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Challenges and Interventions in Sanitation Management Approaches in Mavoko Municipality

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Abstract
Proper urban sanitation management approaches are essential components in the realization of protected and conserved environment for sustainable development. Established sustainability criteria of population densities; climatic and geological conditions of areas; designs; operation and maintenance of these approaches were used in the study to gauge the contribution to sustainable development by interventions made in addressing challenges faced by sanitation management approaches used. The study site covered the urbanizing areas of Athi River, Katani, Kinanie, Mulolongo and Syokimau. A cross sectional study design was adopted to collect quantitative and qualitative data. 385 household Respondents were interviewed. Simple random and purposive sampling methods were used to administer questionnaires to standalone houses and comprehensive housing schemes. Interviews with key informants from the County Government of Machakos, Mavoko Water and Sewerage Company (MAVWASCO) and Export Processing Zone Authority (EPZA) were conducted. Quantitative data was analyzed using descriptive statistics and presented in tables, pie charts, line graphs and percentages. A content analysis from qualitative data was used to develop thematic issues. The study established that the soils and rock type in the study area pose major challenges to sanitation management approaches whereas interventions to address these challenges are not adequate to surmount them. Poor sewerage network coverage, low levels of reuse of waste water, inadequate treatment of effluent in the oxidation ponds and the irreconcilable differences between the key service providers compromise the environment. Recommendations are made to the Government to prioritize investments in the water and sanitation sector and increase the area coverage under sewer network, promote separation of household and industrial waste water and educate the population to reuse waste water. Mandates of the service providers should be clarified to play a complementary role to govern the water and sanitation sector effectively.
Keywords: Challenges and interventions, Mavoko, Sanitation criteria, Sanitation management approaches.

1. Introduction

Cities are where the battle for sustainable development will be won — or lost if we fail because Cities /urban areas are where economic, social, cultural and environmental aspects of human activity come together in a dynamic way (UN Deputy Secretary-General, 2015). Sanitation is one such key environmental aspect and as (Sigel et al 2012) put it a major issue related to sustainable development in many parts of the developing world. Proper management approaches are essential in the realization of protected and conserved environment for sustainable development.

Sustainable Development (SD) advances that continued economic development as we know it today is not sustainable if the other processes of community and ecological development are not balanced. The latter processes are essential for human life and civilization and reproduction of the biological wealth and climatic conditions necessary for life on our planet (UNEP, 2010). For sustainable development to occur there has to be a balance among developmental process of ecology, community and economic development. Ecological development ensures biological wealth and necessary climatic conditions for life while community development provides for responsible citizens and civilization.

Global trends in proportion of population using improved sanitation indicate that North America, Canada, Southern parts of North America, Europe and Australia have 91-100%, Central America and Northern parts of South America are at 76-90%, most of Euro -Russia and the Caribbean Asia, parts of Africa like Botswana and Angola with 50-75%. India and the rest of Africa have the lowest proportion of their population using improved sanitation at less than 50 % (WHO, 2013).

It is acknowledged that rapid urbanization has compounded the ability of many African governments to provide essential services like sanitation let alone the environmental degradation that has come with it. Consequently, more people now lack access to reasonable sanitation services than in 1990; the number of those without has doubled to around 175 million. In 2010 already four in ten of Africa's one billion people lived in urban areas (Jones, 2011) and by 2050, eight out of ten people in the world will be living in cities.

Majority of urban dwellers in Africa and Asia as well as for a considerable proportion in Latin America rely on onsite sanitation systems for excreta disposal (Ingallinela et al; 2002). These systems have emerged as a preferred model of sanitation in cities experiencing rapid urbanization due to the high cost involved in off -site

sanitation which requires conventional sewerage (Pujari et al, 2012). (Murray2012) notes that the trouble with these toilets in the developing world is not their unavailability but rather their fast filling against governments which lack money, technology and incentive to properly manage the waste.

Still in urban areas of many developing countries, the excreta disposal situation is dramatic. Thousands of tons of sludges from on-site sanitation (OSS) installations, i.e. from unsewered ("dry") family, public toilets and from septic tanks, are disposed of untreated. They are either used in agriculture or aquaculture or discharged indiscriminately into lanes, drainage ditches, onto open urban spaces and into inland waters, estuaries and the sea, causing severe stress on ground water sources resulting in environmental degradation through water pollution, serious health impacts, eye and nose sores and general compromise of sustainable development.

Studies by (Wright et al 2012); (Freeman, et al, 2012) (Tumwine, et al, 2003), (Pearson et al 2008) in (Freeman, et al 2012), (Mbula et al 2014); illustrate that the sanitation condition is wanting in the major cities of Kenya. A study conducted to establish the satisfaction levels of residents of Nairobi, Mombasa and Kisumu with among other factors sanitation; found that many people reported experiencing problems with the sewer system mostly overflowing and leakage from broken mains and bad smells. They also experienced problems with pit latrine emptying and public toilets. They were ignorant about the disposal areas of filled FS extracted from other sanitation systems though many suspected emptying into storms sewers and pollution from cess and soak pits (Ministry of Water and Irrigation et al 2007).

Sewerage system in the Nairobi Metropolitan Region (NMR) is limited only to urban centres within it. (Okumu and Osterveer2010) advance that Local Authorities (now county governments) are unable to put in place alternative plans and regulations for physical environmental infrastructure development. They also do not cover the entire urban population. County government of Nairobi and the urban areas of Limuru and Kiambu are 35%, 50% and 94% under sewerage system respectively confirming the inability to match sanitation demand with service provision. Thika, Machakos and Mavoko have both municipal (now Sub County) sewer as well as septic tank and pit latrine system. There are only about 28 sewage treatment plants in NMR of which 24 are in Nairobi and one each in Thika, Limuru, Machakos and Mavoko against a population of 6 million people. Available capacity of sewage treatment plant is only 375793 cum/day against a water supply generation of 1.63 million cum/day (Republic of Kenya, 2013). This illustrates the dire need for sanitation services which are not provided by the authorities charged with this responsibility against an increased reliance on self- help efforts in sanitation management.

At an individual level disposal of FS is overwhelming; a resident of Kiserian was charged in the High Court of Kenya in Miscellaneous Civil Case No 118 of 2004 for indiscriminate discharge of offensive smelling waste matters into open channels along the road, to the environment and the Kiserian River. In his defense he argued that the cost of having treatment works in their respective plots would be out of reach of the individual property owners bringing into the fore the issue of sustainability. Although the High Court did not agree with his argument it recognized that it was the responsibility of government agencies in the names of Olkejuado County Council (now County Government of Kajiado) and the Ministry of Water and Irrigation to provide these sanitation services and as such made orders of mandamus to compel the agencies to take action.

The study focused on the Mavoko municipality and sought to establish the challenges and interventions in sanitation management approaches used. Mavoko municipality is the fastest growing urban centre in the Nairobi Metropolitan Region NMR). Its population is projected to grow from 244259 to 593182 (Republic of Kenya, 2009). The Municipality's existing sewerage treatment capacity stands at 192000m3 against a required treatment sewerage capacity of 1,407,000m3 (National Water Master Plan, 2012) representing a deficit of 86% in sewerage treatment capacity. Its existing sewer network is over 20 years old, comprises only 31.07 km long sewer network and covers a negligible 0.045% of its 963 km^2 of its total jurisdiction. Of concern therefore was the need to identify the challenges experienced in sanitation management approaches used and interventions made as a gauge for sustainable development.

2. Literature Review

Some of the challenges facing sanitation management especially in the developing world range from inadequate finances, distance of sanitation management option from ground water source, increasing population densities, industrial effluent, environmental considerations, ground water susceptibility to pollution, poor designs of sanitation management approaches and climatic conditions among others. Finance provision in sanitation by Governments is difficult. Finances are not readily available to sanitation systems users (Caincross 2003). (Castro 2010) found that the involvement of the private sector in the water and sanitation was associated with increasing inequality and weakening democratic governance though partial public funding factors were found to trigger increased access to household sanitation as illustrated by comparative studies on alternative financing approaches for onsite household sanitation from Bangladesh, Ecuador, India Mozambique, Senegal and Vietnam (Tremolet *et al*, 2010).

The distance of sanitation management option from ground water source is important in determining

ground water protection as ARGOSS (2001) found in their studies in Dhaka, Bangladesh, Rio Cuarto, Argentina, Kampala and Iganga in Uganda and (Odai, *et al* 2003) on pollution reduction in Ashanti Ghana. In India, (Krishnan, 2011) emphasized the need for low population densities and proper design of sanitation systems which require constant desludging of tanks and disposal of waste water especially in areas dependent on ground water sources for protection of these water sources while (Pujari *et al* 2012) established the impact of onsite sanitation on quality of ground water sources in areas of different geological setting in Indore and Kolkata in India. (Tumwebaze *et al* 2011) studied ecological sanitation and factors affecting its uptake in Uganda and concurred with (Drangert, 2004) that rocky and low terrain, loose soil structures and areas greatly affected by floods were factors that made some of the conventional sanitation systems such as pit latrines inappropriate. (Anand 2006) found out that environmental considerations left certain areas with no choice but to use costly methods of sanitation management.

