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Urbanization and Groundwater Pollution in Mombasa-Kenya: Do we have to Transfer the Problem due to Construction of the Dongo-Kundu By-Pass

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Abstract

We show how a bridge and good road network opened up the Mombasa County to rapid urbanization and growth of human settlements beyond the ability of Local Government to provide the infrastructure for human waste management, leading to pollution of groundwater aquifers and effects in public health. We caution that the same would happen in the Kwale County upon construction of the Dongo-Kundu By-Pass linking it to Mombasa. Up to 1979, the population distribution in the Mombasa County was restricted by difficulties of access, particularly at its potential district of Kisauni, which though offering plenty of land for housing development, was not overpopulated due to difficult to access. However, upon construction of the Nyali Bridge the early 1980s, the population dynamics shifted, making Kisauni the most populated area. It remains so and this population uses on-site sanitation systems for human waste management. This has had impact on groundwater aquifers through microbial pollution, rendering otherwise chemically suitable water unsuitable on this account without treatment. Construction of the Dongo-Kundu By-Pass to link Mombasa with the south coast will open the Kwale County to rapid urbanization, replicating the water pollution problem experienced in the Mombasa County, particularly in the locations found along its coastal belt. In this study technical measures, zoning and declaration of areas for conservation of groundwater aquifers have been proposed to forestall the problem in the newly to urbanize area.

Key words: Ease of access, on-site sanitation, groundwater pollution, water borne diseases, effects on public health

1. Introduction

This study is about safeguarding groundwater quality against pollution from poor sanitation systems. Safe drinking water is necessary for a healthy community. Groundwater source must therefore be protected from sources of pollution, particularly, the wastes of human origin through the provision of basic sanitation to ensure hygienic excreta and sullage disposal as a way of providing a clean and healthy living environment. One of the Millennium Development Goals is to increase the proportion of the global population with access to safe drinking water from 77% in 1990 to 88.5% by 2015 (cited in Ngethe, 2012). This goal will not be possible to realize without inclusion of access to basic sanitation for human waste management. Human wastes introduce pathogens to water resources; resulting in freshwater shortages, as such water is not available for human use since it known to cause waterborne diseases. The consequences of not having safe drinking water are known to be severe. About 1.6 million people, die every year from diarrheal diseases (including cholera), attributable to lack of access to safe drinking water and basic sanitation with 90% of the deaths occurring among children under 5 years of age (cited in Ngethe, 2012). Expanding access to water and sanitation is described as a moral and ethical imperative rooted in the cultural and religious traditions of communities around the world as dignity, equity, compassion and solidarity are shared values; hence extending water supply and sanitation services to poor households would promote these values. Access to water (UN General Comment No. 15, 2002) is judged to be "indispensable for leading a life of human dignity" and "a prerequisite for the realization of other human rights" (cited in Ngethe, 2012)

The UN General assembly, in December 2003 proclaimed the years 2005 -2015 as the International Decade for Action “Water for Life”, popularly known as the Water Decade. The goal of the Water Decade is to promote efforts to fulfill international commitments made on water and water related issues, signifying the importance of water in development. The aim of the declaration was to make water accessible to the communities that needed it.

Though progress has been made in providing water and sanitation resources in developing nations, some regions, particularly Southeast Asia and Sub-Saharan Africa are far from reaching their regional targets. Currently, 40% of the population in sub-Saharan Africa is without improved water resources, and 69% are without improved sanitation services (WHO/UNICEF, 2010). Each year about 4 million people die of waterborne diseases, including 2 million children who die of diarrhea. More than 800 million people, 15% of the world population is malnourished, due in part to insufficient water for crops (DFID, 2001). Based on assumptions of population growth, projections of development and climate change, the Stockholm Environment Institute estimated that the proportion of the world's population living in countries with significant water stress will increase from approximately 34% in 1994 to 63% in 2025, including large areas of Africa, Asia, and Latin America. This will impact their lives and livelihood very negatively (Ngethe 2012).

Kenya is classified as a water scarce country with annual water supplies below 1000 m^3/person (UNEP/GRID –Arendal, 2002). The situation is predicted to worsen drastically within the near future as a result of environmental conditions influenced by climate change. This calls for action to safeguard whatever water sources the country may have and protecting groundwater sources is very important since this water sources is often the only source of potable water for many communities. In this research, a desk study was undertaken on the population dynamics, the sanitation systems in application to establish the impact of urbanization on groundwater quality in the Mombasa County. A similar research method of was used to establish the pristine status of groundwater aquifers in the low lying coastal part of the Kwale County in the absence of urbanization.

