

PUBLIC HEALTH PROBLEMS
IN
MOMBASA DISTRICT

A CASE STUDY
ON
SEWAGE MANAGEMENT

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(Reg. No. C50/P/8938/99)

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A Project report submitted in partial fulfillment of the requirements of
the degree of Master of Arts in Environmental Planning and
Management

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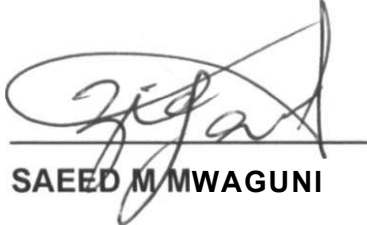

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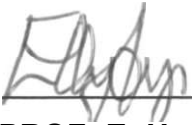

April 2002

DECLARATION

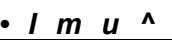
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DEDICATION

This project report is dedicated to my children Hamisi, N'kweli and Anisa, who, I urge, to make the best positive use of their formative years before the demands of adulthood take their toll; and to remember that,

Blessed be youth, for its energy and determination.

" Where others flinch, rash youth will dare!"

I pray to God Almighty, to bless them, and to illuminate to them, His guiding candle of hope in their hearts; to understand the life-long challenges that face mankind, and to appreciate why I was a student in their time. May they be blessed with wisdom to know that all of us, irrespective of our ages, are students of the world, "cherishing the search for knowledge and renewal" for the successes of humanity.

Amen!

ACKNOWLEDGEMENTS

Many people have contributed towards the successful conclusion of this study in one way or another. Though it may not be practicable to thank each by name, I appreciate the various contributions made.

This notwithstanding, special thanks go to Professor Elias. H. O Ayiamba and Ms A. B. Rego, for entertaining and encouraging my ideas of undertaking a study on sewage management, shaping them to a focused research topic and supervising the study. Thanks are also extended to Dr. E M Irandu, Chairman, Geography Department, for taking personal interest in the study topic. Mr. J K Musingi arranged the logistics during the entire course programme, for which I extend my gratitude.

Secondly, I extend my thanks to the Assistant Government Chemist, and the District Water Chemist, both of Mombasa, for making available their laboratory facilities and technologists, to work with me to generate the data on water microbiology presented in this report. Mr. Mohamed Mwaita of the Mombasa Municipal Health Information Systems is acknowledged for providing the data on water related diseases, while Mr. Harrison On'ganda of KMFRI ably drew the maps presented herein.

The Board of Management of the Coast Development Authority (CDA) is acknowledged for the support it gave both material and otherwise, which enabled the successful completion of the course programme, culminating with this final report. The chief executive of (CDA), Professor Juma A Lugogo deserves special thanks for tolerating my unstable presence at work during the entire duration of the course of study.

Finally, I want to make a mention of some special individuals who had direct input to my pursuit for further education. First I would wish to thank Dr. Swazuri, for

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supporting the many days of my stay in Nairobi, without which, my stay would have been unbearable. The second special thanks go to my wife and children, I salute them for the endurance they took with courage, accepting to stay alone during the long periods of my absence from home. This gave me the peace of mind required to concentrate on the rigours of postgraduate work, and to which, I am very grateful. Finally, I wish to thank my parents for the encouragement's they gave me, and may God Almighty bless them to live long, to reap the benefits to arise from this work. *Insha-Allah!*

PUBLIC HEALTH PROBLEMS IN MOMBASA DISTRICT

A Case Study on Sewage Management

ABSTRACT

This study presents the public health problems of concern in Mombasa District through a case study on sewage management, where urbanization has increased the demand for infrastructure and services. The population has doubled in the last 15 years; creating pressure on the existing sewage infrastructure leading to water pollution and the onset of sewage related diseases. The waterborne sewerage in use is old and dilapidated, while the on the site sanitation facilities are not satisfactory. Inadequate sewage management is thought to be responsible for freshwater contamination leading to diseases like typhoid, cholera, diarrhoea and malaria that afflict many residents.

This study has been undertaken on recognition that sewage is a major land-based source of pollution affecting human and ecosystem health, (GPA, Washington, 1985). It is also recognized that only 10% of urban wastes in developing countries receives treatment, (Rio Earth Summit, 1992), which affirms the assertion that sanitation problems in Mombasa have been linked to the poverty condition in the area, (Mombasa Municipal Council, 1997). Sewage pollution also undermines the tourism industry. Finally it has been noted that the decline in water quality in Mombasa, is a major coastal resource management issue. This makes the study worthy undertaking.

Munga et al. (1993), studied the sources of pollution to the marine environment from land based activities. Skanda and Mwanguni, (2001) studied the innovations by the beach hotels in sewage management, but no meaningful studies have attempted to understand the problem of sewage management. This study therefore attempts to fill this gap by exploring the sewage management infrastructure and practices, observing the impacts of sewage on air, vegetation,

and on the soils. The impacts on the marine and groundwater sources are also investigated, so is the extent of sewage related diseases. Strategies that could offer solutions to the problems have been proposed.

Visits to areas affected by sewage have been made and interviews conducted with stakeholders in a bid to understand the problem. Water samples were taken from boreholes and wells, from the creeks and in the lagoons, for analysis in the laboratory to check for sewage contamination. Medical records have been inspected for records of sewage related diseases. Library searches were conducted as a prelude to the exercise.

The scope and limitations of this study hinged on the constraint of time, which limited comprehensive investigations. For this reason, it was not possible to carry out the study to reflect the condition over a more reasonable time scale for trend analysis on the problem. Nevertheless despite the constraint, the study accomplished the intended purpose of providing indicator results of pollution that are presented in this study.

The study found that the sewage infrastructure is inadequate to serve the ever-increasing population. While the population has grown over the years, the infrastructure has not. In some cases, the existing infrastructure was found to be inappropriate. The on-site sanitation methods ranged from good, fair to worse, depending on the settlement types. It was poor in the slum areas, but take good care of in the other habitations.

The sewage management in Mombasa is still offered as a social service, a situation that is not sustainable. Cost recoveries if any, are inadequate to cover operational costs, leading to inadequate sewage management, resulting in impacts at the disposal site, on both fresh and marine waters. Groundwater quality is below safe levels for drinking water, with over 50% of all the public

health problems in the district being water related, as evidenced by the frequent occurrence of such diseases like cholera, diarrhoea, dysentery and malaria.

To address the problems, there is need for political commitment and public awareness, institutional arrangement and legislative framework supportive of sewage management, and technical options that adopt affordable sewage treatment technology, technology transfer and the promotion of re-use of sewage effluents. Financial arrangements that emphasize community financing in sewage management have also been suggested.

TABLE OF CONTENTS

PUBLIC HEALTH PROBLEMS IN MOMBASA DISTRICT	PAGE
DECLARATION	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
ABSTRACT	vi
TABLE OF CONTENTS	ix
List of Figures	xiii
List of Tables	xiii
List of Maps	xiv
List of Plates	xiv
ABBREVIATIONS AND ACRONYMS	xv
CHAPTER 1: INTRODUCTION	1
1.1 Overview	1
1.2 Statement of the study Problem	3
1.3 Objectives of the Study	5
1.4 Literature Review	6
1.5 Significance of the Study	12
1.6 Conceptual Model Framework	15
1.7 Scope of the Study ^	18
1.8 Structure of the Report	18

CHAPTER 2: THE STUDY AREA	21
2.1 Position and Size	22
2.2 Topography and Geology	22
2.3 Climate	23
2.3.1 General Climatic Type	23
2.3.2 Rainfall	24
2.3.3 Temperature	24
2.3.4 Humidity	24
2.4 Population, its Distribution and Density	26
2.5 Water Supply	28
CHAPTER 3: METHODOLOGY	29
3.1 Sampling Framework	29
3.2 Data Collection	29
3.2.1 Primary Data	30
3.2.2 Secondary Data	30
3.3 Techniques of Analysis	30
3.3.1 Techniques for the Analysis of Water	31
3.3.2 Microbiological Indicators of Sewage Pollution	31
3.3.3 Sampling	33
3.3.4 Materials and Methods	33
3.3.5 Interviews	34
3.3.6 Survey of Medical Records	34
3.4 Problems in Data Collection	35
CHAPTER 4: MAIN FINDINGS	36
4.1 The Sewage Management Infrastructure	36
4.1.1 Mombasa Island Division	36
4.1.2 Changamwe Division	38
4.1.3 Kisauni Division v*	40
4.1.4 Likorii Division	40

4.2 The distribution of Sewage Management Systems	
In Mombasa District	41
4.3 The Status of the Individual Sewage Management Systems in the	
Various Settlements	43
4.3.1 Low-cost, high-density Settlements and Informal Settlements	43
4.3.2 Middle-cost, high-density Settlements	46
4.3.3 High-cost, low-density Settlements	47
4.3.4 The Beach hotels along the Kenya Coast	48
4.3.5 Others	52
4.4 The Sewage Management Practice	52
4.4.1 Sewage Management	52
4.4.2 Administrative Set-up	52
4.4.3 Technical Arrangements	54
4.4.4 Financing Mechanisms	55
4.4.5 Cost Recoveries	56
4.5 Environmental Impacts	57
4.5.1 Impact of Sewage at Disposal Site	57
4.5.2 Impact of Sewage on Groundwater	59
4.5.3 Impact of Sewage on Seawater	62
4.6 Impact of Sewage on Human Health	64
CHAPTER 5: CONCLUSIONS	67
5.1 Conclusions	67
5.1.1 Sewage Infrastructure	69
5.1.2 The Sewage Management Practice	69
5.1.3 Environmental Impacts	71
5.1.3.1 Impacts at the disposal site	71
5.1.3.2 Impacts on groundwater	72
5.1.3.3 Impacts on seawater	72
5.1.4 Impacts on Public Health	73

CHAPTER 6: RECOMMENDATIONS	74
6.1 Short-term Actions	74
6.2 Long-term Actions	75
6.2.1 Political Commitment and Public Awareness	75
6.2.2 Institutional Arrangements and Legal Framework	76
6.2.3 Technical Options	77
6.2.4 Financial Arrangements	79
6.2 Areas for Further Research	80
BIBLIOGRAPHY	81
APPENDICES	84
Appendix 1: Environmental Management and Coordination Act, 1999 -Part II; General Principles	84
Appendix 2: List of Interviewees	86

LIST OF FIGURES

Figure 1: The Composition of Sewage	6
Figure 2: Access to Safe Drinking Water and Sanitation Services in Developing Countries, Population served and unserved	8
Figure 3: Conceptual Model Framework of the Relationship Between Public Health Problems and Sewage Management Issues in Mombasa District	16
Figure 4: Temperature, relative humidity and rainfall averages for Mombasa 1989-1999	25

LIST OF TABLES

Table 1: Cost Range per Capita for On-site and Sewered Options	9
Table 2: Monthly average Temperature, relative Humidity and Rainfall for 1989-1999	25
Table 3: Demographic Distribution in the Study Area	26
Table 4: Changamwe Treatment Works- Areas and Population served	38
Table 5: Distribution of Sewage Management Systems with Population in Mombasa	42
Table 6: Sewage Volumes and Characterization by Disposal system	42
Tables 7: Results of Bacteriological Examination of Groundwater	59
7a: Likoni Division	59
7b: Changamwe Division	60
7c: Kisauni	60
7d: Island Division	61
Tables 8: Results of Bacteriological Examination of Seawater	62
8a: Tudor Creek	62
8b: Kilindini and Port Reitz Creeks	63
8c: Mtwapa Creek	63
8d: Lagoon along Nyali-Bamburi-Shanzu Beach Hotels	63
Tables 9: Out Patient Morbidity in Mombasa district- 1998, 1999 & 2000	65
9a: Out Patient Morbidity 1998	65

9b: Out Patient Morbidity 1999	65
9c: Out Patient Morbidity 2000	65

LIST OF MAPS **21**

Map 1: The Location of the Study Area	21
Map 2: Sewerage Network in the Island Division	37
Map 3: Sewerage Network in Chagamwe Division	39
Map 4: Location of Informal Settlements in Mombasa District	45
Map 5: The Distribution of the Major Beach Hotels along the Kenya Coast	50

LIST OF PLATES

Plate 1: Sewage Treatment Plant, Severin Sea Lodge	51
Plate 2: The Official Municipal Solid Waste Dumping Site at Kibarani	58

ABBREVIATIONS AND ACRONYMS

APHA	American Public Health Association
AWWA	American Water Works Association
CBD	Central Business District
CDA	Coast Development Authority
EMCA	Environmental Management and Coordination Act, 1999
FAO	Food and Agriculture Organization
GOK	Government of Kenya
GPA	Global Programme of Action on Municipal Wastewater
GTI	Government Training Institute
HIV	Human Immuno-deficiency Virus
IMS	Institute of Marine Science
KMFRI	Kenya Marine and Fisheries Research Institute
KPLC	Kenya Power and Lighting Company
KPA	Kenya Ports Authority
KR	Kenya Railways
KWS	Kenya Wildlife Service
MEWA	Muslim Education and Welfare Association
MITC	Mombasa Industrial Training Center
MSA	Mombasa
MNP	Most Probable Number
NWCPC	National Water Conservation and Pipeline Corporation
TDS	Total Dissolved Solids
UN	United Nations
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational Scientific and Cultural Organization
WCC	World Coasts' Conference
WHO	World Health Organization
WCED	World Conference on Environment and Development
WPCF	Water Pollution Control Federation
WRI	World Resources Institute

CHAPTER 1

INTRODUCTION

1.1 Overview

Urban centers all over the world are areas of rapidly increasing numbers of the human population and various socioeconomic development activities. It is estimated that half the world population lives in urban centers within 100 kilometers of the coast (Weber 1993). This translates to about 3 billion people. Urbanization, which took place in the last century in much of the developed countries of Europe and America, is a growing phenomenon in the developing world. Its rate has risen from 25 percent to 50 percent in the last 30 years (WRI 1998, World Bank, 1992). Moreover, it is observed that most of the largest urban centers are developing in coastal areas (*ibid*). This is because of the attraction of maritime transport, which allows major industrial activities to take place profitably in coastal towns worldwide. It is now acknowledged that 70% of all pollution to the marine environment emanate from land based activities (UNEP 1984), with domestic sewage, being an area of major concern.

The discharge of large amounts of wastes, from such sources as domestic sewage, industrial wastes, coastal urban and agricultural run off, and river discharges (*ibid.*) lead to pollution, threatening basic natural resources like water, stressing ecosystems and causing many water-related diseases. In many cases, it is now being appreciated that nature is becoming unable to cope with the pollution pressures and that it is now increasingly and negatively impacting on the resources upon which, our livelihood and a number of economic activities depend. With strong, sustained growth in the world population, increased urbanization and burgeoning economies, we are likely to see even more critical impacts on various resources including water.

For centuries, the oceans have served as bottomless sinks for our domestic wastes and those wastes of our commerce and industrial activities. The vastness of the oceans was assumed to be large and with an inexhaustible capacity to dilute whatever wastes we discharged therein. Reality has dawned now that "despite their size and imperturbable appearance, the oceans are vulnerable to the same unsustainable trends that are degrading the terrestrial environment" (Weber 1993)

In modern times in waste management, human genius has discovered new alternative repository sinks for the discharge of the wastes generated. The innovation involves the use of underground-deep ditches, septic tanks-soakage pits, pit latrines as well as aqua privies. This innovation sends polluting materials underground, out of sight, and out of mind, but with emerging consequences.

In the underground are to be found valuable freshwater resources that are essential for our livelihoods and provide life support for the systems that maintain the environment healthy to sustain our socioeconomic activities. The wastes of our commerce, industry and urbanization therefore lead to pollution and the deterioration and decline in quality of water resources to a point where useful functions and services of the water are lost.

Clean freshwater and access to it, are key factors that limit the potential for development and economic growth, because water is essential for human health and welfare, as well as for agricultural, and industrial production (Poverty and the Environment, UNEP 1995). Clean oceans support fisheries and tourism, both of which are important sectors in the economies of many nations. Pollution also has linkage to many important concerns, the most important of which include freshwater shortage, habitat modification and global climate change. These concerns result into the attendant issues of health impacts and economic downturns.

*

The array of causes to declining water quality is a large subject requiring an independent study. However, while not all the causes leading to the decline of water quality can be studied under this research, the overall concept of water pollution and public health concerns due to poor sewage infrastructure and management is its primary interest and focus.

1.2 Statement of the Study Problem

Urbanization concentrates and increases demand for infrastructure and services. The demand for infrastructure to manage domestic sewage is one of them. In the absence of adequate infrastructure, urbanization aggravates environmental and health problems particularly for the poor (WHO 1992). Currently, 43% of the world population is urban. This includes 75% of the population for developed countries and 51% in developing countries (UNEP 1995). UNCED's Agenda 21, Chapter 17, suggests that up to three-quarters of the world's population could be living within 60 kilometers of the shoreline by the year 2020. World Bank experts suggest that two thirds of the population of the developing countries (3.7 billion), is expected to be living along the coast by the end of this century (World Coast Conference, 1993) Urban population in developing countries is growing much faster than in developed countries. From 1950-1990, the urban population in developing countries increased by 1.97 billion people compared to 430 million in developed countries. The annual growth rate of the population in the late 1980's being 3.8% compared to 1% for developed countries. Case studies show that 30-60% of the population in large cities, lives in illegal settlements with no infrastructure or services to manage wastes (UNEP 1995). Thus where infrastructure is least available, like in the cities of the developing countries, we see that population growth is highest.

Most of the Mombasa municipality presents an urban setting, hosting a large urban center in the city of Monibasa that has seen its population double in the last 15 years (Republic of Kenya, 1999). Its population growth rate (at 4%) is

higher than that for the coast province (at 3.1%) and that for the country (at 2.9%) (UNEP/FAO/PAP/CDA 2000). Mombasa town has a population density of 280 persons per square kilometer -the highest for any town in Kenya, exerting massive pressure on the already inadequate infrastructure making sewage related diseases to be issues of public health concern.

The water-borne sanitation systems in operation in the district are old, constructed long before independence, to serve the privileged few, when the districts' population was well below 179,000 people (1962 Population Census). The sewers were designed to serve only one-third of the Island division, leaving two-thirds of the same and the rest of the divisions to rely on septic tanks and pit latrines. Though Changamwe division was later considered for the sewerage services very little has been done.

