinity of industrial activities. This was once more confirmed by a recent study done by the Ministry of Land Reclamation and Regional Development (MLRRD, 1993) (now the Ministry of Water and Irrigation). Many studies indicate that groundwater resources are not seriously threatened with water pollution problem but the major concern has been on the surface waters especially in river systems.

Other research reports which indicated water quality deterioration in Kenya are those by Ongwenyi (1979) and Njunguna (1978). Njunguna (1978) also added that pollution in the river (Nairobi-Athi-Sabaki) was chiefly due to domestic waste, industrial wastes and runoff (both rural and urban).

The most recent studies by Kithiia (1992, 2006), Okoth and Otieno (2000) and Mavuti (2003) revealed degradation trends in water quality within the river system due to changes and intensity in land use activities. The study by Kithiia (1992) in the same area revealed high concentration levels of Mercury and Lead surpassing the critical WHO and the Kenya standards guideline values (Mercury 0.03 and Lead 0.1 mg l⁻¹). In the same study pesticide residues notably DDT, "Ambush", "Ridomil", "Malathion" etc were all found to surpass the WHO and the Kenya standards for drinking water. DDT was measured at 0.000086 mg l⁻¹, "Ambush" 0.1413 mg l⁻¹, "Ridomil" 0.147 mg l⁻¹ and "Malathion" 0.00039 mg l⁻¹. In addition, the study by Kithiia (2006) within the same river systems indicated a downstream increase in water pollutants and water quality degradation. Sediment and Heavy metal concentrations were found to increase downstream the river courses. The increasing trends in pollution levels and water quality deterioration are attributed to increased land use activities and population growth rates within the urban area and the basins in general. This calls for stringent measures to address the problem and reduce the ever increasing water pollutants and water quality degradation. This should incorporate measures devoted towards the reduction of the water quality degradation trends within the Nairobi River basins in order to restore the water quality status as of the time when the city was established.

3. Problem discussion

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 city to form the main Athi River. The total quantity of water in these streams is 23.6 m³ s⁻¹ which amounts to 36.7 X 10⁶ m³ year⁻¹. This amount of water, however, is less than the discharge of waste water from both industry and domestic use in the city. This is a major source of water pollution and hence water quality degradation within the basin and in Kenya generally.

Water demand increase and use is directly proportional to deterioration in water quality in many instances. In most cases, 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. Thus, the nature and extent of human activity will in turn determine the magnitude and nature of pollution as well as the water quality status of the water course/or source.

4. Water quality problems in Nairobi city

The main water pollution problems in the city of Nairobi are closely linked to the various land use systems. Nairobi city and its environs are the focus of the study. The area covers a total of 2435 km² and its part of the upper-Athi drainage basin. It forms a greater part of the

conglomeration of the urban centres of Ruiru, Ngong and Mavoko municipalities. The city and its environs are drained by three sub-streams of Ngong, Nairobi and Mathare rivers, which run in a southeast direction towards the Indian Ocean. These streams drain areas of diverse land use activities. The significant contribution of these land use activities to water pollution and quality degradation is quite enormous. Figure 1 shows the three streams and the major land use activities along the river courses from its headwaters downstream through the city of Nairobi (Kithiia & Mutua, 2006).

5. Methods of study and data collection

An attempt to quantify the data that was used in the over-all analysis of the problem is described in this section of the chapter paper. Most of the data used was derived from measurement of water samples from specific river basins and the laboratory results of the various water quality parameters. These formed the basis of the study of water quality degradation trends in the country and the city as well as the resultant environmental and human health impacts. This further informed the researcher on the mitigation strategies to control and abate the problem as proposed in the chapter presentation.

This chapter paper details the results of two studies conducted within the Nairobi River sub-basins in two distinct time span in the years from 1990-1992 and another period of three years from 1999-2002. The study of 1990-1992 basically revealed the existed of water quality degradation problem and its increasing trends. The 1999-2002 study aimed at finding the best water quality management strategies following the identification of the problem in the previous study. The study methods employed involved water sampling and laboratory analysis of the water samples collected. Water samples were collected at designated points to determine the effects of land use systems and in assessing water pollution levels and degradation status as indicated in Figure 1. The river flows (discharges) were at the same time measured using a propeller type current meter. The water samples were obtained using standard methods according to APHA (1995 & 2001). Water samples for water quality determination were collected at the same designated points in a depth integrated manner at the middle of the rivers investigated. Each sample was subjected to the standard laboratory analysis and the concentration of each parameter determined. The basic method applied in the determination of each parameter was the AAS method.

