CURRENT ENVIRONMENTAL PROBLEMS

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ABSTRACT
Existing environmental problems are general in nature as well as specific to the Kenya Coast. Extensive erosion occurs along the coastline while at the same time there is sizeable sedimentation brought about by the Tana, Sabaki and other smaller rivers. Inland soil erosion is most serious in the hilly ranges and the hinterland plateau. Natural hazards firstly concern floods that occur regularly. As regards biological resources, there are manifold threats to the coral reefs ranging from siltation to physical destruction. Mangroves are threatened due to rapid and unplanned exploitation. The terrestrial forests suffer from overexploitation, mining activities and clearance for cultivation. Air pollution is generally not a problem except in Mombasa and in certain rural areas with industrial emissions. Water pollution is more serious in nature: groundwater is affected by sea water intrusion as well as bacterial contamination; sea water is increasingly contaminated by sewage from beach hotels and urban waste and sewage. Waste disposal facilities are generally inadequate.

INTRODUCTION

Environment can loosely be defined as 'surroundings': the sum total of the physical, chemical, biological and socio-economic conditions and processes which operate within, or otherwise influence, an arbitrarily defined geographic-political entity, and which have a positive or negative impact on the survival, livelihood, and fulfilment of the human development potential of the inhabitants of the geopolitical entity. The environment influences and limits the activities of the inhabitants of a given area, but in turn is influenced by the socio-economic activities of these inhabitants. In the past, man has tried to conquer and 'improve' nature, and maximise the exploitation of natural resources that exist in a given area. With the increased awareness of the limits of the capabilities of the environment to regenerate and sustain socio-economic activities, people the world over have become more cautious about the methods and rates of exploitation of natural resources, and more thought is being put into impact assessments (whether formal or simply at the back

of people's minds without any written statements) of the future consequences of exploitative activities conducted today.

The characteristics of the natural environment of the Kenya Coast are described elsewhere. This review focuses on the existing environmental problems. Most environmental concerns are ethnocentric in the final analysis. However, the dynamic state of the natural environment dictates that, even in the absence of man, physical, chemical and biological processes will still operate to modify (for better or for worse) the existing environment. Man, however, affects the dynamism of natural processes by speeding up their rates, to the extent that changes that would otherwise have taken place over periods of hundreds, thousands, or even millions of years, occur within tens of years. This in turn places limits on the range of activities that can continue to be undertaken, or necessitates a complete change in the types of socio-economic activities that are undertaken, within the given geopolitical entity. It is in the context of interactions between the natural environment and man's activities, and the feedback between the interactions, that the present review examines the Kenyan Coast. The review starts with an overview of physical environment issues which is followed by a discussion of the degradation of biological resources and the problems of pollution and waste disposal. The first section describes the current and near-future environmental problems arising from the physical environment. These include problems due to climatic factors, sea level changes, soil erosion, and natural hazards, such as threats due to land slides, volcanic eruptions, earthquakes, tidal waves, storms and winds, floods, and droughts and famines.

PHYSICAL ENVIRONMENT

Climatic change

The Kenyan Coast is physically a heterogeneous entity. Physical parameters vary perpendicular to the shoreline and remain relatively uniform only in belts running parallel to the shoreline, except for local orographic modifications. For example, altitude ranges from sea level along the shoreline to over 1,000 m above sea level in the Taita Hills. Mean annual rainfall decreases from 1200 mm in the south-eastern part of Kwale District to 400 mm in the hinterland (Nyika), while mean maximum temperatures range from 30°C in the low, flat-lying areas, to 20°C in the higher altitude areas.

Global mean surface temperature has increased by between 0.3 and 0.6^{o}C over the last 100 years, with recent years having been the warmest on record, i.e. since 1860 (IPCC 1996). Analyses of long-term climate trends in the Kenya coastal region are, however, equivocal as to any changes towards increased temperature, in contrast to what has been reported in other parts of the country .