The district therefore lacks proper and adequate facilities to handle sewage with disastrous consequences to public health. Lack of adequate sanitation facilities is causing the contamination of water supplies leading to infectious diseases like typhoid, cholera, diarrhoea, and the wastewater related diseases like malaria.

In most sewage pollution problems, people are not aware that co-operation is needed among them. As soon as residents of a neighbourhood has sewers installed and their local waste flushed away to a downstream neighbourhood; it becomes someone else's problem and no longer their own. This imposes costs on the downstream water users instead of on the polluters, creating an externality. The polluters are usually reluctant to remedy the situation in part because they do not see the problem (UNEP 1995). Thus, reliable data, communication and education are needed to overcome the sewage management problem.

With proper understanding of the benefits to be earned through adequate sewage management, local authorities can be convinced to commit more

resources to its management. Action is thus required in this area. Hence, this study sets out to generate some of the required information to aid the direction on sewage management through the objectives that follow.

1.3 Objectives of the Study

This study looks at the municipal wastewater management in Mombasa, which includes sewage in relation to the growing paradigm that sewage is largely responsible for various public health problems afflicting the people. The paradigm acknowledges the link between many of the public health problems that occur in the district to improper sewage management, through the contamination of both the marine and freshwater sources, resulting in diseases associated with the water use and or contact.

The study examines the extent of spread of the public health problems associated with sewage to raise community responsibility and help to generate the will and interest for holistic participation to address the inadequacies and shortfall that exist in the sewage infrastructure and management practice. Through the study it is hoped to generate sufficient awareness among the public to create a win-win situation to support efforts to participate in sewage management.

The research objectives are: -

- (i) To evaluate the sewage management systems and practices;
- (ii) To observe the impact of sewage sludge on air, vegetation and soils;
- (iii) To investigate the impacts of sewage on groundwater and seawater resources;
- (iv) To determine the extent of sewage related disease, and
- (iv) To recommend strategies and solutions that would address the negative effects of improper sewage management.

v

A literature review is now made to understand the subject.

1.4 Literature Review

The literature review attempts to give an overview of the world efforts in addressing the sewage management problem. The review does this by first giving background information on sewage and then moves on to present the world efforts that have been expended in addressing the problem. A task, that is now attempted.

Sewage is the wastewater of a community. It may be purely domestic or may contain in addition, some wastewater of industrial or agricultural origin or urban run-off. Domestic wastewater is composed of human body wastes (faeces and urine), which is at times called black water. It also contains sullage, which is that component of wastewater resulting from personal washing, laundry, food preparation and the cleaning of kitchen utensils, which is at times called grey water. The composition of sewage is as given in figure 1 below.

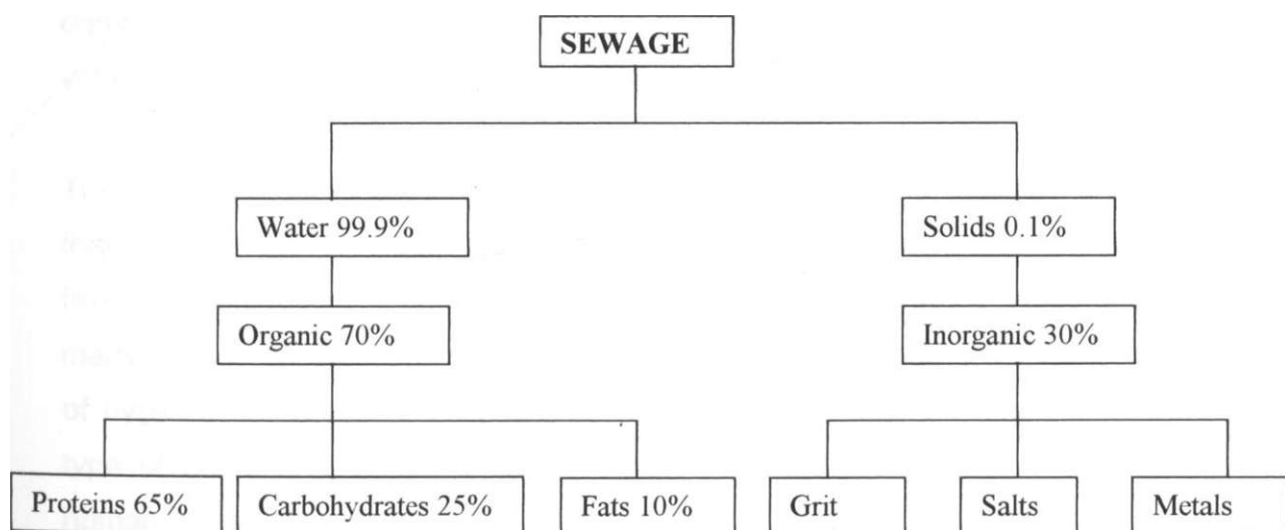


Figure 1: The Composition of Sewage

NB: As reflected in the figure, sewage is essentially almost wholly organic in nature and therefore open to complete oxidation by bacter[^]. the advantage of which is taken in the biological treatment process of this kind of waste.

Fresh sewage, is a grey turbid liquid of an earthy but inoffensive odour. It contains both large and small floating or suspended solids as well as colloidal suspension and pollutants. It is generally objectionable in appearance and extremely hazardous in content, because of the number of disease causing organisms (pathogens) it may contain. In a hot tropical climate like ours, the sewage soon loses its dissolved oxygen content to become septic and produce the offensive characteristic odour of hydrogen sulphide.

Faeces and, to a lesser extent, urine contain millions of intestinal bacteria and a small number of other organisms. The majority of these are harmless; indeed some are even beneficial. Sullage, the other component of domestic water, contributes a wider variety of chemicals in wastewater.

The strength of sewage is determined by the concentration of waste matter it contains. The higher the concentration, the stronger is the sewage said to be. The strength is conventionally judged by the biological or chemical oxygen demands it imposes onto receiving water bodies. In general terms, the higher the volumes of water a community consumes, the weaker the sewage produced.

The important disease causing bacteria commonly found in sewage are those that causes intestinal diseases e.g. cholera, dysentery, typhoid, paratyphoid fever and diarrhoea. These pathogens are infective and hence responsible for many deaths annually worldwide. Poor sanitary conditions and the general lack of hygiene encourage the spread of these diseases. The presence of coliform type of bacteria in water, is an indication that contamination of the water by human faeces has occurred.

Domestic wastewater, which includes sewage, is generated in the neighbourhood of houses, shops, and small factories, in hotels and ships. In urban centers, and cities, if they can afford, the sewage is managed through water-borne sewerage and discharged to receiving water bodies.

The sewage a community produces is treated before disposal in order to reduce the spread of communicable diseases caused by the pathogens present in the sewage, and to prevent the pollution of water resources.

Awareness exists on the significance of the sewage pollution problem worldwide. In the developed world, significant efforts have been made to control water pollution, but not so in the developing world. This is so, because, addressing the pollution problem requires substantial investments and intensive, long-term cooperation among many stakeholders. As a result of this, too little has been done in the developing world relative to the task. In developing countries, for example, the supply of drinking water enjoys a far higher priority than wastewater management. It is no wonder then that even after the International Drinking Water Supply and Sanitation Decade (1981-1990), the disparity in the two is still very monumental (UN, 1997). See Figure 2 for comparisons.

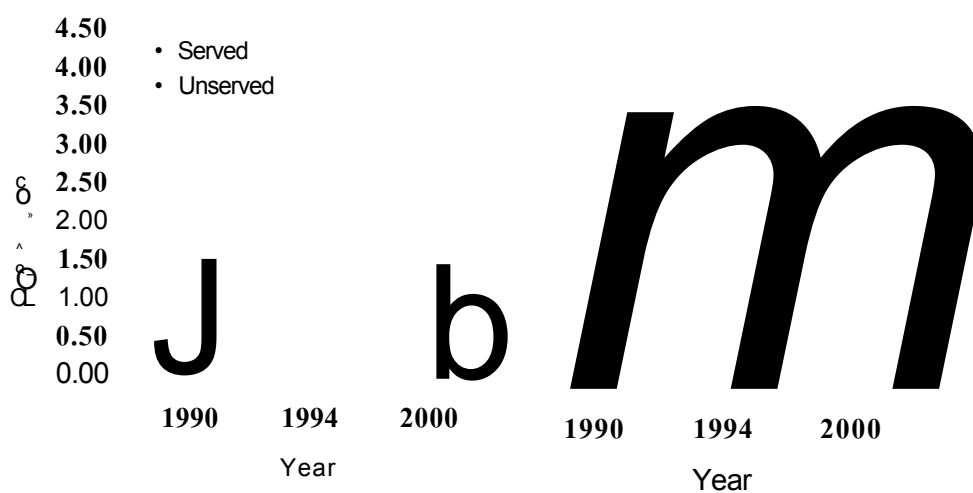


Fig 2a: Safewater

Fig. 2b: Sanitation

Figure 2: Access to safe drinking water and sanitation services in developing countries, population served and unserved: 2a) Safe drinking water, 2b) Sanitation

Slow growing awareness, technical complexity, and the high cost of wastewater management are the main reasons it took several decades for the rich industrialized nations to take effective action. Developing countries face a heavier burden because they have fewer resources and weaker institutions (UN, 1997). But the main constraint to addressing the sewage problem comes about because it is not a problem we can vividly see and easily appreciate; secondly, is the cost element involved in the treatment, which is usually very prohibitive. The second key constraint to addressing sewage pollution is the cost involved. Table 1 demonstrates that even in countries where labour and materials are cheap, the continued cost of addressing the pollution can be prohibitive.

Table 1: Cost Range per Capita for on-site and sewerred (with conventional treatment) options (Kalbermatten et. al. 1982, Alaerts et. al. 1990).

Economy	Option	Capital cost (US\$ per capita)	Total cost (Capital + Operation & Maintenance) US\$ per capita per year
Low-income economics	On-site sanitation	10-100	3-10
	Treatment Plant ¹	20-80	5-15
	Sewer + Treatment ¹	200-400	10-40
Middle-income and transitional economies	Treatment Plant	60-80 ²	.
		30-50 ²	.
	Sewer + Treatment	300-500 ²	30-60 ²
Industrialized countries	Treatment plant	150-300 ²	.
	Sewer + Treatment	100-200 ³	100-150 ³

For primary plus secondary treatment, including land purchase and simple sludge treatment, for a capacity of 30, 000-40, 000 persons. Lower values pertain to low-cost options, such as waste stabilization ponds; higher values pertain to mechanized treatment, such as oxidation ditches and activated sludge treatment plants

² for plant capacity of 100, 000- 250, 000²persons

³ for industrialized countries, this includes tertiary treatment and full sludge treatment; for other countries, this includes basic secondary treatment

Experience has shown that wastewater collection and treatment tend to be two to three times more expensive than the costs to extract, treat and distribute tap water for potable purposes. In addition, the costs to operate and maintain sewage collection and treatment systems are often higher than the annual depreciation of the capital investment in the infrastructure. Treatment plants consume a lot of energy, generate excess sludge that requires sophisticated equipment to manage and demands well-trained operators and engineers to run.

Despite all this, the global thinking is that wastewater management is possible even in the developing countries with limited resources. What are required are candid strategies and priorities. The argument posed is that, in urban centers, wealth is much higher than average, especially in the large cities. Thus local governments can have the resources available to address the problem. Secondly, mixed strategies that apply low cost on-site sanitation, waste minimization, and some conventional sewerage can significantly reduce costs. Thirdly, important efficiencies can be attained and costs reduced by integrating wastewater planning more with that of other sectors, by taking a longer-term planning approach, investing step by step, and by ensuring stronger support from citizens.

In order to achieve the above, the Global Programme of Action recommended on the following: -

- To adopt strategies and policies that are demand driven, opportunity driven and integrated.
- To adopt technical options that include the choice of the most appropriate technology and to consider the waste as a resource.
- To opt for institutional arrangements that includes public participation and new partnerships with the private sector and water users.
- To create financial options that includes private capital and public-private partnerships.

It is thus concluded that opportunity and ample scope exists for targeted and effective wastewater management programmes, spread out over longer periods of one or more decades.

Presently, the world attention is focusing on the problem of municipal wastewater management. This is as attested by Global Programme of Action (GPA), on Municipal Wastewater (GPA Washington, 1985). The "Regional Workshop on Implementation of the GPA in Eastern Africa" (Zanzibar, October 1997), also identified sewage as the major land-based source of pollution, affecting both human and ecosystem health in the region and requested UNEP to give priority to the problem (UNEP 2001).

In response to the requests, a Strategic Action Plan on sewage to address the wastewater problem has evolved. The Strategic Action Plan is in dire need of information to be able to plan for the actions to be taken in addressing the problem.

Unfortunately, in Kenya, only a handful of sewage related research studies have been undertaken. The extent of contamination of the Kenyan coastal waters and estuaries within Mombasa district is yet to be comprehensively investigated. Only sporadic studies have been carried out. Munga (1985) investigated the contamination of fish by chlorinated pesticides (DDT and endosulfan) from the Tana River, which discharges into the Indian Ocean. The Government of Kenya (1975) studied the extent of contamination of seawater and on bivalves from the creeks around Mombasa for heavy metals. Onyari (1985), and Oteko (1987), studied the levels of heavy metals in fish (from the Mombasa market), and sediment from the Tudor creek. The seasonal variation of nutrients in the Kenyan inshore waters was studied by Kazungu et al (1989). Munga et al. (1993&1997), again studied the sources of pollution to the marine environment from land based activities, covering investigations on industrial, domestic, tourism and shipping sources of pollution and their impact to the marine and coastal environment.

Mwangi et al (2000) studied the contamination of seawater by sewage in the Mombasa Marine National Park and Reserve, (refer to the Map of the Study Area, Map 1). School J. and Visser, N (1991) studied the impacts of tourism along the Kenya coast, and cited the problem of sewage management as one of the areas of concern to tourism development. Fredrick Mpendazoe (UNEP, 2000), made an overview of the socio-economic opportunities related to sewage management in the coastal urban centers of the Eastern Africa Region. Skanda et al. (2001) studied the innovations on sewage management by the tourist beach hotels in Kenya.

Sewage has impacts both to the environment and to human health if not managed properly. As reported in the Kenya Population Census-1989 Analytical Report on Child Mortality, the proportions of children dead was directly related to the various sources of drinking water. The drinking of sewage-contaminated water, was one such cause of the deaths. According to the Economic Survey of 1996, the mortality rate in Mombasa was 60/1000 for infants under one year. The national average was 66/1000. These mortalities were related to poor sewage management. Malaria, which is a wastewater related disease, was the major cause of the death among children between the ages of 1-5years. It killed 107/1000 children, and accounted for 19% of all hospital admissions, out of whom, 5.1% succumbed to the disease and died. Mr. Abdulkadir, the Chief Public Health Officer, of the Mombasa City Council, alludes that the presence of thick bushes in Kisauni and Changamwe divisions, contributed immensely to the mosquito menace. So, what is the significance of the study?

1.5 Significance of the Study

In the past, and for a long time, population densities were low; the economies were rural, and this, kept pollution localized, preventing it, from spilling over into the wider environment. Today, due to urbanization, the large volumes of waste generated within the confines of the urban centers have to be dealt with. Though

treatment is anticipated before the discharge takes place, the reality is that it is not, particularly in the developing countries. The treatment process is simply not affordable to them, and the wastewater, including sewage is discharged into the receiving environment without treatment. Water pollution by sewage has thus become the result. This scenario has triggered international calls for action on wastewater because of the effects of pathogens present in the sewage on global food chains, on human health and the potential for disruptions of ecosystems. This makes the study significant.

It is acknowledged that there is a significant number of sewage related problems in urban centers, posing significant threats to the aquatic environment and risks to public health, which is further proof for the significance of undertaking the study ((GPA, Washington, DC (1995) and UNEP (1996-8)).

Seven regional workshops of government-designated experts held between 1996 to 1998 under the framework of the United Nations Environment Programme (UNEP), Regional Seas Programme, involving more than 60 mostly developing countries also asserted that action has to be taken on municipal wastewater discharges including sewage. UNEP Regional Seas Reports and Studies No. 9 of 1982 recognized that environmental health problems are related to among other factors, inadequate potable water supply, the absence of sewerage or poor sanitation facilities, urban congestion, and high incidence of parasitic and communicable diseases. The report recognized further that the above problems occur as a result of poor planning, inadequate operations, maintenance and management of sewage infrastructure. The report asked for joint research on the crucial problems of the human environment, and as one of its specific recommendations, emphasized on the need for studies to be conducted to bring out detailed survey information on the actual sanitary situation of the populations living along coastal urban centers. The study will therefore generate the information required to bridge the gap in knowledge on the sewage problem.

Similarly, during the poverty reduction consultation workshop (April 1996), the Mombasa City Council observed that one of the areas identified for action in poverty reduction was sanitation. Since it is acknowledged that poor sanitation promotes poverty situations, addressing the sewage management problem becomes a significant undertaking as one way of addressing the poverty situation in Mombasa.

The Island division of Mombasa district is served by an old and dilapidated centralized sewer system while the rest of the majority of the residents depends on on-site facilities. This has the implications of polluting the groundwater sources that the district relies on, impacting on the quality of the water for human consumption, and the spread of water related diseases. Diseases attributed to improper sewage management are a burden to many residents, impacting negatively on their productive economic activities, making it imperative to understand the situation in Mombasa.

Martha Mukira, a former Mombasa District Fisheries Officer, is worried that sewage could be polluting the fishing grounds in the creeks.

It is therefore significant for the study to be undertaken to try to trace the source of the coliforms for effective management of the sewage. The limited scope of information on the extent of contamination of the Kenyan marine environment with potential pollutants, makes it imperative that a comprehensive investigation be undertaken, with due impacts on human health and vulnerable ecosystems.

Tourism, the prime mover in the Mombasa and Kenyan economy, is dependent on good quality environment, plentiful supplies of freshwater and clean beaches. For this reason, the aesthetic value of the coastal freshwater and marine environment becomes important because it supports the tourism industry. Its quality attributes therefore must be assured.