A visual assessment of the water quality status in regard to solid wastes, turbidity, foul smell and colour was carried out. To facilitate the assessment, still photographs were taken during the dry and the wet season to indicate areas of solid waste dumping before and after heavy rainfall within the study area sub-streams. This helped in understanding the impact of storm water in cleaning and restoring the water quality status. These were used as tools for awareness campaign regarding the water quality problem in the Nairobi River sub-basins. The findings of the first study were adequately utilized in the Nairobi River clean-up exercises adopted by Ministry of Environment and UNEP in 2009/2010 fiscal year. This measure only managed to remove partially the huge garbage heaps that had dotted the river profile and thus more investigation would be required to ascertain the chemical pollution of the water in the three river systems.

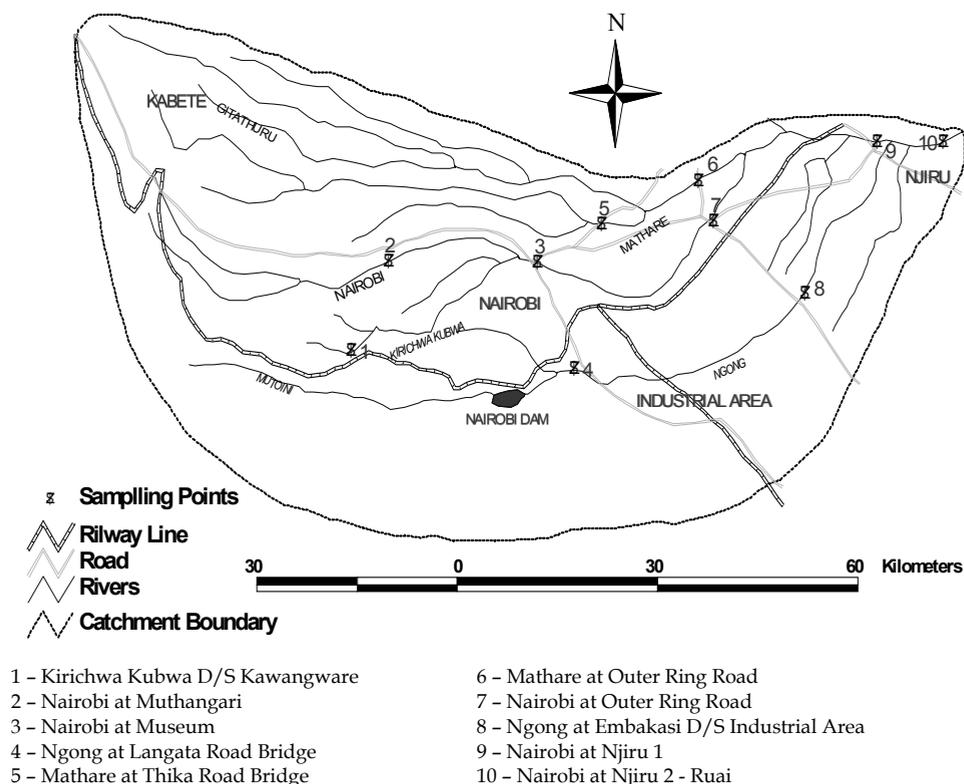


Fig. 1. Distribution of study sampling points (1999-2002)

6. Data analysis and results

Table 1 indicates the distribution of some water quality parameters at various sampling points and the corresponding river discharge changes. The mean concentration of the water quality parameters at each of the sampling point per river illustrates water quality degradation. The table demonstrates an increasing trend in the major metallic ions, possibly due to the effect of leaching from rocks or as a result of effluent discharges into the river courses.