1.1 Groundwater Quality

Groundwater is an important source of potable water supplies particular in Africa where it is tapped through a combination of hand-dug wells and boreholes. This source of water is mostly relied upon for drinking water supplies, though in some instances, it is also being used for irrigation of market crops. In urban centers, groundwater is an important source of affordable public and private freshwater supplies. However, in the past three decades, rapid urbanization has led to the growth of large areas of unplanned sub-standard housing in most cities, and with residents of such areas depending on groundwater as a source of inexpensive, high quality domestic water supply, there is fear that such water may soon be unavailable. This is being brought by the uncontrolled expansion of the said kind of housing, together with increased sewage generation and effluent leakage, indiscriminate waste disposal, and uncontrolled industrial and commercial activities, all leading to increased pollution and the deteriorating of groundwater quality, mounting to several public health problems (UNEP, 2006).

As a result, aquifer stress now constitutes a genuine crisis in some African countries, where cities and towns are often wholly dependent upon groundwater resources (UNEP, 2006). However, the groundwater aquifers along the coastal lowlands of the South-Coast of Mombasa are yet to be stressed and as such require protection. With sand and coral geology, quick recharge through rainfall, replenishes groundwater aquifers of the area. As the water table is generally high in this belt, groundwater is easily tapped from shallow wells and boreholes as water tapping points. The water derived from these sources is generally chemically suitable for domestic purposes as the Total Dissolved Solids levels are below 1,500mg/liter and salt water intrusion is not yet a major problem. Unfortunately, behind the quick recharge, is also the potential for quick infiltration and spread of pollutants through the coral geology basement, where percolation and the movement of water is aided through cracks in this geological formation and the potential for the spread of pollution may be very high. This has led to recognition that though valued as an indispensable resource for human development, the integrity of groundwater sources get undermined by mushrooming human settlements whose growth and expansion, apart from being prompted by other factors, is most often related to the ease of access to the area. Thus, with good road and bridge network, human dwellings come up very quickly and outstrip the ability of local authorities to provide the infrastructure needed for managing human wastes. This shortfall in sewage management infrastructure brings along with impact on groundwater sources from the on-site sanitation systems developed to serve the human dwellings. The Mombasa County represents such a case study where among many factors, the ease of access through improved road and bridge network, opened up the area so quickly, resulting in the mushrooming of human settlements with negative consequences on groundwater quality and effects on public health. This study represents a caution and late lessons from early warning –an approach to learning from history where groundwater sources are protected as urbanization shifts to Mombasa's South Coast with opening up of the area through the Dongo Kundu By-Pass.

2.0 The Mombasa County Case

The Mombasa County is located between the latitudes 3° 80′ and 4° 10′ S and longitudes 39° 60′ and 39° 80′ E.

It has a total land mass of 229.6 Km^2 and inshore waters that cover 65 km^2. The County is composed of Mombasa and Kilindini districts within Mombasa Island, Changamwe in the west, Kisauni in the north and Likoni in the South. Mombasa Island is predominantly urban while the other districts are largely rural, but quickly urbanizing. The population of the Mombasa County currently stands at 1, 387,823 people with a rate of growth that is higher than the national average. This burgeoning and widely spreading population is accommodated in settlements with on-site sanitation systems that are a source of groundwater pollution, causing freshwater shortages in an area already experiencing inadequate supplies of potable water with effects on public health. It is lessons from this case study that a caution is sounded on the need to protect groundwater aquifers anywhere new development of human settlements takes place.

2.1 Topography and Geology

Mombasa County is situated in coastal lowland with extensive flat areas rising gently from 8 meters above sea level to 100 meters above sea level westwards. The County can be divided into three main physiographic belts, namely the coastal lowland plain, extending 6 kilometers inland, and includes Mombasa and Kilindini districts, Kisauni on the north mainland and Mtongwe to the south. Next is the broken, severely dissected and eroded belt that consists of Jurassic shale, overlain in places by residual sandy plateau that is found in Changamwe district. Finally, there is the undulating plateau of sandstone that is divided from the Jurassic belt by a scarp fault.

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 100meters. Along the coastline are also to be found beautiful beaches, which together with a variety of coastal resources and a rich biodiversity, attract tourist, making Mombasa north and the south coast favourite tourist destinations. The tourist population and local residents need water of acceptable quality for domestic uses. Fortunately, the areas with sand geology have provided a source of such water.