Sea level rise

Analysis of long term sea level data from the Kenyan Coast are also equivocal about the sea level rising either, though this may be more due to paucity of data than a reflection of the true situation (Sea Level Rise Conference 1991). Casual observation and anecdotal evidence would suggest otherwise. Various scenarios of coastal plain flooding, sea water

intrusion, enhanced coastal erosion, ecotone and social migrations, and the resultant economic costs that would result from a 40 cm rise in sea level due to global warming, have been put forward (Sea Level Rise Conference 1991; Ng'ang'a 1992; Mwanje 1992; Odada 1993), but these tend to be speculative models with very little quantitative data. More data on physical processes at the Coast are needed to make realistic forecasts of environmental conditions in the future.

Coastline erosion and sedimentation

Erosion takes place to differing extents in the Coast, depending on the morphology and physiography of the particular area of the coast, climate, soil/sea shore type and cover, and land use activities. From available data it is not clear whether the Coastal Plain, varying from 3-20 km inshore and about 30 m above sea level, is a region of net erosion by the sea or of net deposition of sediments brought down by rivers from erosion activities up-country. There are great variations in the rates of erosion and deposition processes down the length of the shoreline.

Processes that affect erosion/deposition of sediments at the shoreline include (i) uplift/subsidence[1] of land relative to the sea due to tectonic or isostatic movements; (ii) sea level rise due to global warming; (iii) ocean processes (currents and wave action); (iv) geometry of the coastline relative to the action of ocean currents and waves; (v) barriers that serve as breakwaters (e.g. coral reef); and (vi) human activities such as saltworks, mining of building sand, and agricultural, industrial, commercial and residential infrastructural development, among others.

The available evidence indicates that north of Malindi town, due to the sediment input from the Sabaki and Tana Rivers, there is a net deposition of sediments. This is evidenced by the presence of sand dunes, which have pushed the shoreline by up to 800 m into the sea near the mouth of the Sabaki over the last 20-30 years (Gauff Ingenieure 1993; Abuodha, in preparation). The annual sediment input from the Sabaki River has been estimated to have increased from 58,000 tonnes per annum in the 1950s to 7,500,000 tonnes in the 1970s (Giesen & Kerkhof 1984). The sediment load of the Tana River is estimated at 35,000,000 tonnes per annum.

South of Malindi town there is net erosion of the shoreline, except locally where rivers, streams and creeks enter the ocean (1-2 km on either side of the river mouths). Erosion of the shoreline is evidenced by the presence and continued fragmentation of coral limestone cliffs and man-made structures such as the Vasco da Gama pillar, sea walls, and hotel constructions, which are now undermined by erosion (Munyao 1998; Abuodha, in preparation). The underlying causes of this erosion phenomenon are not fully understood; the magnitude of the different contributions of sea level rise, tectonic processes, coral reef destruction and other plausible causes, need to be understood, to design appropriate responses.

1 Uplift would be indicated by incision of river valley beds, as is observed at the Sabaki River bridge, while subsidence is indicated by the presence of numerous creeks, presumed to represent drowned channels; in the Kenyan Coast, both features are observed.

Deposition of sediments by rivers near the shoreline is both a blessing and a curse. It is a blessing since the sediments act as a natural sea wall defence system, keeping back the ocean and saving residents millions of shillings in terms of costs of damage to, repairs of and/or relocation from structures that would have been destroyed by sea erosion. No effective sea defence structures have been developed so far for the Kenya Coast, and therefore the Sabaki sediments are playing a very important role in the defence of Malindi town from erosion by the sea. At the same time, ecologists have expressed concern that sedimentation from the Sabaki river is destroying coral reefs due to the impacts of the sediments in (i) reducing light, (ii) physical smothering of the coral polyps, and (iii) the effect of salinity reduction by the fresh river waters (Giesen & Kerkhof 1984; Blom *et al.* 1985; Munyao 1998; Obura 1995). Interestingly, similar concerns have not been expressed with regard to the Tana River. It is important that the magnitudes of the 'costs' of reef and seagrass destruction are evaluated and weighed against the positive impacts of the natural sea wall defence systems created by sediments from the Sabaki and Tana Rivers. It is only then that appropriate recommendations can be made regarding efforts and costs of curbing soil erosion up-country. The much heralded arresting of erosion in the uplands regions of Ukambani, if carried out successfully, will reduce the amount of sediment reaching the sea through to the Sabaki River, and will most likely result in erosion of beaches around Malindi.

