WATER RESOURCES

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ABSTRACT

Water is an important element in the social and economic development of the coastal region. This review reviews and assesses water availability, demand, present status of the water infrastructure and sustainable management of water resources in the face of a rapidly growing population, environmental deterioration and diminishing financial allocations for operation and maintenance in the sector. Both groundwater and surface water have been developed but at very high costs. The Municipality of Mombasa and the entire coastal region rely on water sources from Mzima Springs (Mount Kilimanjaro) and the Athi/Sabaki basin. The transmission lines are old and are liable to breakages, thus increasing the budget for operation and maintenance. The review raises environmental, institutional, policy and legal issues that the ministry in charge of water development needs to address in order to mitigate the looming water scarcity in the region.

INTRODUCTION

The main sources of fresh water in the rural parts of the coastal region are 'traditional', i.e. from groundwater, surface water and roof catchment. Two types of 'modern' water service can be found, namely individual connections and communal water points (or kiosks), the latter being more common than the former. Nearly one-third of the water supply are by communal water points. As an example, Table 1 shows the population served by different sources in Kilifi and Malindi Districts. The large majority of the population in this district draws water from traditional sources while only 8% has access to government-aided water supply. The drinking water situation in Kilifi District is less strained than that in Mombasa and Kwale, which is partly due to the availability of water from the perennial Sabaki River and other small streams. About 56% and 44% of the total population of Mombasa and Kwale District, respectively, have access to safe drinking water. The differences also reflect the level of urbanization in each of the districts

because there has been a strong bias towards urban water supplies (which is also shown by the Malindi District column in Table 1). Out of 29 water supply works, only 9 are for rural consumers. In semi-arid and arid lands, in which most of the coastal region falls, only 10% of the rural population has access to safe water within one km distance (IFAD 1988). Presently, the region caters for over 20,000 tourist hotel beds. However, the expansion of the tourist industry has not led to the development of a strong and reliable water infrastructure.

Table 1 Population of Kilifi and Malindi Districts by type of water source and division, 1982 (%)

	Kilifi District			Malindi	
Division:	Bahari	Ganze	Kaloleni	District	Total
Rural water supply					
Traditional means	66.9	72.5	72.5	58.1	66.8
Communal points	24.4	26.5	26.5	21.2	24.4
Individual connections	0.9	1.0	1.0	0.8	0.9
Urban water supply	7.8	-	-	19.8	7.8
Total	100	100	100	100	100

Source: TARDA 1983.

THE WATER DEMAND

The water demand in the coastal region has been growing rapidly. The demand estimate for 1995 was about 200,000 m^3/day and is expected to rise to 280,000 m^3/day by 2010 and 380,000 m^3 by the year 2020 (World Bank 1996). The water supply system described above is considered largely inadequate and for all practical purposes the supply system has been overtaken by demand as far back as 1975. When demand is greater than supply, the pressure within the pipes decreases and sporadic shortages become common.

The element of peak demand arises due to the fact that the Municipality of Mombasa and the coastal area has an active tourism industry. Fluctuations in the tourism industry have been neglected in the calculations of the water demand. In areas outside Mombasa Island the consumption per capita has been estimated at 64 litres/head/day and within the Island at 105 litres/head/day. This is based simply on the total population as at 1984 and includes the consumption for industry and for domestic use. To meet the demand forecasted as above it became necessary to find other sources to supply the coastal region in general and the Municipality of Mombasa in particular. Another intake, therefore, was built on the Sabaki River (see below).

Domestic water supply accounts for 35% of the total water demand (World Bank 1996). Other water uses include livestock, irrigation and industry. Water for livestock is important, especially in the vast rural arid and semi-arid areas. In the beginning of the 1990s there were 271,000 beef cattle, 3,200 dairy cattle and 245,000 sheep and goats in Kwale District, while Kilifi had 186,000 cattle and 183,000 goats and sheep (Kenya 1992a). The potential for dairying in the humid parts of the region is 47,000 cattle. In order to increase production, efforts are made to develop the water supply for livestock. For instance, a number of dams are planned in Kinango and Msambweni Divisions, both in Kwale District.