(Srinivasamoorthy,*et al* 2011) established that parts of Tamil Nadu state in India had ground water contaminated due to the influence of sewages from industries, domestic and agricultural practices while (Nam *et al*, 2006) found out that septic tanks used did not perform as required in Hanoi and the suburban area of Bangkok,. They just converted the suspended pollutants into dissolved form and released them to the environment due to insufficient maintenance. Effluent from the septic tank was found to be high in chemical oxygen demand (COD), biochemical oxygen demand (BOD), total kjeldahl nitrogen (TKN), total sum of nitrogen ammonia and ammonium (NH4+-N) and phosphate (PO4-3.). (Zawahri, *et al* 2011) also noted that some designs were inappropriate for arid regions as they increased contamination of the surface and ground water supplies while poor maintenance of septic tanks contributed to a rapid deterioration of ground water quality. Cess pits and sewers were found to leach contaminants into shallow aquifers. (Kaminsky, *et al* 2012) supported this notion by noting the importance of sustainable maintenance in the operation of onsite sanitation systems because of the high failure rates associated with the infrastructure.

Challenges highlighted in the research works are not conclusive as they are unique to a geographical area and hence the need to establish those challenges unique to Mavoko municipality and identify the interventions that are employed for improvement and promotion of the environment towards sustainable development.

3. Method Used to Collect Data

A cross sectional design was found most appropriate as it was best suited in establishing an overall picture of study as it stands at the time (Kumar, 2005). Primary and secondary data on challenges experienced and interventions made in managing sanitation was collected through interviews with key informants that is the Households, Developers, County Officials that is the Manager of Mavoko Water and Sewerage Company, County Environment Officer, County Planning Officer in charge of development control, County Engineer and County Public Health Officer. Vacuum Tanker Operators and Exhausters and Residents neighboring fecal sludge disposal sites informed the study. It was found that there were no, Nongovernmental organizations (NGOs), Community Based Organizations (CBO's) and Faith Based Organizations (FBO's) dealing in sanitation management to be interviewed.

Questionnaires and interviews made were informed by the sanitation criteria advanced by SuSanA, (2008) who provides basic categories of criteria as health and hygiene; environment and natural resources; financial and economic issues; socio cultural and institutional aspects and technology and operation. For purposes of the study the factors of sewer network coverage, functionality of the conventional sewer system, reuse of waste water , treatment of effluent at the oxidation ponds, water integrity, storm water drainage design of sanitation management approaches and institutional performance in service delivery in the sanitation sector were considered representative of the sanitation criteria to gauge sustainable development in the management of sanitation approaches used in Mavoko municipality.

Table 1. Ratio for Apportioning Questionnaire Administration

Ward	Population	Ratio	Questionnaires for Administration
Athi River	139,502	139502/244259 = 57	219
Kinanie	7,069	7069/244259 =3	12
Syokimau	42,154	42154/244259 = 17	66
Katani	55,534	55534/244259 = 23	88
Total	244,259	57:3:17:23=100	385

Source: Author, 2015

To ensure that bias was minimized and that each part of the study area had an equal probability of being sampled, the area populations for each of the Wards which make up Mavoko Municipality were used to come up with ratios which guided the apportioning of questionnaires for administration in each of the Ward as seen in table 1.

Table 2. Apportioned Questionnaires for Administration

Ward	Assumed ratio of standalone houses to comprehensive housing schemes is 1:4 based on observation of the study area	Final Questionnaires for administration to stand alone (SA) and Comprehensive Housing Scheme (CHS)	
		SA	CHS
Athi River	(1/4) = 0.25 * 219	165	55
Kinanie	(1/4) = 0.25 * 12	9	3
Syokimau	(1/4)= 0.25 * 66	50	16
Katani	(1/4) = 0.25 * 88	66	22
Sub-Total		290	96
Grand Total		386	

Source: Author, 2015

Purposive sampling method was used to identify comprehensive housing schemes developed at various periods in time. The schemes developed earlier were bound to have tenants/owners who had occupied the houses for longer periods and therefore likely to have had more exposure to sanitation study concerns. Since they made up part of the total population of households in the study, a proportion of the questionnaires were shared amongst comprehensive housing schemes (CHSs) and stand alone houses (SAs) on a ratio of 1:4 on the assumption that the population sizes of the SAs far outnumber the CHSs which are a new development. Once more the ratios were allocated to each of the Wards and final figures calculated as seen in table 2. SAs are individual housing units occupying a distinct parcel of land with own or private entrance while the CHSs are many housing units with similar design, on a common parcel of land and constructed by a common developer. They share a secured common entrance and are confined within a gated community. Random sampling was used to administer the household questionnaires to SAs.

Primary and secondary data gathered was analyzed using descriptive statistics and presented by way of frequencies, percentages, charts and graphs. Qualitative and primary data obtained from the interviews and field notes were transcribed and cleaned. A content analysis was used to develop thematic issues discussed in the paper.

4. Results and Discussion

Table 3 Dealing with Problems Encountered in Sanitation Management

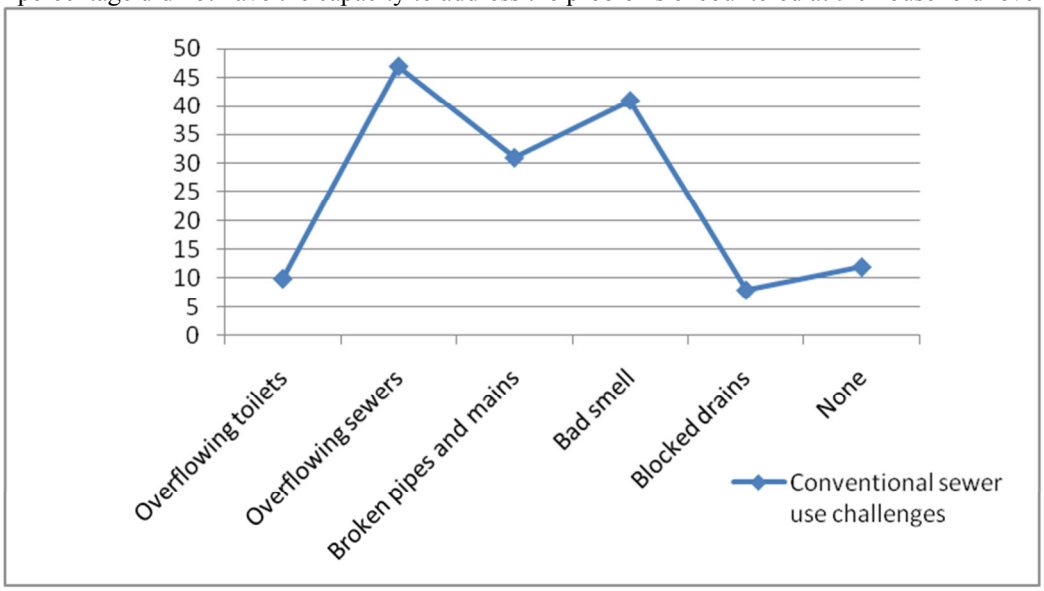
Problems and Challenges	Percent
Report to caretaker/landlord/ manager/relevant authorities	2.3
Cleaning the latrine frequently	1.0
Don't have capacity to deal with the problem	.5
Use of aerosols/disinfectant during emptying/ air fresheners	3.6
Construction of soak pit/ septic tank	.5
Purchase of water storage tanks	.8
Changing exhauster services	2.1
Cope with situation	.5
Advocate for sewer connection	2.3
Unblocking drains	.3
Reuse waste water for toilet	.5
Dispose waste in the main sewer line	.3
Purchase water from water vendors	.5
No response	84.7
Total	100

Source: Field Survey, 2016

Various solutions were mentioned by Respondents with regard to sanitation management approaches as seen in table 3. Of the 15% respondents who answered in the affirmative on the question of whether they solve problems encountered at the household level relative to toilet waste disposal, most of them reported using air fresheners and disinfectants to deal with the bad smell. Those who used this approach made 4 % and were leading in problem solving. Others were advocating for the use of the conventional sewer system to solve their problem and this made 2% of those that responded.

Closely following were those Respondents who opted to changing exhauster service providers to

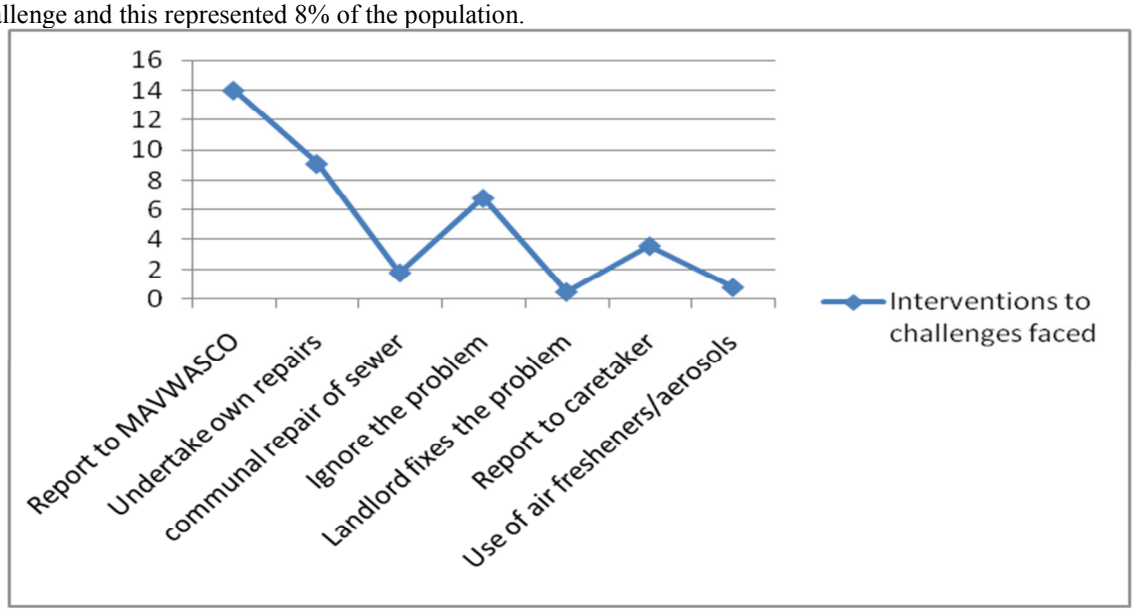
address the problem of unreliability at 2%. Other solutions which were noted to have been used were frequent cleaning of the latrines, construction of soak pits and unblocking of the toilets. Purchase of water storage tanks and water from water vendors was made too. However less than 1% were simply coping with the problems while a similar percentage did not have the capacity to address the problems encountered at the household level.