The processes of erosion and sedimentation along the shoreline are, therefore, subject to long-term fluctuations and are largely determined by actions taking place elsewhere, beyond the control of the local people. Local factors such as sand mining, salt works, mangrove felling, coral reef destruction, building of sea walls and groynes, among others, may enhance erosion to some extent.

Inland soil erosion

Further inland, crop farming and livestock rearing take place in the different ecological zones. Here, vulnerability to soil erosion is dependent on several natural and man-made factors, among them rainfall (amounts, intensity, frequency), soil types, topography, soil cover, and nature and practices of land use patterns. Four different physiographic units are encountered from the shoreline moving inland: the Coastal Plain, the Foot Plateau, the Coastal Range, and the Nyika Plateau. Erosion patterns are different in each physiographic unit.

In the Coastal Plain, most of the land that is not used for tourist facilities or under forest cover, is cultivated with plantation crops and food crops. Large-scale livestock farming is found only in a few places due to high incidence of diseases transmitted by tsetse flies and ticks, as well as to dense human settlement patterns. Because of the relatively flat nature of the Coastal Plain (slopes typically less than 1 in 100), and the sticky nature of the soils developed over coral limestone, soil erosion is not a major problem in this zone. The plantation crops, and low population density of livestock also help to protect the soils from water and wind erosion. However, construction activities for tourist and infrastructural facilities have resulted in the removal of soil cover, and exposure to wind erosion possibilities, especially of the fine sands and buff, silty clays. Mining of coral

limestone and sand is usually done with little attempt at rehabilitation. Very little forest cover remains in this zone with the exception of the occasional *kaya* forests and the well-known Arabuko-Sokoke forest near Gedi. Outside the settlement schemes many of the residents living in this zone are squatters even though the indigenous peoples have lived on the land for centuries. They have little incentive to make investments in long term soil conservation and protection measures. The coastal plain widens north of Malindi into the Tana River flood plain, this area is sparsely inhabited and mainly used for extensive livestock farming and riverside crop cultivation. The irrigation schemes at Hola and Bura experience run-off and erosion problems since the breakdown of the schemes.

The Foot Plateau is underlain by Jurassic shales and limestones. Farming activities and soil erosion hazards are similar to those discussed above for the Coastal Plain with quarrying activities mostly for building stones, marble, limestone and iron ore. Some forest cover still remains in patches, together with *Brachystegia* woodlands in Kilifi and Malindi Districts, affording some protection against soil erosion.

The Coastal Range, comprising of the Mrima-Dzombo Hills in the south and the Shimba Hills, Mazeras and Mangea Hills to the north are underlain by sandstones and grits. Rainfall tends to be high (1000 to 1200 mm per annum) and farming is fairly intensive where the land is not a forest conservation area. Due to the steep slopes, the potential for soil erosion is high, especially where soils have been exposed by farming activities and during episodes of torrential rains that commonly occur in April/May and October/November. In the Shimba Hills settlement scheme contour ploughing was practised in the 1950s and 1960s, but due to wildlife menace from elephants, wild pigs, baboons and monkeys, many farms have been left untended since the 1980s. Where farms are still cultivated, soil protection measures are not practised in any systematic manner. The forest reserves at Mrima, Dzombo, Shimba Hills and Mazeras serve to curb soil erosion within the forest areas, but, by harbouring wild animals, which are viewed as pests by farmers, discourage investment in soil protection measures outside the forest. Unprotected areas such as Mangea Hill show high levels of erosion.