2.2 Water Demand and Supply

The demand for freshwater supplies in the Mombasa County has been growing rapidly over the years. From a demand of an estimated 200,000 m^3day^{-1} in 1995, it rose to 280,000 m^3 day^{-1} in 2010 and is project to reach an estimated 380,000 m^3 day^{-1} by 2020 (World Bank, 1996). The water is mainly used for domestic purposes (which accounts for 35% of the total water uses), for livestock, irrigation and industry (NEMA, 2009). There being no surface water sources in the County to provide for its freshwater needs, the traditional sources of Marere Springs and Tiwi Boreholes in the Kwale County, the Baricho Water supply in the Kilifi County and the Mzima Springs in the Taita Taveta County have been the sources of water consumed. These water supply sources have been overtaken by the demand for water occasioned by the rapid growth in industry, and though there are efforts, expanding the traditional water supply sources, the shortfall will persist until the construction activities are completed. Therefore to address the water shortage, communal boreholes, and wells are common. As such therefore, the shortfall in fresh-water supply is supplemented by groundwater sourced from within the county, and the residents continue to rely on this as a supplementary source for freshwater, and for some areas, the major source for potable water supplies to the households.

Therefore, despite the Mombasa County not having any permanent sources of surface water to cater for its potable needs, favourable geology and high water table gives it quick recharge of its aquifers from rainfall and hence sinking of wells and boreholes have led to increased supplies of freshwater from groundwater sources, supplementing the reticulated supplies considerably. Mapping the chemical quality of the groundwater at the Government Chemist Department (Mwaguni, 2002) showed that groundwater sampled from various locations of the county has the following chemical composition: -

- Groundwater sources developed along the coastal beaches and the low-density residential areas of Nyali, yield water with total dissolved solids (TDS) values above 1,500mg/l. This water is brackish and saline and hardly usable for supplementing the potable supplies.
- Water sources developed in the Shale formations of Mwakirunge and Nguu Tatu in Kisauni and parts of Changamwe Districts, the groundwater is highly mineralized and therefore unsuitable for human use.
- Along the Triasic and Jurassic formations of the flat coastal plain, due to quick recharge with rainwater, the water derived from these aquifers is generally fresh, with TDS ranges of 400-1400m/l and therefore potable.

Unfortunately, on the Triassic and Jurassic bedrock formations where chemically suitable groundwater is found in a shallow water table and tapped are to be found most of the human settlement establishments and these pose the constant threat of sewage contamination of the groundwater aquifers from the on-site sewage systems. The human settlements, their spread and impact on water quality and effects on public health in the Mombasa County are presented and discussed in this report.

2.3 Population distribution and Human Settlements in the Mombasa County

The Mombasa County has experienced a 109% population increase between the years 1999 and 2009. The population distribution in the districts of the Mombasa County is as shown in table 1 below, where the population

Table 1: Population Distribution in the Mombasa County 1979-2009

Administrative Division	Size: Area km^2	Population				% Population increase since last Census+	Population density/ km^2 2009
		1979	1989	1999	2009*		
Island	14.1	136,140	127,720	146,334	523,188	14.57	37,106
Kisauni	109.7	79,995	153,324	249,861	405,930	63.00	3,700
Likoni	51.3	39,665	67,240	94,883	176,426	41.11	3,439
Changamwe	54.5	81,384	113,469	173,930	282,279	53.28	5,179
TOTAL	229.6	336,148	461,753	665,018	1,387,823	44.02	6,045

Sources: Mwaguni 2002 & GoK Population and Housing Census Figures 1979, 1989, 1999 and 2009
NB: *2009 Population figures are based on Political Units, which are different from administrative units
+ Population increase based on 1989 and 1999 Population figures

growth is due both to natural growth and in-migration –mostly of the labour force from other parts of the country in search of opportunities for employment and personal development. This high population and its growth rate have posed a serious challenge in the provision of essential services like water supply, sanitation infrastructure and health care services.

The County's population is distributed in several human settlements within the districts and their distribution is as articulated. In the Mombasa Island districts of Mombasa and Kilindini, this population is found in the high-cost, low density settlements of Kizingo and Tudor; the middle-cost, high-density settlements of the Buxton-Stadium area, Makupa, Saba Saba, Tononoka and Old Town. The other population concentration is found in the various informal settlements of California, Paradise, Kafoka, Kiziwi, Kaloleni, Spaki, Saragoi/Mwembe Tayari, Mwembe Tanganyika and Kibarani within the Island; in Likoni and Changamwe districts, where large pieces of land have been reserved for other uses, people have had to crowd in areas such as Maweni, Timbwani, Kindunguni, Mweza, Ujamaa, Majengo mapya, Shika-Adabu, Shonda and Jamvi la Wageni; the Chaani conglomerate areas of California, Dunga Unuse, Tausa, Kwarasi, and Migadini in Kilindini. Other informal settlements and slum areas in Changamwe are at Kasarani, Fuata Nyayo, Kalahari,