Figure 2 and Table 1 further indicated that increase in river discharge results to decreased water quality physically. Figure 2 illustrates monthly mean river flows per river sub-basin which corresponds well with the bi-modal pattern of rainfall in Kenya. The implication of this is that, storm water can be used to clean up the rivers during the wet seasons (rains), since water can be easily treated if physically polluted. In addition, effects of storm water are to reduce the water quality degradation status thus in essence dilute the water chemically. Plates 1 and 2 demonstrate that water in the Nairobi River can be cleaned through storm water incidents especially after heavy storms.

The two plates demonstrate that runoff can be used to clean up the garbage from the river banks during the rain seasonal. This will only clean up the river physically and therefore further study would be required to establish the chemical pollution of the river basin waters.

Sampling point	River	Mean Concentrations in mg l ⁻¹				
		Q m ³ /s	TSS Mgl ⁻¹	COND μs cm ⁻¹	TDS Mgl ⁻¹	TUR Mgl ⁻¹
Muthangari	Nairobi	0.772	157.6	392.1	239.7	69.4
Museum	Nairobi	1.376	129.4	397.7	244.2	69.3
Outering Rd	Nairobi	2.140	255.7	564.5	290.9	65.5
Njiru 1	Nairobi	5.083	199.2	509.5	310.9	67.8
Njiru 2 (10)	Nairobi	5.341	95.5	474.8	298.8	28.5
Thika Rd	Mathare	0.738	161	352.2	215.5	35
Outering Rd	Mathare	1.371	251.2	527.1	349.9	85
Kibera slums	Ngong	0.110	33	233	88	134
Langata Rd	Ngong	0.305	59	598.8	59	42
Embakasi	Ngong	0.949	180	611.7	174.4	71

Source: Field data 1999-2002; COND=Electric conductivity, TDS=Total dissolved solids, TSS=Total suspended sediments, TUR=Turbidity.

Table 1. Mean measured values of physical water quality parameters at various sampling points (mg l⁻¹)

Sampling point	Main river	Mean concentrations of metal ions in mg l ⁻¹							
		Pb	Zn	Cu	Fe	Mg	Na	Cl	Ca
Muthangari	Nairobi	0.01	0.00	0.00	0.30	6.4	42.6	53.7	18
Museum	Nairobi	0.02	0.00	0.01	0.73	6.4	44.7	55.5	19.3
Outering Rd	Nairobi	0.05	0.01	0.04	1.99	8.4	59	47	17.9
Thika Rd	Mathare	0.00	0.00	0.01	0.40	6.8	39.6	40	17.1
Outering Rd	Mathare	0.01	0.01	0.02	1.59	9.6	45.8	38.8	19.6
Langata Rd	Ngong	0.05	0.00	0.01	1.10	8.6	58.5	52	27.6
Embakasi	Ngong	0.07	0.02	0.15	1.30	7.8	69.5	46	24.3
Njiru 1	Nairobi	0.04	0.02	0.18	1.44	7.2	46.6	39.5	17.1
Njiru 2 (10)	Nairobi	0.03	0.03	0.20	1.17	4.4	42.5	29	16.4
Donyo Sabuk	Athi (middle)	0.00	0.00	0.00	0.30	4.4	28.8	8.0	10.1
Malindi	Athi/Sabaki (Coast)	ND	ND	ND	ND	29.1	118.8	19.1	21.4

