University of Nairobi

School of Engineering

GIS FOR ASSESSING PRO-POOR URBAN WATER SANITATION AND HYGIENE (WASH) SERVICES

CASE STUDY: MRADI EMBAKASI VILLAGE NAIROBI

BY

Maina Lydiah Wanjiru

F56/68890/2013z

A Project submitted in partial fulfillment for the Degree of Master of Science in Geographic Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi

May 2015

Declaration

I, Maina Lydiah Wanjiru, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other institution of Higher Learning.

LYDIA WANJIRU MAINA ....

Name of student Signature Date

This project has been submitted for examination with my approval as university supervisor.

DR.F.N.KARANJA …… ……

Name of supervisor Signature Date

Acknowledgement

My sincere thanks go to my supervisor Dr. F.N Karanja for her guidance and support during this project. Many thanks to our lecturers and other staff at the Department of Geospatial and Space Technology for whatever role they played towards the completion of program.

I convey distinctive thanks to my classmates for standing in as my good advisors and counselors whenever I approached them for guidance. Special thanks to my family for their encouragement and understanding during my studies. I appreciate the social and economic support from my father and mother. I wish to thank the residents of Mradi village in Embakasi for their willingness to participate in. Specifically I would like to thank Mr. John Gitau for helping me during data collection.

Lastly I appreciate all who contributed towards the success of this project especially my friends and workmates.

Abstract

Dense low-income urban communities are often confronted with poor water and sanitation services, which are associated with considerable morbidity and mortality that is highly preventable using inexpensive interventions. This study set out to use Geographic Information Systems to assess water, sanitation and hygiene (WASH) services in Mradi Embakasi village as case of a pro-poor urban.Data was collected using spatial data collection techniques using GPS enabled android mobile phone powered by Open Data kit application. The spatial data was complemented with household, water point, toilet, dumping site and key informant questionnaire others included direct observation, systematic walk about, literature survey and key informant interviewing. Data analysis was done using vector and raster analysis tools in QGIS these tools included cartographic and data management tools, feature extraction, visualization, overlay analysis, proximity analysis and spatial statistical analysis tools. The results were visualized using maps. Statistical data analysis used pivot table in Excel and SPSS was used for quantitative data analysis. Results were displayed in charts and tables.

4 water points, 49 toilets and 8 main dumping sites were mapped and 50 households were sampled. 88% of household obtained water within the 200m from the 4 water points. With Each water point being accessed by an average of 100 residential buildings, the average size per household was 4 persons.78% of respondents did not have enough water for all members.76% of households obtained water from unprotected sources with high risk of contamination, 74% of the households were found to spend between 5 shillings to 15 shilling. The toilets were located 50 meters from the households, with a minimum of 8 households sharing one toilet. No toilets were found in the business areas.

Eight main dumping sites mapped were open and overflowing with mixed waste.47% of households walked less than 50 meters to dump their waste in the main dumping site. The major sanitation problems in regards to WASH in MRADI included dirty and few communal toilets, lack of hand washing facility , poor waste disposal, inconsideration of vulnerable groups in toilets construction, open defecation, contaminated water sources and open sewerage. Using GIS this study identified important geographic inequalities in distribution of WASH services. Using GIS maps and analytical approach provided a mechanism for monitoring future reductions in inequality within the area, reflecting priorities for the post-2015 development agenda.

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Definition of Terms

WASH…….	Water Sanitation and Hygiene
GIS…….	Geographic Information Systems
GPS…….	Global Positioning System
ODK……	Open Data Kit
APHRC ……..	African Population and Health Research Centre
MDGs……	Millennium Development Goals.
KHDS……	Kenya Demographic and Health Survey
NCWSC……	Nairobi Water and Sewerage Company
UNDP …… …….	United Nations Development Programme
GLAAS ……	Global Analysis and Assessment of Sanitation and Drinking-Water

CHAPTER 1.INTRODUCTION

1.1Background to the Study

A key justification for investment in water, sanitation and hygiene (WASH) is to reduce the burden of diseases. In dense pro-poor urban communities with poor water and sanitation services, there can be little doubt that genuine improvements to WASH can have a substantial positive impact on health. However, it seems likely that many specific WASH interventions do not achieve a significant health impact, because they are not well targeted and spatial techniques are neglected during baseline surveys.

A survey conducted in 2000 by the African Population and Health Research Centre, found that compared to other areas in the country, slum residents in Nairobi suffer worse health and reproductive health conditions than their non-slum counterparts, African Population and Research Health Centre (2002). According to APHRC, infant mortality rate in Nairobi slums is 96 per 1,000 live births – higher than any other region of Kenya and 25% higher than the national average of 77%.Under-five mortality rates in the slums (150 per 1,000 live births) are more than double the Nairobi average of 62 and greater than for rural Kenya (113 per 1000 live births).In Nairobi alone, around 100 unplanned settlements with a population of 1.75 million exist, (around 50% of total population in Nairobi) and the number of such settlements and population residing in them are increasing at higher rate (APHRC 2002). The Kenyan government is constrained by capacity and funding to improve basic service provision in informal settlements leaving slum residents in Nairobi vulnerable to a host of health and environmental hazard (Amnesty International July 2010).

Despite the broad ranging water sector reform and the commitment to invest in water supply and sanitation, recent JMP report (2014) indicates that Kenya still faces considerable challenges in reaching the water and sanitation MDGs where 15.8 million more people need to obtain access to clean water and 16.5 million to access sanitation UNDP(Dec 2006).

According to Billing et. al (1999), access to an improved water source implies that the household or compound is directly connected to a piped water system or that a public fountain, well, or stand post is located within 200 meters of the home in urban areas and that maximum distance from any household to the nearest water point is within 500 meters in rural areas. Year-round means that water is available during the time(s) of the year when the water supply is least reliable. Queuing time should be less than 15 minutes and it should not take more than three

minutes to fill a 20-litre container UNHCR (January 2008). Access to sanitation is defined for urban areas as being served by connections to public sewers or household systems such as pit privies, pour-flush latrines, septic tanks, communal toilets and the like. Minimum standard – toilets no more than 50 meters from dwellings or no more than 1 minute walk. Each person should be able to wash hands with water and soap after toilet use, before food preparation, before eating and after cleaning babies.

All households should have access to refuse containers which are emptied twice a week at minimum and are no more than 100 meters from a communal refuse pit, with all waste generated by populations living in settlements is removed from the immediate living environment on a daily basis, and from the settlement environment a minimum of twice a week (WHO, 2004).

This survey sought to bridge this gap by utilizing Geographic Information System, to carry out an assessment on water and sanitation status in Mradi, Embakasi village through spatial mapping techniques, aimed at identifying geographical inequalities in the distribution of facilities.

1.2Problem Statement

Inadequate and unhygienic sanitation in Nairobi's informal settlements has for years led to contaminated waterways on food supply resulting to outbreak of water borne diseases like cholera. Additionally over 50% of hospital visits in Kenya for illnesses are related to insufficient water supply, sanitation and hygiene and these diseases are the number one cause of children under 5 hospitalizations and mortality according to Kenya Demographic and Health Survey (KHDS) (2008-2009).Regional and subsequent sub -county disparity in WASH interventions is evidence in Kenya in both urban and rural areas, with some areas reporting low coverage compared to nationwide coverage which currently stands at 59% WHO (2014). Mradi in Embakasi village is an informal settlement in Nairobi County which is growing every day and is facing overwhelming problems as a result of rapid urbanization. In this area, accessing basic and improved water and sanitation services is a growing challenge. Residents rely on water vendors or unprotected sources where water quality varies and where there is a high risk of contamination. Once people can access WASH facilities, will promote economic growth and as a result culminate in improved standards of living.The capabilities of GIS has not been explored in Kenya in solving this problem in the urban slums, method like use of outdated maps and paper-based data collections methods are used in assessment surveys. Having spatial database with exact geographic location and attribute information of this WASH facilities of target area, it

becomes easy to assess and analyze WASH situation for target based interventions in the post 2015 development agenda toward global coverage of water and sanitation by 2030.

1.3Objectives

Overall objective

The overall purpose of this project was to assess and analyse distribution of water, sanitation and hygiene services using GIS. This will help in understanding the geographic inequalities in coverage of drinking-water supply and sanitation and hygiene practices, therefore able to track progress towards universal coverage of water and sanitation, which will result into increased life expectancy among the urban poor.

Specific objectives

- To map WASH within the supply area.
- To use GIS in analyzing accessibility of WASH within the supply area.
- To assess levels of awareness and practice on sanitation and hygiene.
- To use GIS in selecting new water sites
- To use maps to identify water supply, sanitation and hygiene problems.

1.4 Justification for the Study

Over 50% of the hospital visits in Kenya for illnesses are related to insufficient water supply, poor sanitation and hygiene, which are the important causes of under-five hospitalization and mortality KHDS (2008-2009)

Adequate amount of safe water is necessary to prevent death from water-related disease. Physical access to sufficient, safe, acceptable, and affordable water for personal and domestic use and accessible sanitation facilities is a human right, which is recognized in international legal instruments. This study aimed to investigate if there are geographic inequalities of WASH services provision which may not be apparent within national statistics that may inform policy formulation and thereof target based interventions.

The following describes some of the benefits and beneficiaries of this project:

- Residents of pro-poor urban: this will be a wakeup call for them to improve hygiene practices and a benchmark in measuring performance of their elected leaders.
- Water boards e.g. Water Services Trust Fund (WSTF), Water Services Boards (WSBs), Water Service Providers (WSPs), Water Services Regulatory Board (WASREB) and Nairobi Water and Sewerage Company(NCWSC). This will help them identify the gaps in geographic coverage and how effectively they can correct the issue.
- Ministry of Public Health and Sanitation (MPHS), which will help the government in appreciating how useful GIS is in controlling the spread of water borne diseases e.g. cholera
- The Water and Sanitation Programme (WSP) of the World Bank.
- Non-governmental organizations (NGOs) active in the water sector: this information will guide them in investing and putting up targeted interventions.

This study aimed at using GIS techniques in providing a baseline for various stakeholders to take appropriate action leading to improved WASH facilities in slums, reducing the occurrence of WASH related diseases and increasing household awareness on personal hygiene through hygiene promotion.

1.5Scope of Work and Limitation of the Study

This study was conducted in Mradi in Embakasi village, an informal settlement. Assessment using GIS was needed to identify inequality of WASH distribution and thereof identify risky practices that might increase vulnerability to water related illnesses.

Although there are a lot of areas that can be researched about WASH, this research project was limited to the scope of mapping the main indicators of WASH namely water, toilets, hand wash and waste this was complemented by a household survey. The scope of the spatial data analysis and manipulation was limited to use of QGIS, qualitative and quantitative analysis was limited to SPSS and Excel Software. The main limitation of the study was navigating through the study area during data collection as access was prohibited by congestion and lack of defined routes and poor waste disposal method in the study area.