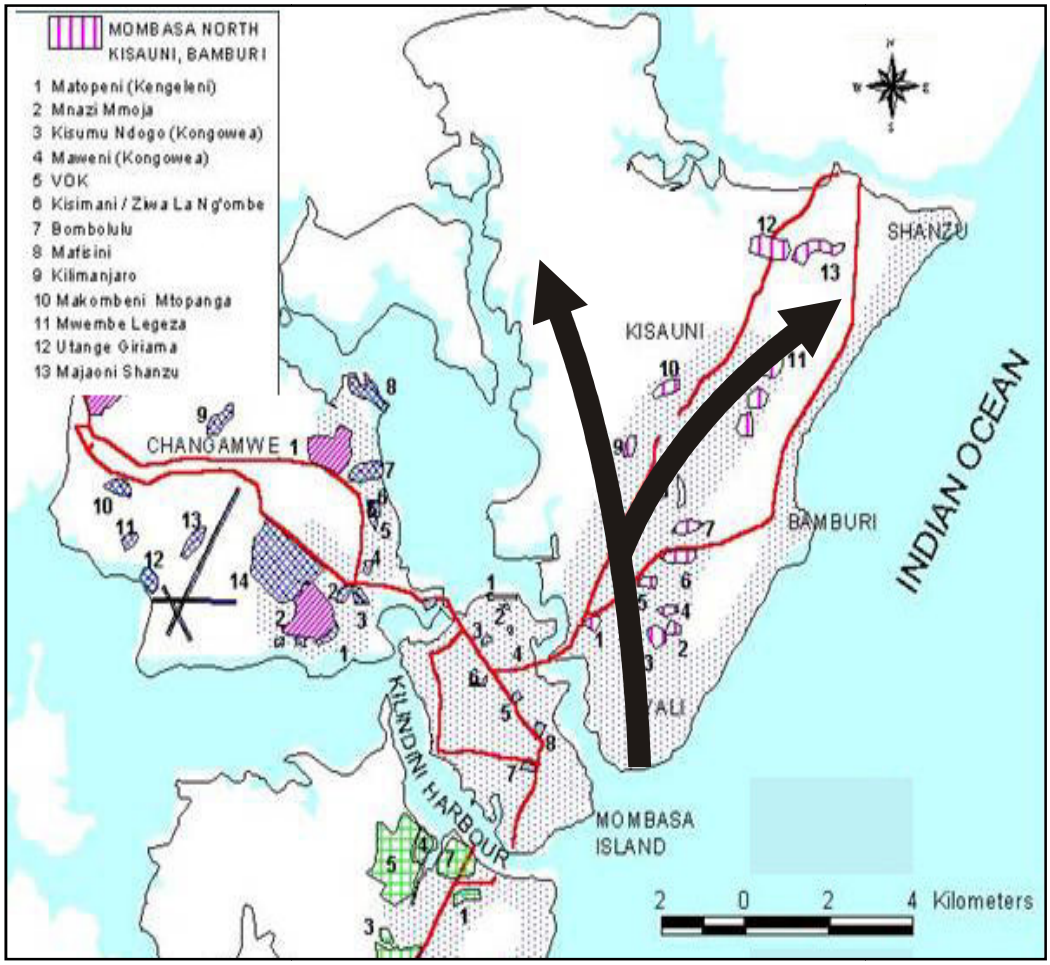

Fig1: Map of the Mombasa County, showing the Distribution of Informal Settlements and direction of growth of human settlements upon construction of the Nyali Bridge

Birikani, Kwa Punda, Bangladesh, Gana Ola, Mikanjuni, Miritini Madukani, Vikobani, Mwamlali, Wayani and Jomvu Kuu. Kisauni District in the north-coast, which has urbanized very fast due to the opening-up of the area through the construction of the Nyali Bridge, (described later) has several large human settlements, made possible due to existence of plenty of open and available land for construction of residences.