The Nyika Plateau comprises the drier zone behind the Coastal Range. The main activity in this zone is livestock rearing, especially of cattle, sheep and goats (although the Tsavo National Park occupies large tracts of land in this zone). The natural vegetation is dominated by acacia and commiphora shrubs, with the latter shedding all their leaves during the dry season. In these dry periods, wind erosion is prevalent, carrying considerable amounts of soils in whirlwind storms. At the onset of the rainy season, gully erosion, as well as sheet erosion take place along the animal tracks and also in extensive areas devoid of continuous vegetation cover. The problems of soil erosion in the Nyika Plateau are compounded by local overstocking and sparse animal watering holes. Especially during the dry season, cattle, sheep and goats, and even wildlife, have to travel long distances to common watering points. The animal tracks to the watering points and the area immediately adjacent to them become zones of soil erosion devoid of vegetation. There is a high incidence of charcoal burning in areas along the Mombasa-Nairobi trunkroad, but also deeper inside in areas such as Chakama, which negatively affects the vegetation cover. New settlement schemes (such as Buguta and Magarini) which are intensively cul-

tivated also expose new areas to soil erosion. Within the Nyika Plateau, there are also mining activities for gemstones, and quarrying for road metal and building materials. For instance, Voi river sand is a popular building material. Most of these mining activities are carried out in ways that do not take soil erosion prevention measures into account. Overgrazing by wild animals in the National Parks, and off-road driving by tourist vehicles, also increase the erosion potential in this zone.

Finally, the Taita Hills have a high erosion potential due to the steep hill slopes, relatively high rainfall, deep soils, and intensive cultivation.

Natural hazards

Among the natural hazards are landslides, volcanic eruptions, earthquakes, tidal waves and tsunamis, storms and winds, floods and droughts, and diseases. Landslides are potential problems in areas covered by deep soils on steep slopes, as present in the Coastal Range and the Taita Hills. However, even in the Coastal Plain, occasionally conditions may occur promoting landslides, as happened at Jomvu in the late 1970s, when a landslide carried off a section of the main Mombasa-Nairobi highway. In addition to the danger posed to infrastructural developments, landslides also pose a danger to life and habitats. As of now, a landslide hazard map for the coastal region does not exist.

The Coast is an area of deep, old faults that were responsible for the rifting that split off Madagascar in Cretaceous times. There are also recent volcanic activities associated with Kilimanjaro and Chyulu. Minor earthquakes are therefore a fairly regular occurrence along the coast, although these rarely exceed magnitude 5 on the Richter scale. No loss of property or life due to an earthquake has ever been reported, although building on faults should be avoided to minimise structural damage.

Volcanic eruptions are not of immediate concern in most areas of the coast, since volcanic rocks are mostly limited to dykes and minor intrusives associated with the Dzombo and Mrima Hills in the south, and close to the Mangea Hills to the north. These intrusives date back to the Cretaceous. However, in the Taita Hills, areas close to the Chyulu Hills may need to be monitored, as there has been an apparent shift of recent volcanism to the south-east, the latest having been the Shaitani and Chaimu volcanic eruptions, which are claimed to have occurred within the last 300 years.

Tidal waves have not occurred, although the fact that there is a possibility of a magnitude 5-6 earthquake centred along offshore faults cannot rule out such an event. A tidal wave hitting the coast would likely cause widespread damage to buildings, roads, and other infrastructural services, in addition to the danger posed to life. Rough seas are observed during the south-east monsoon period (Turyahikayo 1987). Waves as high as four metres and more occur with a frequency of one per cent, while those higher than two metres occur with ten per cent frequency. These waves are much feared by local fishermen, who use small canoes and *dhows*. Occasionally, there is loss of life of fishermen and tourists as a result of rough seas. There is frequently risk of ships running aground, particularly at the entrance to Kilindini harbour in Mombasa, and spills of oil and other hazardous materials as a consequence.