Demand for water for irrigation is growing, albeit slowly. Some parts of the Coast, especially in the Tana River Delta and in Taita Taveta, have potential for irrigation agriculture. The potential of the Sabaki River for the development of irrigation agriculture has been inhibited by the shifting nature of the river bed. Although water is the main limiting factor in agriculture, the area could benefit from use of borehole water for irrigation and possible cultivation of salt-tolerant varieties of crops. However, the extension of irrigation agriculture into semi-arid environments must be treated with caution because of soil salinisation (which is already causing environmental problems in Taveta Division). The soils are underlain by a caliche at shallow depth, the groundwater is saline and poor drainage and flooding are typical problems at the Coast.

Water for industrial use is mostly needed in the Municipality of Mombasa. So far, only 13% of the total water withdrawal is used for industry either for cooling or as an ingredient in production. With the growing importance of Mombasa as an industrial centre, it is expected that the water demand for industrial use will increase rapidly in the next decades.

WATER RESOURCES POTENTIAL

Groundwater resources

The potential of groundwater in the coastal region is determined by the geology, rainfall regime and physiography. Mount Kilimanjaro and the Chyulu Hills determine the extent of the regional aquifer besides some local aquifers. Table 2 indicates the relationship between physiography, rainfall and groundwater yields. The data is for productive boreholes and wells only. The aquifer yield increases with recharge and amount of rainfall.

Table 2 Physiography, rainfall and groundwater yields by region

	Mean rainfall (mm)	Soil type	Depth bore-holes (m)	Yields (m^3/day)	quality*
Coastal Plain	940-1175	sandy	4-231	<920	30/U
Foot Plateau	740-960	-	up to 236	<327	69/F
Coastal Range	960-1200	deep	up to 152	40-500	38/U
Nyika Plateau	<600	sandy	up to 461	<720	42/U

* U = unfit for human consumption (mineralised); F = fit for human consumption.
Source: TARDA 1983.

The hydrogeology of the coastal region has been influenced by the movements of the sea levels, both emergence and submergence, that have occurred during the last 200 million years (Krhoda 1988). Gentle (1965) observed that there were changes in sea levels during the Pleistocene period locking sea water in depressions during submergence. The sea water evaporated and during emergence the salts remained in the soils thus contributing to the salinity of groundwater sources. The types of rocks that are found in the region reflect these changes in sea levels. The oldest sediments in the coastal region belong to the Karoo system, as represented by the Lower Duruma sandstones series. The water from these sandstones — such as Maji-ya-Chumvi beds, Taru grits and Mariakani sandstones — are saline. The salinity of water from boreholes in these areas ranges from

1,680 ppm (parts per million) to 5,000 ppm (Caswell 1953), which is far beyond acceptable standards for drinking water.

The combination of the impact of topography, geology and rainfall in determining the available water resources is well demonstrated in the Shimba Hills (440 m). The Mazeras sandstones and Shimba grits form the Upper Duruma sandstone series situated in the south and are responsible for conspicuous topographical features as Jibana (314 m), Kulalu (440 m) and Lali (425 m), besides the Shimba Hills itself. The Mazeras sandstones reach a thickness of 300 m. The yields of the boreholes located on the Mazeras sandstones around Marere in Kwale District range from 200 to 600 m^3/day (Ituli 1988), and the boreholes are presently used for supplying water to Mombasa and Kwale town.

The Tertiary sediments series form good aquifers, too. For example, the Magarini sands, consisting of sands and gravels reaching a thickness of 130 m, are highly erodible and permeable to allow a maximum rate of infiltration of rain water. Water drawn from wells and boreholes situated on these sands is generally of good quality but often with a high chloride content. The Quarternary sediments are generally made of coral limestones and lagoonal deposits of calcareous and quartz sands. The limestones are of the Pleistocene period, reach a thickness of 100 m and usually lie between 3 and 5 km inland. They are of maritime and lagoonal origin. River deposits constitute alluvium, found mainly in mangrove swamps and the Bababi floodplain. Water in the alluvial deposits is rather good but exploitation requires good knowledge of the geometry of the aquifer and should be carefully controlled to avoid sea water intrusion. In the Tiwi area, the groundwater aquifer in Pleistocene sediments gives a yield ranging from 60 to 80 m^3/hour.