2.3.1 The Nyali Bridge opens up Kisauni to major Human Settlements

Agil, 1999 carried out a study on land use classification in the Mombasa County, which indicated that 31.2% of the total land area was under residential settlements. The study showed a northward direction of growth, increasing both the number of human settlements and population densities in the Kisauni district of the county. This direction of growth was prompted by the Nyali Bridge, constructed in the early 1980's. This bridge made the area easily accessible and with plentiful open lands, became the preferred residential area of choice for many people. Opening of the district therefore, resulted in the migration of a large population from other areas of the county to this resident new area of choice, leading to the rapid construction of housing estates in 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 that developed very fast are those of Matopeni, Mnazi Mmoja, Kisumu Ndogo (Kongowea), Maweni, Mafisini, VOK, Kilimanjaro, Makombeni, Mwembe Legeza, Utange and Majaoni.

The bridge thus promoted the rapid expansion and development of human settlements at a rate that striped the ability of the local authority to provide the supporting infrastructure and services for human waste management, forcing households to develop their own on-site sanitation systems. (Gatabaki-Kamau et.al, 2000), described

most settlements as informal, crowded and with poor sanitation practices. This situation has resulted in the myriad of environmental problems related to pollution that are manifested in the decline in groundwater quality, waterborne diseases and the effects on human health that come with it, greatly undermining the welfare of local the residents.

3.0 Sewage Infrastructure and Groundwater Pollution

3.1 Sewage Infrastructure

The main systems used for human waste management in the human settlements are on-site systems. Such on-site sanitation systems include septic tanks and soakage pit systems, and pit latrines. A majority of the households use the pit latrine system for human waste management in most of the households. It was also observed that in most households, the pit latrine and the shower rooms were close to each other and all shower washings were directed to enter the toilet pit (Mwaguni 2002). This made the pits "wet-cells" and active sources of pollution to groundwater aquifers. This situation has in some locations undermined the integrity of water that was, otherwise, of suitable chemical composition for domestic use. The introduction of micro-bacteria, from the toilets rendered the water unsuitable for potable use without treatment. Similarly, the high hydrologic conductance of the aquifers in the said area meant that the wells and boreholes continually refill with water from the surrounding strata, but behind the quick recharge, was the eminent danger of the aquifer vulnerability to pollution as well; as contaminants released on the ground, or below the surface, rapidly entered the groundwater system (Mwaguni, 2009).

3.2 Groundwater Pollution

Increasing pollution from domestic sewage and solid waste is a severe challenge in coastal Kenya, particularly at hotspots located in and around the main urban centers such as Mombasa. In the Mombasa County, wastewater management is not adequate and only 10% of the population is connected to the sewage system, leaving a majority of the population to rely on septic tank-soakage pit system and pit latrines. These on-site sanitation systems contribute to groundwater pollution.

Mwaguni (2002), determined the microbiological pollution status of groundwater sources in Mombasa through determinations of the Total Coliforms and *Escherichia Coli* (E-Coli) in groundwater samples. The method of analysis used to determine this was the 5-tube, 3- dilution, Most Probable Number (MPN) technique. Groundwater samples collected from water points spread in the area were inoculated into the Mac Conkey broth and incubated at 37^0 C for 24-48 hours for the Total Coliform test. Gas positive tubes were sub-cultured in brilliant green lactose bile broth and incubated for a further 48 hours, and tubes that tested positive for indole production in tryptone water were considered positive for E-Coli. The "Most Probable Numbers" of E.coli were then computed from Probability Tables. The results of analysis gave good indication of the status of groundwater sources in Mombasa. These results are given in Table 2: a, b, c, and d.

Table 2: Bacteriological contamination of groundwater in the Mombasa County

Table 2a: Likoni District

Sampling Location	Coliform counts/100ml	E. Coli counts/100ml	Remarks
Mtongwe Pri. Sch. (w)	30	6	PL, NC, Protected
Mtongwe 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,
Maweni Mosque (w)	1800+	1800+	PL, NC, Open
Kiawairera Mosque (bh)	0	0	PL, C
Caltex Ferry (bh)	1100	1100	ST/SP, NC
Misufini (w)	1100	1100	PL, NC, Open
Kitaruni (w)	1800+	150	ST/ SP, NC, Open

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

Summary: Number of boreholes = 6; Boreholes with water of acceptable quality = 2; number of wells = 6
Wells with water of acceptable quality = 0; Sources with acceptable water quality = 16.7%

Table 2 b: Changamwe District

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 Corner (bh)	23	5	NC; SW Area

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

Boreholes with water of acceptable quality = 1; Wells with water of acceptable quality = 0

Table 2c: Kisauni District

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
KitaruniKongowea (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 setlmts.
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 setlmts
Sch. Phy. Hndcp (bh)	150	9	ST/SP, NC, „
Show ground (bh)	4	0	ST/SP, NC, No. Setlmts.
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; bh –borehole; setlmts –settlements; Hndcp -handicapped