Climatic variations occurring in 4 to 10 year cycles bring alternate droughts and

floods, the latter being most severe in the low-lying areas of the Tana delta and the Sabaki flood plain. Droughts are followed by floods with almost predictable certainty. With improved communication and civil defence efforts, mitigation of flood hazards is therefore possible. Droughts and their impacts, however, tend to be more devastating, notably the famines that result from crop failure and death of livestock, particularly in the less accessible hinterland areas. Improved communication infrastructure and food management policies are required in order to minimise famines in times of droughts and floods.

The hot, humid environment in most of the region, except the hinterland, augers well for proliferation of insect pests such as mosquitoes and flies (both the housefly and tsetse fly). In the rivers, too, schistosomiasis parasites proliferate in their host snails. As a result of this, infant mortality is high from diarrhoeal diseases and malaria, while the adult population is affected with frequent bouts of malaria and, for some, schistosomiasis. These contribute to hinder development efforts by weakening the population and giving rise to many man-hours of work being wasted. Tsetse flies and ticks also impede the production of animals, so that the dairy and beef industries are not very well developed.

NATURAL BIOLOGICAL RESOURCES

Marine biological resources

The marine biological resources include fish, sea shells, coral reefs, seagrasses, and algae. For centuries, fish and sea shells were exploited sustainably, i.e. on a small scale. The fish were for consumption at the village level, while the cowry shells were used as a currency for exchange of goods, for dowry payment and for making decorative ornaments. In recent times though, the scale of fishing and shell collection have increased to serve the tourist trade. Illegal fishing, including that using dynamite within the coral reef area was at one time a threat to the fishing industry, especially in the Shimoni area, ostensibly by fishermen from Tanzania. Trawling by ships from Japan and the former Soviet Union is also taking place illegally, especially in the area between Malindi and Lamu, and also off Shimoni. Fishing for ornamental species, though licensed, is not adequately supervised, so that the methods employed often lead to destruction of corals. Collection of sea shells is banned in the Marine National Parks and Reserves. Although regulated, sea shell collection and sale in areas outside the prescribed areas is threatening some species with extinction. There is need for acceptable guidelines to govern shell collection by the local inhabitants, so that it becomes a sustainable economic activity which is at the same time compatible with the principles of environmental conservation.

Coral reefs are threatened by (i) siltation from rivers due to increased erosion upstream; (ii) dilution of sea water locally, either from increased run-off by rivers due to paving of urban centres or from municipal water discharges; (iii) eutrophication from sewage outfall increasing algae growth, which then smothers the coral; (iv) physical destruction by tourists during glass boat viewing, snorkelling and walking on the reef at low tide; and (v) illegal fishing methods such as dynamiting the corals, use of drag nets or lifting coral to get access to ornamental fish.

Seagrasses and algae are ubiquitous in the Kenyan coast. The seagrasses provide an important ecological substratum for breeding of various marine organisms and also play an important role in the stabilisation of sediments deposited in the sea. They have yet to be exploited as an economic resource, though some farmers collect them for use as compost fertiliser. More often, they are viewed as a nuisance to the beauty of the white beach sands when they are washed ashore. Some beach hotels rake them up and bury them, beneath the beach sand during low tide. Increasing eutrophication is likely to increase the production of seagrasses and algae, while increased sediment input is likely to curtail their growth (Giesen & Kerkhof 1984).

Estuarine biological resources

The most important resource here are the mangrove forests. Mangroves provide nursery grounds for breeding of various fishes, birds, molluscs and crustaceans. They also protect the coast from erosion and remove fine sediments from the water, in addition to supplying nutrients to the ocean. For many years, mangroves had been exploited sustainably for timber, building poles, fuelwood, tanning extract, and other natural products. However, the existing 530 square kilometres of mangrove forests in the Kenyan coast are now threatened with extinction due to rapid exploitation for (i) building poles, firewood and charcoal, and tannins, (ii) setting up of salt manufacturing facilities, (iii) setting up of fish farms, particularly for prawn cultures, and (iv) creating new land for the building industry. Policy measures need to be strengthened to protect these ecosystems since existing legislation under the Forestry Act is not strictly enforced (Munyao 1998).