Source: Field Survey, 2016

Figure 1: Challenges Experienced Using Conventional Sewer

Conventional sewer management challenges were identified as indicated in figure 1.There were challenges which respondents noted as arising from the use of the conventional sewer. These were overflowing sewers which was noted as the leading challenge with 32% of the respondents indicating it. Closely following was bad smell at 28% and broken pipes and mains at 21%. Other challenges were overflowing toilets and blocked drains at 7% and 5% respectively. There were those Respondents who indicated not experiencing any challenge and this represented 8% of the population.



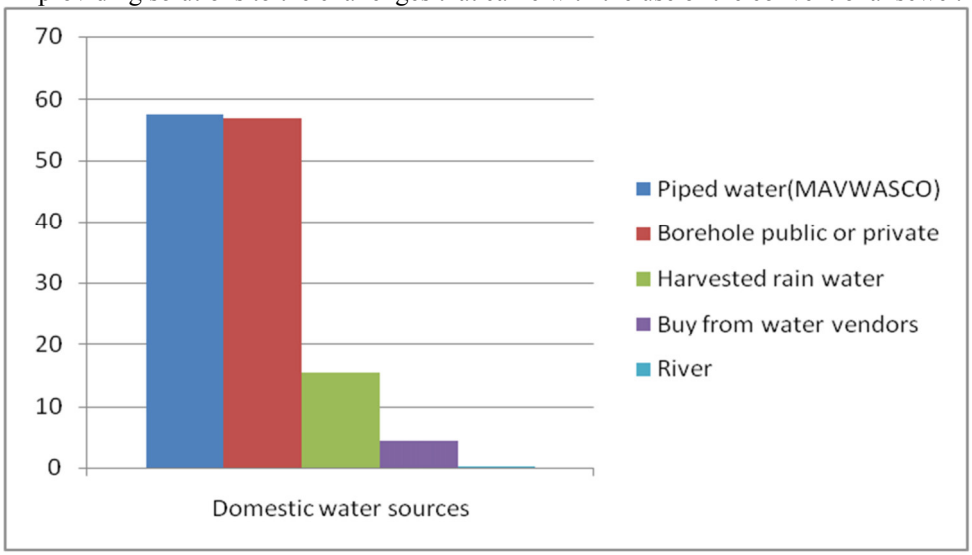
Source: Field Survey, 2016

Figure 2 Interventions in Dealing with Problems Emanating from Using the Conventional Sewer (%)

Some of the interventions used in dealing with problems arising from the use of conventional sewer systems are illustrated in figure 2. Of the 149 respondents who had indicated challenges in the use of conventional sewer, only 141 indicated addressing challenges posed by the sanitation approach. Majority of the Respondents who made up 54 out of the 141 or 14% mentioned reporting to the Mavoko Water and Sewerage Company which is responsible for the provision of the utility infrastructure in question that is the conventional sewer line. 9% of the respondents said that they undertake their own repairs while 7% ignored the problem.

Reporting to the Caretakers was another intervening method which was noted among the Respondents

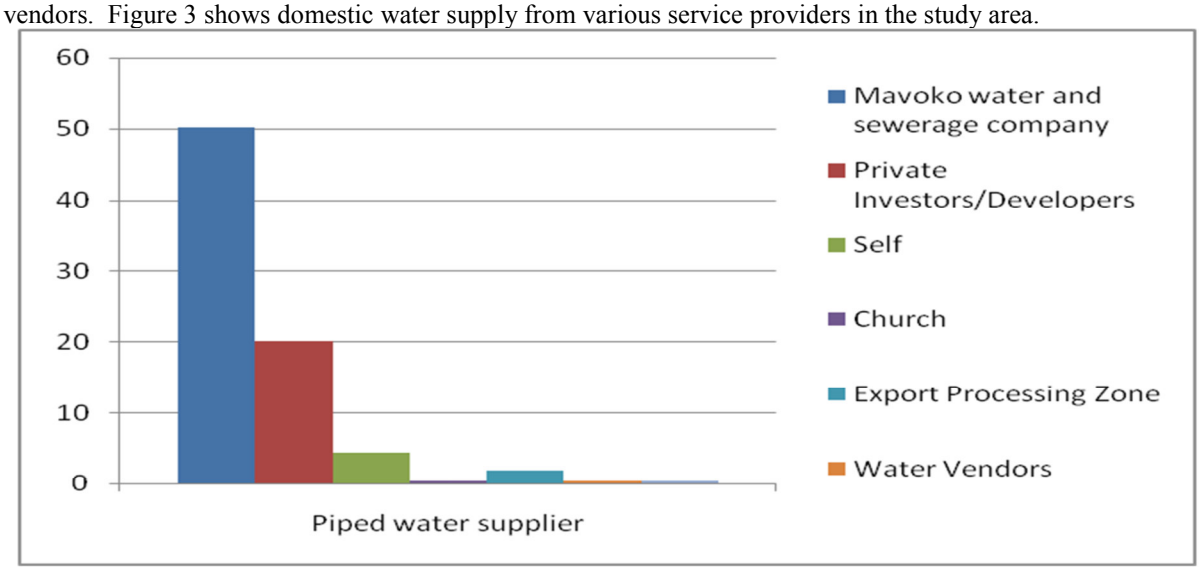
with 4% mentioning it. Mobilization of Residents to communally repair the sewer was low with only 2% Respondents giving this answer. In total, most of the Respondents reported to a second party to intervene on their behalf in providing solutions to the challenges that came with the use of the conventional sewer.



Source: Field Survey, 2016

Figure 3: Source of Domestic Water Supply

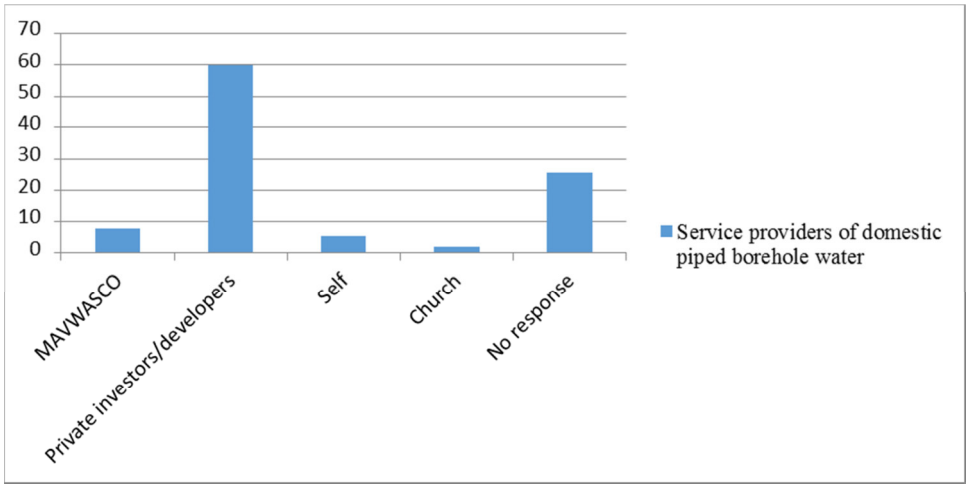
Domestic water supply is either piped or supplied from the public and private bore holes. Only 15% of the Respondents harvest rain water. Others purchased water from secondary service providers like the water vendors. Figure 3 shows domestic water supply from various service providers in the study area.



Source: Field Survey, 2016

Figure 4 Suppliers of Piped Water

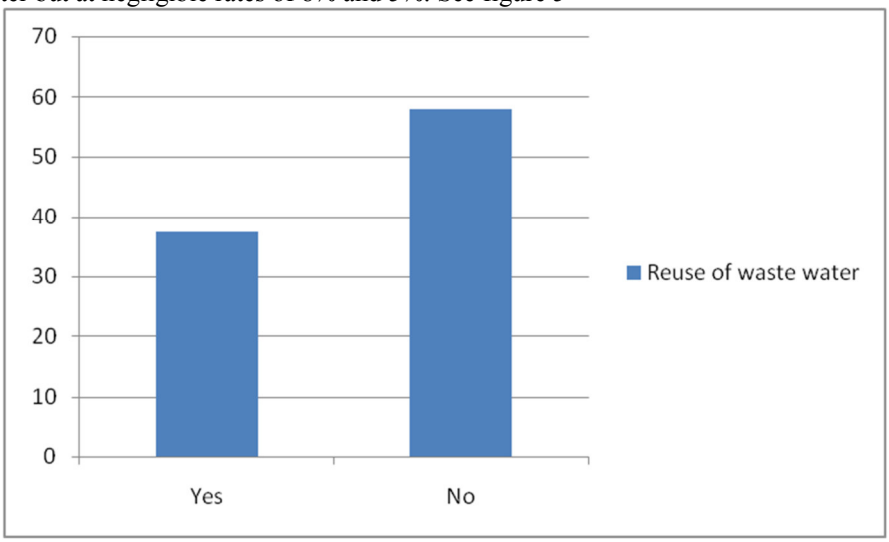
MAVWASCO emerged the leading supplier of fresh piped water with 50% Respondents reporting use of the Company's water. Private Investors trailed with only 20% Respondents reporting reliance on this piped water source. Figure 4 is a representation of the same.