Summary: Number of boreholes = 9; Boreholes with water of acceptable quality = 1; Number of wells = 12; Wells with water of acceptable quality = 0; Sources with acceptable water quality = 4.8%

Table 2d: Mombasa Island

Sampling Station	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 (w)	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 (w)	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
Khamis 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)	3	0	SW, NC
Tudor High Sch. (w)	1100	210	ST/SP, NC, Protected

Summary: Number of boreholes = 29; Boreholes with water of acceptable quality = 7; Number of wells = 4; Wells with water of acceptable quality = 0; Sources with acceptable water quality = 21.2%

The high levels of coliform counts and E.Coli were linked to cross contamination of groundwater by pit latrines and the septic tank-soakage pit systems, confirming fears that on-site sanitation is undermining groundwater quality.

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. Consequently, it is evident that groundwater sources in the Mombasa County are polluted with wastes of human origin. This occurs through cross-contamination from septic tanks and soakage pits and pit latrines; and boreholes with water of accepted quality are either located away from human settlements or in areas served by the municipal sewer.

As the results indicate, sewage pollution is widely distributed in the groundwater sources of Mombasa, and in most cases the quality of water derived from these sources is below the international standards for drinking water.

4. Impact of Sewage on Human Health

Sewage introduces pathogens in water that may cause various waterborne diseases such as cholera, dysentery, typhoid, diarrhea, intestinal worms, skin and eye infections, etc. The way sewage is disposed of therefore hinges directly on the levels of mortality. Many cases of diseases related to sewage contamination have been reported in the developing world, Kenya included. For example, a case was reported in February-March, 1999 in Mombasa where a burst sewer line contaminated the main reticulated water supply line with the following consequences: 470 out of 1628 people tested positive for cholera, with some people losing their lives; 66 out of 179 people tested positive for typhoid, also with reported deaths (UNEP, 2000). Similarly, a search at the Mombasa City Health Information Systems and Records office for the annual reports for the years 1998 to 2000 provided the following daily out-patient return of morbidity of diseases related to sewage disposal problems, Tables 3a, 3b and 3c (Mwaguni, 2002).

Table 3a: 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 3b: 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 3c: 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, 2000& Mwaguni, 2002

Analysis of the results on the diseases of occurrence, showed that more than 50% of all the diseases reported in the district were related to water quality issues, as undermined by inadequate wastewater management practices. This makes the management of municipal wastewater an issue of major concern in areas which depend on groundwater for potable supplies, and which therefore, calls for urgent and immediate measures in new locations where human settlements are to be established. This fits the scenario along the coastal belt of the Kwale County, which will soon open up to the process of quick urbanization on advent of the opening up-the area through the Dongo Kundu By-Pass. Here, the quick development and establishment of housing settlements that use on-site sanitation systems will provide the direct linkage of sewage contamination , causing waterborne diseases, and should therefore provide a wake-up call for strategies towards groundwater protection through advance planning of the development.

5.0 Water Sources of the Kenya South Coast

Kwale District is bounded by the longitudes $39^0$22E´ and $39^0$36E´ and latitudes $4^0$9S´ and $4^0$30S´. The area to be opened up by the Dongo Kundu By-Pass lies within the coastal belt of the Indian Ocean. Its geology is defined by coral limestone of Pleistocene Age (Caswell, 1953) and for purposes of the study; these areas include Ngombeni, Waa, Tiwi, and Diani Locations. Lying in lithologies of coral limestone and being densely populated, groundwater integrity stand to be affected greatly with projected urbanization and the expanding of human settlements. Currently, these areas receive freshwater supplies from the traditional sources Marere springs, originating from the Shimba Hills, and from the Tiwi Borehoes. Water supplies from the Marere springs are inadequate as the pipeline is old. It is now being expanded to meet the increased demand for water, but until then, the shortage from this reticulated supply will persist. The Tiwi Boreholes, which serve this area and Mombasa, draw from the Tiwi aquifers. This source of water, supplements that from the Marere Springs, but, it yields inadequate water volumes to serve the needs of the targeted populations. To increase water supplies and offset the shortfall, the Kwale Water and Sanitation Project (KWSP) supported by Swedish International Development Agency (SIDA) drilled many boreholes and rehabilitated several shallow wells in these areas during the period 1985-1995. Though still not adequate, these combined sources have served the population very well with supplementary water supplies, coming from privately dug boreholes and wells. Now, the fear is that if the groundwater aquifers are not protected from the expected rise in urbanization due to expansion in human settlements anticipated with the opening up of the area by the Dongo Kundu By-Pass, then freshwater shortages will be the result. This study suggests initiation of measures for the protection of groundwater aquifers in the newly to be opened areas to maintain the integrity of the water sources to guarantee the sustainable supply of water for the residents.