The groundwater quality changes as water flows in the underground environment, increasing in dissolved minerals and most major ions. The longer the water remains underground and the further distance it travels, the more it resembles sea water. The salinity of groundwater is determined partly by recharge and depth. The salinity of water of boreholes located in the Lower Duruma sandstones is far beyond acceptable limits of a TDS (Total Dissolved Solids) of 1,000 ppm, although some of the samples are within permissible range (TDS=1,500 ppm) of drinking water standards when blended with brackish water and then treated for distribution. Generally, the poor water quality of the Lower Duruma sandstones and also of the wells along the shoreline places a major constraint on groundwater development. TDS values are usually higher than 1500 ppm. The borehole with the highest salinity is located on the Island and has a TDS of 14,700 ppm as compared to 33,335 ppm for sea water. The salinity of a borehole at Golden Beach Hotel is 10,920 ppm. On the other hand, yields around Ganda, Kikambala, Gazi and Msambweni have low salinity values and the possibility of sea water intrusion is slight to negligible. However, the areas with normal, good groundwater are surrounded by relatively narrow zones that are highly contaminated by sea water indicating the location of depressions in which sea water was dammed.

There are no groundwater basins as such. Productive boreholes and wells are located in perched alluvial deposits and along fractures. The artesian pressures are very low ranging from less than one to about fifty metres and pressure increases northwards and inland.

Surface water resources

More than three-quarters of the total water supply to the coastal region is from river sources. The two major river systems that traverse the region are the Lower Tana and the Lower Athi/Sabaki.[1] These perennial rivers rise from the humid tropical highlands in Central Kenya. The Sabaki River is more utilised in the coastal region than the Tana River because it is closer to the major areas of population concentration. The Sabaki has a mean annual runoff of about 720 million m^3 at Baricho but 1,410 million m^3/year has been estimated during the wet years. This is because the flow fluctuates over a very wide range of stage. The river has been dry at Baricho for a total of 17 months during the 1947-1979 record. At the low and medium stages the Sabaki River flows in a broad sand bed channel within a wide alluvial floodplain. The river banks are highly erodible and the channel follows an irregular and meandering course. Floods are flashy, causing over-bank flow, channel bank erosion, scouring of the bed and changing of the river's course. The Tsavo River, the most important tributary of the Athi River system, rises from the northeastern slopes of Mt. Kilimanjaro 200 km away from the Coast and is fed by the Mzima Springs in Tsavo West National Park. Water is, therefore, imported from outside the region which limits the ability of the beneficiaries to protect the water catchments.

Mzima Springs/Chyulu Mountain Range is a very important water catchment for the Mombasa water supply. The Chyulu Mountains are situated 64 km northeast of Mt. Kilimanjaro. There is a large groundwater potential in the region as may be observed by the numerous springs, of which Mzima Springs are the most productive. The freshwater resource potential is due to two favourable factors, namely high rainfall in the mountain range — about 700 mm but occasionally rising to 1500 mm a year — and the highly porous nature of the lavas and volcanic soils covering the range. Surface runoff is completely absent in the Chyulu Range, even after very heavy storms. The volcanic soils on the hills are loose and non-clayey and much of the rain water percolates to recharge ground water. Water from the springs are of very good quality while water obtained from boreholes in the surrounding basement system rocks is usually slightly saline and hard.

Another source of water supply for Mombasa is the Shimba Hills region in Kwale District. The water potential of the area is caused by ample rainfall, mainly due to the high relief and the weathered rocks that allow infiltration to occur and recharge groundwater. The two main water sources are seasonal springs and rivers, each of various reliability and water quality. Besides, other sources of water include seasonal earth dams and pans, mainly for livestock watering. These dams and pans are unprotected and many were constructed in the 1950s and 1960s and are therefore silted and polluted. The Swedish International Development Agency (SIDA) and the Kenya Women for Health Organisation (KWAHO) are currently supporting communities in digging boreholes, providing and maintaining pumps and training in health issues. The project involves spring protection, hand-dug wells, machine-drilled wells and rehabilitation of existing wells and dams.