Source: Field Survey, 2016

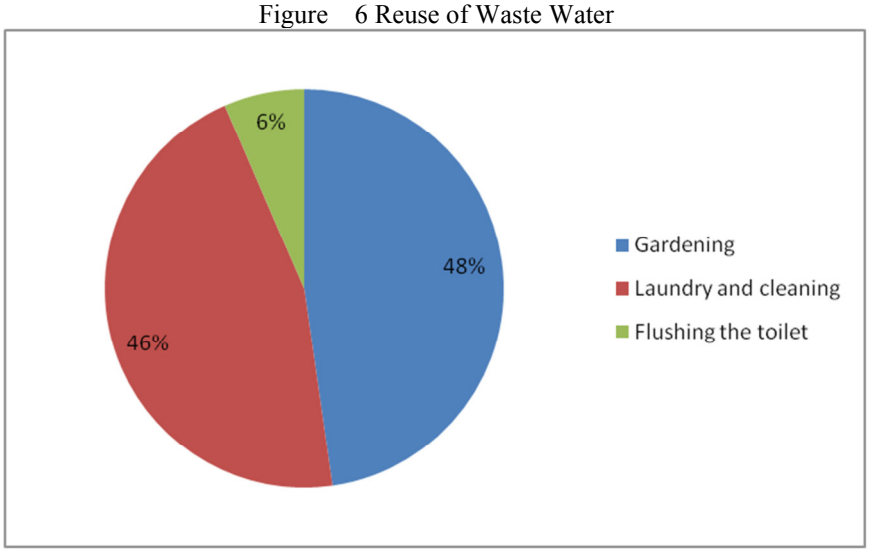
Figure 5 Suppliers of Borehole Water

Private Investors and Developers are leading with the provision of borehole water supply with 60% of the respondents mentioning them. Mavoko Water and Sewerage Companies and the Church were other suppliers of borehole water but at negligible rates of 8% and 5%. See figure 5



Source: Field Survey, 2016

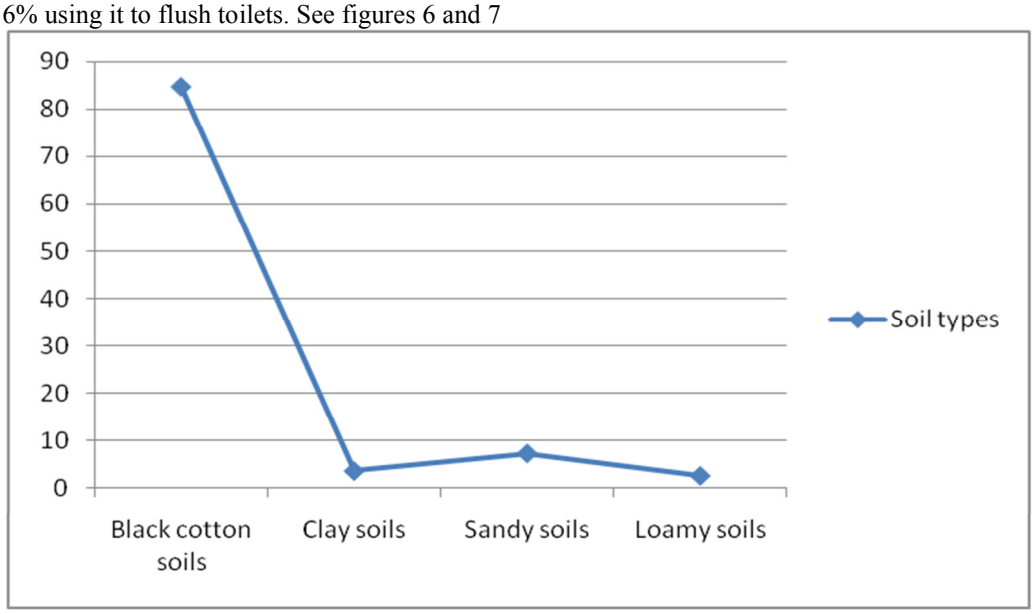
Figure 6 Reuse of Waste Water



Source: Field Survey, 2016

Figure 7 Uses of Recycled water at the Household Level

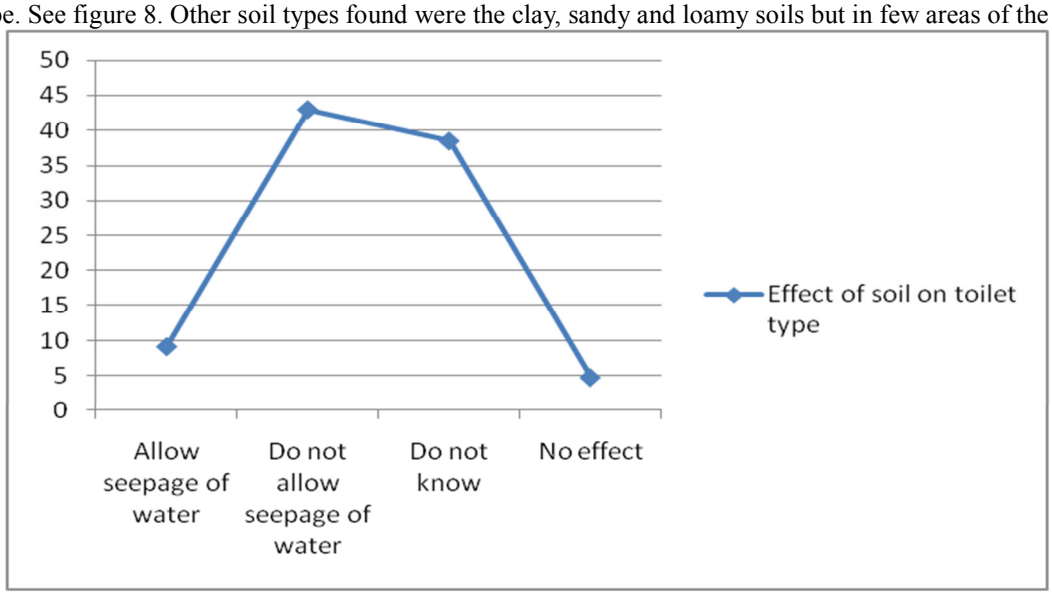
Only 37 % of the Respondents reuse water with the majority 58% indicating non use of waste water. Of the 37% who reuse waste water, 48% and 46% used it for gardening and laundry and cleaning with a negligible number 6% using it to flush toilets. See figures 6 and 7



Source: Field Survey, 2016

Figure 8 Soils in the Study Area as per Respondents

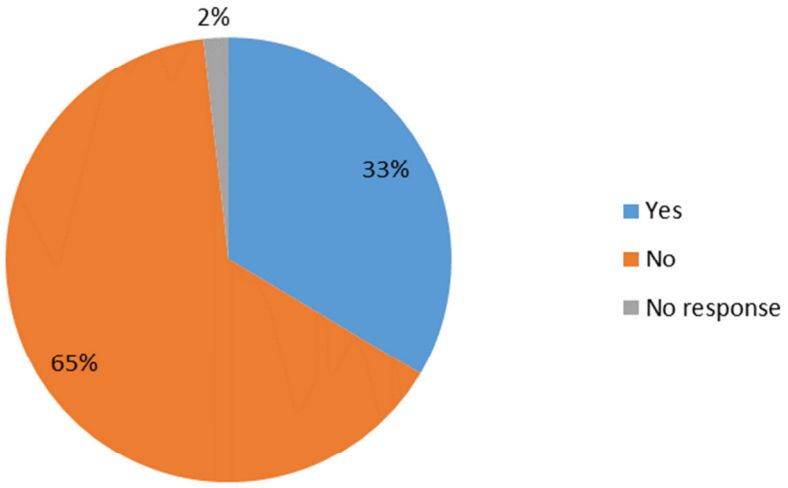
Most of the study area is made up of the black cotton soils with 86% of the Respondents indicating this soil type. See figure 8. Other soil types found were the clay, sandy and loamy soils but in few areas of the study.