Additionally, worldwide, the decline in water quality, both freshwater and marine has been identified as one of the coastal management resource issues (UNEP 1985). This makes it significant to appraise the situation in Mombasa

The issues to be studied under this project are therefore problems of concern and significance in the area. The information generated by the study should provide a useful basis for the drive and force to convince decision -makers to push for action on sewage, if they understand its conceptual framework.

1.6 Conceptual Model Framework

The study is conceptualized in Fig.3, where the causes of the sewage management problem are identified. The inadequacies in sewage management are then linked to the problem of microbiological pollution of water, which ultimately leads to the public health problems identified and their socio-economic impacts and implications.

In general, the microbiological pollution of water can result from a host of causes. Chief among which, can be improper discharge of sewage, animal waste, contaminated urban run-off, improper discharge of industrial agriculture waste and inadequately treated hospital waste. The one singled out by this study, as the immediate major cause of microbiological pollution is the improper discharge of sewage, which has been caused by inadequate sewage infrastructure and poor sewage management practice. These two proximate causes have resulted from the secondary deficiencies in regulation of sewage management activities and lack of enforcement of regulation. These two deficiencies have come about because of lack of education and awareness, poor governance and institutional failures, the deficiencies inherent in single sector bureaucracies and the lack of internalization of costs for sustainability in sewage management undertakings.

CONCEPTUAL MODEL FRAMEWORK OF THE RELATIONSHIP BETWEEN PUBLIC HEALTH PROBLEMS AND SEWAGE MANAGEMENT ISSUES IN MOMBASA DISTRICT

Public Health Problems

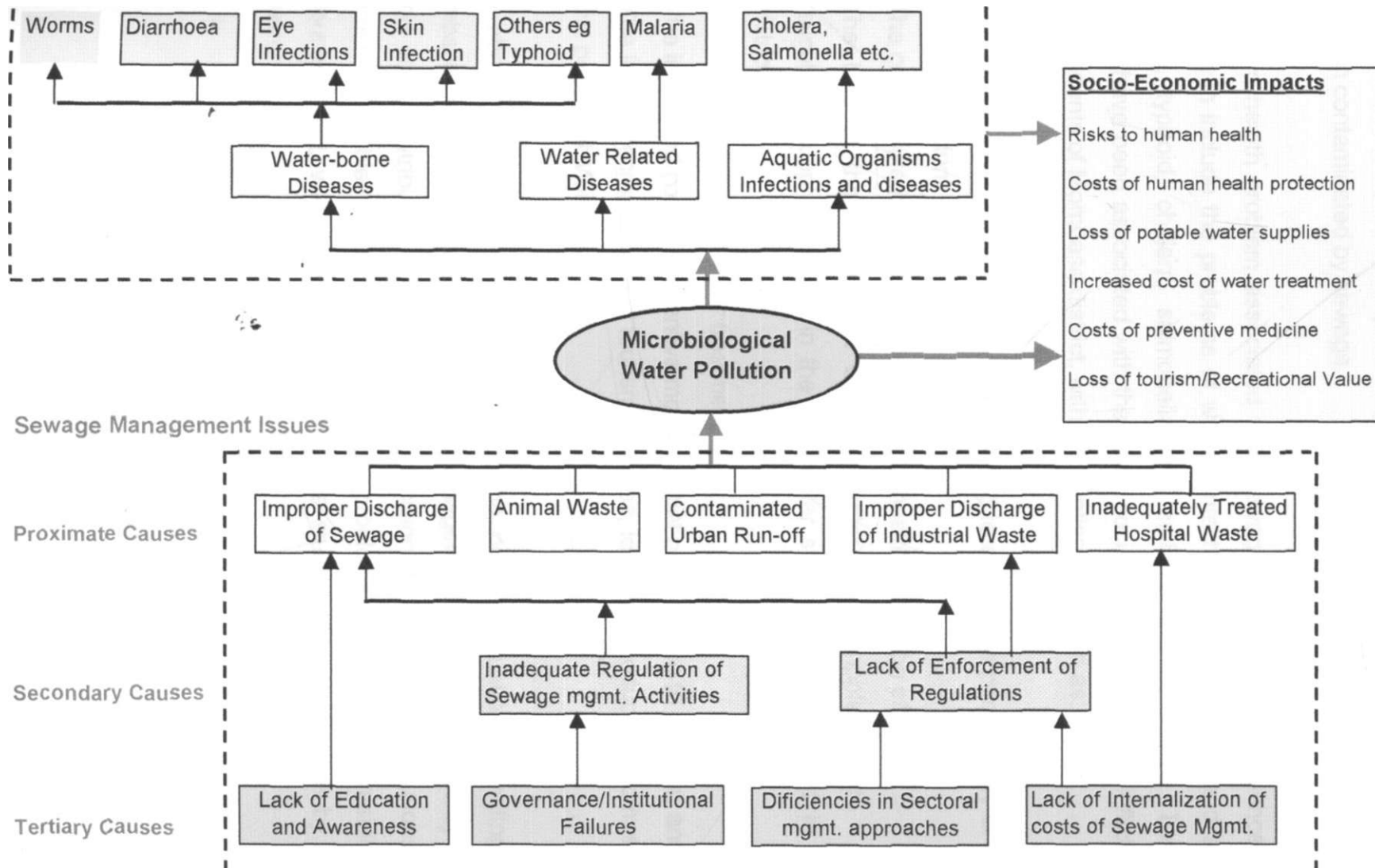


Figure 3: Conceptual Model Framework
Source: Researcher, 2002

As a result of these deficiencies, microbiological water pollution has occurred, resulting in water-borne and water related diseases, contracted through the drinking of sewage contaminated water, through contact with such waters, or through the consumption of aquatic organisms, like fish or the bivalves which have been contaminated by sewage.

The public health problem associated with sewage pollution of prevalence in Mombasa include the problems of worms infection, diarrhoea, eye and skin infections, typhoid, cholera, salmonella and malaria, among others. These diseases have been associated with the many socio-economic impacts inflicting many residents of Mombasa district, with the implications such as: -

- The human health risks people are exposed to due to the poor quality of the waters they drink or bath;
- The cost people incur as a result of human health protection efforts;
- The loss of the contribution of groundwater as a supplement to the reticulated supply resulting in the freshwater shortages experienced in the district
- The increased cost of water treatment;
- The increased cost of preventive medicine that people have to partake; and
- The loss of recreational and tourism activities, leading to reduced incomes for the people of Mombasa.

The above factors have been blamed for the poverty situation prevailing in Mombasa, which are traced to the sewage management issues discussed by this report as a contribution toward informed decisions in looking for solutions to address the problem and alleviate the social problems that Mombasa residents encounter. Next, we present the scope of the study to be undertaken by this research.

1.7 The Scope of the Study

This study has been confined to the research on sewage management as a source of water pollution and the resulting public health concerns. There are of course other sources that can cause water pollution such as industrial wastes, agricultural wastes, livestock waste and urban run-off, among others, which could lead to public health problems, but were not studied under the ambit of this project. This was because of the limitations of time and the level of the study asked for. Similarly, because the study only wanted to give indications of the sewage problem, the trend in pollution, covering the dry season, the wet season, or the differences in results in the seawater analyzed at either at high tides or low tides was also not considered. The number of people interviewed is also small. This, too, was because of the limitations of time.

1.8 Structure of the Report

Chapter 1 presents the overview to the study. It presents the statement of the study problem and its objectives. The literature review for the study is then given, followed by the significance of the study, the conceptual model framework and the scope of the study.

Chapter 2 presents the geographical layout of the study area, its position and size, topography, geology, climatic conditions, the demography and its distribution, and the water supply sources for the district. The implication of topography and geology to groundwater resources and attractions to human settlements is discussed so are the population figures, the distribution and the density of population contributing to the study problem from the individual divisions comprising the district. Water supply sources for the district are then given. The attributes of the sewage infrastructure in the various divisions and the types of settlements: high-cost/low-density, middle-cost/high-density, low-cost/high-density, informal settlements to slums is described. Land uses

classification for the various socio-economic activities and the implication of this to the crowding of human populations and sewage management is also explained in this chapter.

Chapter 3 presents the methodology used in undertaking this study. This comprised the search for both primary and secondary information. The search for primary information was done through the physical inspection of the condition of the sewage management infrastructure in the various settlements and the condition at the sewage disposal sites. Groundwater, from which residents supplement their freshwater supplies, and seawater from the fish spawning creeks and the swimming lagoon along the tourist beach hotels were then sampled and taken for microbiological analysis in the laboratory to obtain indications for sewage contamination. Interviews were carried out with residents, business people, visitors and hoteliers, to get a perception of their feelings about the sewage management problem. Further interviews were continued with the professionals in sewage management and from those mandated to manage the sewage in order to appreciate the problems encountered in its undertaking.

The primary search for information was complemented with survey of medical records from the local authority to obtain a record of the public health problems, their level of prevalence and impact to the people. Secondary information was sourced from various publications

Thereafter, chapter 4 presents the main findings of the study giving a detailed survey of the sewage infrastructure in the different human settlements, the beach hotels and other establishments. It presents the findings on the sewage management practice in Mombasa, and the role of the private sector on the issue. Findings on the financing mechanisms, costs and costs recoveries are also given. This is followed by the presentation of the findings on the impact of sewage at the disposal site and on water resources, which include both ground water and seawater. The Sewage related diseases impacting on human health

close this chapter on findings before the conclusions of the study are given in chapter five.

Chapter 5 draws the conclusions of the assessment on the sewage infrastructure, the management practice, and the impact of sewage on disposal sites, water resources and on human health and its socio-economic implications, before moving to chapter six for recommendations.

Chapter 6 presents a series of recommendations for appropriate and environmentally sound systems in sewage management and associated investments. The recommendations given are aimed at the decision-makers within local authorities and at national levels. The role of the private sector, possible financing and policy revisions are also presented. Finally, the areas for some further research are proposed.

The study area is now presented, with all its necessary attributes in the chapter that follows, to serve as a guide to the study and to focus the reader on the different localities, where the work was undertaken. This is necessary because it informs the reader of the importance of the study in the area.

CHAPTER 2: THE STUDY AREA

MOMBASA DISTRICT ADMINISTRATIVE BOUNDARIES



°-water sampling points

SOURCES OF INFORMATION

This base map is derived from the 1999 Kenya Population Census charts & the GIS coastal resources database at KMFRI

Data digitization and map composition: Pamela Ochieng, Phyllis Mutere, & Harrison Ong'anda

4 Kilometers

Scale 1:120,000

Mombasa, December 2001

2.1 Position and Size

The focus of this study is Mombasa district, one of the seven, and the smallest districts in the Coast Province with a total landmass of 229.6 square kilometers. It lies between the latitudes 3° 80' and 4° 10' south of the equator and between the longitudes 39° 60' and 39° 80' east of the Greenwich Meridian. It borders the Indian Ocean to the east, Kilifi district to the north, and Kwale district to the south and west. The district is made up the Island division, surrounded by a crescent shaped portion that comprises the Changamwe, Kisauni and Likoni Divisions to form the administrative boundaries. The district has an area of 65 square kilometers of open water. Refer to Map 1.

The Island division is the smallest and the most developed, while the three other divisions are rural in characteristics. We present the geology of the area next.

2.2 Topography and Geology

The district is situated in coastal lowland with extensive flat areas rising gently from 8 meters above sea level to 100 meters above sea level in the west. It can be divided into three main physiographic belts, namely, the flat coastal plain, which is 6 kilometers wide, and includes the Island division, Kisauni on the north mainland and Mtongwe to the south. Next, we find the broken, severely dissected and eroded belt that consists of Jurassic shale overlain in places by residual sandy plateau found in Changamwe division. Finally, we have the undulating plateau of sandstone that is divided from the Jurassic belt by a scarp fault (UNEP/FAO/PAP/CDA, 2000).

Nearer the sea, the land is composed of coral reef of Pleistocene Age that offers excellent drainage. The coral limestone and lagoonal deposit reach a thickness of 100 meters^ Along the coastline are to be found beautiful beaches, which

together with a variety of coastal resources and a rich biodiversity, has attracted tourists making Mombasa a favourite tourist destination.

Mombasa district has no permanent rivers, but due to the favourable geology of some parts of the district, the water table is high and the sinking of boreholes has led to the increased supply of water.

It is further observed that typical analysis results from the Government Chemist's Department indicate the following scenarios: -

- Ground water sources developed along the Beach hotels and the low-density high cost residential areas of Nyali, yield brackish water with total dissolved solid (TDS) values above 1,500 mg/l, and hardly are these sources used to supplement potable supplies.
- In the Shale formation areas of Mwakirunge and Nguu Tatu in Kisauni division and parts of Changamwe division, the ground water sources derived are very highly mineralized and therefore not suitable for potable purposes.
- Along the Triassic and Jurassic formations of the flat coastal plain, the water derived from these aquifers is generally fresh TDS 400-1000 mg/l. Unfortunately these sources are developed alongside human settlements and therefore under the constant threat of sewage contamination, and hence the subject of this investigative study. Such areas include the low and medium cost, high-density settlement areas of Kisauni and Likoni divisions.

2.3 Climate

2.3.1 General Climatic Type

The blowing of the monsoon winds influences the climate in Mombasa. The shifting of the monsoons results in two rainy and two relatively dry seasons. The

long rains fall during the shifting of the monsoons between late March and May, followed by a relatively cooler dry period, that lasts until November. The short rains occur during the shifting of the S.E. to N.E. Monsoons between October and November, culminating in the dry warm period.

2.3.2 Rainfall

The long rains occur between late March and early June, peaking in May. After June the rain decreases until October/November when the short rains produce another peak. The total annual rainfall in Mombasa normally ranges between 1000 and 1200 mm, with about 40 % occurring during the long rains (GOK 1975, NES 1985), and the minimum precipitation experienced between January and February. Presented in Table 2 and figure 4 is the average rainfall distribution from 1989 to 1999.

2.3.3 Temperature

In the 1989 - 1999 period, the mean maximum temperature varied from 27.5 °C in August to 32.8 °C in February. The corresponding mean minimum temperature ranged from 19.5 °C in July (and August) to 22.9 °C in February (table 2, figure 4). Notably the coolest period was during the S.E. Monsoon season, with the warmest period occurring during the N.E. Monsoon season.

2.3.4 Humidity

The relative humidity showed seasonal variations with about the lowest humidity experienced during the warm period of January to March and the highest during the relatively cool and wet season of May to July. There is a markedly diurnal variation in the relative humidity, with the highest humidity occurring at night and early morning and the lowest occurring in the afternoon (GOK 1975). Thus, in the 1989 - 1999 period the mean relative humidity at 09:00 hrs ranged from 75 to 86

% (overall mean 81 ± 3 %), and at 15:00 hrs, 59 to 72 % (overall mean 66 ± 4 %) (table 2, figure 4).

Table 2: Monthly average temperature, relative humidity and rainfall for 1989-1999

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (°C)	Max	32.1	32.8	32.6	31.1	29.4	28.5	27.6	27.5	28.3	29.5	30.2	31.5
	Min	22.7	22.9	23.5	23.3	22.0	20.6	19.5	19.5	20.2	21.3	22.3	22.7
Relative Humidity (%)	Max	78	75	78	81	84	85	86	83	83	80	81	81
	Min	62	59	61	57	72	67	69	67	66	67	68	68
Mean Rainfall (mm)		33.9	11.6	53.8	163.7	287.3	76.3	78.7	64.8	39.7	155.1	129.3	91.9

(Source: Kenya Meteorological Department, Moi International Airport, Mombasa)

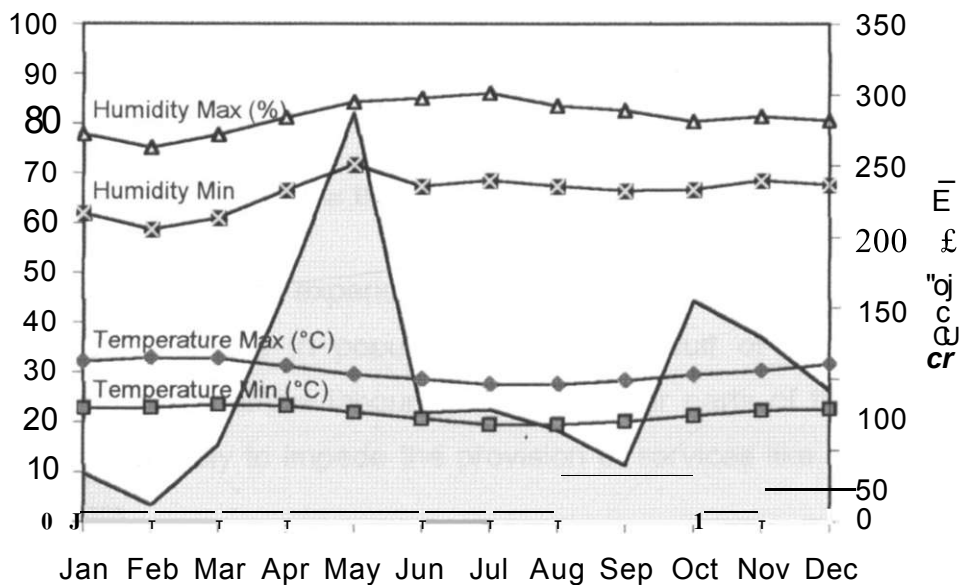


Figure 4: Temperature, relative humidity and rainfall averages for Mombasa for 1989-1999.

Under such wet, hot and humid climatic condition regimes, water borne diseases can be very rampant if a polluting source to the water supplies readily exists.

2.4 Population, its Distribution and Density

The population of Mombasa District according to the 1999 Population and Housing Census stood at 665,000 persons distributed in the four divisions of the District as tabulated below over the last three decades.

Table 3. Demographic Distribution in the Study Area

Administrative Division	Size: Area knr	Population			% Population increase since last Census	Population density/ km ² 1999
		1979	1989	1999		
Likoni	51.3	39,665	67,240	94,883	41.11	1.850
Island	14.1	136,140	127,720	146,334	14.57	10.379
Changamwe	54.5	81,348	113,469	173,930	53.28	3.191
Kisauni	109.7	79,995	153,324	249,861	63.00	2.278
TOTAL	229.6	336,148	461,753	665,018	44.02	2.896

Source: GOK Population Census 1979,1989 & 1999

Mombasa district has experienced a 44% increase in population in the last 10 years. The increase in population is as a result of natural growth and immigration, mostly of the labour force from other parts of the country. The high population is likely to impede the provision of services like water, sanitation and health care.