1.6Organization of the report

This report is organized in five chapters. Chapter one presents the background, the problem statement, objectives, justification and scope and limitation. Chapter two contains literature that

is relevant to the study. Chapter three has the methodology, while chapter four presents the results and discussion and chapter five contains conclusions and recommendation

CHAPTER 2. LITERATURE REVIEW

2.1 Introduction

Water and sanitation improvements, in association with hygiene behavior change, can have significant effects on population and health by reducing a variety of disease conditions such as; diarrhea, intestinal helminthes, guinea worm, and skin diseases. These improvements in health can, in turn, lead to reduced morbidity and mortality and improved nutritional status. The WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation, known as the JMP, reports every two years on access to drinking water and sanitation worldwide on progress towards related targets under Millennium Development Goal 7,global target to "reduce by half the proportion of people without sustainable access to safe drinking water and basic sanitation, by 2015"WHO (2004) target 7.D of the MDG aims at achieving a significant improvement in the lives of at least 100 million slum .According to (WHO/UNICEF JMP 2012), it is estimated that nearly one billion people in the world currently live without reliable access to safe drinking water; 2.4 billion people still lack access to hygienic sanitation facilities, while half of these people without sanitation facilities at all JMP (2012), approximately 5,000 childhood deaths occurs daily due to illnesses related to poor access to water and hygienic sanitation. Africa is one of the two major regions with the least improvement in accomplishing the MDG on sanitation by 2015. Despite the fact that North Africa has 90% coverage, Sub-Saharan Africa has a startling 30% coverage with only a 4% increase from 1990. This is a serious concern because of the associated massive health burden as many people who lack basic sanitation engage in unsanitary activities like open defecation, solid waste disposal and wastewater disposal. The practice of open defecation is the primary cause of faecal oral transmission of disease with children being the most vulnerable. Figure 2.1Africa as a whole, especially Sub-Saharan Africa despite efforts and approaches to extend and sustain water, sanitation and hygiene (WASH) systems and services has led to different health complications leading to death within the region.

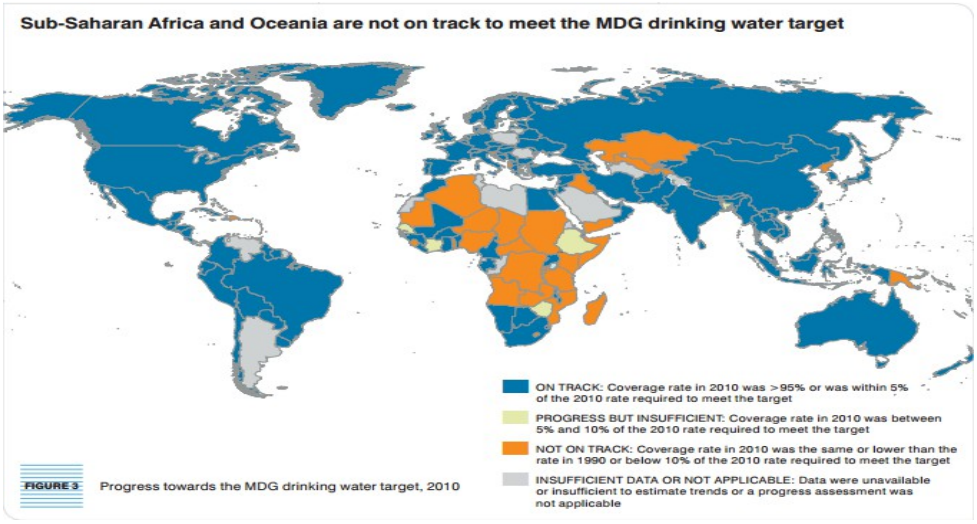


Figure 2.2 Progress toward MDG drinking water target 2010

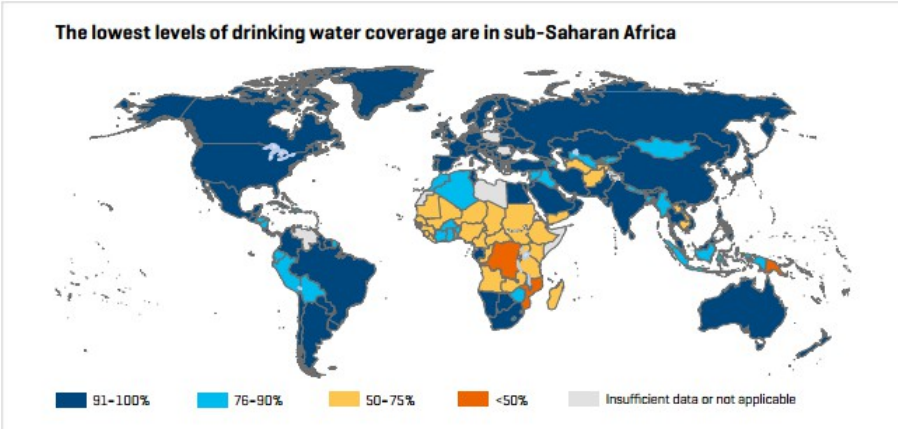
Source: (WHO/UNICEF Progress on Drinking Water and Sanitation 2012 Report)

2.2 Why Focus on Pro-poor WASH Services

Slums are characterized by the absence of basic services, such as clean drinking water and adequate sanitation, along with insecure tenure, non-durable housing and overcrowding. Despite these living conditions, the number of slum dwellers have continued to grow due, in part, to the fast pace of urbanization. Water and sanitation improvements affect health primarily by interrupting or reducing the transmission of disease agents. By 2007, for the first time in history, half of the world's population inhabited urban areas. Over one billion people currently live in urban slums, 300 million without access to a clean water supply, while 400 million people do not have access to improved sanitation .By 2030, the number of people living in urban areas is predicted to increase by a further 4.9 billion over 2007 figures, equivalent to roughly 70% of the world's current population World Bank. The number of urban residents living in slum conditions was estimated at 863 million in 2012, compared to 760 million in 2000, and 650 million in 1990. These were mostly from sub-Saharan Africa (62 per cent) and, to a lesser extent, in Southern Asia (35 per cent), compared to 24 per cent in Latin America and the Caribbean, and 13 per cent in North Africa. Efforts are needed to improve the lives of the urban poor across the developing world, and to decongest the slum (Figure 2.2) Millennium Development Goals Report (2014).

2.3 Global context on WASH services

The MDG drinking water target -, to reduce the number of without sustainable access to safe drinking water by half (an increase in coverage from 76% to 88%) between 1990 and 2015 - was met in 2010. Between 1990 and 2012, 2.3 billion people gained access to improved drinking water sources, raising global coverage to 89% in 2012. There were only three countries (Democratic Republic of the Congo, Mozambique and Papua New Guinea) with less than half the population had access to an improved drinking water source. In a further 35 countries, 26 of which are in sub-Saharan Africa, coverage of improved drinking water supply was between 50% and 75%. In Latin America and the Caribbean, the lowest levels of coverage are found in Dominican Republic, Ecuador, Haiti, Nicaragua and Peru as shown in (Figure 2.3).



2.3 Proportion of the population using improved drinking water sources in 2012

Source: (WHO/UNICEF Progress on Drinking Water and Sanitation 2014 Report)

According to UN-water global analysis and assessment of sanitation and drinking-water (GLAAS 2014):

- 2.3 billion People gained access to improved drinking-water 1990–2012.
- The number of children dying from diarrhea, which is strongly associated with pure drinking water, inadequate sanitation and hygiene, have steadily fallen over the last two decades from approximately 1.5 million deaths in 1990 to just above 600,000 in 2012.
- 2.5 billion People lack access to improved sanitation.
- 1 billion People practice open defecation, nine out of ten in rural areas.
- 748 million people lack access to improved drinking-water and it is estimated that 1.8 billion people use a source of drinking-water that is contaminated with faeces.

- Hundreds of millions of people have no access to soap and water to wash their hands, preventing a basic act that would empower them to block the spread of disease.

2.4 Status of Water Sanitation and Hygiene in Africa

According to (Millennium Development Goals Report 2012.UN, July 2012),Northern Africa and Sub-Saharan Africa even though in one continent, have made different levels of progress towards the Millennium Development Goal on water. North Africa has 92% coverage and is on track to meet its 94% target before 2015. However, Sub-Saharan Africa experiences a contrasting case with 40% of the 783 million people without access to an improved source of drinking water from the region. Sub-Saharan Africa is off track from meeting the MDG on water with just 61% water coverage and with the current pace it cannot reach the 75% target set for the regions. Over 90% of the richest quintile in urban areas use improved water sources, and over 60% have piped water on premises. In rural areas, piped-in water is non-existent in the poorest 40% of households, and less than half of the population use any form of improved source of water. (Figure 2.3).About one in every 5 people in Africa practice open defecation, an improvement from the 1990 baseline of one in three. Overall there has been an 11% drop in the number of people practicing open defecation in Sub-Saharan Africa, unfortunately due to population growth the absolute number of open defecators has increased by 33 million (JMP, 2012). Currently 223 million people in Africa still defecate in the open JMP report (2014)

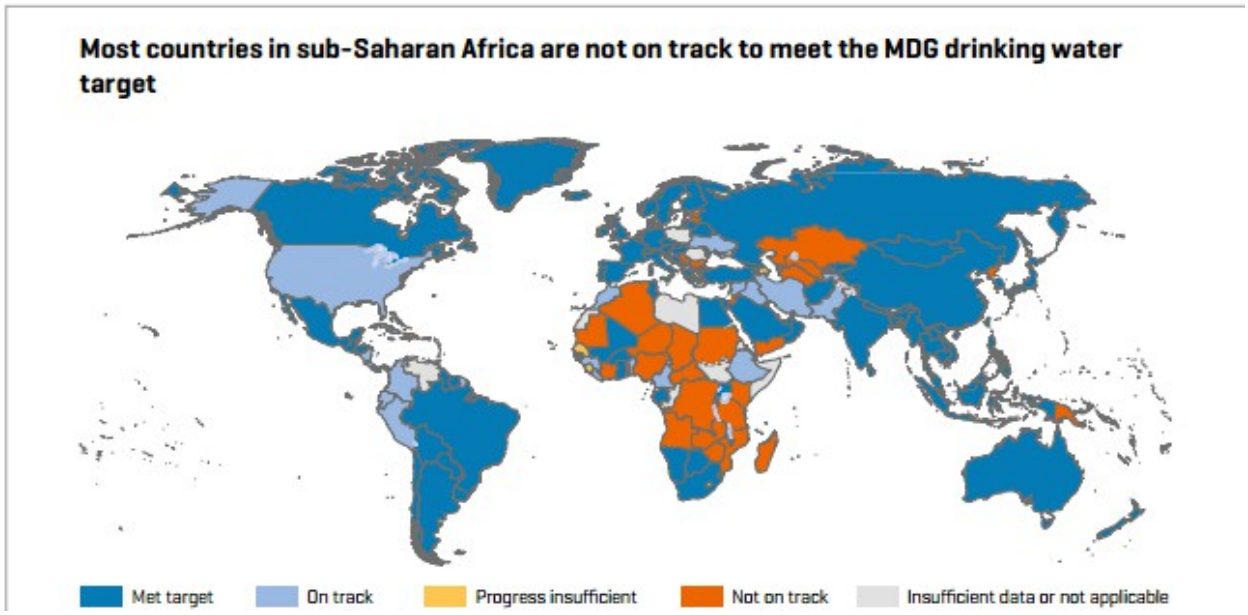


Figure 2.4 Progress towards the MDG drinking water target, 2012

Source: (WHO/UNICEF Progress on Drinking Water and Sanitation 2014 Report)

2.5 WASH Context in Kenya

Despite the broad ranging water sector reform and the commitment to invest in water supply and sanitation, Kenya still faces considerable challenges in reaching the water and sanitation Millennium Development Goals (MDGs). To achieve the MDGs, 15.8 million more people need to obtain (in access to water and 16.5 million to sanitation. Even if those targets are met, 8.5 million people will remain without access to safe water, and 12.2 million will lack proper sanitation UNDP (Dec. 2006).