Source: Field Survey, 2016

Figure 9 Effect of Soil Type on Choice of Toilet during the Rainy Season

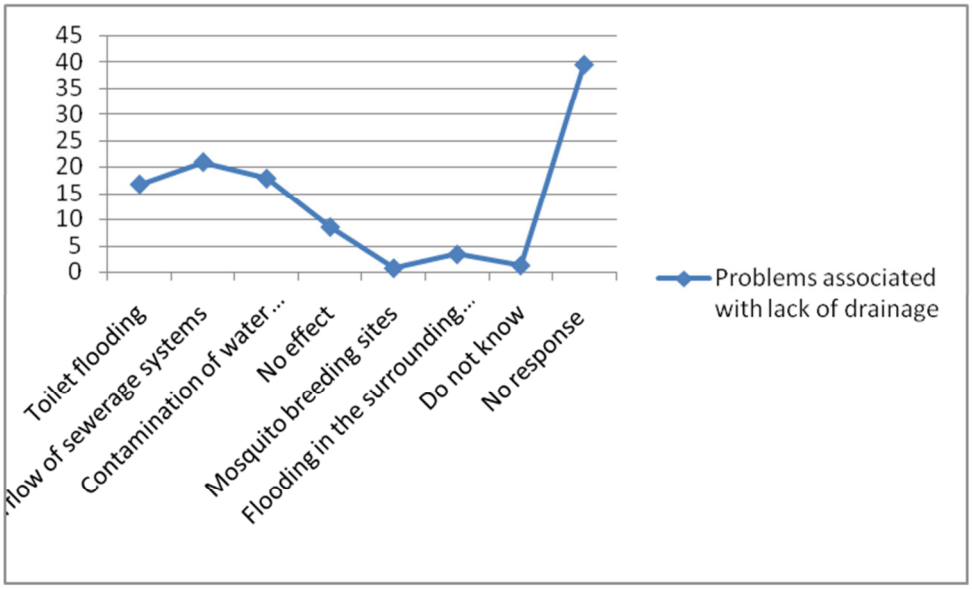
Figure 9 shows that 40% of the respondents reported not knowing the impact of the black cotton soils on sanitation management approach used. However 45% said that these soil types do not allow seepage of water. Less than 5% indicated not knowing the effects of rainy season on soils with regard to the choice of toilet.



Source: Field Survey, 2016

Figure 10 Storm Water Drainage Coverage

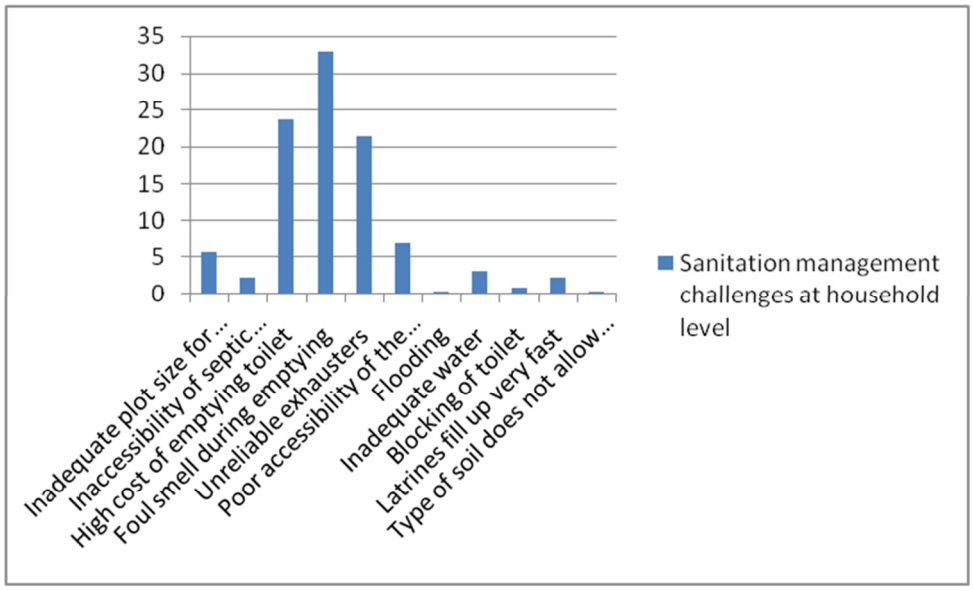
Most of the study area lacks storm water drainage (figure 10) with 65% of the respondents reporting absence of the same.



Source: Field Survey, 2016

Figure 11 Problems Associated with Lack of Drainage

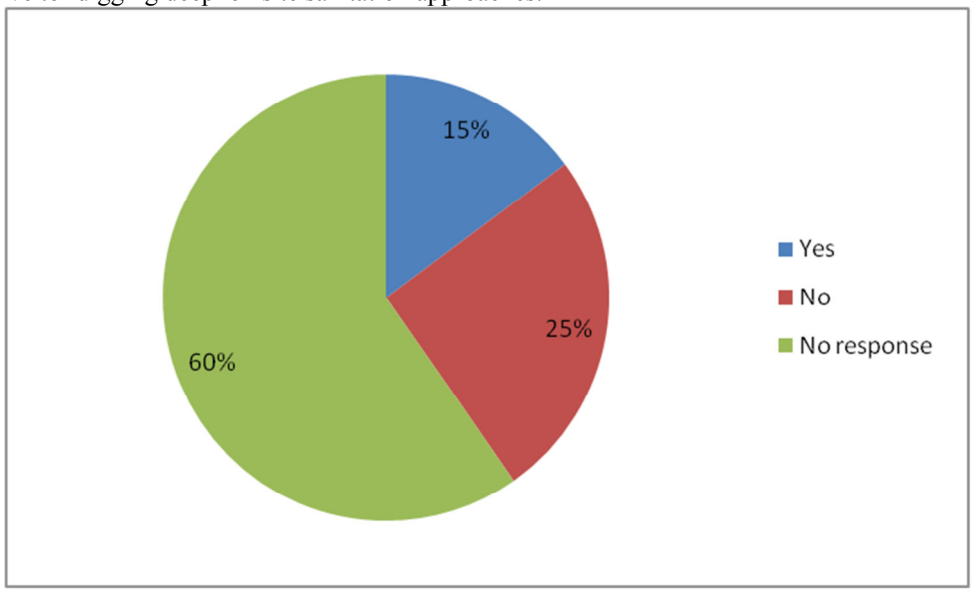
Overflow of sewerage systems, contamination of the water supply and toilet flooding emerged as the three main challenges arising from the lack of a storm water drainage system. Figure 11 shows that 21% of the respondents reported overflow of the sewerage systems, 18% complained of contaminated water during the rainy season while 17 % indicated toilet flooding.



Source: Field Survey, 2016

Figure 12 Challenges Encountered in Sanitation Management at the Household Level

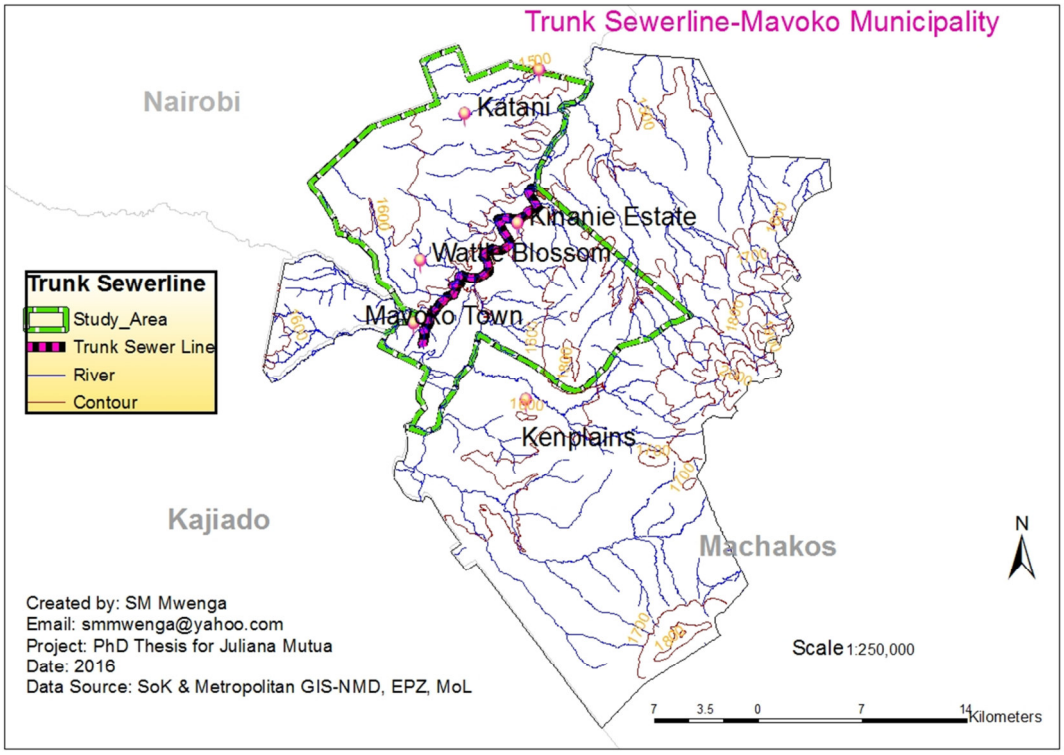
Figure 12 illustrates that major challenges encountered at the household level associated with toilet waste disposal were foul smell with 33% indicating this concern. High cost of emptying the toilet came second at 24% while challenges with unreliable exhausters closely followed at 22%. Other problems such as poor accessibility of the house by the Exhausters due to bad roads, inadequate plot size, inadequate water, quick filling up of latrines and inaccessibility of the onsite sanitation approach all registered less than 10% in frequency of occurrence. Other problems registered were blocking of toilets, flooding and type of soil which was not conducive to 'digging deep' on site sanitation approaches.