The Island division of Mombasa district is the Central Business District (CBD). It is the most built up area and has the highest population density. High cost low-density settlements within the Island are found in Kizingo and Tudor, while middle cost, high-density settlements are found around the Buxton-Stadium area, Makupa and Saba Saba. Then we have the low cost high-density settlements

found around Buxton, Tononoka, and Old Town. Informal and slum settlements found on the Island include Muoroto California, Muoroto Paradise, Muoroto Kafoka, Kiziwi, Kaloleni, Spaki, Sarigoi/Mwembe Tayari, Mwembe Taganyika and Kibarani.

A land use classification study (Agil Saleh, 1999) indicates that only 31.2% of the total land area in Mombasa district are under residential settlements. The direction of growth in human settlements is found concentrated northwards in Kisauni Division where other socio-economic activities occupy large parcels of land. This has entailed the crowding of many people in small land areas with many implications. For example in the Kisauni division, large beef and dairy farms, the tourist hotels, Shimo La Tewa School and Prison and Bamburi Cement, occupy large tracts of land. The result of this is population concentrations in the sprawling low cost high density settlements of Kisauni Estate, Mlaleo, Barsheba, Mwandoni, Bakarani, Magogoni, Mishomoroni, Mtopanga, Shanzu; and the squatter areas of Ziwa la Ngombe, Kisimani and the Bombolulu slums. Other informal settlements and slum areas are Matopeni (Kengeleni), Mnazi Mmoja, Kisumu Ndogo (Kongowea), Maweni (Kongowea), VOK, Mafisini, Kilimanjaro, Makombeni (Mtopanga), Mwembe Legeza, Utange Giriama, and Majaoni.

A similar situation exists in Likoni and Changamwe divisions, where large pieces of land having been reserved for productive economic activities; people have been left to concentrate on small areas in several informal settlements. Such of the areas include Maweni, Timbwani, Kidunguni, Mweza, Ujamaa/Shika-Adabu, Mtongwe (Shonda) and Jamvi La Wageni all in Likoni division. In Changamwe division, concentrations of human settlements are found at the Chaani conglomerate areas of California, Dunga Unuse, Tausa, Kwarasi, and Migadini. Other informal settlements and slums are found at Kasarani, Fuata Nyayo, Kalahari, Birikani, Kwa Punda, Bangladesh, Gana Ola, Mikanjuni, Miritini Madukani, Vikobani, Mwamlali, Cha Munyu, Magongo-Wayani, and Jomvu Kuu.

These are areas where the sanitation status is poorest: crowded human settlements and generally poor infrastructure facilities resulting in a myriad of environmental problems as a consequence. (Gatabaki-Kamau, et al., 2000). The water supply situation in Mombasa is appraised next.

2.5 Water Supply

Mombasa district heavily depends on water sources from outside the district for its potable needs. It supplements this water need from groundwater sources in the district. The district has a daily water demand of 200,000 cubic meters of water against the available 130,000 cubic meters that come from the traditional supply sources of Kwale, Malindi and Taita-Taveta. There is therefore a water shortfall of 70, 000 cubic meters, (NWPCPC, 2000). This 35% shortfall is met by tapping the groundwater sources, which are potential in the district. Also, as the reticulated supplies experience constant breakdowns, groundwater sources, not only supplement the supply, but they sometimes become the major source of water available in the district. In fact, 13,286 out of the 183,540 households in the district are almost permanently dependant on groundwater. These are distributed as follows: - wells- 6,245 households, boreholes- 6,941 households (GOK, Kenya Population Census 1999).

A significant number of the population therefore relies on groundwater for their potable needs. As groundwater is an important source of potable water, it must be protected from sewage pollution. This does not seem to be the case. The sewage infrastructure, which is developed along these water sources pose a constant threat to these groundwater sources. Therefore a methodology has been developed under this research to generate information, to help understand the situation in Mombasa district. The methodology used in this is study is thus presented in the chapter three, which follows.

CHAPTER 3

METHODOLOGY

3.1 Sampling Framework

The research for this study was carried out in two parts. Part one involved the search for primary information, while part two comprised a library survey for secondary information. Ten weeks were spent in generating the primary data through field visits and physical inspection of the sewage infrastructure including the condition at the disposal site. This was followed by extracting information from health records on water related diseases, running in parallel with interviews with various stakeholders, (see appendix. 1), to obtain their perception and input towards possible measures to address the sewage problem.

This was followed by a desk study for secondary information, which unearthed the efforts currently expended on addressing the sewage management problem in the outcomes of national, regional and international conferences. From the recommendations of the various conferences, mechanisms to address the sewage problem were spelt out. Against this background, a study on the Kenyan sewage management practice focusing on the city of Mombasa was set out.

3.2 Collection of Data

Visits were made to appraise the conditions of the sewage infrastructure and that of disposal site. Visits were also made to the city health services office to collect information on wastewater related diseases. This was followed by interviews with residents, visitors and some professionals to get a perception of their understanding of sewage problem. Both seawater and groundwater were sampled for laboratory analyses to check for sewage pollution. Library searches were carried out to obtain the secondary information.

3.2.1 Primary Data

Field observations were used to obtain visual impression on the state of the sewage sludge disposal site and to offer descriptive information on the impact of the sludge on air, soils and vegetation. This method was also used to describe the state of the various sewage management infrastructures, while laboratory analyses were used to generate data on indicator parameters of pollution through microbiological analyses. Medical records were searched for records of sewage pollution related disease. Semi-structured personal interviews were used to obtain the perception of people on the sewage management problem and for inputs from professionals towards the mechanisms of addressing the problem.

3.2.2 Secondary Data

The search for secondary data was done, first, to help understand the subject of sewage management and secondly, to review the global efforts towards addressing the problem by looking at the outcomes of both regional and international conferences. Sewage management in Mombasa was then studied through a perusal of the existing sewage management infrastructure and the management practice against the physical attributes of the study area. Through library information, wastewater related diseases were identified so was their link to sewage.

3.3 Techniques of Analysis

The technique used to analyze the state of the sewage infrastructure was descriptive, so was the impact of sewage sludge at the disposal site on soil, air and vegetation. To obtain information on the impacts of sewage on water, microbiological laboratory techniques were used. These are described below, so is the theory behind the materials and methods used. The semi-structured

interview technique was used to obtain information on the feelings of the people on the sewage problem and for professional input.

3.3.1 Techniques for the Analysis of Water

The theory, sampling techniques, materials and methods, and analytical procedures used in the microbiological analysis of the water samples are now presented.

3.3.2 Microbiological Indicators of Sewage Pollution

Sewage may contain a variety of intestinal pathogens, which cause diseases. Depending on the occurrence of certain other diseases of common prevalence in a community, other viruses and parasites may also be present. Raw sewage can contain up to 100 million coliform bacteria (bacteria originating from the gut) per 100 ml and 1 to 50 million *Escherichia coli* or faecal *streptococci* per 100 milliliters. Sewage treatment at various levels is capable of reducing the pathogens by a factor of 10 to 100; and the receiving water body, reduces the concentrations even further through its dilution capacity. Although pathogens interfere only marginally with aquatic life in general, they are known to be responsible for severe public health problems and are considered responsible for most of the infant mortality in developing countries (UNESCO, WHO, UNEP 1992). To avoid human infection, the World Health Organization recommends that the concentration of faecal matter in drinking water is zero organisms per 100ml.

Under normal circumstances, natural groundwater contains no faecal bacteria unless contaminated, whereas surface water, even in remote areas, may contain up to one hundred per 100ml. Freshwater also contains microorganisms indigenous to itself, a few of which are known to produce toxins and transmit, or cause, diseases. The monitoring for the presence of pathogenic bacteria is

therefore an essential component of water quality assessment (UNESCO, WHO, UNEP 1992).

The organisms most commonly used as indicator of faecal pollution are the coliform bacteria, particularly *Escherichia coli* and other faecal coliforms. A count of total viable bacteria in freshwater sample can distinguish between freshwater species and those from human and animal faeces by their different optimal growth temperatures. Water bacteria show optimal growth at 15 °C to 25 °C and faecal bacteria at 37 °C.; the difference in temperatures for the optimal growth of the two is taken advantage of to offer results of the coliform counts with confidence. Careful sample handling and processing methods ensures that there is no contamination from other sources. Conducted carefully, the microbiological methods generate reliable results.

As the examination and detection of all possible pathogens would be a costly and very expensive exercise, the method, which detects only the organisms indicative of the presence of faecal pollution, such as the normal intestinal bacteria is used. If evidence for faecal material is found in a water sample, it can be assumed that faecal pathogens may be present but if no evidence is found, then it is likely, although not necessarily totally certain, that the water is safe for human use. As bacteriology offers a suitable test for the detection of recent faecal contamination, it is used in the study being undertaken.

There is today increasing attention being given to the pollution problems of tidal estuaries and other bodies of saline water, focusing attention on the need to modify the existing bacteriological techniques so as to be effective in the examination of samples from such sources. However, the application of specific techniques to saline" water has not been discussed in this study because available experience suggests that the methods used for fresh waters also can be used satisfactorily with saline water.

3.3.3 Sampling

Both seawater and groundwater were sampled for analyses in this study. The sampling of freshwater was undertaken from the wells and boreholes in the study area. All the sampling took place during the dry season. Three samples were taken from each sampling point over three week's period.

Seawater was sampled from the Kilindini and Makupa Creeks, which are characterized by the anthropogenic influences of the Changamwe sewage treatment plant at Kipevu, the Kenya Ports Authority, and the Kibarani solid waste-dumping site. The second sampling area was the Tudor creek and Tudor creek entrance, which are recipient to sewage from the Kizingo sewage out-fall, the Mombasa Hospital, the Coast General Hospital and the surrounding housing estates. Another area sampled was along the lagoon of Nyali, Bamburi, and Shanzu and around the mouth of the Mtwapa creek into the areas near the Shimo la Tewa GK Prison and housing establishments. Refer to Map. 1.

3.3.4 Materials and Methods

The bacteriological method used in the analysis of water is conventional and is given below.

The samples for bacteriological analysis from the field were taken in sterile glass bottles with caps. All consequent handling of the samples was done in sterile conditions to avoid contamination after collection. The samples were stored at 4 ° C in iceboxes while awaiting transfer to the laboratory on the same day.

Total coliforms and *Escherichia coli* were determined using the 5-tube, 3 dilution, Most Probable Number (MPN), technique. Samples were inoculated into the Mac Conkey broth and incubated at 37 C for 24-48 hours for total coliform count.

Gas positive tubes were sub-cultured in brilliant green lactose bile broth and incubated for 48 hours. Those tubes that tested positive for indole production in tryptone water were considered positive for E. Coli. The Most Probable Numbers were computed from Probability tables.

3.3.5 Interviews

Semi structured personal interviews were used in the search for the feelings of the people on the existing practice of sewage management. Primary information was sought from the professionals in the field in a similar way.

The semi-structured personal interviews were thought to be the most appropriate method to obtain information from the professionals, residents and visitors. This method is particularly thought to be very effective if administered on lay people and visitors because the information sought from them, is more "linguistic rather than statistical"(Burgess 1992). The use of questionnaires would have made the acquisition of such information less easy (Allan 1992, Bridge 1992). Interviews encourage flexibility and allow for answers and perceptions to be perused to greater depth than a questionnaire would allow. It also gives the interviewee leverage to present their opinion with less opportunity for interviewer bias through the presumption of limited set of questions (Furtze, et al. 1996). While facts were also being sought on sewage management, it was the nebulous concept of feeling that was the most important. (The list of interviewees is found as appendix 2 to this report).

3.3.6 Survey of Medical Records

The offices of the Mombasa City Health Department were visited to obtain the record of water-related diseases from their annual divisional health reports.

3.4 Problems in Data Collection

The main challenge met in the collection of data during this study, was the identification of the freshwater sources. There is no official record of the location and numbers of the wells and boreholes. Many such sources in Changamwe Division, therefore, could have been missed out for sampling and analysis. The sampling for seawater also posed a challenge. Reaching the intended spot areas for sampling was sometimes not possible due to the unreliable condition of the dinghy used for transport. It was also not possible to have access for assessment to most pit latrines, in private homes. The number of respondents to the interview was similarly small due to the constraints of time. Nevertheless, adequate information has been obtained on the subject and the main findings of the study are now presented in chapter four.

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CHAPTER 4

MAIN FINDINGS

4.1 The Sewage Infrastructure

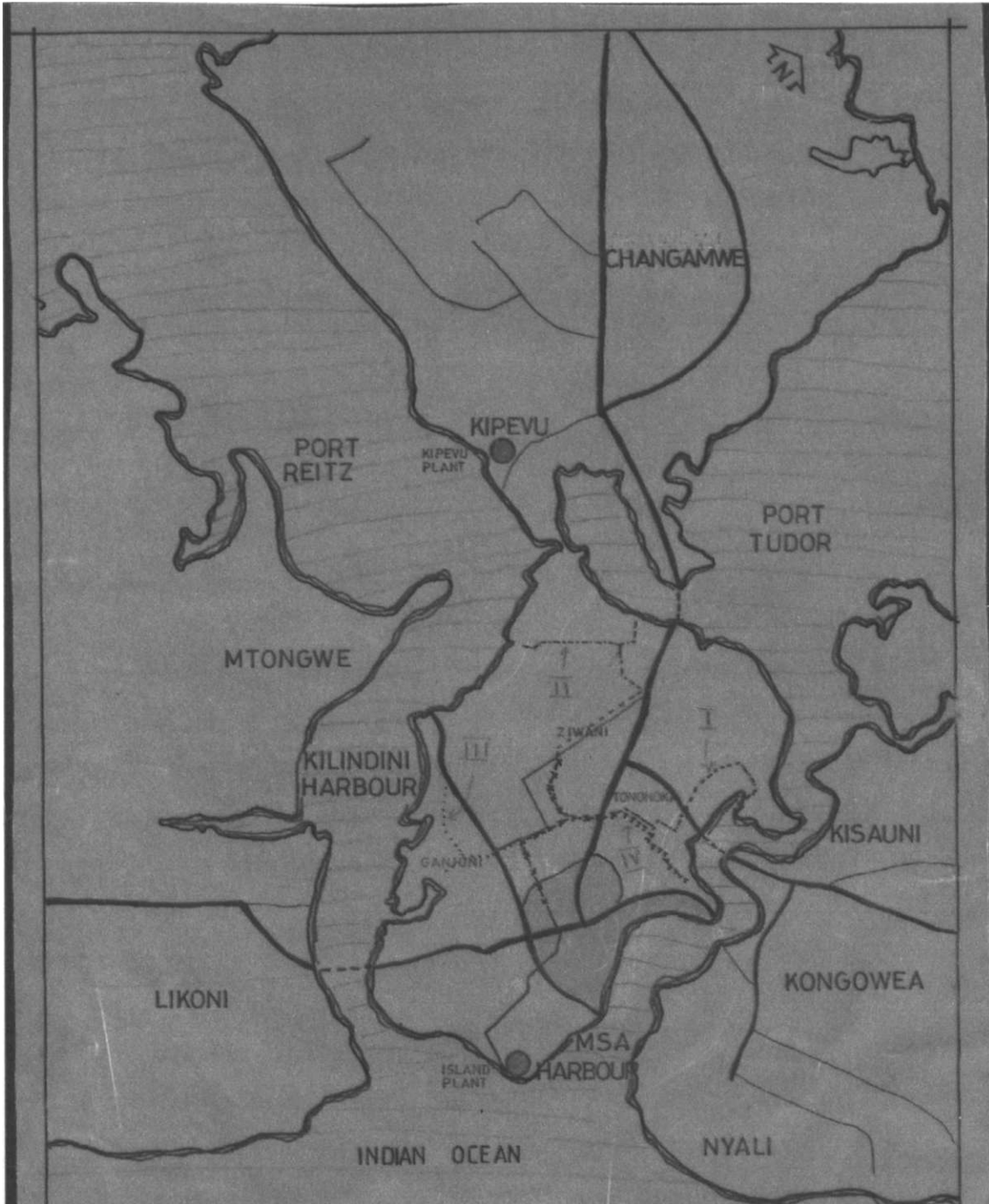
The study has found that the main systems available for sewage management in Mombasa district include the following: -

- Centralized sewers and treatment plants
- Septic tanks and soakage pits, and
- Pit latrines.

The centralized sewer system serves only a small proportion of the population in the district. The use of septic tanks and soakage pits is largely limited to the planned areas of development. The majority of the population is served by the use of pit latrines. The condition of the sewage management system in the various divisions of the district as found by the study is described below.

4.1.1 Mombasa Island Division

About one third of the Island is on a centralized sewer system, this serves about 12 percent of the households. The treatment plant serving this system is currently non-functional and requires rehabilitation, refer to Map 2, for the sewer network and area of coverage. Though rehabilitation work on the same was under consideration under the Mombasa Water Supply Project, financed by the World Bank, except for the feasibility studies, nothing has been done to date. Sewage from this part of the Island, which include the catchment areas of Kizingo, and part of the Central Business District is therefore discharged untreated into the waters of the Indian Ocean via an out-fall at Kizingo. The rest of the two thirds of Island depends on either septic tanks or cesspits.