In Nairobi alone around 100 unplanned settlements with a population of 1.75 million exist (around 50% of Nairobi's population). These settlements are increasing and consequently raising the population. The Kenyan government is constrained by capacity and funding to improve basic service provision in informal settlements leaving slum residents in Nairobi vulnerable to a host of health and environmental hazards (www.majidata.ke).

According to the Joint Monitoring Programme's 2012 report(JMP 2012), in Kenya, about 59% of the people have access to safe water supplies while only 32% have access to improved sanitation is 32% (http://water.org/country/kenya/). There are still challenges in meeting water and sanitation requirements in both rural and urban areas. Kenya faces challenges in water provision with erratic weather patterns in the past few years causing droughts and water shortages.

Due to lack of access to water and sanitation, diarrhea is the second leading cause of under-five mortality (excluding neonatal) – pneumonia is the leading cause Water, sanitation and hygiene related illnesses and conditions are the number one cause of hospitalization in children under age five. Access to water and sanitation also contribute to time savings for women, more hours in school for girls, and fewer health costs UNICEF, WHO report (2009).

2.6 Indicators of pro-poor WASH services

2.6.1Water

Water as one of the great necessities of human life needs to be easily accessible to every person. However, water accessibility in the developing countries faces various challenges due to inadequate funding to the sector WHO (2004**)**).The supply of clean water is absolutely necessary for life and good health, yet almost 2 billion people lack access to adequate water supply or can only obtain it at high prices. In many cities, households in informal settlements are rarely connected to the network and can only rely on water from vendors at up to 200 times the tap price. Improving access to safe water implies fewer burdens to population, especially women, who collect water from available sources, which leads to reduced global burden on water related diseases and improved quality of life.

Table 2.1 WHO standards below shows what it means when the population is with sustainable access to an improved water source. In urban, it means the percentage of the urban population who use any of the following types of water supply for drinking. Piped water into dwelling, plot or yard; public tap/standpipe; borehole/tube well; protected dug well; protected spring; rainwater collection and bottled water. The water should be affordable and at a sufficient quantity that is available without excessive physical effort and time. Improved water sources do not include unprotected wells, unprotected springs, water provided by carts with small tanks/drums, tanker truck-provided water and bottled water (if a secondary source is not improved) or surface water taken directly from rivers, ponds, streams, lakes, dams, or irrigation channels.

Table 2.1 Drinking water sources WHO (2004)

Improved Drinking Water Sources	**Unimproved water source**
Piped water into dwelling, plot or yard, public standpipe/tap, borehole/tube well, protected dug well, protected spring, Rainwater collection	Unprotected dug well, unprotected spring, surface water (river, dam, lake, pond, stream, canal, irrigation channel),vendor-provided water (cart with small tank/drum,

	tanker),tanker truck water

Table 2.2 list of basic water requirements

Survival needs. water intake (drinking and food)	2.5-3 liters per day depends on	Depends on. the climate and individual Physiology
Basic hygiene practices (hands and face washing)	2-6 liters per day	Depends on. social and cultural norms
Basic cooking needs	3-6 liters per day	Depends on. food type, social as well as cultural norms
Total basic water needs	7.5-15 liters per day	

The guidelines in table 2.2 assume that the water point is accessible for approximately eight hours a day and water supply is constant during that time. If access is greater than this, people can collect more than the 15 liters/day minimum requirement. These targets must be used with caution, as reaching them does not necessarily guarantee a minimum quantity of water or equitable access.

Quantity of water used per capita per day

This indicator includes all water collected by or delivered to the household and used there for drinking, cooking, bathing, personal and household hygiene and sanitation by the inhabitants of the household. It does not include water used for gardening or for watering animals. A day is a 24-hour period. All adults and children in the household are counted. It is assumed that the amount collected is the amount used. Calculation is in volume of water (in liters) collected for domestic use per day by all households in the sample divided by total number of persons in the sample households.

2.6.3Sanitation and Hygiene

Sanitation generally refers to the provision of facilities and services for the safe disposal of human urine and feaces (WHO).Inadequate sanitation is a major cause of disease world-wide and

improving sanitation is known to have a significant beneficial impact on health both in households and across communities (WHO).The word 'sanitation' also can refer to the maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal. A sanitation facility is defined as a functioning excreta disposal facility, typically a toilet or latrine table 2.3. Hygiene means that there are no feces on the floor, seat, or walls and that there are few flies. Using sanitation facilities means that a sanitation facility is the predominant means of excreta disposal for household members >12 months of age.

Based on WHO standards access means that the household has a private facility or shares a facility with others in the building or compound. Access is a fraction of the number of households in the sample with access to a sanitation facility divided by number of households.
Appropriate hand washing behavior includes two dimensions. Critical times and technique, Critical times for hand washing after defecation, after cleaning babies' bottoms, before food preparation, before eating, before feeding children hand washing technique.

Table 2.2 List of basic sanitation requirements Sphere Project (2004)

Improved Sanitation	**Unimproved sanitation**
Flush or pour–flush to. piped sewer system septic tank, pit latrine, ventilated improved Pit latrine. Pit latrine with slab, Composting toilet	No piped sewer system, septic tank or pit latrine. Pit latrine without slab/open pit •Bucket • Hanging toilet or hanging latrine Shared facilities of any type No facilities, bush or field

Sanitation in urban pro poor areas, mainly refers to the access to, and use of, excreta and wastewater facilities and services that provide privacy while at the same time ensuring a clean and healthful living environment both at home and in the immediate neighborhood of users[Ref]. One improved household table 2.3 or plot-level sanitation unit can adequately provide sanitation access to 10 persons provided they are living on the same plot (within the same yard or compound) or on the same floor (in case of a block of flats).

The MDG indicator for access to basic sanitation is the proportion of people using an improved sanitation facility in urban and rural areas.

In Table 2.4 people should have adequate, appropriate and acceptable toilet facilities, sufficiently close to their dwellings, to allow rapid, safe and secure access at all times, day and night.

Table 2.4 Appropriate and Adequate Toilet Facilities Sphere Project (2004)

Safe excreta disposal type	Application remarks
Demarcated defecation area (e.g. with sheeted-off segments)	First phase. the first two to three days when a huge number of people need immediate facilities
Trench latrines	First phase. up to two months
	Plan from the start through to long-term use
Ventilated improved pit (VIP) Latrines	Context-based for middle- to long-term response
Ecological sanitation (Eosin) with urine diversion	Context-based. in response to high water table and flood situations, right from the start or middle to long term
Septic tanks	Middle- to long-term phase

Hygiene

Hygiene is commonly known as cleanliness or conditions and practices that serve to promote or preserve health. A population that does not take into consideration hygiene is at risk of infection and illness. Improved housing, improved nutrition and improved hygiene are the essential components for the war against infectious diseases. (Greene, 2001.)Table 2.5 list basic item according to humanitarian charter and minimum standards in humanitarian response

Many people living in poor urban areas experience that they practice personal hygiene such as brushing teeth, bathing the body although not as frequent as it is desired. Lack of resources, such as water, results in poor hygiene levels; toilets cannot be washed and there is not enough water to shower (Mahasneh and Sawsa 2001.)

Table 2.5 List of basic hygiene items (Sphere Project)

10–20litre capacity water container for transportation	One per household
10–20 liter capacity water container for storage	One per household
250g bathing soap	One per person per month
200g laundry soap	One per person per month
Acceptable material for menstrual hygiene, e.g. washable cotton cloth	One per person

2.6.4 Solid Waste Management

Solid waste management is the process of handling and disposal of organic and hazardous solid waste which, if unattended appropriately, can pose public health risks to the affected population and can have a negative impact on the environment. Centre for appropriate technology (2003)

- All households have access to refuse containers which are emptied twice a week at minimum and are no more than 100 meters from a communal refuse pit
- All waste generated by populations living in settlements is removed from the immediate living environment on a daily basis, and from the settlement environment a minimum of twice a week.
- At least one 100-litre refuse container is available per 10 households, where domestic refuse is not buried on-sit
- There is timely and controlled safe disposal of solid waste with a consequent minimum risk of solid waste pollution to the environment

- All medical waste (including dangerous waste such as glasses, needles, dressings and drugs) is isolated and disposed of separately in a correctly designed, constructed and operated pit or incinerator with a deep ash pit, within the boundaries of each health facility

2.7Pro-poor WASH Programme Design and Implementation

WASH needs of the affected population are met and users are involved in the design, management and maintenance of the facilities where appropriate. WASH improvements have the greatest and most sustainable impact on health when a balance of the following three elements is achieved (USAID Water Implementation Guide, 2014)

- Expanded access to hardware (e.g., water and sanitation infrastructure and hygiene commodities.
- Required behavior changes for sustained improvements in water and sanitation access/service and hygiene practices.
- Improved enabling policy and institutional environment. These three aspects are mutually reinforcing and equally critical to success

Key Principles to Programming WASH Sustainably and Effectively

- Consider relative cost and impacts of different programmatic approaches in light of available resources, those of other development partners, country context, and programmatic constraints, i.e., between rural and urban interventions, direct service delivery and enabling environment, etc.
- Program with appropriate attention to environmental, financial, governance, social, and technical constraints that affect sustainability
- Consider financial, market-based, and technological interventions that can transform sectors Program in accordance with World Health Organization (WHO) Guidelines for Drinking Water Quality and Water Safety Plans

2.7.1Key Indicators of Successful WASH

- All groups within the population have safe and equitable access to WASH resources and facilities, use the facilities provided and take action to reduce the public health risk

- All WASH staff communicates clearly and respectfully with those affected and share project information openly with them, including knowing how to answer questions from community members about the project.
- There is a system in place for the management and maintenance of facilities as appropriate, and different groups contribute equitably.
- All users are satisfied that the design and implementation of the WASH programmed have led to increased security and restoration of dignity.

2.8Challenges of pro-poor WASH programmes

Key challenges in pro-poor WASH implementation globally include.

- Critical gaps in monitoring. Though many countries have WASH monitoring frameworks in place, most report inconsistent gathering of data and poor capacity for analysis.
- Weak country capacity to implement plans. Lack of capacity to fully implement their national WASH plans and conduct meaningful reviews.
- Insufficient funding. Though international aid for the WASH sector has increased, national funding needs continue to outweigh available resources. Most countries report that current funding levels are insufficient to meet their targets for drinking-water and sanitation.