1 The Athi/Sabaki system is one and the same river with three different names. The upper stream is called Athi, the middle section Galana and the lower section (i.e. the stretch at the coast) Sabaki. The river has its origin in the highlands near Nairobi.

THE PRESENT SUPPLY NETWORK

The development prior to the Baricho intake

The demand for water in the coastal region has grown very fast during the last three decades. The spiralling demand has been aggravated by the natural increase of the population and by the in-migration from up-country, especially to Mombasa. Table 3 indicates for different parts of Mombasa Municipality, the sources of supply, the operational condition of the distribution line, as well as the designed number of households at the end of the 1980s. It should be noted that meanwhile the designed number of households per any given line has already been exceeded considerably.

Table 3 Water supply to the Municipality of Mombasa

Division	Source	Operational condition	No. of households served
Mombasa Island (Mvita)	Mzima pipeline Marere pipeline Sabaki water supply	good	25,544
West Mainland (Changamwe)	Mzima pipeline Marere pipeline	good	5,363
North Mainland (Kisauni)	Mzima pipeline Sabaki water supply	good	9,956
South Mainland (Likoni)	Marere pipeline Tiwi boreholes	good	1,726

Source: Kenya 1989.

The Marere pipeline was completed in 1925 and is the oldest supply system. It has its source from springs issuing from the Mazeras sandstone at Marere, at the western foot of the Shimba Hills and it mainly supplies the South Mainland of Mombasa. The pipeline is 40 km long and delivers water to pipeline is 40 km long and delivers water to Changamwe via a pipe with a diameter of 425/300 mm. It has a capacity of about 9,100 m^3/day. The Pemba river and treatment works was built in 1982 to augment the Marere supply but was de-commissioned after it was found that the latter could not safely carry more flow. A 12 km long branch line of 200/500 mm diameter transfers water to Kaya Bombo for distribution to the South Coast. The pipeline is old and is therefore being spared to avoid excessive leakage. Yet, the operational quality is good. It is supplemented by boreholes drilled in the same locality and other streams from the northern end of the Shimba Hills.

The Mzima-Mazeras pipeline has its sources in Mzima Springs in Tsavo West National Park. Water flows by gravity to reservoirs at Mazeras with a storage capacity of 80,000 m^3. The pipeline which was laid in the 1950s has a capacity of 36,400 m^3/day and delivers a maximum of 27,800 m^3/day to Mazeras; the rest is for intervening demand. The pipeline supplies Mombasa Island and the West Mainland.

The Mazeras-Changamwe pipeline has twin 550 mm diameter pipes conveying water from Mazeras to service reservoirs at Changamwe and intervening distribution systems. The Changamwe pipeline has a capacity of 36,000 m^3/day but it has weak sections that are unreliable and restrict its full utilisation. Low pressures are experienced in most parts

of the supply system.

The Mazeras-Jaribuni pipeline, a branch of the Mzima pipeline, serves Kilifi-Tezo-Roka, Rabai, Ribe, Kaloleni, Dzitsoni and Jaribuni, as well as the North Mainland of Mombasa. The Jaribuni pipeline comprises of storages of 450 m^3 at Kaloleni, 450 m^3 at Dzitsoni and 360 m^3 at Kilifi. North Mainland obtains its supplies through a boosted 250 mm diameter pipeline connected near Miritini to the twin 550 mm diameter pipeline between Mazeras and Changamwe reservoirs.

The Mtwapa Creek pipeline has a capacity of 5,900 m^3/day and discharges to service reservoirs at Nguru Tatu with a total storage capacity of 9,100 m^3. Supplies are also obtained from the Mombasa Island distribution system by means of a 150 mm diameter boosted pipeline across the Nyali bridge and supplying up to 1,350 m^3/day.

Malindi, Ganda and Watamu areas obtain their water supply from boreholes at Ganda and from an intake and treatment works at Kwa Alyani on the Sabaki River. The boreholes at Ganda produce a maximum of 2,300 m^3/day. The intake and treatment works at Kwa Alyani produce a total of 4,800 m^3/day. Water from the borehole is pumped to bulk storage reservoirs with a capacity of 1,600 m^3 at Ganda, while storage for the intake at the Sabaki river is provided at Kisimani (1,135 m^3).