SEWAGE SYSTEM MSA ISLAND

- ▭ EXISTING CATCHMENT AREA
- EXISTING LINE
- - - EXTENSION LINE *

- PROPOSED PHASE I
- PROPOSED PHASE II
- PROPOSED PHASE III
- PROPOSED PHASE IV

Figure 4: Sewerage System Mombasa Island Division

4.1.2 Changamwe Division

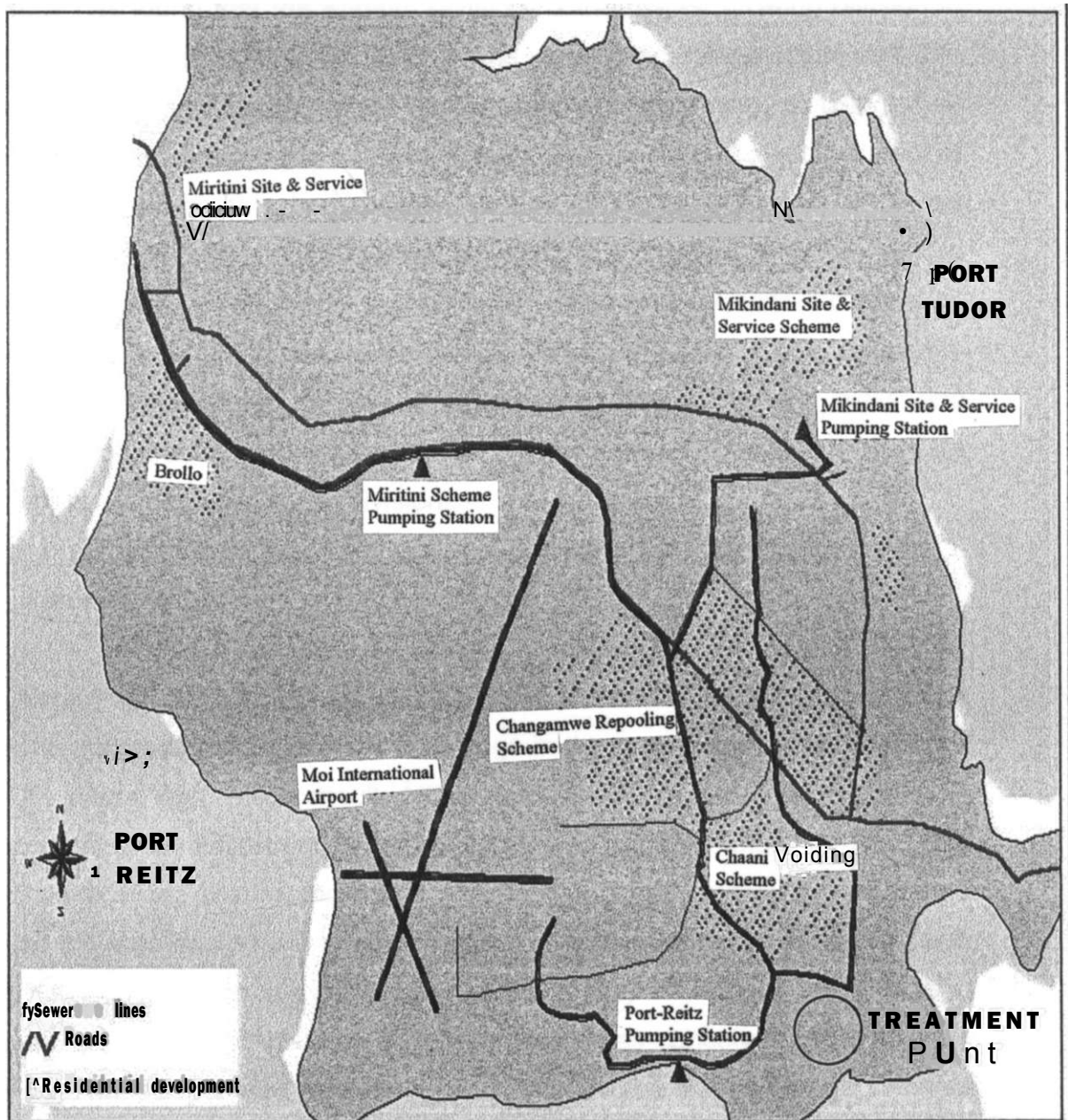
As shown in Map 3, part of Changamwe Division is sewered, serving a population of about 77,000 people in the residential areas of Chaani Upgrading Scheme, Changamwe Estate, Brollo, and Mikindani Site and Service Schemes.

Table 4: Changamwe Treatment Works - Areas and Population covered

Residential Area	Population Targeted
Chaani Upgrading Scheme	30,000
Changamwe Estate	15,000
Mikindani Site and Service Scheme	32,000
Total	77,000

Source: Mombasa Municipal Engineers Dept, 1992

The treatment plant serving the settlements mentioned above is located at Kipevu. For a very long time now, this plant has suffered efficiency problems, and as a result of which, the sewage from this part of the Changamwe Division is largely discharged untreated into the Makupa Creek. In a new development, the sewage network and the treatment plant in Changamwe has been re-designed and the new sewage treatment facility is being constructed at Kipevu. Once completed and commissioned, the system would serve a significantly increased size of the population. Additional trunk sewers and extension of the above scheme is planned to serve the existing Changamwe Repooling Scheme. This was targeted to add another 27,000 people to the extension scheme once the internal sewerage system is fully developed. Unfortunately, the project design did not include sewer reticulation in the areas of Changamwe and Port-Reitz. Implementation work on this project had reached near completion and the commissioning dates were already in the minds of the promoters, when unforeseen massive damage occurred during the El-Nino Southern Pacific weather phenomena washing away large parts of the sewage pipe network rendering it non-operational up to this day.



Data digitization and map composition
 Pamela Oduro, Ph.D. M.Eng.
 & Harrison Oduro
 Mombasa Municipality, 2001

2 Kilometers

Map 3: Sewerage Network in Changamwe Division

Source Town Engineers Dept, Mombasa Municipality, 1992

It is important to note that the sewage treatment plant for this area is located on the edge of the Makupa Creek

4.1.3 Kisauni Division

The study has found that the Kisauni Division, is the fastest growing division in Mombasa district. This is so because of the good road infrastructure and the presence of the Nyali Bridge, which makes communication easy. Housing of all types is readily availability and relatively cheap. The division also houses most of the tourist establishments in Mombasa and a variety of high-cost residential houses. The whole of this division is not sewerred. The disposal of human wastes is practiced mainly through the use of septic tanks and cesspits including pit latrines. The use of pit latrines, is the highest of all the divisions. The division is also highly endowed with groundwater resources tapped through wells and boreholes constructed alongside human settlements. Groundwater is very important for human uses in the division.

4.1.4 Likoni Division

The Likoni division, just like Kisauni, is not sewerred. The study has found that studies to construct comprehensive sewerage in the area, were conducted more than 27 years ago, (Norconsult 1974) and again in the 1990's, but the development of the infrastructure for the same, has not taken place to date. This study has affirmed that water borne sanitation is urgently required in Likoni, because the area has potential for the growth of tourism, residential housing and other business activities. It was because of these reasons, among other factors, that the development of the sewage infrastructure was conceived more than 27 years ago. Mr. Ali Gakweli, a resident of Likoni, advises that sewerage systems need to be put in place soonest to avoid the potential threat of groundwater contamination, which has been detected to be slowly creeping in.

The distribution of the sewage management systems in operation in Mombasa is now presented in the section th3t follows.

4.2 The Distribution of the Sewage Management Systems in Mombasa District

As a result of the differences in levels of development, the various settlements have different systems for managing wastes. Some settlements are connected to the central sewer system; others are served by septic tank, soakage pit systems only, some have combined the former with pit latrines, while others rely on pit latrines only. For the homeless and some of those who live in slums, the use of plastics takes the role of the above leading to the emerging phenomena referred to as the "flying toilets". In this scenario, people help themselves in plastic bags and then throw the bags away, resulting in the coined terminology "flying toilets."

The shortages of water in the district and the lack of funds to undertake capital investments projects has delayed extensions of water borne sewerage, forcing the residents to rely on on-site systems for sewage management.

About 17% of the households in Mombasa, as well as hotels and most public buildings, have septic tanks. Of the 13,000 septic tanks that are in use in Mombasa, most of them are found in high-income residential areas. However, in the Island Division, they are widely distributed even in low-income, high-density settlements. An encounter of the researcher with Mr. Mwamwindi, a businessman, found out that Mr. Mwamwindi is in favour of the construction of pit latrines even in high-cost residential areas. He posed, "Why would you have a flush toilet, when there is no water to flush away the waste?"

A great majority of households in Mombasa, (70% of them) use pits latrines. Of the 34,000 latrines found in the district, 5% of them are on the Island Division, in high-density settlements. The Chagamwe Division in the west mainland, has 15% of them, 25% are in the south mainland, in the Likoni division; the remaining 55% are found in the mainland north, in the Kisauni division. It is an officially sanctioned practice to dig the pit latrines down the ground to reach the water

table so that they do not fill-up in a short time. This practice has implications for ground water quality.

An assessment of the estimates of sewage waste volumes generated and managed through the various disposal systems together with its characteristics has been carried out using the "rapid assessment" techniques developed by WHO, in 1989. The results are presented in the Tables 5 and 6. So what is the status of the systems that manage this waste? This is a subject we turn to.

Table 5: Distribution of Sewage Disposal Systems with Population in Mombasa District

Disposal System	Pit Latrines	Septic tank/soakage pit	Central Sewer	Total
Population	457, 100	111,010	78, 360	646, 470
% disposal system	70	17	12	99*

* It is estimated that 1% of the population in rural areas of the district use the bush as the toilet. An increasing number of those who live in the slums defecate in plastic bags, which are ultimately disposed of on land through the flying toilet phenomenon.

Table 6: Sewage Volumes and Characterization by Disposal System

Disposal System	Population ('000)	WV		BOD		SS		N		P	
		nrVcy	10·m·y	Kg/cy	tn/y	Kg/cy	tn/y	Kg/cy	tn/y	Kg/cy	tn/y
Pit latrines	457.1	-	-	5.1	2331	-	-	-	-	-	-
Septic tank/ Soakage pits	111.01	-	-	6.9	766	16.0	1776	3.3	366	0.4	44
Central Sewer	78.36	• 35.4	2774	17.9	1403	18.6	1457	1.6	125	0.4	31
Total	646.47		2774		4500		3233		491		75

WV= Waste Volume; BOD= Biochemical-Oxygen Demand; SS= Suspended Solids; N= Total Nitrogen; P= Total Phosphorous; Units: # = Number of persons; cy = capita/year; tn= tonnes; (-)= No data available

Source of per capita data, WHO (1989).

4.3 The Status of the Individual Sewage Management Systems in the various Settlements

The status of the individual sewage management systems for the various housing settlements is now appraised.

4.3.1 Low-cost, high-density Housing and Informal Settlements

The low-cost high-density housing and informal settlements in Mombasa include the low-grade housing schemes of government, the Swahili housing type and the slums, all of which are represented in the different divisions of the district. The government-housing schemes in this category use communal septic tanks and soakage pits for managing human wastes. The systems are not adequately managed; they are prone to blockages and both the septic tanks and soakage pits are usually left to fill up to overflow levels before being attended to, and usually after complaints by the residents.

For the Swahili housing residences, sewage management is either by the use of pit latrines or the use of septic tank-soakage pit systems. In most cases, it was observed that the toilets were properly built and well managed. It was also observed that the Swahili houses were either planned or unplanned. The planned ones are those which were built according to an approved village layout plan prepared for the owner by the local authority. The septic tank, soakage pit systems served most of the houses for sewage management in this category of planned housing. The unplanned houses used pit latrines almost exclusively. Like the soakage pits that serve the septic tanks, it was found that most of the pit latrines were dug down ground to reach the water table to prevent them from filling up fast. This is a good practice on local sanitation considerations, but it pushes sewage down the ground to contaminate groundwater resources. A common feature found in the Swahili houses that use pit latrines was the

observation that almost all of them had a shower room next to the toilet and all washings from the shower rooms were directed to the toilet pit. This method of draining the wastewater from personal washing to the pit latrines left the pits permanently wet and therefore provided a route to the accelerated contamination of groundwater.

For the case of slum dwellings, pit latrines were the only mode for human waste management. For all the slum areas visited and the toilets inspected, it was observed that most of toilets were very shallow and prone to flooding during the rainy season. The flooded toilets constituted a major threat of pollution both to the ground and surface water sources. The use of "flying toilets" was also found to be very common in the slum areas. Mr. Alii Mutta, a resident of Changanwe, abhors the smell of sewage, which engulfs the air at times, as a result of the disposed plastic bags.

Location of Informal Settlements in Mombasa, 1997

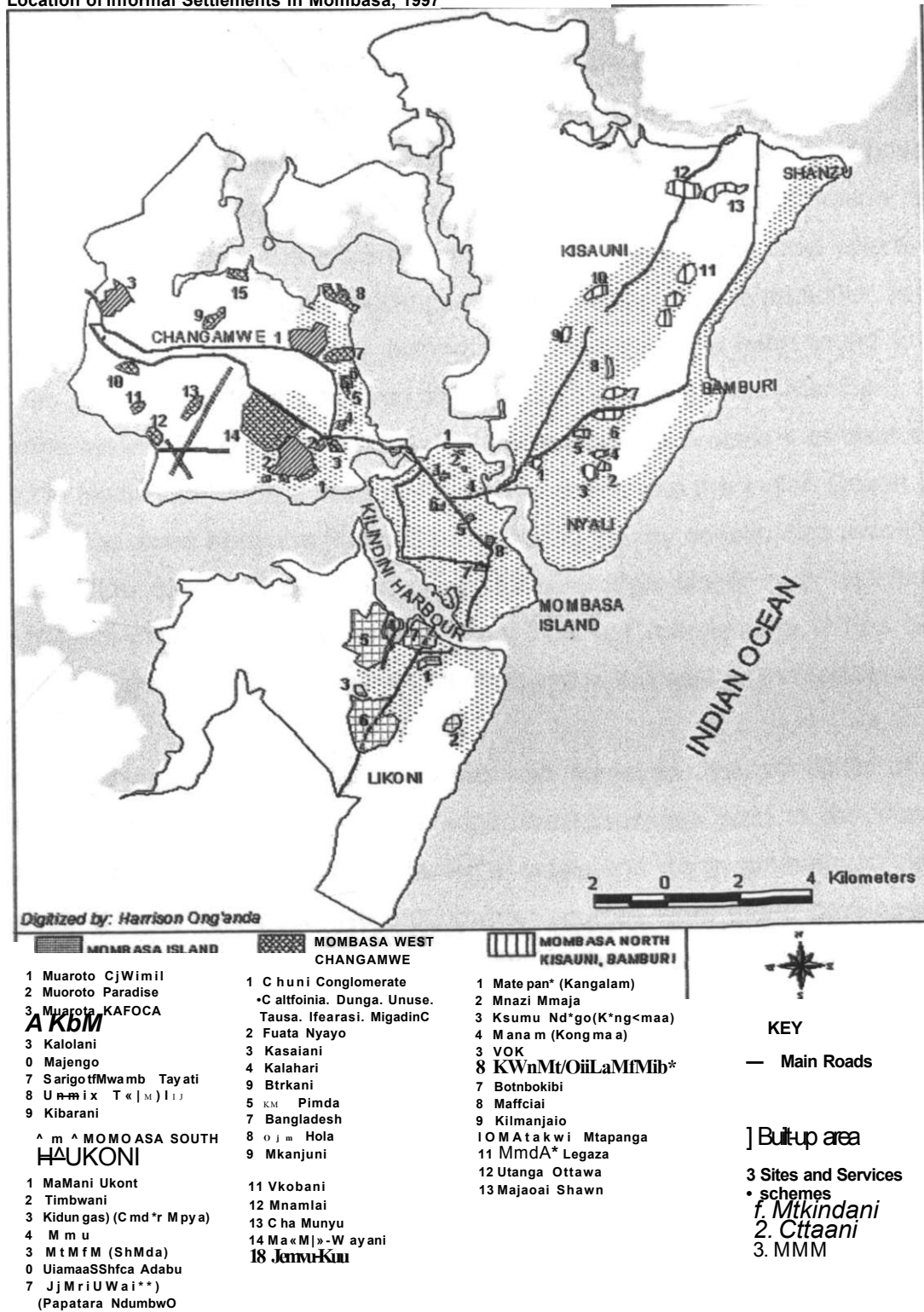


Figure 6: Location of Informal settlements in Mombasa District

4.3.2 Middle-cost, high-density Settlements

In the middle-cost, high-density settlements, sewage is managed by the use of septic tanks-soakage pit systems only. These systems are either communal, where a whole estate shares one large septic tank and soakage pit, or private, where each dwelling has its own system. The later is the most common, and where this is the case, the systems are well maintained. In the case where the system is communal, frequent blockages have been reported. In particular, in the estates owned by the local city authority, the situation has been found to be worse. It has also been observed that for some estates, like Kiembeni, the sewage system in operation collected all the waste and directed it to discharge into the Hodi Hodi River, a seasonal river that drains into the Indian Ocean just up north the Jomo Kenyatta Public Beach. During the dry season, this river dries up or its flow ceases to reach the ocean for discharge. Under such conditions, the Kisauni estates, smell of with sewage. This notwithstanding, it has been observed in general that sewage is well managed in this category of residences.

For the several housing estates visited and surveyed, the condition of the sewage management infrastructure (septic tanks/soakage pits) in the Vescon estate, Nairobi estate, Benkay estate, Raha estate and the Swaminarayan estate was found to be very good. No groundwater sources were found developed in these settlements; the residents depended on the reticulated supply for their potable needs. On enquiry it was found out that the alternative source the residents turn to during water shortages is outright purchase from water vendors or have it supplied by private water tank owners. All the above housing estates are relatively new. In the older settlements, where the residents occupy large pieces of land, wells and boreholes have been developed to tap the water for irrigation purposes, growing vegetables for the market.

4.3.3 High-cost, low-density Settlements

The high cost, low-density settlement of Kizingo on the Island division is lucky to be served by central sewers. In the other residential areas of the same type, sewage management is effected by the use of individual septic tanks. The later include the following housing areas: - Nyali, Mamba village, Kenya Re-insurance housing scheme, Shah Cummunity, English Point, Customs housing in Bamburi, Shanzu, Mugoya estate, Palm Garden estate, Baobab estate, Arthi villas, Ratna square, and Velji Shamji estates, all in Kisauni division. The study observed that it is not uncommon to see sewage sludge dumped in the open undeveloped plots held for speculative purposes, by the infamous so called land grabbers. Khadija, a resident of Nyali, and a property owner suggests that the owners of such plots should fence them to arrest the illegal dumping, or held responsible by NEMA for this vice and fined accordingly. In Kizingo, Mr. Lawrence Mbandi complained of the frequent periods without water, which makes the sewerage system to serve no purpose. In Likoni, high cost housing estates are few, but mention should be made of the Shelly Beach housing, the Navy and Kenya Ports Authority (KPA) estate at Mtongwe, while in Changamwe we have the KPA estate at Port Reitz and the World Bank housing Scheme in Mikindani. These housing estates also rely on the septic tank, soakage pit system, for sewage management.