2.9WASH Problems in Kenya Urban Slums

Slums are informal, high density and low income settlements that are not included in the city planning for any kind of sewage, drainage or water services. Lack of these services render slums unhygienic living place for the residents.

In Kenya, 8.5 million people live in such low income settlements and the population is increasing rapidly at 6% per year. In these congested and resource-constrained urban informal settlements that lack access to sewer or water lines, improvements to the sanitary conditions require more than the current approach of just building toilets. Areas lack or have limited access to basic services such as safe water and sanitation. The existing infrastructure is usually in poor technical condition, not user-friendly and poorly managed. Where water supply and sanitation (WSS) services are available they are usually shared. Residents use public stand pipes and shared ablution blocks. In areas with very high population densities using flying toilets is a common practice. Residents rely on informal water and sanitation service providers (water resellers).The price residents have to pay for water is not regulated. The quality of water fetched from sources

within the area (boreholes, protected open wells is poor. Lack of space (due to poor planning and high population densities) needed for the provision of basic infrastructure/services such as roads, safe water, adequate sanitation, drainage and solid waste management.

2.10Using GIS for decision making in WASH context

2.10.1John Snow Example

One of the most interesting and earliest examples of GIS and spatial analysis is the study on the outbreak of cholera in the 1850's in London. When cholera was poorly understood, there was large scale outbreak at the time of the industrial revolution. One approach to studying the causes of cholera was based on a map which was done by John Snow. Dr. Snow noticed that the outbreak appeared to be centered on public water pump in Broad Street and he thought that the cause of cholera might have been due to the contaminated water contrary to the then belief of people that cholera is due to polluted air. He then tried to establish trends between the supposedly pollute water pump and the causalities who drank from the pump. Upon his investigation it was discovered that among the deaths of people situated farther from the Broad Street pump, half of the deceased preferred the water from the Broad Street pump to their nearer pump, and another third attended school near the Broad Street pump. After presenting his findings to the community leaders, the handle of the Broad Street pump was removed, and the epidemic diminished. It was found out that a sewer pipe underground was leaking raw sewage into the drinking water of the Broad Street pump. In the process of his discovery Dr. Snow thought that a map would be a useful tool to his report.

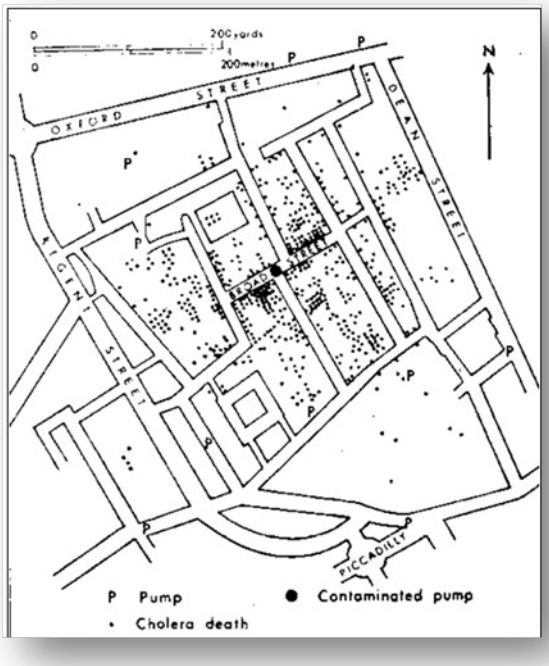


Figure 2.5 John Snow Cholera outbreaks Map

Source: "John Snow - a Historical Giant in Epidemiology."

In a series of case studies carried out in Malawi, Tanzania, Pakistan, Nepal, Nigeria and Ghana, WaterAid [2004] investigate the use of mapping, and in most cases, the application of GIS and GPS technologies, as an advocacy tool to build arguments for the implementation of water and sanitation.

Mapping – especially with the use of GIS and GPS – was found to be in its nascent stages in most of the countries studied, and there is little attention given to how these organizations had or were building their mapping capacity

In South Africa, Mobile Researcher Platform has been successfully applied to gathering social data within an Integrated Water Resource Management project. This mobile phone application is especially relevant to development organizations that want to monitor social and health patterns and to keep track of behavior change – and as such, has a similar relevance as GIS and GPS do to development organizations.

Mobile Researcher was found to be a very effective and efficient tool for assessing community activity and household health [Africa AHEAD, 2010]. This application could be put to even greater use if the data collected through the Mobile Researcher Platform were to be tied into a GIS so that the data could be clearly represented spatially. A similar programme to Mobile Researcher Platform that is specifically focused to creating maps from mobile phone data is called Ushahidi (meaning 'testimony' in Swahili) *Ushahidi, 2010+, the same variables and mapping area are monitored periodically then temporal analysis can be implemented creating a pa powerful tool for baseline surveys on evaluating changes in the outcome of the interest.

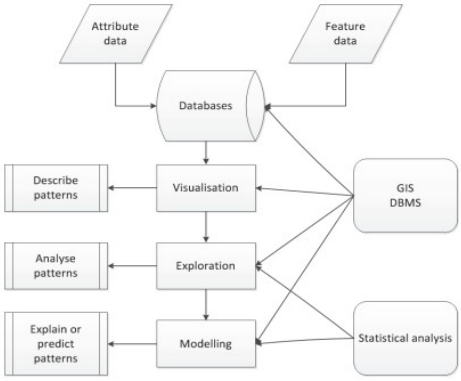


Figure 2.6 spatial analysis frameworks taken from Pfeiffer et. al adapted from Bailey and Gatrell.

Source: asaana. (2012).

2.11Concepts and methods in spatial analysis in GIS in WASH context

2.11.1 Spatial Dependency

Spatial dependency is a key concept in understanding and analyzing a spatial phenomenon. Such notion stems from what Waldo Tobler calls the first law of geography. “Everything is related to everything else, but near things are more related than distant things.” or, as Noel Cressie states, “the spatial dependency is present in every direction and gets weaker the more the dispersion in the data localization increases.”Generalizing we can state that most of the occurrences, natural or social, present among themselves a relationship that depends on distance. This implies that if a polluted spot is found in a lake it is very probable that places close to this sample spot are also polluted. Also the presence of an adult tree inhibits the development of others, such inhibition decreases with distance, and beyond a certain radius other big trees will be found. [PFEIFFER, D.U. 1996]

2.11.2 Spatial Autocorrelation

The computational expression of the concept of spatial dependence is the spatial autocorrelation. This term comes from the statistical concept of correlation, used to measure the relationship between two random variables. The preposition “auto” indicates that the measurement of the correlation is done with the same random variable, measured in different places in space. We can use different indicators to measure the spatial autocorrelation, all of them based on the same

concept of how the spatial dependency varies by comparing the values of a sample and those of their neighbors.

2.12 Point Pattern Analysis

Formally, a point pattern may be thought of as consisting of a set of locations (s_1, s_2,…, sn.) in a defined 'study region', sR, at which 'events' of interest have been recorded. The use of the vector, s_i , referring to the location of the i^{th} observed event, identifies the 'x' coordinate, s_{i1}, and the 'y' coordinate, s_{i2}, of an event. Use of the term 'event' has become standard in spatial point process analysis as a means of distinguishing the location of an observation from any other arbitrary location within the study region.

- **Point pattern terminology** Point is the term used for an arbitrary location}
- **Event** is the term used for an observation}
- **Mapped point pattern**. all relevant events in a study} area R have been recorded
- **Sampled point pattern**. events are recorded from a} sample of different areas within a region

Objective of point pattern analysis To determine if there is a tendency of events to exhibit a systematic pattern over an area as opposed to being randomly distributed point data often have attributes.

Three general patterns

- **Random** - any point is equally likely to occur at any location and the position of any point is not affected by the position of any other point
- **Uniform** - every point is as far from all of its neighbors as possible
- **Clustered** - many points are concentrated close together, and large areas that contain very few, if any, points.

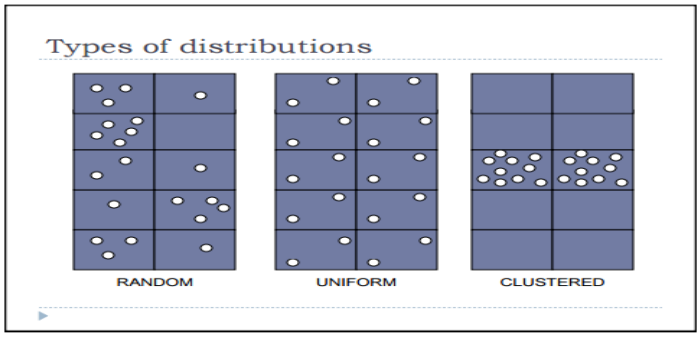


Figure 2.7 types of point distribution

Source:http://www.colorado.edu/geography/class_homepages/geog_4023_s11/Lecture12_PointPat1.pdf2.12.1

2.13Methods used in point analysis

Exploratory analysis

- Visualization **(maps)**
- **Geographic correlation studies**
- Clustering/Cluster detection
- Estimate how intensity of point pattern varies over an area e.g.**Quadrat analysis, kernel estimation**

Spatial weights and neighborhoods

An important aspect of defining spatial association is the determination of the relevant neighborhood of a given area. This means the areal units surrounding a given data point (area) would be considered to have a higher influence on the observation at that data point that points which are far away. To estimate the presence of spatial dependence among the events statistical measures such as the nearest neighbor distances and K-function modeling techniques are used. . It tests the null hypothesis of Complete Spatial Randomness (CSR) against the alternative hypothesis of dependence on point locations.

Exploring 1st order properties

Measuring intensity – based on the density (or mean number of events) in an area Quadrat analysis and Kernel estimation

Quadrat methods

1. Divide the study area into sub regions of equal size often squares
2. Count the frequency of events in each sub region
3. Calculate the intensity of events in each sub region based on the size of the area