Finally, there are nine boreholes within the Tiwi aquifer currently producing a total of 4,500 m^3/day. The water is pumped directly to the distribution system and finally to the South Coast area. It has been estimated that the Tiwi aquifer has a potential of as much as 30,000 m^3/day, a potential that has remained largely unutilized until now.

The Baricho intake site

The Baricho intake was commissioned in 1981. The position of the intake had to be chosen very carefully because the Sabaki River changes its course rapidly in its lower reaches. Considerable past movements of the river course in the upstream vicinity of the site are apparent from aerial photographs. Because the bed gradient is slight, the effect of pumping up water has been to create slack currents at the intake and upstream and accretion, shoal, sandbank and channel patterns have been affected and the regime unsettled.

The principal problem of operating the treatment works is largely due to high sand/silt loads which cause rapid wear of raw water pumps. The treatment process requires excessive use of coagulants and consequently causes continuous problems of de-sludging the raw water intake and channel. The treatment works has a design capacity of 54,000 m^3/day but it produces only 30-35,000 m^3/day due to operational problems. Improvement on the water works was planned for the 1989-93 period but was not realized because of lack of funds.

ENVIRONMENTAL ISSUES

Waste water treatment

In Mombasa District, only 10% of the population is connected to sewerage lines. Individual houses have pit latrines while most institutions dispose their waste into soakaways which may contribute to groundwater pollution. The sewered areas still do not contribute

to the environmental health of the town because the treatment works are not operational and the sewage is disposed into the Tudor Creek and the sea. In addition, the top end of the sewer drains are not functioning as designed, partly because the storm drains from the roads have been blocked (NES 1985) and partly because of the marked flat gradient of the terrain.

The waste water treatment works located in Changamwe some 50 m from the outfall is not in working order. The Res Serani works were designed not as a treatment works, but as a screening and settlement system so as to allow flushing during high tides times. The system is currently by-passed, the outfall broken, and leaching 10 m away into the sea. Presently, Kenya does not have any effluent standards for discharge into the sea.

Sanitation

Water projects have been implemented in isolation without due consideration of sanitation and other complementary infrastructures that enhance the benefits of such supplies. In Kilifi District, for example, there is no sewage collection and treatment facilities. In Kilifi town, only 57% of the people have any form of sanitation including septic tanks and latrines. In Kwale District, groundwater is heavily contaminated by pit latrines (Mzuga, Tole & Ucakuwun 1997).

The urban water systems have suffered from poor planning, mismanagement and lack of technical expertise similar to those of rural water supplies, except their magnitudes have been greater than the former. Most of the urban water supply and sanitation systems are either defective or out of order for one reason or the other. The systems are generally old and are incapable of coping with demand from a rapidly growing population that doubles every 18 years and also with the incorporation of rural areas into urban fringes as human settlements expand to such areas. Mombasa generates 150,000 tonnes of solid waste per year, out of which only 50% is collected. There are two waste disposal sites on the banks of Makupa Creek. The uncollected portion decompose into an unsightly and unhygienic situation. These sites pose a danger to groundwater through leachate.

The Sabaki River water contains many pollutants from upstream, in particular from the Nairobi area. Hence, before distribution, the water has to be treated. The process involves settlement which generally takes a period of one hour. After settlement, chemicals are added and filtration is done. The water is chlorinated before its distribution. These conventional methods of water treatment are very expensive and, without a clear policy of tariffs, unsustainable. Simple treatment methods such as protection of water storage — either in dams, reservoirs or pans — from contamination, treatment by settling and filtration and disinfection must be adopted to increase safety of domestic water supply at affordable and sustainable levels. Sedimentation and slow sand infiltration have been used to improve the physical and biological quality of water. Traditional water treatment systems that use charcoal filters or simple sand require further research and adoption.