Source: Field data (1999-2002), ND- not detected

Table 2. Mean concentrations of metal ions at various sampling points and rivers

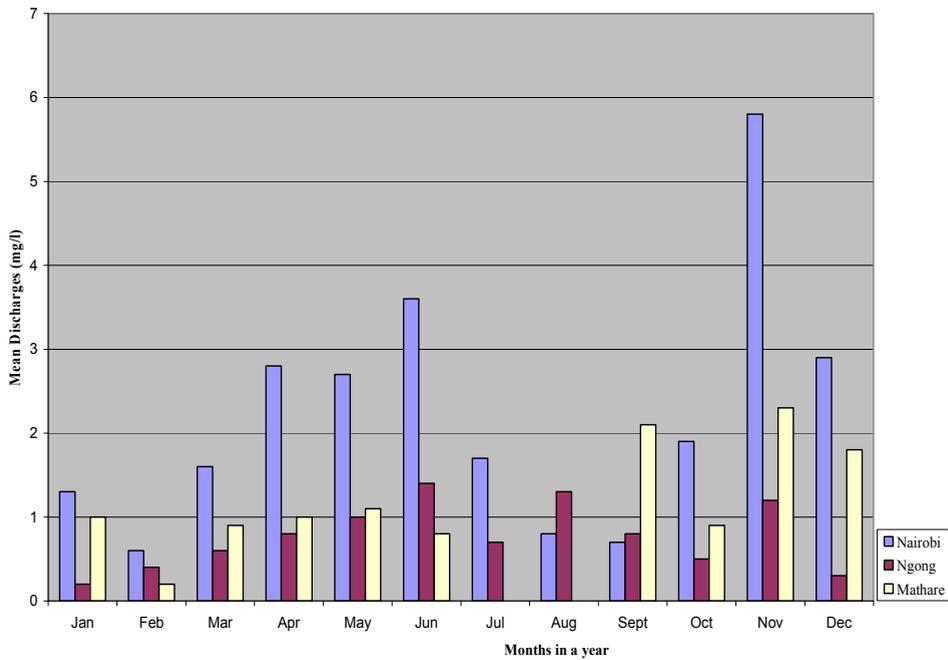


Fig. 2. Mean monthly river flows per sub-basin (mg/l)



Photo 1. Gikomba-Shauri Moyo Bridge D/S Gikomba open-air market-solid wastes, Car shells and *Jua Kali* garages in the foreground.



Source: Field data (1999-2002).

Photo 2. Gikomba-Shauri Moyo Bridge D/S Gikomba open air market-showing clean river bank with all garbage and solid wastes washed away after a storm.

7. Land-use effects on water quality

A range of water quality parameters were investigated for areas under agricultural and industrial land uses in the first study of 1990-1992. 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 in Table 3 revealed that most metal concentrations exceeded those recommended by the Republic of Kenya (1985) and by the WHO (1984) as indicated in Table 4, 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 content of suspended solids, and is highly coloured, although conductivity is low reflecting the dilution of total dissolved solids (TDS) 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 3 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 as depicted in 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.

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

Source: Field data 1990-1992

Table 3. Mean concentrations of chemical parameters in the Study Rivers.

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)	0.005

Source: Field data 1990-1992

Table 4. Concentration limits for chemical substances in drinking water after WHO (1984) and Republic of Kenya (1985).

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.

8. 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 as shown in Table 5. 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 pesticide, while the presence of "Malathion" reflects the relatively high frequency of application. Table 6 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 mg l⁻¹ in the Gatara River, and "Malathion" at concentrations of 0.14 and 0.63 mg 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 as at that time made it complicated to assess the risk to water users from this source of pollution.

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

Source: Field data 1990-1992.

Table 5. Pesticide residues in soil samples.

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

Source: Field data 1990-1992.

Table 6. Pesticide residues in water.

9. Recent development in tackling the problem

The present institutional arrangements for the management of the water resources in Kenya can be traced to the launch in 1974 of the National water Master Plan whose primary aim was to ensure availability of potable water, at a reasonable distance, to all households by the year 2000. The Plan aimed to achieve this objective by actively developing water supply systems, sinking of boreholes, construction of catchments dams and provision of the conveyance infrastructure in the form of pipes and furrows. To do so require that the Government directly provide water services to consumers, in addition to its other roles of making policy, regulating the use of water resources and financing activities in the water sector.

The legal framework for carrying out these functions was found in the law then prevailing, the water Act, Chapter 372 of the Laws of Kenya. In line with the Master Plan, the Government upgraded the Department of water Development (DWD) of the ministry of Agriculture into a full ministry of Water which embarked on an ambitious water supply development programme. By the year 2000, it had developed, and was managing, 73 piped urban water systems serving about 1.4 million people and 555 piped rural water supply systems serving 4.7 million people.