6.0 The Proposed Dongo-Kundu By-Pass

The government received a Sh29 billion loan from the Japanese government through, Japanese International Cooperation Agency (JICA) to construct a 26km bypass that will link the island of Mombasa to South Coast. The road also referred to as the Dongo Kundu Bypass –is aimed at easing movement of cargo from the port and is the second largest project after the LAPSSET Corridor. It will serve as an alternative link from the hinterland to the South Coast and to the planned Dongo Kundu Port. It was scheduled to start in December, 2012 and be complete by August 2018. The project as proposed will feature a road that will branch off from the main Mombasa to Nairobi (A109) road, and traverse Miritini, Kipevu, Tsunza, Mtenza to end at Kibundani in the South Coast.

According to Kenya National Highway Authority (KeNHA), the scope of the Project will include construction of roads, bridges and drainage facilities at selected locations, installation of slope protection works, provision of road safety facilities and other amenities. On completion, the road will decongest the city of Mombasa since it will provide an alternative route to the Likoni ferry. It will also connect the new container terminal near Moi International Airport with the Northern transport corridor and the South Coast.

Decongesting Mombasa means people will have an additional place for residence. This will be the immediate out-come of the Dongo Kundu project. This project will open up Mombasa's south-coast, bringing development of all forms to the area. Such one development will be the quick urbanization of the area as seen in the rapid development and mushrooming of human settlements. Human settlements as deduced earlier have impact on groundwater, and it is in line with this concern that this precious resource is protected for the benefit of the Kwale area residents as the area is opened-up.

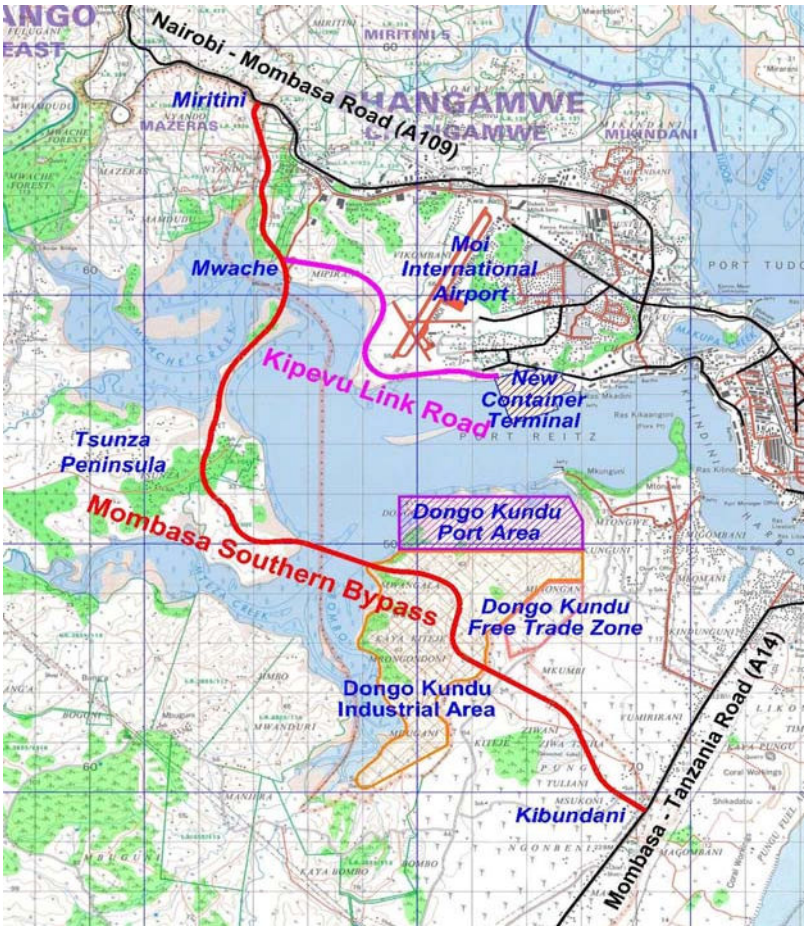

Fig 3: Map of Mombasa Port Area Road Development Project (The Project is to construct Mombasa Southern Bypass and Kipevu Link Road) Source, JICA 2012

7.0 Protecting Groundwater from Pollution Sources

With the establishment of human settlements, promoted by the urbanization engineered by the Dongo-Kundu By-Pass, paradise will be lost and the once potable sources of water will be contaminated with human waste from the on-site sanitation systems used in the newly expanded urban areas. This situation can be avoided through precautionary measures. Thus, having shown that the pollution problem in Mombasa was facilitated by open access, protecting the integrity of groundwater in a new area should be undertaken as a priority for would be residents to benefit from the groundwater it produces. As such therefore, there should be deliberate effort and endeavor of both the local community and the government towards this direction. Here, the government and communities, play different, but complimenting roles. In this case, the government in particular, should play the major role in guiding the protection measures where in the interim, it guide the short term objectives, while

pursuing a long-term objective in this front –an objective, which can be realized through zoning of the area for designated land uses.