Integrated land/water resources planning

There is need for comprehensive planning of the river basins that supply water to the coastal region. As a result of population growth and intensification of land use, the size of

land holdings has decreased (Kenya/IFAD 1989). At the same time, cultivation has extended into marginal areas of semi-arid climates and to steep slopes, river banks and other fragile ecosystems. All this results in increasing soil erosion. Soil erosion in the Taita Hills increased from 32 to 78 tonnes/ha/year over the same period. In Kilifi District alone, most of the 71 pans and dams are silted up and require rehabilitation. Similar trends may be observed in Kwale District, especially in Kinango Division, which is a livestock rearing area. Because of the trend of degradation of forest cover, DANIDA targeted an expenditure of 25% of its entire aid programme in the district to afforestation and soil conservation in 1985.

The Athi/Sabaki River system has its source in the forested Nyandarua Range, Ngong Hills and Chyulu Hills. The flow contribution of this limited forest cover explains the reason why the Athi/Sabaki is prone to excessive annual droughts and floods. The existing forest cover is endangered by extensive deforestation, cultivation and over-grazing which has caused accelerated soil erosion, leading to very high sedimentation rates. The Chyulu Hills forest has been degraded by squatters who have burned the wood for charcoal and turned the former forest land into farms. As a result, the Mzima Springs show fluctuations in supply that is mostly an element of reduced infiltration over the Chyulu Hills. The Baricho intake suffers from siltation that disrupts the water intake. It has become necessary to drill the channel to get rid of this sediment ever so often. The silt-laden water also makes the cost of treatment particularly prohibitive and shortens the lifespan of treatment equipment. Watershed management as a tool for augmenting water supply to the coastal region must be enforced.

Towns like Malindi and Mombasa continue to grow rapidly in population and industry and therefore demand grows faster than supply. If anything, the growth of water supply infrastructure in the last few years has not kept pace with the population increase in the coastal region. However, additional water requirement implies more waste water, which currently cannot be treated adequately because of the low capacity and poorly maintained sewage treatment works. This situation is best demonstrated by the Sabaki River which is threatened by pollution from industries in Nairobi and Athi River township. Methods of controlling pollution and urgent measures to re-use waste water must be sought.

Seawater intrusion

Groundwater resources in coastal areas are always in danger of seawater intrusion. The danger increases when rates of water extraction near the shoreline are greater than the rate of recharge. In other cases, concern arises when there is a possibility of sea level rise resulting from global warming. These dangers are real for the Kenyan coast because the demand for water has outstripped supply. Besides, land use changes are beginning to reduce the rate of infiltration of rain water into the ground. The highly porous limestones and corals along the coast make it easy for seawater to intrude inland. Caswell (1953), Gentle (1965), Majanga (1987) and Tole (1996) have expressed concern that seawater intrusion was imminent along the Kenyan Coast. Evidence shows that Tiwi and Ukunda/Diani groundwater aquifers have been deteriorating over the last ten years.

ISSUES IN FUTURE WATER RESOURCES DEVELOPMENT

Community participation

The success of rural water supply or any other development project greatly depends on whether the local community has been involved in its planning and implementation. Rural water supply development has been bereft with difficulties because it was the national government who basically designed, implemented and operated rural water infrastructures in the region. The water projects also emphasised the technical rather than the social aspects.

Community empowerment requires that the beneficiaries be a part of the development process. In the past, their participation was restricted to *harambee* contributions in the form of cash, labour or land. The issue of ownership was never discussed, and consequently many of these projects have gone to disuse. Usually, no arrangements for operation and maintenance were taken into account.

Several non-governmental organisations have come onto the scene. These NGOs work through local institutions such as women groups, youth clubs, boys' scouts, etc. Kenya Women for Health Organisation (KWAHO), Action Aid and Plan International have been active in the region. In addition, there has been donors' support to water development, mainly in the rural areas. Such donors include Britain, Sweden, Denmark and The Netherlands and other multi-lateral agencies, such as the International Fund for Agricultural Development (IFAD), Unicef, and the World Bank.