Terrestrial biological resources

Aside from the mangrove forests, the *Kaya* forests, as well as other forests are also threatened. This is caused by the rapid population expansion and the concomitant demand for agricultural and residential land and for commercial property. Requirements for timber and firewood are also taking their toll. However, recent studies in other high potential areas of Kenya have shown that farm forestry (otherwise known as agro-forestry) is more than making up for forest destruction, so that the total biomass in Kenya is actually increasing at a faster rate than the rate of population increase (Holmgren, Masakha & Sjoholm 1994).

The main protected forests at Mrima, Dzombo, Shimba Hills and Arabuko-Sokoke face occasional (and recurring) pressures from mining groups (Mrima), farmers (Mrima, Dzombo) and loggers (Shimba Hills, Arabuko-Sokoke) who have to be fended off periodically. The dryland forests (Acacia/Euphorbia) in the hinterland face pressures from new developments and settlement schemes, as well as from charcoal and woodfuel demands. Mining activities also reduce the area under forest cover and more forests need to be gazetted to control extraction as well as intrusion by farmers. Except for Bamburi, and to a lesser extent Kinangoni, other mining concerns do not rehabilitate the land after mining. Even the much heralded Bamburi Quarry Nature Park has ‘rehabilitated’ the former limestone quarries by planting casuarinas, rather than restoring the ecosystem to its previous status, although indigenous species have also been planted (Haller & Baer

1995).

Diverse species of mammals, birds, insects, reptiles, amphibians, molluscs, and crustaceans can be seen in the Coast, both inside and outside the protected areas. In the latter case, they are often in conflict with human existence. The Tsavo National Park and the Shimba Hills National Reserve are the main terrestrial protected areas; the latter has been the habitat of animals that destroy crops in the nearby settlement scheme both at night (elephants, wild pigs, porcupine) and during the daytime (baboons, monkeys, antelopes). Many farms have been abandoned the last 20 years in an area which could potentially be the breadbasket of the centres at Tiwi, Diani, Ng'ombeni-Likoni, and Mombasa Island. In the North there are the national reserves of Boni and Dodori as well as the Tana River Primate Reserve.

POLLUTION AND WASTE DISPOSAL

Air pollution

The clean fresh air of the coast is one of the tourist attractions and it can generally be said that air pollution is not a main problem. Although quantitative data are lacking air pollution in the Kenya Coast is predominantly a problem of the urban areas such as Mombasa and possibly Malindi. Particularly of industrial sites in Mombasa; motor vehicle emissions are also a factor in urban areas.

In rural areas, particulate air pollution from wind erosion may be locally important, especially where the vegetation cover is sparse. Wind-borne dust can be entrained in the atmosphere for long periods of time. Mining activities (blasting, crushing, and grinding, especially of ballast) contribute to airborne particulates in otherwise rural settings where they are located. The most dramatic examples of dust pollution in rural settings are the Bamburi Portland Cement factory, the Kaloleni Cement Factory and the Kinangoni lead mine. Foul smells from waste disposal sites (such as Kibarani in Mombasa) and from organic waste discharged near sugar, sisal and fruit processing plants (for example near Voi and at Vipingo), make the immediate surrounding areas unpleasant to live in.

Combustion-induced air pollution not only exacerbates the greenhouse warming problem, but directly affects the housewives who use firewood in poorly ventilated kitchens in the rural areas, and the men who make charcoal. Bush fires, whether accidental or during slash and burn agriculture, also contribute variable amounts of CO_2, smoke, and other particulates to the atmosphere. The contribution of SO_2 from bush fires is not expected to be high, because the coastal region as a whole uses relatively little fertiliser (except in the intensively farmed areas such as Wundanyi and Mtwapa).