Thus zoning will be seen an expression of achieving a long term objective and areas with groundwater aquifers are given preference as conservation areas, and other land uses are thus prohibited for particular locations. This will guide urbanization and the establishment of human settlements will take place away from major groundwater aquifers, which will in turn, alleviate the detrimental effects of human wastes on groundwater sources. The government therefore needs to plan for this, as, left without guidance and a structured approach; people are not known to adhere to plan adequately for sewage management! Having played the above role, it would be expected at the minimum that the government engages communities to realize the short term objective, which seek to ensure the following:

- Boreholes are constructed to a sanitary standard and appropriate sanitation facilities built;
- Safe separation distance between water point sources and on-site sanitation units, and
- Follow-up monitoring is carried out.

As the above is being achieved, the government should concentrate on the long-term undertakings designed to achieve the long terms objectives, and this entails that the following is being undertaken:

- Controls on various pollution sources;
- Restrictions on certain land-uses, and
- Acquisition of land is made to maintain water quality objectives (Y Xu and E Braune, 1995)

8.0 Conclusion and Recommendations

Fresh water for domestic use is scarce in both the counties of Mombasa and Kwale in Kenya. In Mombasa, groundwater aquifers, which otherwise produced water of suitable chemical quality and therefore supplementing the reticulated water supplies have seen this good chemical quality undermined by micro-bacterial contamination from the on-site sewage management systems in the human settlements. This problem is exacerbated by the ease of access made possible by the Nyali Bridge and the Makupa Cause-way, which have promoted rapid urbanization. As such, therefore ground water taped from locations of most these areas is not suitable for human use without treatment, and the effects of pollution have manifested themselves water borne diseases. In the Kwale County, groundwater aquifers are largely free from microbial contamination because the human settlements are widely sparse. However, the situation is about to change, and the water pollution burden experienced in Mombasa, will see itself transferred here, as the area opens up to rapid urbanization due to the Dongo-Kundu By-Pass, linking it to Mombasa, and therefore easing the burden of access to human settlement developments, if, immediate steps to protect the groundwater aquifers are not undertaken.

Pollution causes freshwater shortages. Pollution of freshwater sources by human wastes causes water borne diseases. Waterborne diseases, impact the health of residents, undermining their socio-economic activities and welfare, which is in addition to the health costs borne in seeking medical care. These situations are undesirable, and therefore, the integrity of water as a commodity that sustains life must be ensured. Precaution is therefore called as urbanization sets foot in a new area. In order to achieve this, sanitation facilities in the newly to urbanize area must meet some standard requirements and they should therefore be constructed under supervision. Similarly, as there is tendency for water points such as boreholes and wells to be developed privately, this activity should be allowed only if permission is granted from authorities, and such development, guided. As to where water points and on-site sanitation systems should be sited should also be guided and supervised so that the required separation distance between a water point and an on-site sanitation system is met and that topography requirements guide this. Where possible, follow-up monitoring for functionality of the on-site sanitation systems should be part of the groundwater protection measures. Water sampling and analysis should be routine to detect any problems before they spiral out of control.

On long term basis, control of the various potential sources of pollution should be considered; restriction on land uses should be implemented as part of policy in groundwater conservation. More so, where an area is designated as a groundwater aquifer, then the development of human settlements in such an area should be prohibited. Acquisition of land, in such areas, where it is necessary, should be enforced, and the land use for these areas categorized as conservation. Socio-economic activities, which have potential for impacting groundwater resources, should be located away from the water conservation zone. The development of human settlements should be planned and appropriate sewage management systems integrated as part of the development. Residents should be sensitized that groundwater resources, once polluted, are difficult to clean-up, and that the costs of drinking contaminated water are enormous. This will impart knowledge for good environmental citizenship, protecting the environment in the process, and moving towards achieving the goals of sustainable development.

In this way, opening up of the south coast through the Dongo Kundu By-Pass shall not be a cause for concern.

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