Source: Field Survey, 2016

Figure 13 Attempts at solving the challenges Encountered in Sanitation Management

Very few people solve challenges encountered at the household level. Out of the 385 respondents, 230 or 60% did not respond. Figure 13 illustrates that of the 155 who responded to the question of whether they attempted solving toilet disposal problems at home only 57 or 15% gave an affirmative answer.

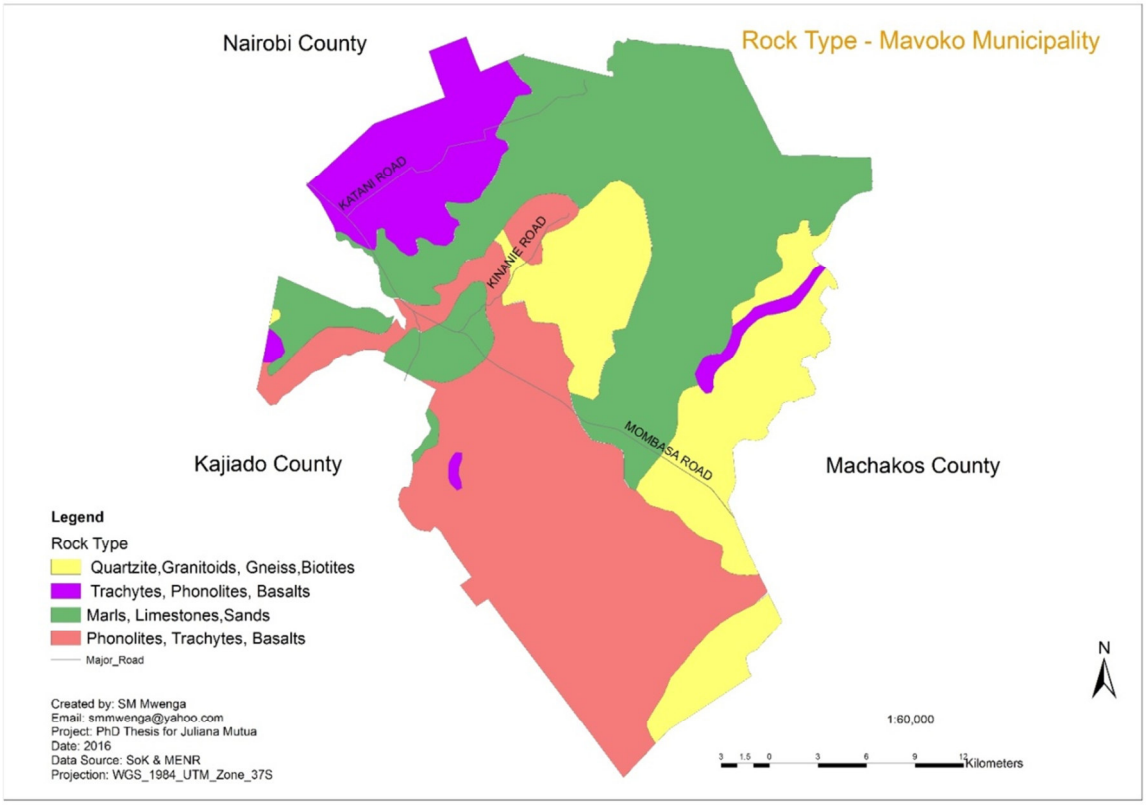


Source: Extracted from the EPZA sketch plan and the Athi River Development Plan for1970.

Figure 14 Sewer Line and Drainage in Mavoko Municipality

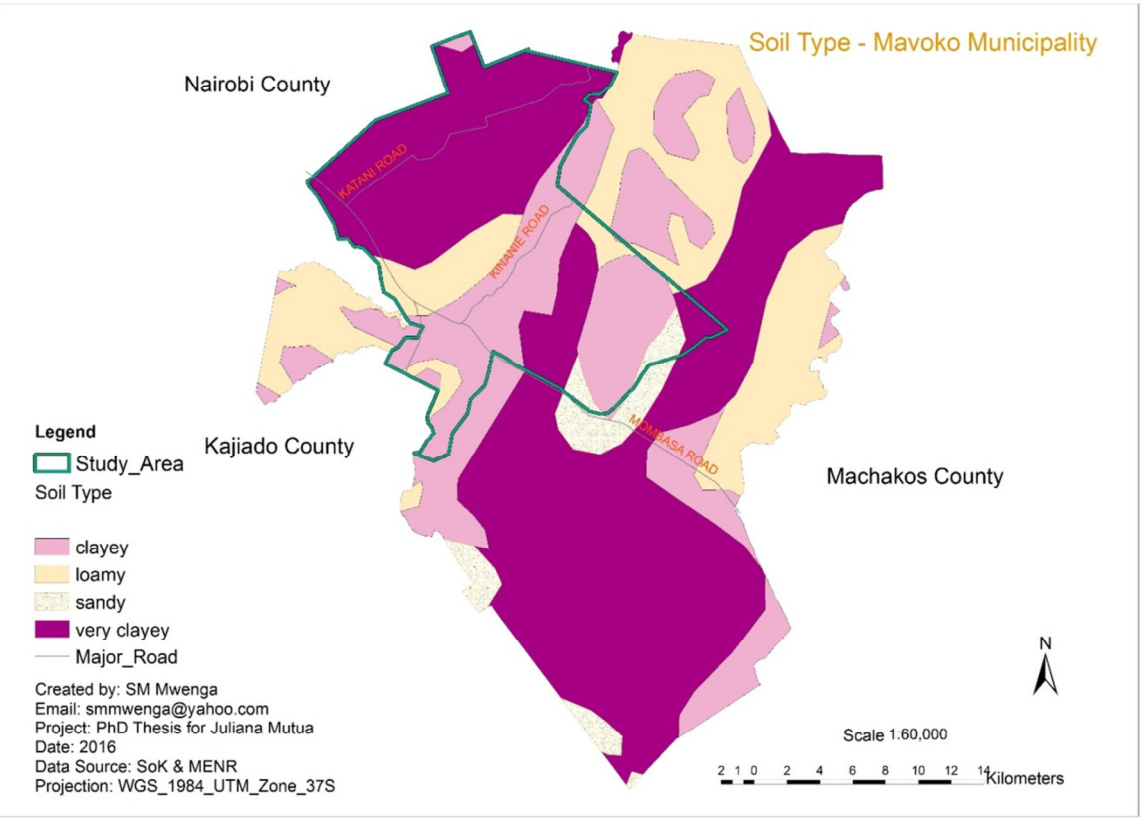
Figure 14 illustrates the existing sewer line running from the Athi River ward to Kinanie where the oxidation ponds are located. Notice that the larger area is not served by the sewer network confirming the Managing Director (MD) of Mavoko Water and Sewerage Company (MAVWASCO) sewer network coverage estimations at 25%.

Limitations of Black Cotton Soils



Source: Field Survey, 2016

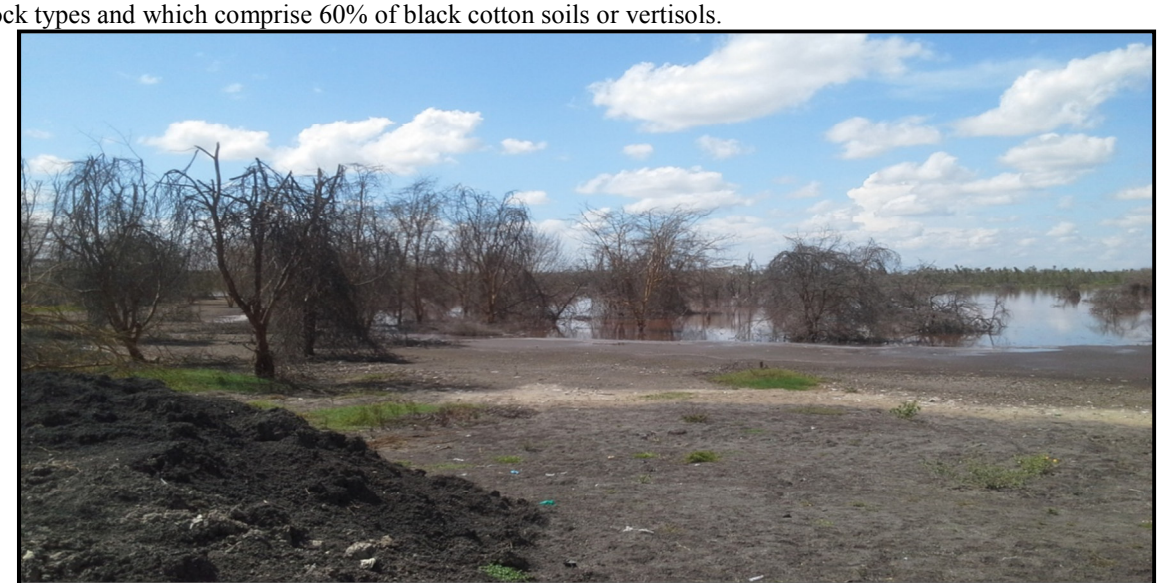
Figure 15 Rock type found in Mavoko Municipality



Source: Field Survey, 2016

Figure 16 Soil type found in Mavoko Municipality

The larger part of Mavoko Municipality is covered by black cotton soils with 86% of respondents citing the type of soil in their areas. This information was triangulated with the analysis of the geology and soils maps of the area (see figure 15 and 16) which shows the prevalence of clay soils formed on Pliocene and Miocene rock types and which comprise 60% of black cotton soils or vertisols.