In 1988 the Government established the National Water Conservation and Pipeline Corporation (NWCPC), as a state corporation under the State Corporations Act, Chapter 446 of the Laws of Kenya, to take over the Management of Government operated water supply systems that could be run on a commercial basis. By 2000 the NWCPC was operating piped water supply systems in 21 urban centre serving a population of 2.3 million people and 14 large water supply systems in rural areas serving a population of 1.5 million people. Alongside the DWD and the NWCPC, the large municipalities were licensed to supply water within their areas and by the year 2000, ten municipalities supplied 3.9 million urban dwellers. Additionally, about 2.3 million people were receiving some level of service from systems operated by self- help (community) groups who had built the systems, often with funding from donor organizations and technical support from the district officers of the Department of water Development (Government of Kenya, 1999). Persons not served under any of the above arrangements did not have a systematic water service, and had to make do with such supply as they were able to provide for themselves, typically by directly collecting water from a watercourse or some other water source on a daily basis. Indeed, despite the Government's ambitious water supply development programme, by 2000, less than half the rural population had access to potable water and, in urban areas, only two thirds of the population had access to potable and reliable supplies.

In the 1980s the Government began experiencing budgetary constraints and it became clear that, on its own, it could not deliver water to all Kenyans by the year 2000. Attention therefore turned to finding ways of involving others in the provision of water services in place of the Government, a process that came to be known popularly as "handing over." There was general agreement over the need to hand over Government water supply systems but much less agreement over what it meant for the Government to hand over public water supply systems to others. In 1997 the Government published manual giving guidelines on handing over of rural water supply systems to communities (Ministry of Land Reclamation, Regional and Water Development, 1997). The Manual indicated that "... at the moment the ministry is only transferring the management of the water supply schemes. The communities will act as custodians of the water supply schemes, including the assets, when they take over the responsibility for operating and maintaining them." But, the goal of community management should be ownership of the water supplies, including the associated assets. The Manual stated the criteria for handing over to be the capacity of the community to take over; ability to pay; capacity to operate and maintain the system; involvement of women in management and ability and willingness to form a community based group with legal status. By 2002 ten schemes serving about 85, 000 people had been handed over under these guidelines, focusing on management and revenue collection, not full asset transfer.

Building on this experience, the Government developed a full-fledged policy, the National Water Policy in 1999. It has tackled issues pertaining to water resources management, water and sewerage development, institutional framework and financing of the sector. In each case an attempt has been made to discuss the problems associated with each area and suggest the appropriate strategies and the desired policies that the government will put in place to resolve those problems. The Policy stated that the Government's role would be redefined away from direct service provision to regulatory functions: service provision would be left to municipalities, the private sector and communities.

The Policy also stated that the Water Act, Chapter 372 would be reviewed and updated, attention being paid to the transfer of water facilities. Regulations would be introduced to give other institutions the legal mandate to provide water services and to provide mechanisms for regulation. The Policy justified handing over, arguing that ownership of water facility encourages proper operation and maintenance: facilities should therefore be handed over to those responsible for their operation and maintenance. The Policy stated that the Government would hand over urban water systems to autonomous departments within local authorities and rural water supplies to communities. While developing the National Water Policy, the Government also established a National Task Force to review the Water Act, Chapter 372 and draft a Bill to replace the Water Act. The Water Bill 2002 was published on 15th March 2002 and passed by Parliament on 18th July 2002. It was gazetted in October 2002 as the Water Act, 2002 and went into effect in 2003 when effective implementation of its provisions commenced. The New Water Act Building on this initiative, the current government set out on an agenda of reform with water resources development and management as one of its priorities. In his opening address to parliament, President Mwai Kibaki stated that his Government, " is committed to ensuring that Kenyans have access to clean water." In this context, the Minister for Water Affairs established the new 2002 Water Act, intended to tackle the worsening water services experienced over the earlier decade. This step has given poverty reduction in Kenya a new possibility.