In all these housing schemes, sewage is very well managed. Here also, as in the other housing estates, that relied on pit latrines, the observation made was that all soakage pits sunk to serve the septic tanks were similarly dug to reach the water table, often on advice of the local authority for the same reason as above. This would have been very disastrous if groundwater sources from these areas were also to provide water for potable uses. Fortunately for most of these places, the ground water obtained is not of potable quality, being saline beyond potable levels, (Anthony Kombo, personal communications).

A few exceptions existed where it was found that the residents tapped the ground water for their potable needs. Such places included the housing schemes at Mtongwe and the Kenya Navy, but the water obtained, was generally reported to be saline.

In the sewered areas of Kizingo, there is no threat to ground water pollution from sewage, as attested by Munga et al 1993. However, since the treatment plant broke down many years ago, contamination of the marine environment goes unchecked from the discharge out-falls located here.

4.3.4 The Beach Hotels along the Kenya Coast

A few Beach hotels have shown innovativeness in waste management by installing their own sewage treatment facilities. But largely almost all the hotel establishments use the septic tank-soakage pit system for managing sewage. Severin Sea Lodge for example has installed a mechanized biological sewage treatment plant, while both Bamburi and Travellers beach hotels are making use of waste stabilization ponds for treating their sewage. These hotels also use the treated wastewater for watering their flower gardens.

For those hotels that use septic tanks, emptying of the same is carried out either by the Mombasa City Council or by private contractors. Usually, suction trucks are used in the emptying process, but it is not uncommon for private contractors to use simple containers to take out the sludge from the septic tanks and fill it into bigger containers that are eventually transported away for subsequent disposal. It is not known where the private contractors dispose off the sludge. The Council on the other hand, when it carried out the operation, the sewage sludge was discharged at the official dumping site located at Kibarani on the edge of the Makupa Creek, which borders the Indian Ocean. An encounter with Mr. Kuldip Sondhi-a hotelier tells you thatthe City Council services for sewage management exist only in name. He poses the question, "How do you request them to come

today, only for them to come three weeks later, when in actual fact your hotel is faced with septic tanks that are full of sludge?" Faced with this dilemma, some hotels have hired private sewage service providers who might not even be professional in the job, and who, at times discharge the sludge in the sea. Mr. Fumo, a boat operator, said that it is disgusting to our visitors and to us, when you ferry tourists for bird watching tours in the creeks, only to be greeted by the smell of sewage. Mr. Bakari Bardale shared this view.

It is therefore inferred from the foregoing that both underground and surface water systems are endangered by the existing inadequate sewage disposal system of the hotel establishments. Fortunately however, these hotels, do not rely on groundwater for potable water supply. Sited on coral limestone basement and being near the ocean, the groundwater found here is prone to salt water intrusion, with the water obtained from the few attempted developed boreholes so saline that further development had to be abandoned. This notwithstanding, despite the generally good practice in sewage management practiced in these areas, the few illegal wastewater discharges are a potential threat to the marine environment and to the swimming waters of the lagoons. These lagoons also seem to be the main attractions to the tourism industry, and therefore need to be aesthetically beautiful.

From the beach hotel establishments, we now move to the remaining other types of establishments that also generate sewage.

Figure 7: The Distribution of Beach Hotels along the Kenya Coast

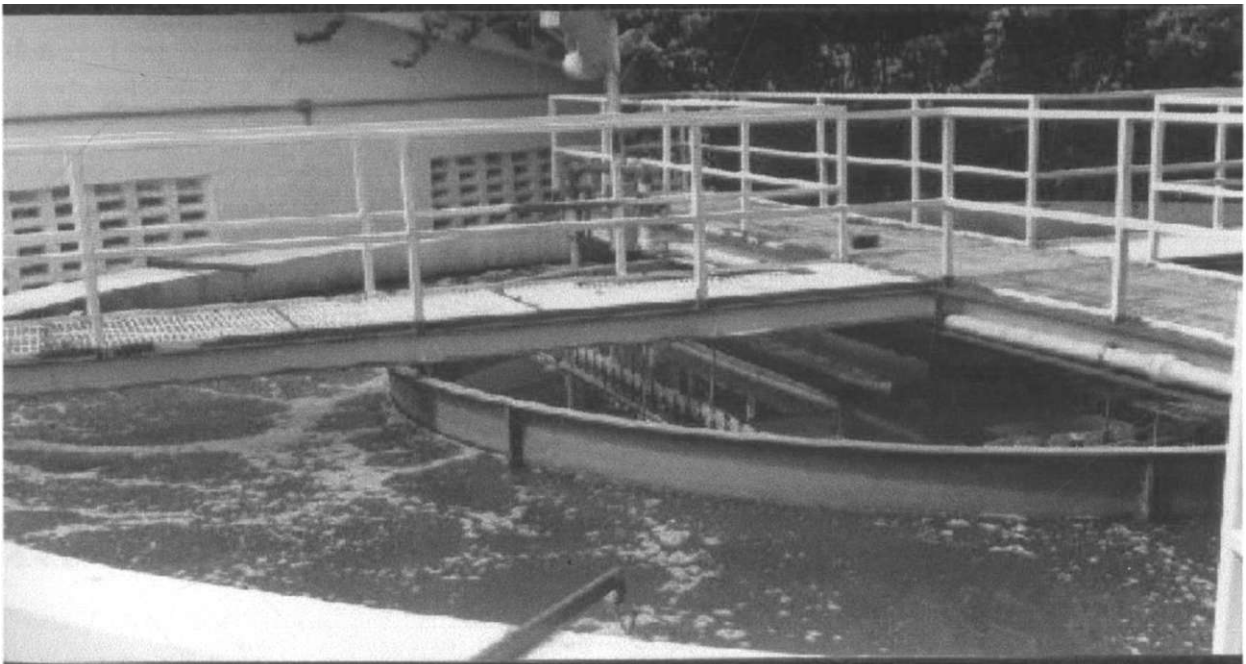
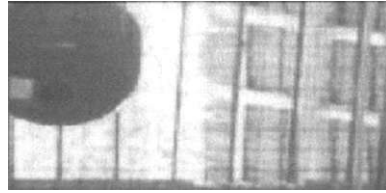


Plate 1: Sewage Treatment Plant, Severin Sea Lodge

Top part of the plate shows the pumping station of the sewage treatment works. The lower part of the plate shows the oxidation ponds, where the water constantly being stirred to ensure adequate aeration in this biological oxidation sewage treatment process. Grit and other solid materials are also filtered off and removed at this stage

4.3.5 Others

The other places of interest to this study, including the Coast General Hospital, the Mombasa Polytechnic and Shimo La Tewa prison, sewage discharge to the ocean seemed to be a problem. Though access to the prison compound was not granted to inspect the sewage system in use by the prison, water in the nearby Mtwapa creek was found to give the unpleasant characteristic smell of sewage.

Both the Coast General Hospital and the Mombasa Polytechnic use septic tanks and soakage pit systems. However, it was reported that over-flows are very common (Interviews with Jacton, a polytechnic 3rd year student, and Chuma, a sanitation attendant, Coast General Hospital, November 2001). Next we turn to the management practice in operation in management of the waste

4.4 The Sewage Management Practice

4.4.1 Sewage Management

This study found out that just like elsewhere in the country, the responsibility of managing domestic sewage in Mombasa district is vested in the Local Authority. For the case of Mombasa district, this function is the responsibility of the Mombasa City Council. Increasingly, however, the private sector is also participating under license from the Local Authority in sewage management.

4.4.2 Administrative Set-up

Administratively, the sewage management function falls under the office of the Town Clerk, who is also the principal executive officer of the local authority. Until recently, the Town Clerk used to delegate this function to the Town Engineers Department, under who the relevant technical services to handle sewage was located. This is what used to tie the traditional practice. However, this since changed, giving way to new arrangements. The changes seem to be

countrywide, and for the case of the Mombasa City Council, just like that of the other large local authorities, the new departments of Environment have been created to deal with all environmental matters. It is under this department that the management of sewage now falls. This department, being at the infancy stage, still feels the full force of the strong presence of the Town Engineers department, which previously carried out this function. The presence of the Engineer's department is causing some confusion in the administration of the new Environment department.

Similarly the Public Health Department, which is under the Medical Officer of Health, sees the new Environment Department as a competitor to its mandates and not a partner on public health environmental issues. Complementarity of functions between the two, which would have been seen to be a natural thing, is thin, despite the two needing each other. Another hurdle that the study found out and has to be overcome emanates from the Town Engineers Department. Controlling vast technical resources of the Local Authority, this department does not consider some environmental programmes as priority. This denies the environment department some vital support for its activities. Mr. Bilafif, the director of Environment, says his department cannot function properly without adequate funding and support of the other departments.

The Council, in a new development has allowed private firms and individuals to be sewage service providers. Some of the private sewage providers' have poor ethics in sewage management, discharging sewage sludge into storm water drains, into the marine water body or on to open grounds. As a result of this, there has been numerous complaints from some residents on the conduct of some of the private sewage services providers' This, the residents complain, contaminates their living environment, impacting on water sources and putting their health into danger. Khadija, a resident of Nyali, was again, very emphatic on this point. She thinks that there is need to address this issue by empowering the council to be in position to have full capacity to undertake and execute the

activity professionally. Najib Balala, the former mayor, reiterated that the Council needed to involve stakeholders in the beautification of Mombasa. He referred this researcher, to the "Terms of Reference for the Beautification of the City," developed during his tenure of office, which emphasized community participation in sewage management as part of the war on litter. From administration we turn to the technical arrangements in place.

4.4.3 Technical Arrangements

At the city of Mombasa, Sewage is managed as part of liquid waste in a separate section headed by a drainage engineer with the rank of Superintendent. Under the Superintendent Engineer are a number of foremen, headmen, and a number of cleansing inspectors and public health officers, who oversee the drainage and sewerage supervision on a zonal basis, to cover the whole municipality.

In addition, there is a Mechanical Engineering Unit, under the Town Engineer's Department, which is responsible for the maintenance of all equipment and tools. Budgeting for the purchases of requirements including equipment is under the preserve of the Director of Environment to sort out with the Town Clerk. This study has found out that the arrangement, where the department of environment relies on the City engineers department, and the department of Health, for maintenance, and the inspection service, is not an adequate arrangement, where the departments separately compete for financial resources.

The department of Environment has a total workforce of 1000 people, with one fifth of them falling under the drainage section, where liquid wastes including sewage are managed. This number, the superintendent says is sufficiently for the section. However, it was explained, it is the shortage of equipment and transport that hampers the activities of this section. In an interview with the drainage superintendent, the researcher was informed that the whole section had only one pick-up truck that is used for supervision work in the whole city boundaries. The

section has a single sludge tanker, which was defective at the time of this research. The section is grossly under-equipped to perform the work, which is expected of it. To cover for this shortfall, the section licenses private pits emptier, plumbers and drain layers to provide the service on a commercial basis. The private firms and individuals engaged, pay the relevant municipal fees in order to be allowed to offer the service.

The Environmental department also runs a laboratory for water quality monitoring to support the sewage management practice in Mombasa. The laboratory is ill staffed and ill equipped. It is a skeleton analytical laboratory, which cannot cope with the necessary routine monitoring of pollution by sewage, expected of it. We now turn to how sewage management is financed.

4.4.4 Financing Mechanisms

It has been found by the study that the Council depends on the revenue it collects for the several services it offers, to finance the budget for sewage management in its area of jurisdiction. Also, because sewage management goes hand in hand with wastewater, there is an arrangement where residents pay a fee for the sewage service based on their consumption classification of water, as either domestic or commercial water consumers. The National Waters Conservation and Pipeline Corporation (NWPC), which is the water undertaker in Mombasa, collect this charge on behalf of the Council. Additionally, the Council raises some revenue from the licensed private sewage service providers as another source of funds.

The study has found out that the NWPC lags behind in submitting the funds it collects on behalf of the Council, crippling its ability to offer the sewage management service. Though the Council has put up a case to take over the
vt
water undertaking, it is observed that the Local Authority does not have the capacity to manage the water undertaking as a business. This should not be

taken to mean that the NWPC is doing any better. Cases of water wastage under its management abound. Ziro Pore, a resident of Kisauni, felt that water undertaking should be taken away from the NWPC and privatized and run as a business as way of raising funds for sewage management from the taxes collected. Mr. Luggo, the Assistant Cleansing Superintendent, concurs with this only is if the water and sewage tariffs were adjusted upwards to recover the costs.

4.4.5 Cost Recoveries

It has been found that the Council used to charge a small fee for the services of emptying pit latrines, septic tanks and soakage pits. However, the Council no longer undertakes this service. The fees it charged were too low and did not cover the true cost of the service rendered. This is because the council considered the provision of this service as a social service to its residents. In the long run however, this social service has had to be literally abandoned because the council did not have a strong financial base to sustain it. If the service were to be revived and sustained, the Town Clerk, Mr. Edward Karani, was of the opinion that there had to be a change in policy to effect for full cost recoveries for the service, if rendered by the Council. The Director of Social Services, Mr. Hamisi Mboga, shares this view.

This study has confirmed that the charges the Council levies for sewage management are way below the commercial rates charged by the private firms. As an example, in the immediate past, the council used to charge US\$ 20, (which is about Kshs.1, 500) for the emptying of pit latrines and soakage pits, while private firms, like Fisher and Wolf, would charge between US\$ 450-640, (which is about KShs. 35,000- 50,000), for the same undertaking. Having failed to sustain offering this service, and in order to encourage private initiative and to reduce the illegal dumping of sewage, the* Mombasa City Council, decided to suspend the charges it levied and in its place introduced a dumping license. This has come

with a cost in reduced revenue base for waste management in the municipality. The council now charges a fee of US\$ 22, (which is about KShs. 1,700) per year, as the sludge disposal fee, paid by the private firms, which now undertake the sewage management activity as a business. It is a sad reality, but it has been observed that, in most cases the private firms charge a lot more money, but for a less professional job. This state of affairs calls for action to be pursued if effective sewage handling by the private firms is to be guaranteed. Mr. Edward Jefwa, a resident of Tudor, argues it to be made a requirement to hire trained personnel as a condition for licensing. This is because sewage has various impacts, which we now present.

4.5 Environmental Impacts

4.5.1 Impacts of Sewage at Disposal Site

The study informs us that 87% of the population in Mombasa relies on on-site sanitation for sewage management, and these on-site sewage systems have to be serviced periodically. Therefore desludging is routine practice in the city of Mombasa. The sludge removed is usually discharged on the Municipal's official dumping site at Kibarani on the edge of the Makupa Creek bordering the Indian Ocean. About 550 tonnes of solid waste is generated in Mombasa District every day (Personal Communications, Mr. Mohamed Skanda, and (retired Director of Environment, Mombasa Municipality). This waste does not include sewage sludge, but adds to it because the sludge is also officially dumped at the same location.

Due to the prohibitive costs in waste management, "controlled tipping" has been abandoned in favour of "crude tipping" raising many concerns that needed to be addressed. It is feared that crude tipping has driven away the oyster collectors of the Makupa Creek, says Athman, a fisherman. It has also been observed that there is usually a heavy noxious smell from the putrid decaying matter dumped at Kibarani, making common a very unpopular and obnoxious smell on the Makupa

courseway as one approaches Mombasa town, from the airport. Vegetation is lacking along the dumpsite and mangroves have died, evidently, largely due to the oil pollution that took place in 1988 when 5,000 tonnes of heavy fuel oil spilled accidentally, but the wastes dumped here, also contribute to the problem.

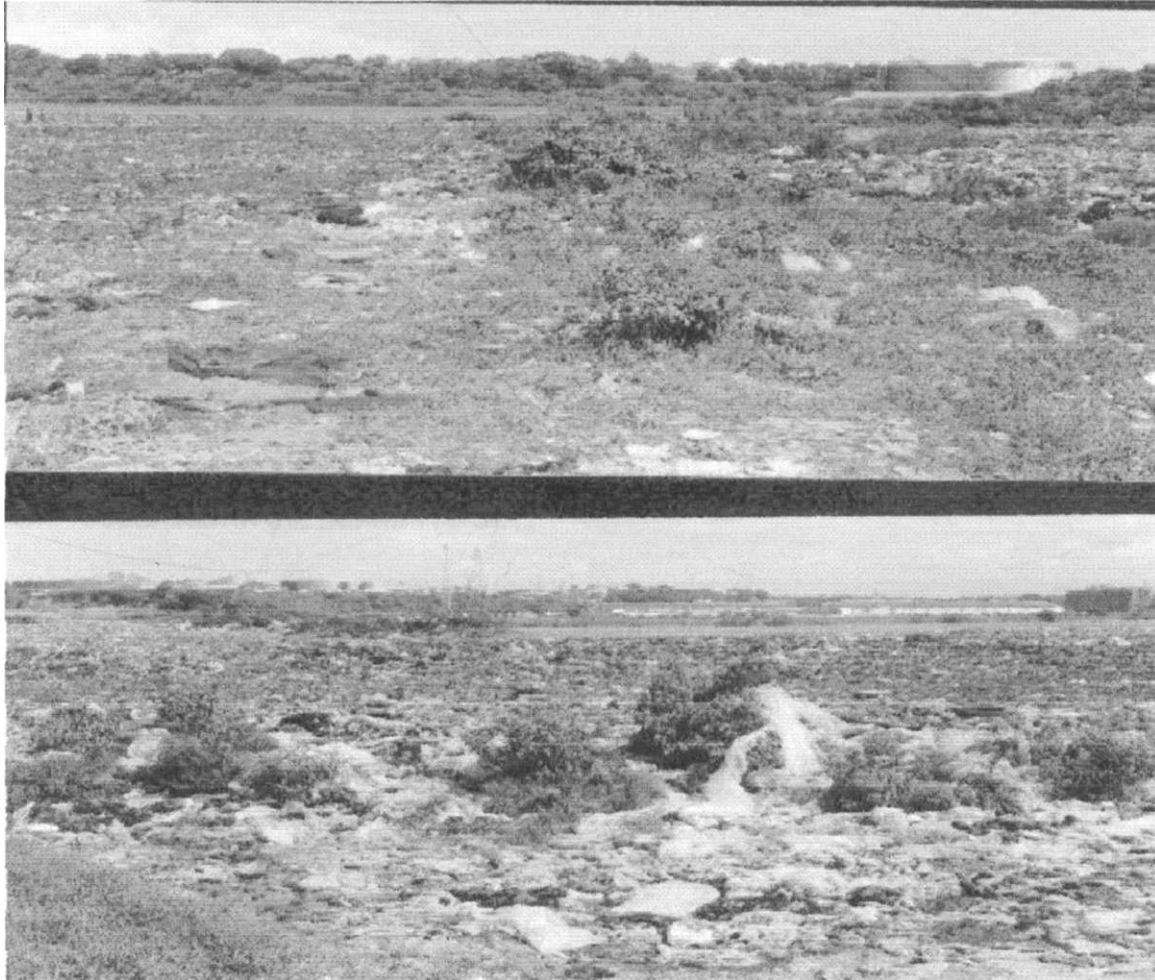


Plate 2: The Official Municipal Solid Waste Dumping Site at Kibarani

The plate shows the location of Kibarani on the edge of the Indian Ocean at the Makupa Creek. The foreground of the upper plate shows, fuel oil storage tanks of the Kipevu power generating station; the waters of the Indian ocean and the solid waste that is littered on the background of the plate, which pollutes the waters of the creek. In the lower plate, we see more fuel oil storage tanks and the warehouses at the Kilindini Port; we also see that the solid wastes dumped extend into the sea. The expanse of the solid waste on the background of the lower plate shows that no vegetation can grow here. This once highly vegetated place is largely bare of vegetation, except for the patches as seen in both plates due to the pollution effects of the wastes dumping.