Source: Field Survey, 2016

Plate 1 Drying vegetation at the point of discharge to Athi River from Kinanie oxidation ponds

Source: Field Survey, 2016
Plate 2 Pink residues from the Kinanie oxidation ponds

4.1 Inadequate Sewer Network Coverage

The Managing Director (MD) of MAVWASCO estimated sewer network coverage at 25% and noted as a challenge areas not covered by the sewer network. This concern was also raised by the Mavoko Sub-County Public Works Officer, who indicated that the area of coverage was very small compared to the large housing estates. The larger area did not have sanitation services of this nature.

A notice by the Export Processing Zone Authority (EPZA) to the public, Daily Nation, (2013) for unauthorized persons to disconnect from their sewer line was a confirmation of illegal connections to the existing sewer line as a result of the mentioned inadequate sewer network coverage.

However it was clear too from the topography of the study area that it has many tributaries which were well spread out and are opportunities for increasing sewer coverage in the area. Figure 15 illustrates the sewer coverage and the drainage of the study area.

4.2 Malfunctioning Conventional Sewer System

It emerged from the study that out of the 385 respondents interviewed, 123 reported using the conventional sewer which contributed to the leading challenges of overflowing sewers and bad smell with 32% and 28% respondents indicating this. 21% said that they experienced broken pipes and mains while 7% and 5 % respondents complained of overflowing toilets and blocked drains respectively. This agrees with the study by the (Ministry of Water and Irrigation et al 2007) which established that many people in the leading urban areas of Nairobi, Mombasa and Kisumu reported experiencing problems with the sewer system mostly overflowing and leakage from broken mains and bad smells. However the situation in Mavoko is more severe with overflowing toilets and blocked drains in addition to the challenges already observed in the mentioned urban areas.

4.3 Inadequate Reuse of Waste Water

There were no complains emanating from the supply of water as both MAVWASCO and the private sector were providing the commodity in the study area. However of concern was the low level of reuse of the waste water at the household level with only 37% of the population reusing waste water despite effluent reuse becoming more widespread with increasing consciousness of the need for water Palmer *et al* retrieved (23/8/16) from www.efm.leeds.ac.uk/CIVE/sewerage/articles/australia.pdf.

According to the Chief Executive Officer of MAVWASCO, “The African mentality is not receptive to re use of waste water” highlighting (Franceys et al 1992) observations that there were negative attitudes towards using excreta for fertilizer.. This is not in tandem with the theory on waste management advanced by (Prongraz *et al* 2004) on the promotion of resource conservation through waste minimization and resource use optimization. Unless this concern is addressed to raise awareness of the households need to minimize waste, sustainable development is compromised because the society and economy cannot be lived on a global scale (Kardt 2009).

4.4 Inadequate Treatment at the Oxidation Ponds

Still at another level, Export Processing Zone Authority (EPZA) which is one of the Authorities that has been providing safe drinking water to the study area has not ventured into recycling waste water for use. The EPZA

Officer responsible for the water sector indicated industrial disposal of chemical wastes which eventually empty into the Kinanie oxidation ponds rendering the water unfit for recycling. This was corroborated by the grounds man manning the Kinanie ponds when he gave a history of the events leading to the stoppage of use of water and sale of manure (processed night soil) from the ponds. He said

> "In the early 1980's people from the neighbouring area would fetch both water and manure from the Kinanie ponds but since the introduction of a leather company all that was forgone. People started getting ill on use of the water whilst farmers who dared use the resultant manure regretted ever using it as their farms became barren."(Kinanie farm hand, 23/4/16)

This confirms (Srinivasamoorthy,*et al* 2011) study that found that poor industrial effluent management was a danger to environmental protection and conservation.

Observations captured in the final oxidation pond as seen in plates 1 and 2 before discharge into the Athi River water showed lack of life in the water. There was no sign of fish or birds flocking in the ponds to prey on fish. There was a thick pink residue of waste from the ponds. Vegetation along the channel flow used by the water released from the ponds to the Athi River was yellowing with some drying up. Though yellowing of vegetation may occur as a consequence of water logging, excessively high levels of soluble zinc, manganese, copper or nickel hamper the iron uptake by vegetation causing the yellowing (Kumar, 2013). This is illustrative of resources not being used in accordance with the theory of waste management resulting in conflicting resource use and waste. This is an indicator of deteriorating living conditions as a consequence of a compromised environment leading to the conclusion of unsustainable development in the area.

4.5 Underground and Surface Water Integrity

A sample of records available from the County Water Office indicated that available boreholes in the study area were 196 with 144 falling in Athi River, 17 each in Syokimau, and Kinanie. Mulolongo and Katani had 13 and 5 boreholes respectively. Borehole depths in the study area ranged from 98 metres (m) to 192m while most of the water had been struck at levels from 32.4m to 128m.

Average borehole depth was 149m while the average level at which water had been struck was 83m. This has the implication that water table is low and ground water sources are not compromised as Cave et al (1999) illustrated that bacteria could only be transported some distance through the ground by liquid leacheate from a pit latrine or septic tank and thus contaminate local ground water supplies. (Pujari et al 2010) showed too that microbial and chemical contaminants reduced with the increasing depth of ground water source.

This is supported further by (Krishnan, 2011) and (ARGOSS 2002) as the risk to ground water by OSS is determined by the distance taken to travel to the same. The longer the effluent takes to travel to the ground water, the lesser the risk of contamination. The travel time depends among other factors on water table conditions which have been shown to be low.

However the integrity of the surface water is not assured as 24% of Respondents in the study area complained of contaminated water during the rainy season. This could be attributed to the storm water runoff which aggravates poorly maintained sewer network systems to cause sewage leaks which contaminate the domestic water reticulation systems. It confirms the observation made by (Tian 2011) that storm water runoff from impervious surfaces is the key contributor to the degradation of water quality and the natural ecosystem in urban environments. This contaminated water is a threat to the health and environment of the people of Mavoko Municipality and requires mitigation through well thought out trunk infrastructure provision to study area to actualize sustainable development.

4.6 Limitations of Black Cotton Soils

The larger part of Mavoko Municipality is covered by black cotton soils with 86% of respondents citing the type of soil in their areas. This information was triangulated with the analysis of the geology and soils maps of the area (see figure 16 and 17) which shows the prevalence of clay soils formed on Pliocene and Miocene rock types and which comprise 60% of black cotton soils or vertisols.

Vertisols form from highly basic rocks such as basalt and phonolites in climates that are seasonally humid or subject to erratic droughts and floods, or due to impeded drainage. These soils have the characteristics of high swelling and shrinking when exposed to changes in moisture content (Gaikwad et al 2014) and may result in subsidence. (Tumwebaze et al 2011) proved that soil type and vulnerability to flooding were important factors in determining the uptake of ecological sanitation.

However the sanitation management approaches used in the study and especially the onsite sanitation systems have not taken into consideration the soils and geology of the area. For septic tanks to work efficiently they require effluent from the septic tank to be channeled to a soak pit which finally discharges into the ground where pathogens are further broken down. (Tilley et al, 2014) opines that sanitation management options which use infiltration technologies must of necessity be in areas where the soil has a suitable capacity to absorb effluent.

The challenge in the study area is in the discharge from the soak pit which does not infiltrate the ground but instead saturates the subsurface which leads to flooding and overflow onto the surface. There is therefore a very high likelihood that they do not perform as expected since septic tank effluent contains approximately 70% of the original pollutants. Burnham Environmental Services Ltd (2015). This alludes to (Nam et al, 2006) study in Hanoi and the suburban area of Bangkok which found out that septic tanks used did not perform as required.

4.7 Inadequate Storm Water Drainage

Overflow of sewerage systems, contamination of the water supply and toilet flooding emerged as the three main challenges arising from the lack of a storm water drainage system. 30% of the respondents reported overflow of the sewerage systems, 26% complained of contaminated water during the rainy season while 24% indicated toilet flooding.

Due to the lack of storm water drainage coupled with the soils which swell on increase of runoff and an impervious rock type, sanitation management approaches of onsite type result in malfunctioning leading to over flow and discharge of raw sewage into the surface further compromising the health of the populations resident in the study area.

The Mulolongo area was cited by the County Public Works Officer as an area experiencing' likely water pollution because most of the septic tanks are not done properly'. The MD, MAWASCO noted Mulolongo as an area in a depression and as a result suffers serious effluent discharge requiring frequent septic tank emptying.

4.8 Poor Design of Sanitation Management Approaches

(Gunawardana et al 2011) illustrated that septic tanks and cess pits could not be considered as improved sanitation if the septage was not treated and disposed safely. According to the County Environment Officer, a comprehensive housing scheme's environmental impact report in Syokimau indicated that the system of sewage disposal was by bio-digester but was actually by a septic tank which broke down in a year's time after installation. As a result, raw sewage had been flowing into the Sabaki stream /waterway.

The septic tank serves 398 apartments whose population when extrapolated reaches about 2000 people going by the national average household size of 5. This is only from one CHS. If this is extrapolated further to assume about 10 more CHS of this magnitude, this would contribute to a population of 20000 people having their sanitation needs being mismanaged by a system which is not cost effective as the frequency of emptying the septic tank (even if it is assumed it functioned well), would have to be increased negating maximization of profitability. It is only a matter of time before the environment becomes severely compromised if this sanitation management approach is not addressed.