Water pollution

In the coastal plain, where groundwater is the main source of domestic water supply, two important sources of pollution have been identified. Anyango, Tole & Ucakuwun (1998) noticed sea water intrusion as being on the increase, penetrating up to six kilometres inland from the shoreline in the Diani area, where tourist hotels have been allowed to pump out large quantities of water from the groundwater system. There was relatively less

penetration by sea water intrusion in areas far from hotel developments. Mzuga, Tole & Ucakuwun (1998) identified contamination of groundwater with E. Coli as being a major factor, particularly around large population centres and where pit latrines were located close to the groundwater source (well, borehole or spring). Areas underlain by coral limestone had contaminated wells up to 150 m from pit latrines, while areas underlain by sandstones had contaminated wells up to 120 m away. This has very serious implications for densely populated areas such as the Mombasa wards of Majengo, Likoni and Kisauni, where it is not possible to have wells located 150 m away from the nearest pit latrine. Yet, the residents rely on wells for their water supply and definitely have to be sensitised to the need to boil or otherwise disinfect their domestic water sources.

Surface waters are mostly contaminated with sediment. The Sabaki River discharges about ten million tonnes of sediment per year (Abuodha, in preparation) and is indicative of the sediment loads of rivers in the coast. Pesticides have also been detected in the Sabaki River system (Gauff Ingenieure 1993), indicating input from agricultural activities up-country. A growing problem is that of floating macrophytes in rivers, especially where water movement is slow. A good example of this is the Ramisi River in the south coast. This is again indicative of eutrophication of surface water bodies by nutrients from farming activities. Studies are urgently required to provide quantitative data on the present state and future trends of surface water pollution. For example, a recent proposal to treat the sewage from Malindi town and discharge the effluent into the Sabaki River some 20 km upstream from the mouth which threatens to turn the Sabaki into a cesspool needs assessment.

Sea water for recreational purposes and as a source of fish is also increasingly being contaminated from sewage outfall from beach hotels, from surface run-off from urban centres and from waste disposal leachates as at Kibarani in Mombasa. Ocean going traffic has already been mentioned above as an increasing pollutant of sea water. As the magnitude of this problem increases, local eutrophication of sea water, with concomitant bloom of algae and seagrasses, death of coral reefs, and contamination of seafood with pathogens and heavy metals will become significant. Currently, the levels of contaminants are probably still low enough that wave and current action sufficiently disperse pollutants so that they are not an immediate threat except locally. For example, preliminary results of determination of the water quality of the Tudor Creek did not show a critical pollution level at any time in the year 1990, although peak pollution levels occurred at the beginning of the rainy season (Wijnant, cited in Schoorl & Visser 1991). There are no known problems of salinisation of water bodies resulting from irrigation projects, although the proposed use of Lake Jipe for irrigation in Taveta may need careful monitoring to avoid build up of salinity, both in the lake and in the irrigated soils.

Waste disposal

Several methods are used to dispose of solid wastes. In the towns, solid wastes are collected (though increasingly rarely in recent times) by the Municipal authorities and dumped at centralised open waste dumps. These waste dumps have attracted the jobless, who search through the waste for any usable materials which they then sell off. This pro-

vides a recycling economy, which also serves to reduce the volumes of wastes and conserve resources. Generally in Kenya, residents will also recycle old newspapers, bottles and old clothes, and rarely do these reach the waste dumps. Periodically, the wastes are burnt off to reduce volume. None of the dump sites were engineered to be protected against leaching by rain or sea water, or against methane combustion. Indeed, it has been thought that some of the fires are not deliberately started, but result from auto-combustion of accumulated methane gas. The Municipal authorities also collect solid wastes from hotels outside their municipal boundaries, to be disposed of in the open centralised disposal sites. Industrial solid wastes are similarly disposed of in Municipal dump sites. Outside the towns, domestic wastes are often buried in pits, or burnt off.