The widespread dumping of refuse and sewage sludge from the many years of uncontrolled tipping are also thought to be responsible for the pollution of the

Makupa creek. As the Kibarani tipping site is not fenced, thus offering free access to it over the many years of its use, large layers of the waste have formed to cover the soils and therefore inhibiting the growth of vegetation.

4.5.2 Impacts of Sewage on Groundwater

As groundwater is a very important source of potable water in the district, its quality has to be assured. As has been observed, since most of the wells and boreholes are sited alongside human settlements, they may be under a constant threat from pollution by human wastes, which this study has verified. The Government Chemist Department, according to Mr. Kombo, the Assistant Government Chemist, used to undertake bacteriological examination of freshwater supplies almost routinely but the exercise had to stop due to lack of funds. The present condition of the water quality is presented from the studies of the researcher in the tables 7(a-d).

Table 7: Results of Bacteriological Examination of Seawater

Table 7a: Likoni Division

Sampling Location	Coliform counts/100ml	E. Coli counts/ 100ml	Remarks
Mtongwe Pri. Sch. (w)	30	6	PL, NC, Protected
Mtongwe Kenya Navy (w)	1800+	45	ST/SP. NC, Protected
Mtongwe Village (w)	1800+	1800+	PL. NC. Not Protected
Kenya Navy HQ (bh)	0	0	ST/SP. C
Kenya Nvy Mosque (bh)	43	23	ST/SP. NC
Kenya Nvy Women (bh)	210	4	ST/SP. NC
Approved School (bh)	150	23	ST/SP,
Mavveni Mosque (w)	1800+	1800+	PL. NC. Open
Kiavvairera Mosque (bh)	0	0	PL. C
Caltex Ferry (bh)	1100	1100	ST/SP. NC
Misufini (w)	1100	1100	PL. NC, Open
Kitaruni (w)	180CH-	150	ST/ SP. NC, Open

Key: PL-Pit Latriite; C-Chlorinated; NC-Not Chlorinated; ST/SP-Septic Tank-Soakage Pit; bh -borehole; w -

Table 7 b: Changamwe Division

Sampling Location	Coliform counts/ 100ml	E. Coli counts/100ml	Remarks
Port-Reitz Hospital (w)	1800+	1600	NC; ST/SP Area
KR Shed (bh)	0	0	NC; no ST/SP nearby
Port-Reitz Comer (bh)	23	5	NC; SW Area

Key: SW-Sewered area; NC -Not Chlorinated; ST/SP -Septic Tank/Soakage Pit

Table 7c: Kisauni Division

Sampling Location	Coliform counts/ 100ml	E. Coli counts/100ml	Remarks
Utange former RC (w)	80	17	NC; PL Area
Shimo Prison (ow) older	8	2	C; ST/SP Area
Shimo Prison (ow) old	1800+	1800+	Open: NC; ST/SP Area
Kitaruni Kongowea (ow)	110	35	NC; ST/SP Area
Near Ratna Sq. (ow)	1600	20	NC; ST/SP Area
Mkomani (ow)	350	30	NC; Pit Lat.: ST/SP
Mkomani Sagaaf (w)	1800+	200	NC; Pit Lat.; ST/SP
Bombolulu Bohra (ow)	1600	710	NC; Pit Lat.; ST/SP
Kisauni Sokoni (w)	17	0	Pit Lat.; ST/SP
Show ground (bh)	11	4	ST/SP. NC. No setlmnts.
Dhamji Kongowea (bh)	1100	240	PL. ST/SP. NC
Jeta Kongowea (bh)	460	7	PL, ST/SP, NC
Abdalla Kongowea (bh)	460	240	PL. ST/SP. NC
Customs Bamburi (bh)	1800+	210	ST/SP. NC
MITC (bh)	43	0	ST/SP. NC. No setlmnts
Sch. Phy. Hndcp (bh)	150	9	ST/SP. NC, „
Show ground (bh)	4	0	ST/SP. NC, No. Setlmnts.
Mtopanga (w)	460	43	ST/SP. NC. Protected
Kiembeni Damaga(bh)	23	9	ST/SP. NC
Bamburi Kitaruni (w)	240	24	ST/SP. NC. Protected
Kiembeni Mulji (w)	43	9	ST/SP. NC Protected

Key: C- Chlorinated; w -well; ow -old well; toh -borehole; setlmnts -settlements; Hndcp -handicapped

Table 7d: Island Division

Sampling Location	Coliform counts/100ml	E. Coli counts/100ml	Remarks
Kibokoni (bh)	0	0	NC;
Makadara (bh)	50	2	SW, NC;
Kuze (bh)	175	2	SW. NC;
Mji wa Kale (bh)	25	5	SW. NC;
Anisa's Cafe Kilifi (bh)	35	5	SW. NC;
Coast Bottlers (bh)	25	0	NC; ST/SP Area
Arya-Samaj Pri. (bh)	900	8	NC; ST/SP Area
Near Manor Hotel (bh)	35	2	NC; ST/ST Area
Makupa church (bh)	32	2	NC; ST/SP Area
Makupa Church (vv)	1800	40	NC; ST/SP Area
MEWA Hospital (w)	1800+	25	NC; Open well*
Railway Station(bh)	35	0	NC; ST/SP Area
Kizingo. Hyder s (bh)	50	0	SW. NC,
Blue Room HLA (bh)	1800+	7	NC; SW
KPLC (bh)	50	2	NC; ST/SP Area
Sapphire Hotel (bh)	2	0	ST/SP. C;*
St. Aug. Pri. Sch. (bh)	95	5	NC; ST/SP Area
Msa Polytechnic (vv)	1800+	45	NC; ST/SP Area
Central Bank Bldg (bh)	25	0	NC; ST/SP Area
Star of the Sea (bh)	0	0	C *
Kizingo (bh)	0	0	SW. NC,
Coast Car Park (bh)	43	43	SW. NC,
Shimanzi (bh)	23	0	ST/SP. NC
Law Courts (bh)	4	4	SW. NC
Central Bank (bh)	0	0	SW. NC
Makupa Nursing Hm bh	4	0	ST/SP. NC
Msa Polytechnic (bh)	15	4	ST/SP. NC
CDA ((bh)	93	40	SW. NC
Khainis High Sch. (bh)	1800+	240	ST/SP. NC
Std Bank Tr. Sq. (bh)	38	9	SW. NC
Ziwani Msq. (bh)	93	25	ST/SP. NC
GTI (bh)		0	SW. NC
Tudor High Sch.^w)	1100	210	ST/SP. NC. Protected

The international standards for drinking water specify that the coliform count in drinking water should not be more than 10 per 100 ml of sample; and that there should be no E. Coli in the water.

As the tables of results indicate, sewage pollution is widely distributed in the groundwater sources of Mombasa. In most cases it has been found that the quality of the water derived from these sources is well below the international standards for drinking water.

As it has been suspected that seawater may also be impacted, we move to appraise the situation in this marine water environment.

4.5.3 Impacts of Sewage on Seawater

As has been stated earlier on in this research, the Kenyan marine environment is increasingly being subjected to pollution pressure from the human population and its various socio-economic activities. Sewage discharges enter the marine environment with no treatment at all. The study verified the situation and the results of analysis are presented in the tables 8(a-d)

Tables 8: Results of Bacteriological Examination of Seawater

Table 8a: Tudor Creek

Sampling Point	Coliform Counts/100ml	E. Coli/100ml	Remarks
Mombasa Hospital	1200	10	The influence of these establishments to sewage pollution is brought out.
Coast General Hospital	1600	12	
Mombasa Polytechnic	1700	14	
Tudor Housing	2310	15	

Table 8b: Kilindini and Port-Reitz Creeks

Sampling Point	Coliform Counts/100ml	E. Coli/100ml	Remarks
Kibarani	2250	500	The influence by Kipevu discharge point and the Kibarani dumping ground are brought out.
Kipevu	2450	1800	
KPA	900	250	
E A Molasses	500	210	

Table 8c: Mtwapa Creek

Sampling Point	Coliform Counts/100ml	E. Coli/100ml	Remarks
Shimo la Tewa School	600	125	The creek waters show evidence of pollution by sewage.
Mtwapa Bridge	1500	350	
GK Prison Shimo la Tewa	2100	1200	

All the creeks have shown high levels of sewage contamination, making the water to be unsuitable for recreational purposes. The water may also pose a threat to these nursery grounds for juvenile fish and to human health.

Table 8d: Lagoon along Nyali-Bamburi-Shanzu Beach Hotels

Sampling Point	Coiliform Count	E.Coli	Remarks
Nyali	110	25	These lagoon waters qualify under EEC Regulations for recreational purposes.
Mombasa Beach	31	10	
Reef Hotel	30	12	
Bamburi	30	9	
JK Public Beach	130	35	
Serena	35	9	
Shanzu	40	8	
Mtwapa Creek mouth	150	40	

The coliform and E. coli counts in the lagoon waters along the beach hotel were found in most cases to be below 100/100ml. The water therefore meets the European Union standard for recreation purposes. Only at Nyali, the Jomo Kenyatta Public Beach and the mouth of the Mtwapa Creek, were the counts higher than 100/100 ml. This happens to be so because of the influence of the sewage contaminated Tudor and Mtwapa Creeks, while at the public beach, the over 3000 people who frequent and bath in these waters, (some of who, defecate in the nearby bushes), all of which has health implications

4.6 Impacts of Sewage on Human Health

Sewage is responsible for the introduction of pathogens in water that may lead to many water borne diseases like cholera, dysentery, typhoid, diarrhoea, intestinal worms, diseases of the skin and eye infections among others. The way sewage is disposed of impinges directly on the levels of mortality. A case is reported in February-March 1999, where a burst sewer line contaminated the main reticulated water supply with the following consequences: 470 out of 1628 people tested positive for cholera with reported deaths; 66 out of 179 tested positive for typhoid, also with reported deaths, (UNEP, 2000). This occurrence has presented the important link between sewage contamination and water borne diseases.

A search at the Mombasa City health information systems and record office for the annual reports of the years 1998 to 2000 yielded the following daily outpatient return of morbidity of diseases related to the sewage problem, tables 8(a-c).

Tables 9: Out Patient Morbidity in Mombasa District, 1998-2000

Table 9a: Out Patient Morbidity 1998

Disease	Island	Kisauni	Changamwe	Likoni	Total	%
Diarrhoea	2, 401	1, 998	2, 359	107	6, 865	5.2
Malaria	13, 895	15,727	15, 164	1, 730	46, 516	35.2
Worms	943	1,006	1,103	82	3, 134	2.4
Eye Inf.	692	637	587	72	1, 988	1.5
Skin Inf.	4, 444	5,647	5, 308	613	16, 012	12.1
Others	17, 392	17, 314	20, 938	1, 840	57, 484	43.5

Table 9b: Out Patient Morbidity 1999

Disease	Island	Kisauni	Changamwe	Likoni	Total	%
Diarrhoea	1,627	2, 251	1, 381	145	5, 404	4.8
Malaria	10, 933	16, 933	10, 354	1, 459	39, 679	35.3
Worms	1,255	1,284	523	97	3, 159	2.8
Eye Inf.	784	496	268	44	1, 592	1.4
Skin Inf.	2, 970	4, 725	3, 534	493	11,722	10.4
Others	19, 360	17, 197	12, 661	1, 610	50, 828	45.2

Table 9c: Out Patient Morbidity 2000

Disease	Island	Kisauni	Changamwe	Likoni	Total	%
Diarrhoea	1, 509	1, 809	1, 401	220	4, 939	5.4
Malaria	11,444	12, 133	8, 621	1, 180	33, 378	36.2
Worms	1, 047	976	512	36	2,571	2.8
Eye Inf.	991	419	246	37	1,693	1.8
Skin Inf.	3, 177	3, 555	2, 149	413	9, 294	10.1
Others	16, 963	13, 911	8, 615	921	40, 410	43.8

Source: Municipal Health Department, Mombasa

In the analysis of the above results, it is observed that more than 50% of all the diseases reported in the district have a relationship to water quality issues, and center on inadequate wastewater management. This makes the management of municipal wastewater to be an issue of major concern, and which, calls for immediate interventions.

A consistence occurrence of the water-borne and wastewater related diseases of diarrhoea, malaria, worms, eye and skin infections are observed over the three years of the data collected. The upsurge of skin diseases to the constant high figure of 10% over the period studied is largely attributed to the advent of the prevalence of high incidences of the HIV pandemic in the district. Contact with contaminated water is still considered to be one of the contributors to the problem of skin infections, however, the contribution through the HIV condition is thought to be the most significant factor now.

Malaria contributes over 30% of all the diseases in Mombasa. It is a disease of the single highest occurrence. The grey water discharges that take place on the surface at the backyard of most the informal houses and the leakage from burst wastewater pipes are thought to contribute to the conditions ambient for mosquito breeding resulting in the significant malaria problem. This is more of a problem associated with dirty and wet environmental conditions than to sewage, but it is, nevertheless, a wastewater management problem, that cannot be divorced from the management of sewage. The presence of bushes also offers good habitation for mosquitoes.

The problems of eye infections and the recurring cases of worms have also been blamed on the use of contaminated bathing and drinking water sources. In most cases, the contamination by faecal matter has been thought to be the main cause. From the findings of this study, pertinent conclusions have been drawn, and these are now presented in the chapter five, which follows.

CHAPTER 5:

CONCLUSIONS

5.1 Conclusions

5.1.1 The Sewage Infrastructure

From the findings of the study, it is concluded that Mombasa district suffers the same sewage management problems characteristic of any large urban center with an inadequately planned growth. Lack of funds for capital investment in infrastructure, inadequate resources for maintenance, uncoordinated institutional arrangements, weak legislation coupled with the "out-of-site, out-of-mind" attitude of the stakeholders, is among the factors that have contributed to the problem.

While the population in the district has grown over the years, as revealed by the study, the sewage infrastructure has not done so. It is therefore concluded that the high rate of population growth has overwhelmed the existing sewage infrastructure beyond its limit. Water borne sanitation is limited and only serves a small population of the Municipality, leaving the majority to rely on pit latrines. This on-site method for human waste disposal is not appropriate if we are to consider the importance of groundwater as an alternative source of potable water supply.

The study has also found out that the central sewage network also serves for industrial effluents. This puts toxic substances into the sewage, rendering the now moribund biological oxidation treatment plants (that depend on bacteria) ineffective even if they were operational. This notwithstanding, the sewage treatment plants are nevertheless old beyond repair and presently only serve as point sources of marine pollution.

While efforts have been taken to build a new plant for the Chagamwe division to replace the now moribund one, similar efforts are not in place for the Kizingo treatment plant. Though these existing networks serve only a few people and a few places, they nevertheless cause concern because the raw sewage enters the marine environment.

Neither are there any efforts to have in place a sewerage system for the Kisauni and Likoni divisions, which means that on-site disposal will have to be relied well into the future, thereby posing a continued threat to the groundwater quality of the area.

Though the study appreciates the good condition of the septic tanks and soakage pit systems in most of the areas where development is planned, the poor condition of a few of these systems, pose a threat to human health. This notwithstanding, despite the deficiency, they still offer an acceptable and reliable on-site sewage management option.

The other systems for human waste management are the pit latrines. The study concludes that the pit latrines in most of the planned Swahili houses are well maintained. The same cannot be said for the slum areas. But good or bad condition apart, the toilets have been inappropriately constructed in relation to groundwater sources. The pit latrines, which are found alongside wells and boreholes in the human settlements, and dug down ground to the water table, are ultimately responsible for the sewage contamination of the groundwater, polluting it in the process and causing environmental and public health concerns.

In the slum areas, the shallow pit latrines fill-up very fast on use. They are also prone to flooding during the rainy season when the water table has risen. It is therefore worthy to hold them responsible for the surface diffuse pollution and the spread of sewage contamination to unprotected wells. The water-borne and

water related diseases of major occurrence in the district are partly traced to this root as one of the causal chains.

For the Beach hotels and other institutions like hospitals and learning institutions, it is concluded that the septic tank-soakage pit system is still the preferred mode for sewage management. Though some hotels have shown innovation by installing their own treatment plants and recycling the wastewater, the study concludes that the use of on-site sanitation for these establishments will continue well into the future. As many establishments still rely on this method of sewage disposal, the abuses by unscrupulous sewage handlers', which has been reported, needs to be checked. The vigilance to protect the swimming waters of the lagoons and artisan fishing grounds, which is missing, needs to be put in place, and to charge the offenders for their crimes.