4.9 Sanitation Management Challenges at the Household Level

Major problems encountered at the household level associated with toilet waste disposal were foul smell with 33% indicating this concern. High cost of emptying the toilet came second at 24% while challenges with unreliable exhausters closely followed at 21.5%. Other problems such as poor accessibility of the house by the Exhausters due to bad roads, inadequate plot size, inadequate water, quick filling up of latrines and inaccessibility of the onsite sanitation approach all registered less than 10% in frequency of occurrence. Other problems registered were blocking of toilets, flooding and type of soil which was not conducive to 'digging deep' on site sanitation approaches.

A challenge singled out was the high cost of emptying the septic tank. It needs to be treated with utmost care as failure to contain the high cost of emptying (by regulatory bodies) might lead to compromised environments through discharge of sewage into open fields as it has been shown by (Caincross, 2003) that finances are not readily available to sanitation systems users. It has been argued that partial public funding factors trigger increased access to household sanitation (Tremolet et al, 2010) however (Toubkiss 2010) has also shown that finances either directly or in the form of subsidies are unavailable. Whichever way we look at it, the best approach to be adopted in this case would be for Government to provide a modicum of subsidies to cushion sanitation at the household level. These may be in the form of investing in partnership with the Residents in the study area to provide trunk sewerage infrastructure to address high cost of septic tank emptying.

4.10 Institutional Challenges

There are conflicting responsibilities as practiced by both EPZA and MAVWASCO. According to the Export Processing Zone Act Cap 517, EPZA was established to provide for the promotion and facilitation of export oriented investments and the development of enabling environment for such investment and for connected purposes. It has as one of its objectives, the development of all aspects of the export processing zones with particular emphasis on provision of advice on the removal of impediments to, and creation of incentives for, export-oriented production in areas designated as export processing zones provided in section 9 (1) (a). To carry out this function, it is further provided in section 2(d) to plan the development and maintenance, and to finance

the basic infrastructure up to the perimeter of the export processing zones. EPZA is involved in sanitation management because of the interest of providing incentives to Investors. EPZA has invested in a sewer line that runs from its parcel of land on the boundary of Mavoko and Kajiado Counties through the Athi River Municipality towards Kinanie area which hosts the oxidation ponds.

MAVWASCO was established in 2006 as a limited liability company under the water sector reforms enshrined in the Water Act 2002 (Mavoko Water Strategic Plan 2016). It is mandated to provide water service provision in its area of jurisdiction by a Service Provision Agreement (SPA) and license from Tanathi Water Service Board (TWSB). According to the EPZA Officer in charge of the water sector, in 2002 when the water reforms were introduced through the Water Act, MAVWASCO and EPZA entered into a merger and formed the Mavoko EPZA Water and Sewerage Company in November 2006. The aim was to ensure that surplus water which EPZA had sourced and invested in from Nairobi was sold to MAVWASCO.

However the merger collapsed in November 2007 due to 'irreconcilable differences'. MAVWASCO wanted all the bulk water supply from EPZA without giving an assurance that they would supply water to EPZA Investors on a 24 hour basis. It claims the assets put in place by the EPZA on grounds that they have the mandate to supply water to Consumers in Mavoko and Kitengela through the license from TWSB, , claims the infrastructure passes through its 'ancestral land' refuses to pay sewer revenue to EPZA and wants staff of EPZA dealing with water and sewerage services laid off. EPZA claims that the matter was over politicized confirming Zawahri, et al (2011) observations on the role of politics in sanitation provision. Due to these 'irreconcilable differences' the matters have been taken to court and this has slowed down service delivery to the people of Mavoko Municipality.

At the County and National government levels, Key Informants that is the County Physical Planner, County Environment Officer, County Public Health Officer, County Water Officer and the County Public Officers all complained of difficulty in enforcing the prevailing laws and regulations due to low personnel capacity, inadequate facilitation and transport logistics to field visits and poor monitoring as a result of non adoption of new technologies to aid work. Inadequate investment in sewerage infrastructure kept on recurring with all Key Informants emphasizing it.

4.11 Devolution

The Constitution of Kenya (CoK) 2010 was promulgated in August, 2010 and provides in article 174 for devolution. Among the nine objectives of devolution, those that stand out with regard to the study are the promotion of social and economic development and the provision of proximate easily accessible services throughout Kenya and the decentralization of state organs, their functions and services from capital of Kenya. Over Six years since the Country started implementing the CoK 2010; the County Environment and Public Health officers cited devolution as a challenge. According to the County Environment Officer, 'devolution had created duplicating roles in the sanitation sector between the national and county governments' while the County Public Health Officer said that functions and powers were now centralized in the County headquarters with employment of personnel being based on 'who voted for who'. On one hand there is overlap in the mandates of both the national and county employees and simultaneously lack of skilled personnel to deliver requisite services. The end result is poor enforcement of prevailing policy, laws and regulations in place.

4.12 Interventions in Conventional Sewer System Management

Of the 115 respondents who indicated addressing challenges posed by the sanitation approach, only 30% respondents said that they undertake their own repairs while less than 1% Respondents indicated mobilization of Residents to communally repair the sewer. Though this could be viewed as a window of opportunity in which the population takes personal responsibility in the management of household sanitation, it is too low compared to the majority 47% and 23% Respondents who preferred to pass on the challenge to a secondary authority like the Mavoko Water and Sewerage Company (which is responsible for the conventional sewer provision) and Caretaker. This presents a very bleak picture when it is noted that on site sanitation is considered a household responsibility outside the public domain and support from external actors is often very limited, Jones et al (2006).

4.13 Interventions at the Household Level

Generally people did not provide solutions to problems and challenges. Only 15% respondents answered in the affirmative on the question of whether they solve problems encountered at the household level relative to toilet waste disposal. 24% reported using air fresheners and disinfectants to deal with the bad smell while others undertook frequent cleaning of the latrines. Construction of soak pits and unblocking of the toilet, purchase of water storage tanks and water from water vendors were other interventions. However Respondents did not seem to be in control of weighty interventions in service provision by exhausters and public sanitation infrastructure providers as they were externally controlled and dependent on effective Government intervention through regulation of policies and laws by relevant Institutions.

4.14 Interventions at the Institutional Level

MAVWASCO and EPZA are already in Court awaiting the determination of the mandates of the latter which were challenged by MAVWASCO. Once determined, pursuit of development projects relevant to sanitation management shall be undertaken. Even as the situation stands, MAVWASCO has entered into an agreement with the Belgium Government to provide development funds worth 2.5 billion in readiness for investment in the water and sanitation sector. Kenya shillings 1.25 billion will be a direct loan while the other half will be a concession where only principal loan shall be repaid. (Managing Director, MAVWASCO)

Improvement of service provision by County governments through devolution into lower levels within the governance structures was cited by the County Public Health Officer as an intervening strategy. Investment in the sewerage infrastructure and modernization of the existing sewerage infrastructure are other intervening measures that were mentioned by all the County Officers interviewed. Sensitization of the Citizens and enforcement of prevailing laws and policies were considered other areas which could encourage the positive change of behavior towards sanitation management approaches such as increased reuse of waste water, adoption of appropriate sanitation management approaches such as the use of the conventional sewer in areas limited by black cotton soils and investment in storm water drainage to collect both run off and effluent discharged from septic tanks and bio digesters where already installed and in use as a short term measure.

The National Government through the Ministry of Transport, Infrastructure, and Housing and Urban Development has proposals to put up the 7.5 km long Lukenya sewer line and is at 50% completion though faces problems of encroachment on the way leave which have delayed the project. It is also not clear what population levels are targeted by this sewer line and therefore presents an obstacle in assessing the actual contribution of the sewer line once laid down.

4.15 Design of Sanitation Management Approaches

According to the County Public Works Officer, the office is not mandated to play a role in sanitation management improvement. However building plans submitted to their offices were indicative of the capacities of various sizes of septic tanks for use by different household sizes and authored by relevant Engineers. The office should be tasked with the responsibility to either avail prototype designs for recommended sanitation management approaches or enforce those provided in the submitted building plans as the office has the requisite competencies to provide these designs. Housing and Physical Planning Offices could play the complimentary role of ensuring that capacities are built in the construction of the designs. Physical Planning office should in addition to preparing urban development plans to guide development, prepare subject plans relative to water and sewerage reticulation plans to guide sanitation management.

5. Conclusion and Recommendations

It has been illustrated that the soils and rock type in the study area pose major challenges to sanitation management approaches whereas interventions to address these challenges are not adequate to surmount them. Poor and inadequate sewerage network coverage, insufficient storm water drainage, poor design of sanitation management approaches, low levels of reuse of waste water, derisory treatment of effluent in the oxidation ponds and the irreconcilable differences between the key services providers are indicators of compromised environment which can only lead to unsustainable development.

Recommendations are made to the effect that measures be put in place by the Government to prioritize investments in the water and sanitation sector to increase the area coverage under sewer network and storm water drainage. The population should be educated on the need for reuse of waste water with the promotion of separation of household and industrial waste water while the mandates of the service providers are clarified to play a complementary role and promote proper effluent management in the oxidation ponds. Service provision by the County Government in addition to the EPZA and MAWASCO should be monitored and evaluated regularly to promote effective and efficient service delivery. Research into the collaboration mechanisms between the Government and the private sector should be undertaken to inform cost sharing and economies of scale in sanitation management.

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Biography

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