Mombasa has been a port of call for vessels plying the Indian Ocean routes for many hundreds of years. The increased traffic has raised the risks of pollution that could arise from normal ship operations, and also from ships that accidentally run aground at the narrow entrance to Mombasa harbour. Oil tankers have particularly posed a threat to plant, bird, fish, and human health and well-being when they have spilled their cargo. More frequent are tar balls that wash up on the beaches, presumably from illegal cleaning up of vessels in the open sea. The environmental health task force of the Kenya Ports Authority has limited capability to police and to respond to individual pollution cases. It will require more human and material resources to be able to adequately prevent pollution through formulation and enforcement of policies and regulations that address the unique situation of the Kenyan Coast.

Imported crude oil is refined at the Kenya Petroleum Refineries plant in Changamwe, and thereafter pumped in the oil pipeline to Nairobi (currently being extended to Eldoret and Kisumu). The storage tanks built for receiving crude oil have ruptured at least once in 1988, spilling millions of litres of crude oil into the Kipevu Creek. At that time, the lack of established emergency procedures resulted in the destruction of many mangroves in the creek. Six years later, there are barely signs that the mangroves will regenerate. So far, the refinery as such has had a relatively safe operation record, and there have also been no reported leakages along the pipeline, which passes through some densely populated areas, as well as throughout the Tsavo National Park. More common are oil spills along the roads and railway lines from overturned road and rail tankers along the route between Mombasa and Nairobi. Further, since Kenya still uses leaded petrol, it is to be expected that in urban centres, and close to the main roads, lead pollution of soils and the air is a significant problem (Kunguru & Tole 1994).

Although groundwater pollution from oil leakages has not yet been reported, this problem is expected to feature in the coming years, as more people withdraw greater amounts of groundwater; as underground storage tanks of many petrol stations age and start to leak; and as surface spillage increase. This would particularly be an important problem in and around the population centres of Mombasa, Malindi and Diani/Ukunda. The highly porous nature of the underlying coral limestone formations will make it easy for leaking oil to enter the groundwater system.

In both the rural areas and the towns, sewage disposal is mainly by use of pit latrines, although septic tanks are also used. Only a small proportion of the population in Mom-

basa (17%) is connected to a centralised sewage treatment system, which has a primary waste treatment capability only. Other towns lack reticulated drainage systems with centralised treatment facilities. This means that the danger of contamination of groundwater systems is always present. The problem is particularly made acute by the shortage of piped water, which obliges the majority of residents to rely on untreated surface water (rivers, streams), boreholes, springs or wells. There are water and sanitation projects in Kilifi and Kwale, which have placed great emphasis on provision of water from boreholes, wells and springs. Recent studies have shown that some of the groundwater sources developed through these sanitation projects are heavily contaminated with sewage and sea water (Mzuga *et al.* 1998; Anyango *et al.* 1998; Mwaguni).

Some tourist hotels are targeting the ecotourism market and have developed environmental guidelines both for their in-house operations and for their clients' observance. The Severin Sea Lodge, for example, has a full-time environment manager and emphasises conservation of energy, water and nature in general, as well as recycling of wastes. The hotel has its own sewage treatment facility on its premises. Solid waste that is not properly disposed of (e.g. plastic bags) is not only an eyesore, but, when blown by wind into the sea, poses life threatening danger to fish and other marine life that may ingest it. Bacteriological contamination of oysters by waste outfall has been reported in Dar es Salaam, but similar studies are lacking for the Kenyan Coast.

CONCLUSION

The Kenya Coast is a vulnerable region, with a great variation in local, physical environments. There is pressure from (-) increasing population (higher pressure on the land, both cultivation and livestock), (-) tourism (all kinds of environmental problems along the seashores), and (-) external causes (rivers, harbour activities). Some environmental problems are not specific for the coast (soil erosion, pollution as such), but others are. The latter are related to tourism and concern e.g. coral reefs. It is difficult to tackle the problems, even though awareness is increasing, for the following reasons: lack of knowledge and a need for scientific research (the start of the Coast Environment Research Station of the School of Environmental Studies of Moi University is a positive development in this respect.); lack of funds; too much money is invested in tourist facilities, at the cost of local development; lack of juridical regulations and otherwise lack of 'implementation capacities'; and, finally, mismanagement and corruption.

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