Policy and legal issues

The main source of water supply to the coastal region is surface water from the Sabaki River, augmented by supply from Mzima Springs. The use of groundwater has been increasing and it is anticipated that groundwater utilisation will increase with tourist and port development. The growing number of actors in water supply — such as non-governmental organisations, community-based organisations and aid agencies — has not been streamlined with respect to the Water Act. In the past, the Ministry of Land Reclamation, Regional and Water Development (MLRRWD) had the sole responsibility of establishing, operating and maintaining public water supplies throughout the country. Applying the Water Act, MLRRWD is able to allocate water to different users through the Water Apportionment Board who then issues permits. Private institutions and individuals, especially along the Coast, have increased in number and there is no policy to control and coordinate their activities. Presently, the office of the District Water Engineer (DWE) is the implementation and coordination branch of the ministry according to the District Focus for Rural Development Strategy.

In 1988, the National Water Conservation and Pipeline Corporation (NWCPC), a parastatal, was established to operate, on a commercial basis, all piped schemes, especially in urban areas. Their operations are limited but there has been growth in the last five years. The Coast Development Authority (CDA), constituted by an Act of Parliament on November 2, 1990, has jurisdiction over the planning of natural resources including water. The mandate of the Authority covers the entire Coast Province. In addition, there are municipal (local) authorities acting as water undertakers.

The Ministry of Health is responsible for sanitation in the country. The Public Health Act empowers the Ministry to regulate activities concerning human waste disposal and prescribes standards and procedures to be followed, failure to which corrective and punitive measures may be taken. The activities in the sanitation sub-sector need to be streamlined recognising that only 69% of the population has any form of sanitation. The bush system of waste disposal is prevalent among many rural and urban slum communities. Over 40% of the water samples taken from rural areas appears to have faecal pollution (Kenya 1996). This is due partly to the fact that groundwater abstraction in the rural areas is carried through hand dug wells equipped with buckets for drawing water, and partly to lack of technical advise on the siting of pit latrines and shallow wells. One of the problems at the policy level is that there are 30 governmental and non-governmental institutions engaged in the sanitation sector without any single one of them having the role of co-ordinating or over-seeing sanitation activities in the country. With the completion of the National Water Master Plan and the formulation of a new water policy, it will be possible to obtain a comprehensive picture of the water development needs and suitable institutional framework for managing the water resources of the region.

Operation and maintenance

Current conventional strategies of water resources development have not been successful with the construction of dams and reservoirs, boreholes and pumped water systems because of high operation and maintenance costs. About 30% of the domestic water supplies are by boreholes and 10% by riverside pits and various forms of water harvesting techniques. The dams and reservoirs have high siltation and evaporation rates and require periodic maintenance. The water budgets for the coastal districts continuously request for funds for rehabilitation and for desilting of dams and reservoirs. Pumping systems require continuous expense for energy as well as maintenance of pumps. When the pumps break down parts and mechanics are required because the technology cannot be handled by the local communities who use the resource. Finally, the main transmission lines are long and have pipes with substantial diameters. These pipelines are not only expensive, but also old. They often break, thus increasing the cost of maintenance.

Water conservation

In terms of the discrepancy between water demand and water supply, the most affected divisions in the coastal region are Mombasa Island and Changamwe, partly because of their density of population and partly because of the established industries in these two areas. The supply from the Baricho intake has been outstripped by the growing demand. Moreover, water losses, currently estimated to be more than 40% of the total volume of treated water, continue to increase due to weaknesses of connection pipes and to the users' carelessness. As for the latter, the community is unaware of methods of reducing water consumption. A programme on water conservation does not presently exist. Moreover, there are illegal connections to the present supply system. Because the NWCPC does not have the capacity, there is no way of detecting the amount of water taken illegally.

Water tariffs

The water supply and sewerage systems need to be self-financing. The revenue collected from tariffs should be sufficient to pay for operation and maintenance of the systems. The principle of cost-sharing is an appropriate requirement for fixing tariffs, while the impact on conservation of the rich consumers subsidising poor consumers needs to be examined. Industrial consumers and tourist hotels are able to pay the full cost of water development without government subsidies. More than 50% of the population in the region are able to pay for sewer connections. Currently, Mombasa and the other coastal urban centres are responsible for sewerage and sanitation, while NWCPC bills and collects the sewerage revenue on behalf of the Municipality.