This *Water Act* established an autonomous Water Resources Management Authority, destined to manage and protect Kenya's resources. It also shaped an institutional framework that gave responsibility for providing decentralized services to seven regional Water Services Boards (WSB). These Boards manage water services assets and ensure that they remain in the public realm. An essential aspect of the reform outlined in the *Water Act* is the separation of water and sanitation from the management of resources. Overall supervision of water services will consequently be carried out by the Water Services Regulatory Board (WSRB), an organ in charge of regulating the services supplied by the regional Boards and their providers. From mid-2005, the responsibility for water services provision – originally falling under the Ministry of Water and Irrigation was put entirely to the WSRB. Simultaneously, representatives for the new Area Catchments Advisory Committees are being selected and the Water Users Associations are being encouraged to define their new roles. These efforts were meant to encourage proper use and management of the water resources in the country as well as try to minimize pollution of the meager resources by creating sanitation infrastructure in many of the urban and rural areas.

10. State of water environment: Water pollution in Kenya

Water resources in Kenya are increasingly becoming polluted from both point and non-point sources due to agriculture, urbanization, and industry which contribute to organic, inorganic and aesthetic pollution of water. Ground-water is threatened by intrusion of saline water in the coastal region, leachates from solid waste dumps, and infiltration of fertilizer and pesticide residues. The five principal sources of water pollution in Kenya include, among others, the categories listed below, (JICA/GOK, 1992).

- a. Agricultural activities which produce sediments and agro-chemical residues (biocides and fertilizers).
- b. Industrial processing of agricultural and forestry products which produce liquid effluents, gaseous emissions and solid wastes.
- c. Industrial manufacturing - heavy metals, acids, dyes, oils.
- d. Domestic/municipal effluents - sewage and garbage.
- e. Sedimentation - soil erosion; and mining which produces tailings and effluents.

Municipalities and industries constitute the largest source of waste water discharges; however, industries discharge an enormous variety of wastes some of which are toxic to human beings and the general environment. Examples of such industrial wastes, which are a critical environmental issue in Kenya, include effluents, sludge and solid waste from sugar, coffee pulping and textile factories, leather tanneries, paper-mills and slaughter-houses.

All these wastes impact on water quality and are manifested through:

- i. Deterioration of the quality of the aquatic environment, namely, deoxygenation, eutrophication, siltation, habitat modification and toxicity, among others;
- ii. Environmental health effects with the occurrence of water-borne diseases, for example, typhoid and cholera, and chemical poisoning in humans and animals;
- iii. aesthetic effects leading to loss of scenic beauty with water becoming unsuitable for recreation;
- iv. high cost of water supply as polluted water is expensive to treat; and,

- v. Water rights conflicts due to shortage of water of suitable quality for domestic, industrial and irrigation purposes. In order to protect Kenya's water resources from further degradation, water pollution or effluent discharge standards are necessary.

11. Water pollution control guidelines/standards setting

- In practice, standards can be set from either first principles or based on existing guidelines; international or national. For first principles, classification, and prioritization of pollutants is necessary. Pollutant exposure processes and their ecological effects should be determined. Predicted environmental concentrations (PEC) and predicted no effect concentration (PNEC) for the aquatic environment should be derived. Usually, actual analytical data (baseline data) relevant to the locality or country situation are preferred.
- Standards can also be based on existing guidelines such as those of the International Standards Organization (ISO) or other similar country standards. Baseline data collection is then undertaken to improve or adapt the initial standards to own country situation. Thus, baseline data is important for the setting of standards for water pollution as well as:(a) forming a basis for zoning; where general or special standards should apply; (b) assessing the assimilative capacity of various streams; (c) identifying the water courses which require stringent or less stringent application of standards; and, (d) formulating rehabilitation and/or conservation measures.

12. Water pollution effects

Waterborne diseases caused by polluted drinking water may include:

- Typhoid
- Amoebiasis
- Giardiasis
- Ascariasis
- Hookworm

Waterborne diseases caused by polluted beach water may include:

- Rashes, ear ache, pink eye
- Respiratory infections
- Hepatitis, encephalitis, gastroenteritis, diarrhoea, vomiting, and stomach aches

Conditions related to water polluted by chemicals (such as pesticides, hydrocarbons, persistent organic pollutants, heavy metals etc) may include but not exclusive of the following:

- Cancer, incl. prostate cancer and non-Hodgkin's lymphoma
- Hormonal problems that can disrupt reproductive and developmental processes
- Damage to the nervous system
- Liver and kidney damage
- Damage to the DNA
- Exposure to mercury (heavy metal) may further result :
 - *In the womb*: may cause neurological problems including slower reflexes, learning deficits, delayed or incomplete mental development, autism and brain damage.
 - *In adults*: Parkinson's disease, multiple sclerosis, Alzheimer's disease, heart disease, and even death.