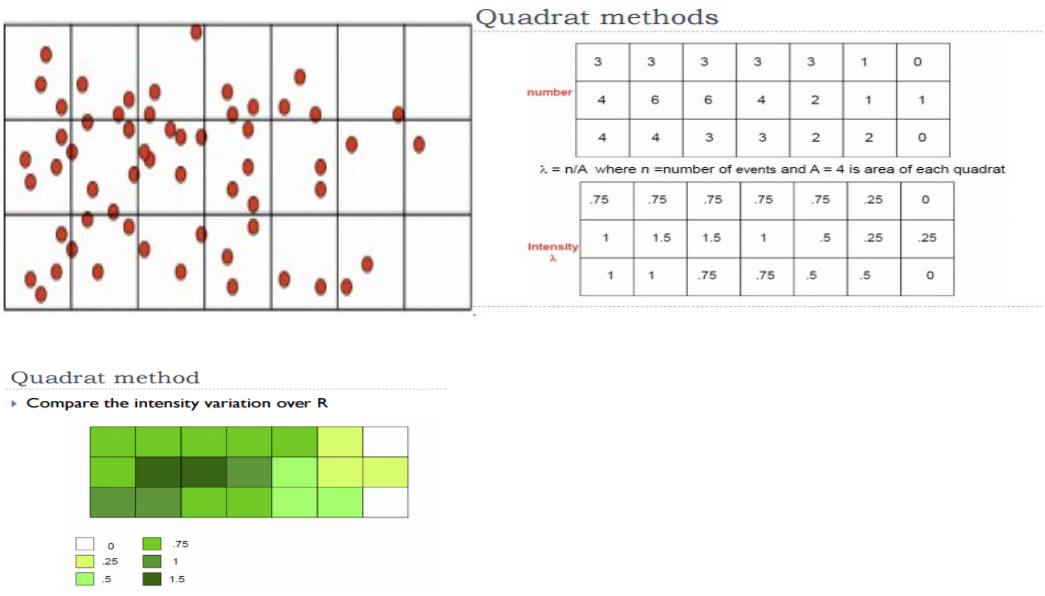


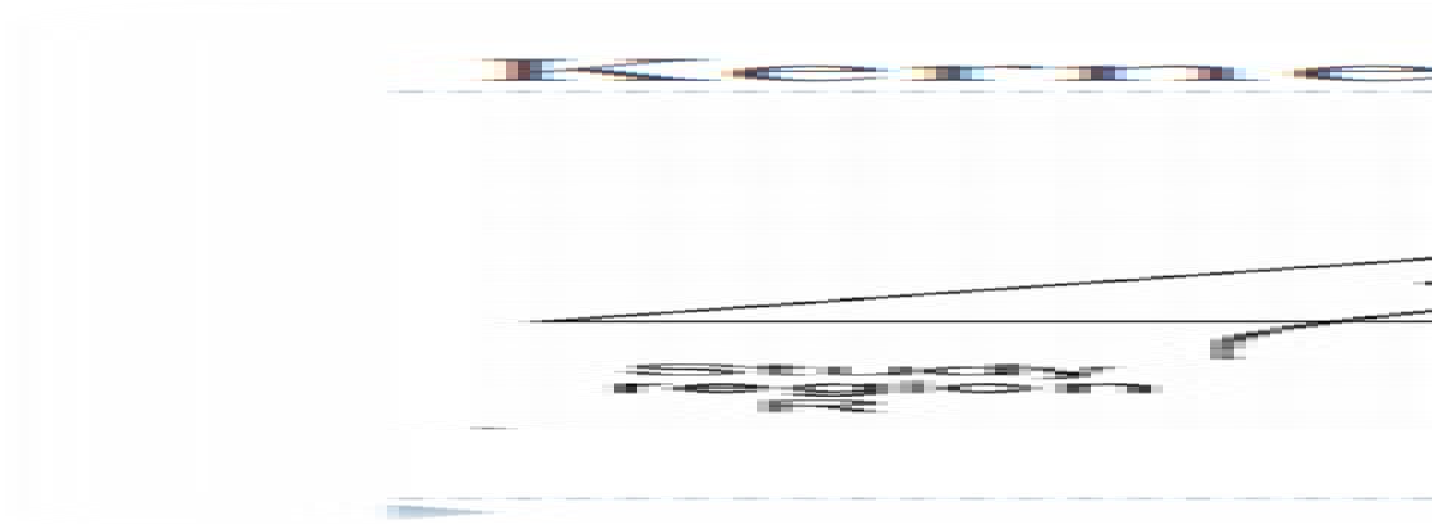
Figure 2.8 Quadrant methods

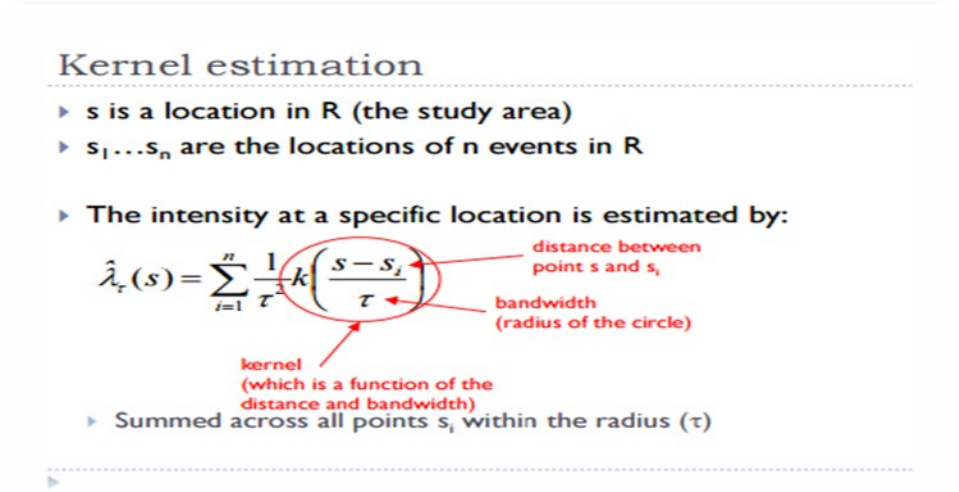
Source:http://www.colorado.edu/geography/class_homepages/geog_4023_s11/Lecture12_Pointt1.pdf[Accessed 31st July 2015]

This method gives the picture on the variation of the particular process of event in space. In WASH context it will be used to show the number of water points, toilets or garbage sites over an area in each quadrant, and therefore area with huge gaps are identified and correlated with other underlying factors.

I. Kernel estimation

Calculating the density of events within a specified search radius around each eventual moving three-dimensional function (the kernel) of a given radius (bandwidth) “visits‟ each point in the study area kernel are used to measure area surrounding the point proportionately to its distance to the event .





Equation 2.1 kernel estimation

Source:http://www.colorado.edu/geography/class_homepages/geog_4023_s11/Lecture12_PointPat1.pdf [Accessed 31st July 2015]

Exploring 2nd order properties

Measuring spatial dependence based on distances of points from one another nearest neighbor distances, K-function

II. Modeling techniques

We can conduct statistical tests for significant patterns in our data

- H_0: events exhibit complete spatial randomness (CSR)
- H_a: events are spatially clustered or dispersed

Complete spatial randomness CSR assumes that points follow a homogeneous Poisson process over the study area the density of points is constant (homogeneous) over the study area.

CHAPTER 3: MATERIALS AND METHODS

This chapter describes the study setting and the methodology for assessing the pro-poor urban WASH facilities. It has six sections, the study area, the data sources and tools, data collection, processing and analysis and presentation

3.1 Area of study

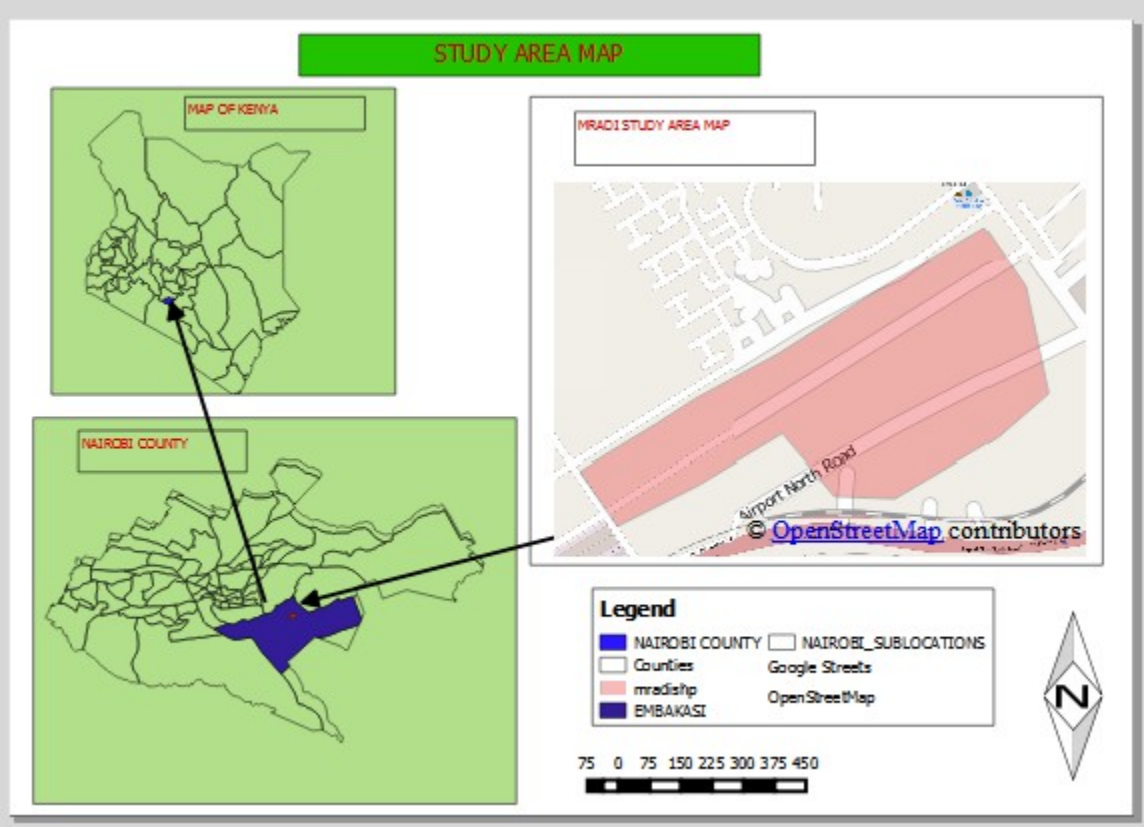


Figure 3.3 Area of Study

Location

Mradi is in Embakasi East Sub County in Nairobi County. It is located east of the central business district. As an estate, it houses mostly lower middle income citizens. It is approximately 14km from Nairobi business Centre. It is located in between Simba village, Baraka estate, Nyayo and Jua kali.Embakasi village started off in the 1950s as the location of the infamous Embakasi Prison, nicknamed “Satan’s Paradise”, one of the most notorious prisons during the State of Emergency imposed by the British Colonial government at the time (http://www.jambonairobi.co.ke/).

Urban development is poor with no urban projects. The area has no road reserves and the roads are in poor condition. It has Poor water quality, poor drainage system and blockage of the sewer network. It is composed of different ethnicities. The quality of life is generally poor.

Plate 3.1 Showing the drainage and sanitation problems in Mradi

3.2 Data Sources

This research, utilized both qualitative and quantitative methods of inquiry. The quantitative aspects were used to capture quantifiable patterns and the qualitative aspect was used to explore in-depth the WASH related issues at hand in Mradi Embakasi village. Spatial data collection method used GPS enabled mobile phone w powered by the Open Data kit(ODK) application which was used to obtain coordinates of the location of the WASH facilities. The data was collected in March, 2015. The exercise was carried out by 2 research assistants using smart phones (which served as the GPS and camera) other data sources are stated in the Table 3.1

Table 3.3 Data sources

Data	Source	Characteristics

Roads layer	Geomaps Africa	Digitizing Aerial image of Mradi obtained from Geomaps Africa taken in July 2014
Administrative boundaries, county and sub county	Survey of Kenya	Narrowing down to the area of interest using Google earth pro
Building layer	Geomaps Africa	Digitizing Aerial image of Mradi obtained from Geomaps Africa taken in July 2014
Water points, Garbage points, Toilet points	Mradi	Data collection through a GPS enabled phone. And attribute information through field work
Household data	Mradi	Through field questionnaire
Hygiene practices	Mradi	Through key informant persons

Data tools

a) Hardware requirements

Hardware used in project included:

1. Host computer: Intel(R)CeleronR2955@1.40HGz 1.40 GHz
2. RAM:2.0 GB
3. Dell Desktop
4. Storage media: 500

5. Mobile Phone: Itel1501

b) Software requirements

1. QGIS 2.8.1: editing, overlay, projection, conversion, analysis and map making.
2. ODK Collect 1.4.5: app /web application for smart phone data collection
3. Excel 2007
4. SPSS and Microsoft word 2007

3.3 Sampling

To achieve the study objectives within the financial and time limits available, this study employed simple random sampling and purposive sampling. With defined objectives, Purposive sampling proved to be very efficient, the study focused mainly on achieving the defined objectives within the scope to collect spatial data, where all toilets, main garbage sites and water points were mapped.