According to financial estimates of the years 1994-96, the water rates are expected to cover only 18% of the recurrent expenditure of the MLRRWD. Up to 96% of the income collected is spent on salaries of personnel. It is expected that government funding in the water sector will decrease and community participation and contribution will increase. But these areas of management require new policies and additional capacity both within the community and in the water sector.

It is also known that for conservation to be meaningful, water must stop to be a cheap and free commodity. In Mombasa Island, for example, the water kiosk business is thriving because of shortage. Presently there are 35 water kiosks in Mombasa Island selling about 150,000 m^3 of water per year, 188 kiosks in West Mainland selling the same amount, 113 kiosks in North Mainland selling 240,000 m^3/year, and 48 kiosks in South Mainland selling 145 m^3 per day. Moreover, a way must be found to break the vicious cycle of sewers that are not working with nobody wanting to pay for a non-functioning sewer system, or pay little for what is not delivered.

Capacity building and institutional framework

The Water Development Department of MLRRWD is under-funded and has a poor tariff system. Lack of equipment, transport and skills to collect water data and supervise the supply and poor staffing have reduced the capacity of the District Water Engineer's office to cope with operation and maintenance that is required in order to deliver safe water. However, even where tariffs exist, they are incapable of collecting revenue from water consumers. For this reason, the consumers receive water sporadically, receive their bills infrequently and are sometimes billed for what they have not consumed. Current data and information management within the sector are poor, inter-sectoral planning is under-developed and monitoring of the quantity and quality of water resources have been ignored for a long time. Progress gained and the impetus observed during the United Nations Decade of Drinking Water has been lost as a result of poor planning and programming. It is anticipated that the NWCPC will introduce policies that will be in line with the current perception of water scarcity.

Alternative sources of water supply

There are three alternative sources for increasing water supply to the coastal region. The

first one is rain harvesting, especially roof catchment for large institutions such as schools, hospitals, etc. The initial investment that is required for rainwater harvesting is a roof catchment and gutters. Some external support from SIDA, DANIDA and other NGOs has come handy in providing local communities with water tanks or cylinders. The second alternative concerns water recycling, which is gaining prominence in other water-deficit countries, especially in North Africa. The future of house gardening, common among urban and peri-urban dwellers depends on the extension of water recycling. Finally, water desalination, as practised in the Arab states and in the Middle East lacks the technology and necessary investments to be tried in many developing countries. One desalination plant, funded by the Italian government, is located at Ras Ngomeni and is run on an experimental basis. Each of these options will experience rising costs in order to be implemented. There are several avenues to augment the supply of water to the Municipality of Mombasa, notably reinforcement and extension of the primary distribution system, extension of the secondary and tertiary distribution systems based on land use, reduction of water losses by renewals, and introduction of an appropriate tariff system to commensurate with the cost of providing water.

Several options are currently being studied by NWCPC. For example, there is an assessment study regarding a second Mzima pipeline which will, however, considerably reduce the flow of water in the Tsavo River. A second option is to construct a dam on the Athi River at Chakama, Yatta or near Rare. Another option is further exploitation of the coastal aquifers or of the Kilimanjaro sources, especially at Lake Chala. However, the environmental impact of all of these options should be carefully considered.

CONCLUSION

The development of water resources in the Coast may be viewed in the context of inadequate local supplies, on the one hand, and increasing demand for a rapidly increasing population and industrial development, on the other. The problems associated with operation and maintenance of an old, over-stretched system are expected to increase. Although there is a water surplus outside the region, the escalating costs and environmental problems make such conventional water supplies unaffordable and unsustainable. The present water infrastructure suffers from poor national water policies and management strategies, including pricing, apportionment and planning for water development.

An integrated approach to water planning and land use needs to be adopted within the policy framework of the development of freshwater resources in the region. This will not only halt the degradation of water catchments by actions of upstream users jeopardising the interests of the downstream users, but also control the urban planning and property development in the coastal region. The reservoirs that have been built on the upstream portions of the rivers and those planned for the future will require a detailed environmental impact assessment to determine their roles in seawater intrusion and marine ecology in general. Community-based water supply projects that emphasise local technology with the use of available materials need to be promoted.

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REVIEW DETAILS

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