In summary, it is concluded that the sewage infrastructure in use in the different areas of the district is inadequate to cope with the rising population and the rapidly growing urbanization, which is taking place. It is also concluded that in some settlements, the infrastructure is inappropriate. In others, the maintenance is poor. From this narrative therefore, it is concluded, that the different types of the sewage infrastructure have failed to keep pace with the demands of current development trends, urging for the need to adopt other innovative infrastructure types and adopting them.

5.1.2 The Sewage Management Practice

The sewage management practice in Mombasa is still traditional and offered as a social service by the Local Authority, based on what we call the *supply-driven approach*. The adoption of this approach to sewage service provision is based on the country's policy of providing free and adequate sanitation to all in the overall context of development. This approach to sewage management requires support, both in human expertise and functional administrative set-up, let alone

sustainable and adequate financing. Unfortunately, the local authority lacks these. The poor or missing coordination among the different sections of the city council hinders effective actions on sewage management. It is also concluded that, the lack of supervision of the private sewage service providers by the local authority, is responsible for the abuses of sewage dumping in unauthorized areas, and has to be checked.

Technically, the Department of Environment is very elaborate in terms of personnel, but very grossly under equipped for the tasks under its tutelage. The lack of maintenance of infrastructure relating to sewage has also left the little available equipment to be in a state of disrepair and inefficiently utilization. This explains the constant breakdowns reported, which negate effective sewage management. Thus without the means of transportation and equipment, the equipment, the study concludes that the labour-force idles around most of the time albeit at a cost in terms of remuneration. The same held true for the laboratory facilities meant to support the monitoring of sewage. Hence, the study concludes that, there is lack of capacity for sewage undertaking by the City Council.

The cost of putting up and running a conventional sewage delivery and treatment facility is high. That is why we see a mixture of the less costly sewage management technologies in practice in Mombasa. Nevertheless, even the low cost technologies demand a solid financial revenue base to sustain, which is missing in the Council.

There is a weak revenue generation and cost recovery mechanism for the sewage management service in Mombasa. The municipality does have a strong revenue base to finance neither the service nor an effective cost recovery strategy compensatory of it. Its financing has depended on revenue collected from services that have no bearing to sewage. This does not sound palatable in modern economics. As the cost recoveries imposed by the Local Authority when

it undertakes the service are not commensurate with the effort and man-hours spent doing the job, sustainability for future operations is lost. The study concludes further that despite the existence of sewage tariffs, there has been a large operational deficit due to a number of reasons including inadequate collection of bills and illegal connections to sewer lines, depriving the municipality of badly needed operational funds. This is compounded by the country's policy, which places the provision of sewage as a social service to be subsidized by the government, as a result of which, the citizens have not appreciated to see themselves as stakeholders in sewage generation and therefore its management, including its cost implications. This, it is affirmed, has thwarted all the efforts in sustainable sewage management.

In conclusion, it can be said that the existing financial arrangements of revenue generation to finance sewage management in Mombasa are not adequate and the *status quo* cannot be sustained. Innovative methods and approaches for generating funds to finance the management of sewage have to be sought.

5.1.3 Environmental Impacts

5.1.3.1 Impacts at the disposal site

The impact of sewage at the disposal site is largely that associated with the loss of aesthetics of the nearby shoreline environment, attraction of flies, and for this case, the introduction into the nearby marine water of organic matter that leaches out through from the other solid wastes. At the disposal site, the study concludes that due to constant disposal, the vegetation growth has been badly affected and in many areas of the disposal site the land is bare of vegetation. This has needless to say exacerbated the coastal erosion problem, (refer to Plate 2).

5.1.3.2 Impacts on groundwater

The study has also confirmed the wide spread contamination of groundwater by sewage in Mombasa. This is so because; pit latrines exist alongside the wells and boreholes in the human settlements. In larger parts of Mombasa, because the water table is generally high, and the rock basement coral, groundwater movement is accelerated through cracks and fissures in the limestone with little filtration. This, coupled with the high density of human settlements and the pit latrines that go with the settlements means that the use of groundwater as a substitute for the reticulated water supply by implications means that people drink sewage contaminated water.

5.1.3.3 Impacts on seawater

As far as the contamination of the marine environment by sewage is concerned, the study concludes that the hot-spot locations are those areas adjacent to sewage out-falls, where both legal and illegal discharges take place. Due to these unabating discharges, all the Creeks in Mombasa have shown a high degree of sewage pollution. The levels of sewage contamination in the creeks is worrying, bearing in mind that, the creeks offer breeding grounds for fish and are nursery grounds for the juveniles.

Another point to be noted is that, in the creeks are to be found the *bi-valves* like oysters, which have filter-feeding mechanisms and are capable of accumulating high concentrations of coliforms and *e-coli* in their bodies. Since oysters are a delicacy in the hotel industry and are usually eaten raw, sewage pollution is potential threat for those who like eating oysters.

Tourist dhow cruises used to be very popular in the creeks with dinner served in the process. With sewage discharges and the obnoxious smell emanating, the cruises are no longer popular, thus impacting negatively on an otherwise very

popular tourist activity. As a result of the sewage pollution, it is concluded that, the cruises are only of minimal occurrence these days, with loss of revenue from tourism, and the loss of livelihood means for those who depended on this trade.

The lagoons along the beach hotels are relatively free from sewage contamination as alluded by the study. The dilution factor of the waters of the Indian Ocean at the moment seem capable of doing the trick, receiving confirmed sewage contaminated waters from the creeks and diluting it to levels of coliform and *e-coli* bacteria acceptable for recreational uses of the water like swimming. This, notwithstanding, it is still very worrying because sewage pollution from the creeks seems not to abate; on the contrary; the volumes discharged are increasing with urbanization.

5.2 Impacts on Public Health

The study has revealed that over 50% of all the public health problems in Mombasa district are water related. This is a worrying situation, unless the sources of pollution and poor wastewater management are addressed. The reported death from the drinking of sewage contaminated water lends credence to the impact of sewage on health, as is the case of the prevalence of malaria cases at above 30% rate of occurrence. These water related and water-borne diseases, which result from poor sewage management, as the study has found, evidently burden the population.

The proposed interventions are now presented as recommendations in chapter six as the way forward in addressing the sewage problem.

CHAPTER 6

RECOMMENDATIONS

6.1 Short term Actions

To remedy the immediate sewage management problems, the steps that can be taken include the proper siting of pit latrines and to ensure that they are constructed according to set guidelines. There should therefore be effective control of pit latrine development in the unplanned settlements. Mr. Haji Massa, a chemist with the Ministry of Environment and Natural Resources recommends that if the residents of Mombasa value the groundwater resources, then the unplanned development in human settlements should be stopped.

The careless discharge of wastewater at the back of most human settlements should be checked to avoid creating conditions that are ambient to mosquito breeding. This will reduce the impact of malaria on public health. To counter the malaria problem, a multi-sectoral approach, involving many stakeholders is necessary if the problem is to be put under control. The efforts of the residents and health workers must be drawn together if lasting solutions are to be found.

The development of wells and boreholes as sources of potable water along human settlements ought to be discouraged if sewage related diseases are to be minimized. The residents of Mombasa should be discouraged from relying on groundwater, and in its place be advised to diversify to rainwater harvesting as a source of potable water.

To avoid the pollution of the waters of the creeks, the Kibarani dumpsite should be relocated as had been proposed by other studies. Similarly, the institutions that discharge their sewage ^{it} to the marine environment should be advised to stop, and concentrate with the rehabilitation of their on-site sanitation.

While these short-term recommendations will offer short-term remedies, long-term solutions must be sought. Recommendations for long-term solutions to the problems are now suggested.

6.2 Long Term Actions

The approaches for long-term solutions to the sewage management problem are given in four categories: political commitment and public awareness; institutional arrangements and legal framework; technical options; and financial arrangements. The four recommendations are now discussed.

6.2.1 Political Commitment and Public Awareness

Kenya has shown political commitment in the formulation and adoption of policies and the enactment of laws and regulations on sewage management. This can be seen through the Environmental Management and Coordination Act of 1999. This Act presents elaborate mechanisms for sewage management and therefore needs to be operationalized quickly. The Act has devolved regulatory authority to local authorities on sewage management by law. Therefore, there is need for political commitment to invest resources for training of staff to impart the required practical skills in environmental management including policy and financial planning with a focus on the reduction of environmental impacts by sewage. To achieve success in sewage management there is a need to involve the private sector in the awareness campaigns.

There will have to be followed with awareness raising campaigns and knowledge building about sanitary practices in sewage management as a central feature in all sewage related projects. Extensive education and information campaigns are required to secure awareness[^] among the residents that as stakeholders in sewage generation, they should participate in its management. Environmental education should therefore be emphasized in schools, in refugee camps, in

individual households and in public meetings, as a long term approach to remedying the impacts of sewage. *(In order for environmental activity to be successful in the long term, it must take root in the hearts and minds of the world's people. When people understand the reasons for making responsible environmental choices, there is a greater chance they will take the reasons to heart and incorporate the actions into their daily lives, (UNEP/NGLS, 1995)).*

6.2.2 Institutional Arrangements and Legal Framework

Effective sewage management requires adequate legislation, such that laws cover every aspect that needs to be regulated (GPA, Washington 1995). The effectiveness of such laws and regulations depends on whether they are enforceable and deterrent enough. For the case of our country, the Environmental Management and Co-ordination Act, 1999, (EMCA), which is being operationalized must be enforceable and seen to be deterrent enough on sewage issues. Strong institutional arrangements must therefore be built to effect the law. In the new setting, institutions need to be empowered to take up tools like Environmental Impact Assessment and Environmental Auditing applied, in to addressing the sewage problem. Also as water supply and sanitation services go hand in hand, there may be need to charge a single institution with these responsibilities for ease of coordination, as opposed to the current practice where these services are offered separately.

Similarly, because the enforcement- of laws requires a system of quality monitoring for standards compliance, it is important that adequate technical and financial capacities are developed within the local authorities, which are mandated for sewage management. As, policing and enforcement of fines and penalties alone may not be enough in sewage management; a shift in emphasis towards economic instruments as outlined in the Environmental Act should be relied upon as a complement to improve compliance.

Finally, it is an acknowledged fact that growing population and urban migration causes urban environmental problems. These root causes must be addressed through appropriate policies and improved urban planning. Mr. Maddy, Agil and Jabu, all trained physical planners, recommend the encouragement of the development of a satellite town around Mombasa to take away the migration pressure, which is swelling the population of the municipality, leading to the immense pressure on the sewage infrastructure. This recommendation should be taken seriously.

6.2.3 Technical Options

Conventional sewerage undertakings are expensive to run for poor municipalities without adequate financial resources. The experience in Mombasa District has shown that the maintenance problem constitutes the main cause for the inoperational plants. Other innovations therefore have to be considered, and a few examples are given below: -

- Tested non-conventional sewage treatment technologies should be adopted. These include natural and artificial soil filtration and multi-level biological systems based on natural and artificial wetlands.
- Reuse of sewage effluent offers another technical option. Citizens could be educated for change of attitude to accept that sludge from sewage has nutrient value, while the treated effluent can be used other ways. Such uses include the composting of the sludge to form manure for agricultural uses or the use of the effluent for the watering of gardens or farmlands. As attitude begins to be positive towards this re-use value, a "no-discharge" policy regarding sewage should be encouraged. As the use of sewage effluents becomes effective, the no-discharge policy can be enforced.

- Dry sewage management options could be tried. This calls for households that use the pit latrine to ensure that they do not mix bathroom water with the toilet contents. There should be separate pits for wash water and toilets. This is to avoid having the pit latrines being in permanent wet states and therefore act as cells of underground pollution to water sources.
- The use of cheap, but appropriate and efficient technology, developed elsewhere should be pursued, and where appropriate, the transfer of such technology, should be encouraged

As a corrective measure, deliberate efforts need to be put in place to upgrade the existing sewage infrastructure or change some of it altogether, for example: -

- As the beach hotels occur in clusters, such establishments could pull resources to put up small scale plants, where for example, a cluster of say five hotels pull resources to finance the treatment of the sewage they generate. This could be more cost effective than each hotel going it alone as is currently practiced by some hotels. The sewage effluent could then be channeled for the watering of the extensive gardens of the hotels
- The existing sewage out-fall at Kipevu is certainly poorly located in terms of the tides and currents dynamics of the area. As a corrective measure, extension of the sewage network to be served by this out-fall should be avoided. Further to this, it should be ensured that out-falls developed in the future are sited based on scientific studies of the tides and currents of the area. This is so because tides and currents play an important role in minimizing or even eliminating sewage problems, and advantage must be taken of this.

The other option that could be encouraged is: -

- Requesting the government to encourage the private sector through economic incentives to adopt ecological engineering for sewage treatment, a technology that is available in the market. The uses of other incentives like the opportunity to import duty free, all equipment to be used in sewage management. Grant financing could be sought. Other methods that could be used include equity or revolving funds, which the government could set up for sewage management.

6.2.4 Financial Arrangements

Given the limited resources of the Mombasa municipality in financing the management of sewage, public-private sector partnership approaches as outlined in the Mombasa beautification campaign Terms of Reference, provide a promising approach in involving the business community to finance infrastructure development in the district. This approach should be pursued vigorously in addition to adopting the following: -

- The 'polluter pays principle' as contained in the EMCA of 1999, should be operationalized to act as a precautionary measure against wanton pollution and deter potential polluters from risking the financial penalty
- As the costs of providing effective sewage management services are high and variable subject to the vagaries of inflation, sewage tariffs as out lined in the EMCA should be reviewed on a regular basis to keep up with inflation and other costs. In the event that full costs cannot be recovered for the service, then efforts should be made to at least recover the operational costs, where people pay for common but differentiated responsibilities according to their financial endowments.

- Consideration should be given that in future the sewerage service is demand driven before it is provided so that the recipients pay for it. Full cost recoveries in water and waste water supply services to support sanitation projects could be pursued.
- Finally there should be concerted efforts to provide the sewage service to the poor members of society to relieve them of the disease burden of the sewage-related diseases. This could be done through small scale, but widely distributed projects in the poverty stricken areas to save them from the sewage maladies and to capture their strength for productive economic activities to alleviate the poverty situation they find themselves in and to contribute towards nation-building.

6.3 Areas for Further Research

Since the creeks around Mombasa are nursery ground for juvenile fish, for prawns and offer habitat for bi-valves like oysters, which are collected and eaten raw, the impact of sewage on the juvenile fish and the levels of pathogens the bi-valves accumulate in their bodies need further investigations. Another fertile ground for research in this field is the need to commission studies on the costs and benefit of treating sewage so as to get a glimpse of the cost of no action. Such information would be useful for decision making on this vital service to society.

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APPENDICES

Appendix 1

Environmental Management and Coordination Act, 1999

PART II - GENERAL PRINCIPLES

3. (1) Every person in Kenya is entitled to a clean and healthy environment and has a duty to safeguard and enhance the environment

(2) The entitlement to a clean and healthy environment under subsection (1) includes the access by any person in Kenya to the various public elements or segments of the environment for recreational, educational, health, spiritual and cultural purposes.

(3) If a person alleges that the entitlement conferred under section (1) has been, is being or is likely to be contravened in relation to him, then without prejudice to any other action with respect to the same matter which is lawfully available, that person may apply to the High Court for redress and the High Court may make such orders, issue such writs or give directions as it may deem appropriate to: -

- (a) prevent, stop or discontinue any act or omission deleterious to the environment;
- (b) compel any public officer to take measures to prevent or discontinue any act or omission deleterious to the environment;
- (c) require that any on-going activity be subjected to an environmental audit in accordance with the provisions of this Act;
- (d) compel the persons responsible for the environmental degradation to restore the degraded environment as far as practicable to its immediate condition prior to the damage; and
- (e) provide compensation for any victim of pollution and the cost of beneficial uses lost as an act of pollution and other losses that are connected with or incidental to the foregoing.

- (4) A person proceeding under subsection (3) of this section shall have the capacity to bring an action notwithstanding that such a person cannot show that the defendant's act or omission has caused or is likely to cause him any personal loss or injury provided such action: -
- (a) is not frivolous or vexatious; or
 - (b) is not an abuse of the court process.
- (5) In exercising the jurisdiction conferred upon it under subsection (3), the High Court shall be guided by the following principles of sustainable development;
- (a) the principle of public participation in the development of policies, plans and process for the management of the environment;
 - (b) the cultural and social principles traditionally applied by any community in Kenya for the management of the environment or natural resources in so far as the same are relevant and are not repugnant to justice and morality or inconsistent with any written law;
 - (c) the principle of international cooperation in the management of the environmental resources by two or more states
 - (d) the principle of inter-generation and intra-generation equity;
 - (e) the polluter pays principle; and,
 - (f) the precautionary principle.

Source: Republic of Kenya, EMCA, 1999, The Government Printer, pp. 63-65

Appendix 2

List of interviewees

Abubakar Maddy	-Chief Planning Officer, Mombasa Municipality
2. Abdulkadir Said	-Chief Public Health Officer, Mombasa Municipality
3. Agil Swaleh	-Provincial Physical Planner, Coast
4. Anthony Kombo	-Assistant Govt. Chemist and Resident of Kisauni
5. Alii Mutta	-Resident, Changamwe
6. Ali Gakweli	-Resident Likoni
7. Bakari Bardale	-Honorary Warden, KWS
8. Bilaff	-Ag. Director of Environment, Mombasa Municipality
9. Edward Jefwa	-Resident, Kisauni
10. Edward Karani	-Town Clerk, Mombasa Municipality
11. Fumo	-Boat Operator
12. Hamisi Mboga	-Director of Social Services
13. Jabu Salim	-District Physical Planner, Mombasa
14. Johnson Kazungu	-Director, KMFRI
15. Khadija Shakombo	-Resident, Nyali
16. Kuldip Sondhi	- Hotelier
17. Lawrence Nyawa	-Resident Kizingo
18. Luggo	-Cleansing Superintendent, Mombasa Municipality
19. Martha Mukira	-Fisheries Officer
20. Mohamed Skanda	-Retired Director of Environment, Mombasa Municipality
21. Mohamed Mwaita	-Health Records Officer, Mombasa Municipality
22. Mwamwindi	-Businessman, Island Division
23. Mzee Athmani	-Fisherman
24. Ziro Pore	-Resident Kisauni

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