The following steps were undertaken to select a random sample for the household survey. The buildings in the entire area were digitized and a number was generated for each building. There were to 437 buildings. 50 sample sizes were selected for the survey using a probability proportional to size (PPS) sampling technique.

3.4 Data collection

1. Desk top review

This approach was used in order to gather background knowledge about the water and sanitation situation, how GIS can be applied in assessing and analyzing of WASH, approaches used in mapping indicators, and current statistics and how they relate to MDGs. This helped to set a benchmark on what outputs and outcomes were expected from the study. The literature reviewed consisted of journals, government publications, sector guidelines and procedures, reports and project plans among others.Extensive reading was done from books, WHO reports, WASH dissertations. These reports gave much information on the various standards that are internationally recognized in implementing WASH programmes. Literature on theories related with WASH was used to aid in analysis, interpretation and recommendation.

2. Questionnaires

This approach was mainly used to collect the main data for this project (appendix1). The questionnaires included both open and close ended questions. Four questionnaires were developed.

a) Household Questionnaire

This questionnaire aimed at collecting data relating to water sanitation and hygiene at a household level. It consisted of twelve which captured information on household size, distance from water point, amount of water used and water charges per day, distance from garbage site and charges and how they dispose their waste, sources of household water for daily use. The survey questionnaires were pre-tested in the field by the research assistants. Data from completed surveys were exported into Microsoft excel 2007 and SPSS for statistical analysis and spatial data collected was exported to QGIS 2.8.1.

b) Water Point Questionnaire

This questionnaire aimed at collecting data relating to water facility in the study area. It consisted of 6 questions, which captured data on functionality, contamination, protection, household's capacity number, operators and Cost per 20 liters. A total of 4 water points were mapped as they were operational during the study period.

c) Sanitation/hygiene questionnaire

The sanitation questionnaire was used to collect data relating to garbage, toilets and bathroom. This questionnaire aimed at capturing data on sanitation and hygiene, the specific information captured in this questionnaire included number of toilets in one building, number of households using the facility, the condition of the bathroom if present and hand wash facility if any. A total of 50 toilets were mapped .appendix 1

d) Key informant questionnaire

This questionnaire was used to collect data relating to the general practice in regards to WASH of the study area. It was inform of an oral interview and was administered to three knowledgeable member of community who included a health expert, religious leader, and a teacher. The data collected using this method included questions on the accessibility of WASH facility within the study area, the level of awareness in terms of public health risk, how waste is generally disposed. Information on open defecation was also obtained.

e) Use of Global Positioning System (GPS) and Mobile phone

The mobile phone with GPS enabled and camera was used to capture the household location, the water point location, the toilet/bathroom the garbage site precise location.

f) **Field survey checklist**

This method included a checklist and where appropriate photographs were taken as a tool to aid in analysis. This tool was mainly used to obtain firsthand information on hygiene practices in around people's homes. Systematic walkabout, which involved walking across the study in meandering fashion were to familiarize with the physical context in which hygiene practices occur. This enabled the researcher to find out the location of water sources and garbage sites and to assess levels of visible faecal traces in the public as well as the domestic environment.

3.5 Data pre-processing

The mapping process was the main item in this project as it was used for collection of spatial data on WASH facilities. The aerial image which was geo-referenced was used to digitize and build a base map. Buildings and roads were digitized.

Household questionnaire, water point questionnaire, sanitation/hygiene questionnaire and the key informant questionnaire were developed into web based data forms and uploaded into ODK (Open Data Kit) –a web application for the generation of data forms and freely hosted project websites (using Google's AppEngine) for mobile data collection - that was installed in the android smart phones and appropriately configured for data collection. Data was entered to the data forms in the smart phones for each WASH facility and the records were saved before being. Absolute totals, percentages and correlations were computed using pivot tables and bar/pie charts

in separate tab sheets in the same Excel file and SPSS containing the raw data for all WASH facilities .Spatial data was analyzed in QGIS .The data was loaded into QGIS for analysis as a comma delimited (CSV) file and shape files were generated. Point pattern analysis was the main analysis done using the kernel density. Grid proximity analysis, near neighbor analysis, weighting and overlays were also performed.

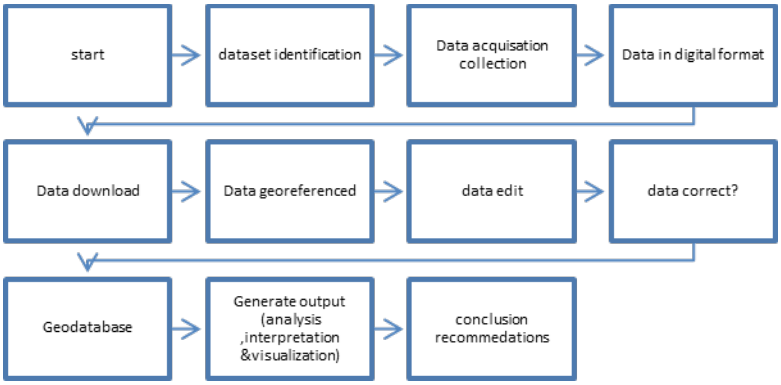


Figure3.4 Flow chart of the methodology

3.6 Spatial Data Analysis

In this research exploratory method of point pattern analysis were largely used in interpretation of the results. The tools used included the maps for visualization. Kernel estimation was used to estimate the presence of spatial dependence among the mapped WASH facilities using nearest neighbor and proximity analysis using hub lines algorithm in QGIS toolbox.

To perform the spatial analysis, data collected from the field surveys through mobile phones were converted into a Comma separated value (CSV) and loaded to QGIS. It was then cleaned and projected to WGS 84 UTM zone 37M, and analyzed to establish the water sanitation and hygiene coverage and to investigate factors that had an impact on WASH. The results were displayed in maps. Data from the household surveys was analyzed to understand current sanitation, hygiene and water practice, awareness, and perceptions. Results from this survey were compared with international WASH standards and other key national surveys to understand how findings from the target area compare with national-level data. The statistics were presented mainly as percentages and simple averages presented in form of Maps, tables and figures.

Spatial and non-spatial data collected was checked and examined for completeness and accuracy. Data was sorted; qualitative data was grouped into themes, which were converted into quantitative data. The quantitative data was analyzed using excel to generate frequencies and percentages. Some of these in turn were used to construct pie charts and graphs, which were used to draw conclusions. The spatial data was linked to its respective attribute in QGIS software where the data was analyzed coded and used to generate thematic map of each attribute collected in the field.

CHAPTER 4: RESULTS AND DISCUSSION

This chapter presents the findings and discussion

4.1 Household Survey Result

4.1.1Respondent Profile

50 respondents were randomly selected from the study area, of whom 30 (60.8%) were females and 20 (39.2%) males (Table 4.1 and Figure 4.1).The spatial distribution of males and females respondent (Figure 4.2).

Table 4.4 Respondent by Gender Table

Gender	Nom of respondents	Percent (%)
Female	30	60.8
Male	20	39.2
Total	50	100.0

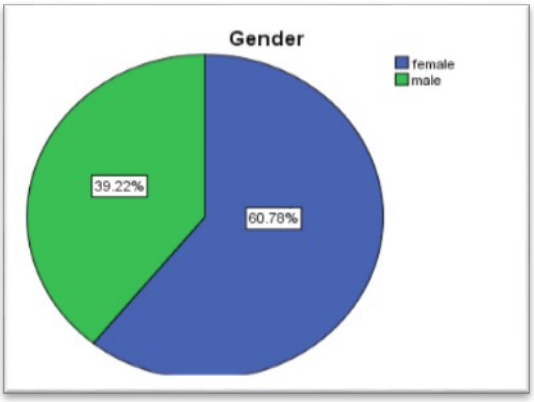


Figure 4.5 Percentage total of respondent by gender

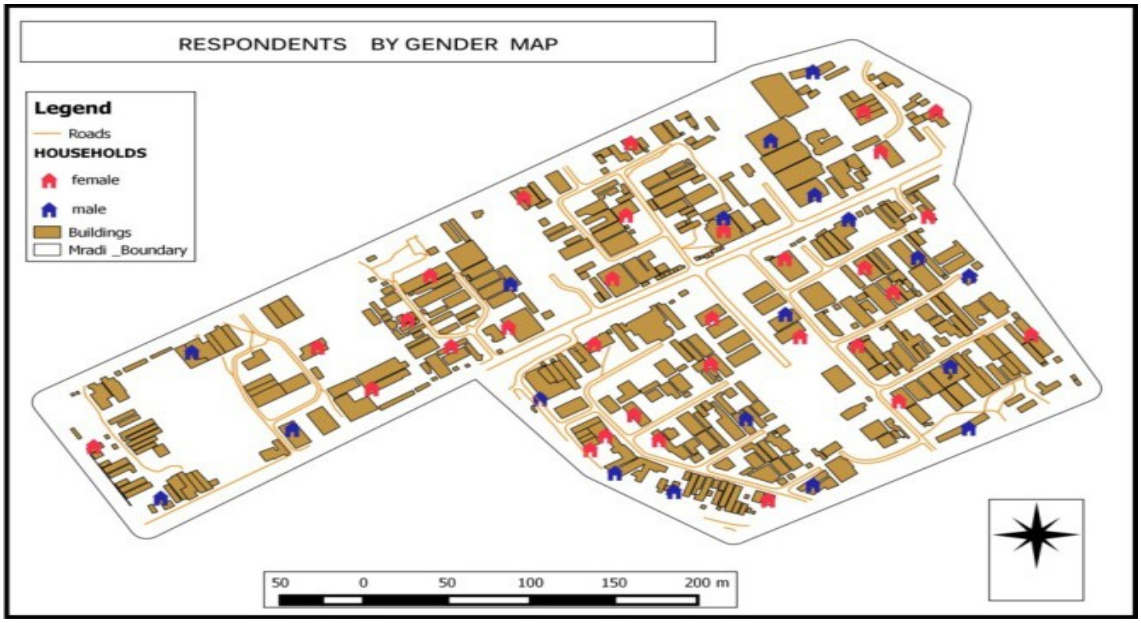


Figure 4.2 Spatial distribution of respondent by gender

4.1.2 Household Size Results

Households in Mradi had a minimum of one person per household and a maximum number of six persons (Table 4.2 and Figure 4.3).The average household size was found to be 4 persons.