Other notes:

- Water pollution may also result from interactions between water and contaminated soil, as well as from deposition of air contaminants (such as acid rain).
- Damage to people may be caused by fish foods coming from polluted water (a well known example is high mercury levels in fish).
- Damage to people may be caused by vegetable crops grown / washed with polluted water (author's own conclusion).

13. Water quality control strategies

Sources of the various pollutants should be identified and mechanisms put in place especially proper land management practices which minimize surface runoff and maximize ground infiltration of surface runoff. An integrated approach to the management of water resources should be adopted to encompass soil conservation and management, forest conservation and re-forestation, protection of water catchment areas as well as river courses and prohibiting dumping of wastes into river courses and banks. This also should create buffer zones along the river systems to allow for the growth of riverine vegetation (macrophytes) which can take up some of the water pollutants and hence reduce water quality degradation and restore the quality of water. In the slum areas with inadequate drainage and sewerage systems, well constructed pit latrines should be provided far away from river banks, in addition to a better drainage system. Good housing structures with toilets will also reduce direct discharge of raw human wastes into the rivers flowing through these slum areas and to any other water courses in the country.

There are indications that, land use changes and activities have profound effects on water quality. There is therefore, need to review the existing land use policy in the country to guard against encroachment of land use activities into watershed areas. This will encourage land management control and conservation measures as well as riparian use of water resources in the headwater and downstream areas. Use of modern techniques and strategies (Best Management Practices-BMP) to control water quality degradation and maintain the quality of water need be emphasized. These should include Integrated Water Resources Management (IWRM) with emphasis on community participation and policy formulation.

There is also need for public awareness regarding the pollution problem and the consequences arising thereof in the rivers and basins facing water quality degradation. In overall, a sound integrated Environmental Education (EE) programme need be adopted with emphasis on communities' participation and use of green environmental policy.

Research findings and conclusions

- Water quality deterioration within the study area sub-streams was found to vary with increasing stream discharge. Thus, the study revealed that stream discharge and concentration of water pollutants exhibited a discordant relationship. This was found to be true in all the streams investigated.
- Storm water run-off was found useful in cleaning up the river systems by washing away the solid wastes, diluting the chemical industrial effluents and waste water from residential areas and burst sewers. In addition, the water was found to be physically polluted and therefore easily treatable using conventional methods of treating water such as filtration and sedimentation processes.

- Specific plant species were found to take up some of the heavy metals from the water resources and hence contributing to cleaning up the water resources within the basin.

14. Recommendations

- There is need for public awareness regarding the pollution problems and the consequences arising thereof in the rivers and basins investigated. In over all there is need for an integrated Environmental Education (EE) programme within the basins. The programme should focus on the need for people living within the city of Nairobi and its environs to appreciate a cleaner environment. It should try to encourage people to properly manage their domestic raw wastes and avoid dumping these into the rivers. Domestic wastes separation and sorting out would a better option. People should be encouraged to treat the Nairobi River as their friend and therefore protect its water quality for the present and future generations and to enjoy its aesthetic values.
- Integrated water resources management (IWRM) approach would be very integral in addressing the problem of water quality degradation within the city and the country in general. The approach need to involve all Government Ministries, water resources stakeholders and the participation of the people (community) in understanding the implication of declining water quality status and the need to guard against polluting the resources. This will ensure continued safe supply of clean and potable water resources to the people and minimize disease outbreaks.

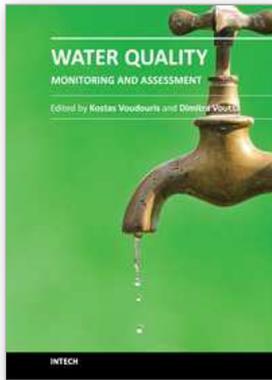
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