Table 4.5 Household size findings

Household Size	Nom of respondents	Total Percent

1	5	9.8
2	2	3.9
3	4	7.8
4	14	27.5
5	20	39.2
6	5	9.8
Total	50	100.0

Figure 4.3 below shows spatial distribution of household size. The purple color shows the highest number of respondents had 5 people living in one household, the red symbol representing 1 household member had the least number of household members.

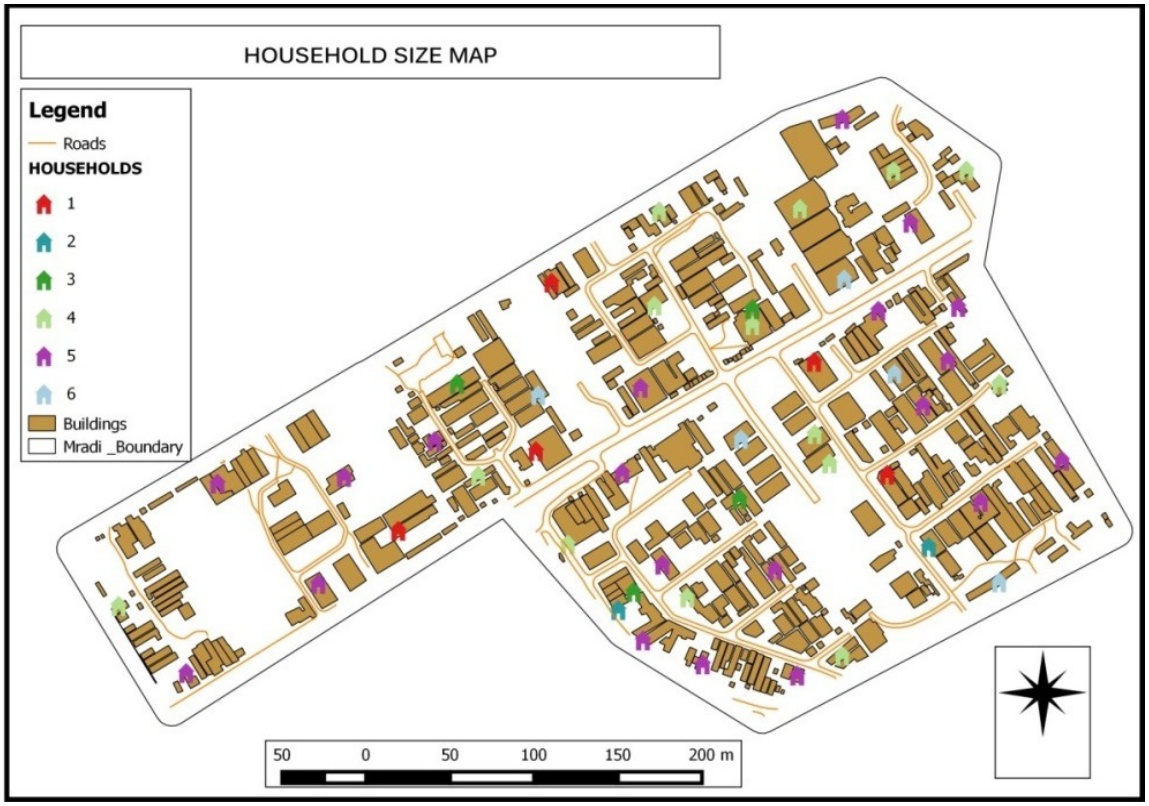


Figure 4.6 Household size distribution map

4.1.3 Households Water Charges per Day Results

Of the 50 respondents only 6 spent a total of 15 to 25 Kenya Shillings for water, which is equivalent to 60 liters to 125 liters per day (Table 4.3 figure 4.4). 38 (74.5%) respondent spends 5 shilling to 15 shilling per day, which is equivalent to 20 liters to 60 liters per day. While 13.7% uses more than 25 shillings per day which translates to more than 125 liters of water per day.

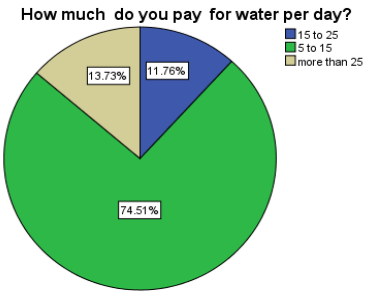


Figure 4.4 proportion of money spent

Table 4.3 **Money spent by households**

Amount	Nom of respondents	Percent (%)
15 to 25	6	11.8
5 to 15	38	74.5
more than 25	6	13.7
Total	50	100.0

Plate 4.1 20 liter Jeri can on a cart

Plate 4.1 shows the 20litre jerican used by the water vendors to distribute water to the household's doorstep at the price of 5shilling.

Plate 4.1 shows the size of Jeri can that cost Kshs 5.Therefore it can be concluded that the highest number of people of Mradi uses 5-15 shilling per day which is equivalent of 20 to 60 liter

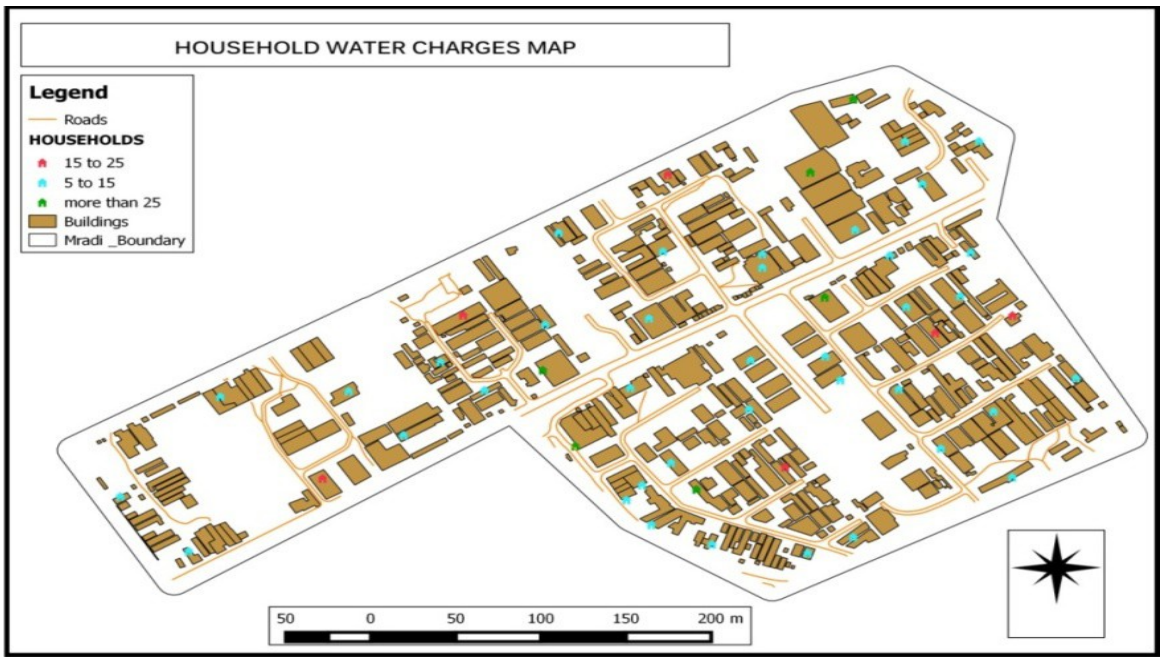


Figure 4.5 Map showing distribution of household water charges

Figure 4.5 shows spatial distribution of amount spent by household per day. Majority of households spent between KShs5-15 for water as shown by blue color while fewer people spent more than 25 shilling as symbolized by the green color in the map.

4.1.4 Households Water source result

This represents findings for the sources of water by the household

Table 4.4 household water source.

Water source	Nom of respondents	Percent
protected sources/tap	11	21.6
vendor/unprotected source	39	76.5
Total	50	100.0

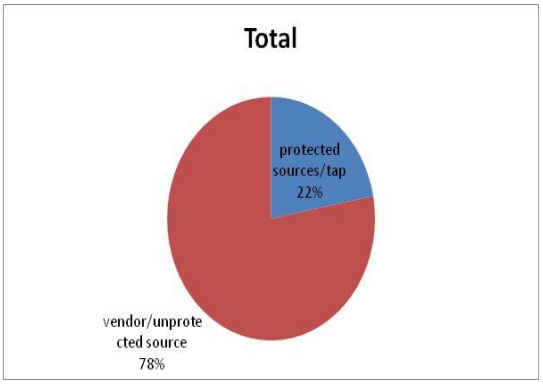


Table 4.4 presents the findings of household's water sources. From the Figure 4.6, the highest percentages of households in Mradi (78%) were found to obtain their water from unprotected sources (vendors; Plate 4.2).

Figure 4.6 proportion of household's water source

Plate 4.2 unprotected water sources

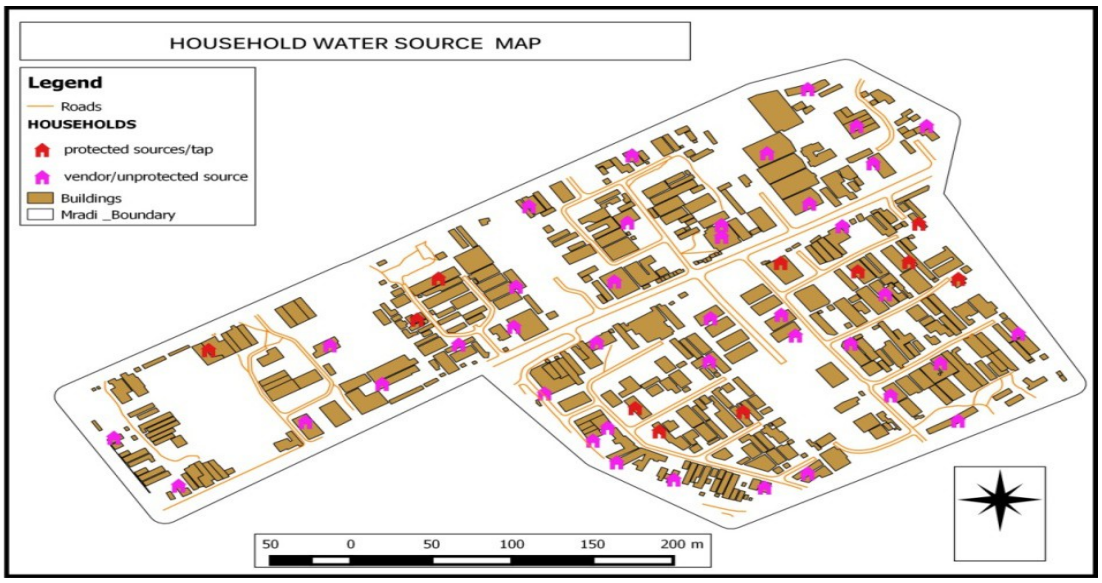


Figure 4.7 Maps showing household water source

Figure 4.7 show spatial distribution of household source of water. From the map the purple color, which is predominant represents the households that source water from the vendors. Most of the households obtained water from unprotected sources.

4.1.5 Household water equitability

Table 4.5 presented the findings on household equitability of water meaning if the water was enough or not for their households needs.

Table 4.5 Household water equitability

Water is enough	Number of Respondents	Percent (%)
No	44	78
Yes	6	12
Total	50	100.0

From table 4.5 above it was found out that 44(78%) respondent reported that they did not have enough water.

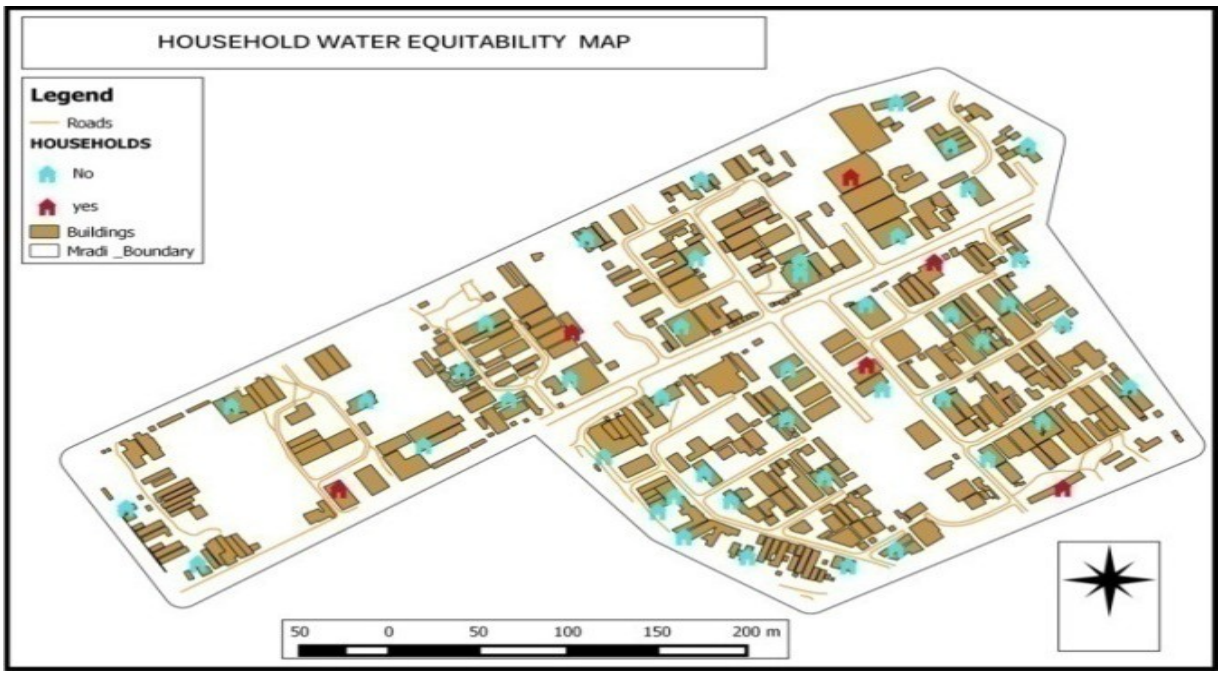


Figure 4.8 spatial distribution of household level of water equitability

Plate 4.3 Water carrying materials

Plate 4.3 show the various water collection equipment displaying how water problem is serious in the area.

In figure 4.8 the green color represents findings of households which dint not have enough water. And the red color represents the household whose water was enough. This therefore means that water accessibility is still a major problem.

4.1.6 Garbage Distance From Households

Table 4.6 represented results about how far the household walks to throw garbage from their house dwelling

Table 4.6 Garbage distance from Household

Distance	Nom of respondents	Percent
less than 50m	23	47.1
more than 50m	27	52.9

Total	50	100.0

Figure 4.9 household garbage distance results

From table 4.9 above it was found that 23 respondents an equivalent of 47.1% walked for less than 50metres to dump garbage while 27 (52.9%) s walked more than 50 meters.

Plate 4.4 show garbage sites scattered all over the entire area. The buildings were very close to dumping site, which is a health hazard due to the bad smell this was found to encourage children to defecate in the dumping site.

Plate 4.4 Household waste littered

Most of the dumping sites were open and almost full and they had mixture of all kind of trash ranging from human waste plastic waste and other different type of waste as plate 4.4 shows.

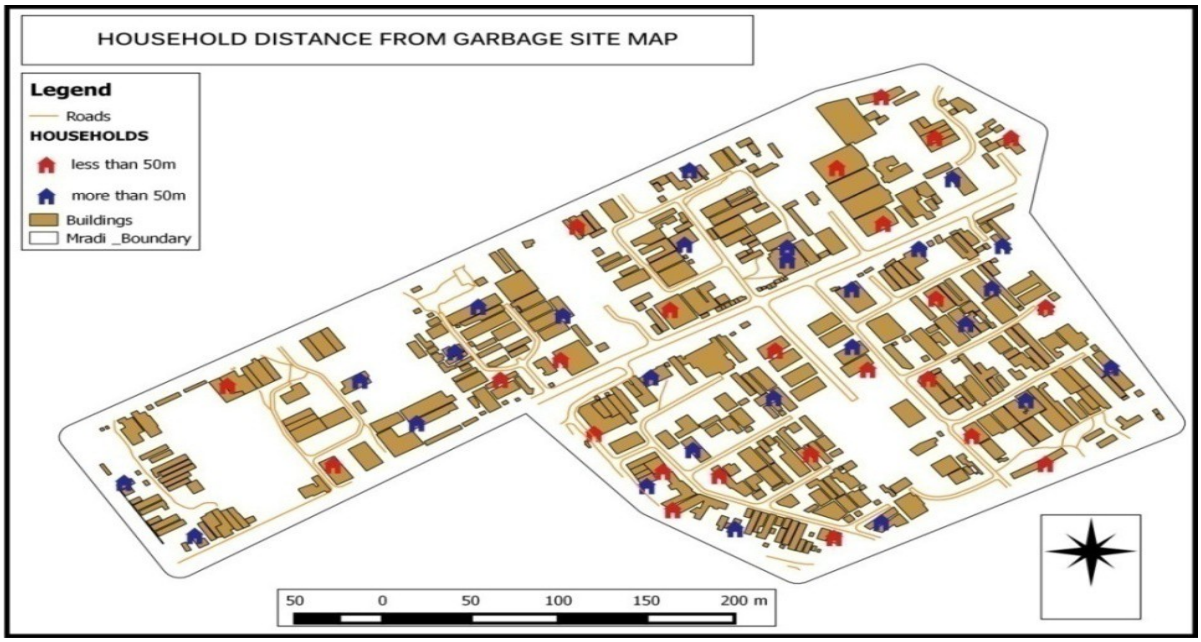


Figure 4.10 Household garbage distance map

From figure 4.10 the spatial distribution of household walking distance is almost equal and distributed randomly with the household symbolized in blue walking more than 50 meter to garbage sites, red symbolizes less than 50m.The area with households walking more than 50m has less garbage while the areas with walking less than 50m had more dumping sites scattered .

4.1.7 Households Distance of water collection point

Table 4.7 and figure 4.11 represented findings on the distance the household walked to collect water , 88% walked less than 500 meters to collect water which is an equivalent of 45.11.76% walked for more than 500metres to collect water which was based on their preference .From above analysis it was found that most.

Table 4.7 Water collection distance from household

Distance	Nom of respondents	Percent
	44	

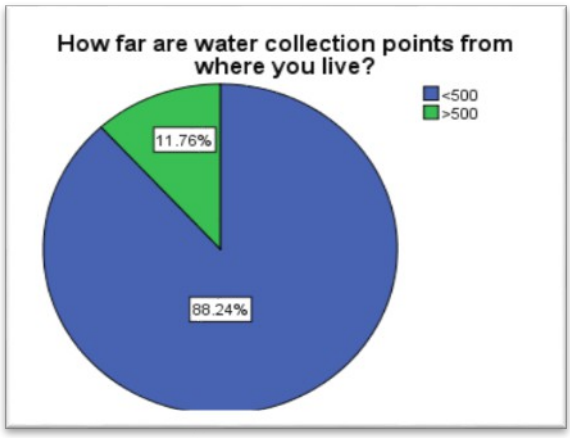


Figure 4.11 Proportions of Water collection distance

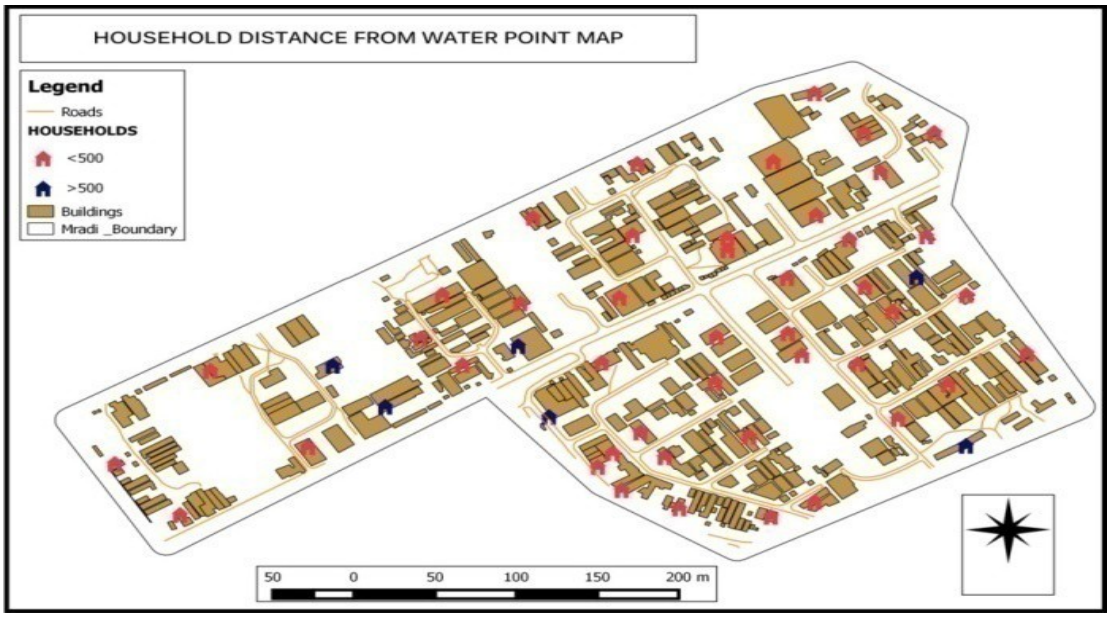


Figure 4.12 Household distance from water collection points map

From figure 4.12 red symbolizes distribution of households walking less than 500m to fetch water which depicts majority of the households, while blue color on the map shows households walking more than 500m to fetch water.

4.1.8 Households Garbage charges

This represented findings from the results the amount of money paid if any for garbage

Table4.8 Garbage charges table

Payment in kshs	Nom of respondents	Percent (%)
	50	100.0
Total	50	100.0

From the above analysis in table 4.8 the entire respondent (50) said that they did not pay for garbage this explains why they were hip of garbage as residents dumped their waste in open garbage sites.

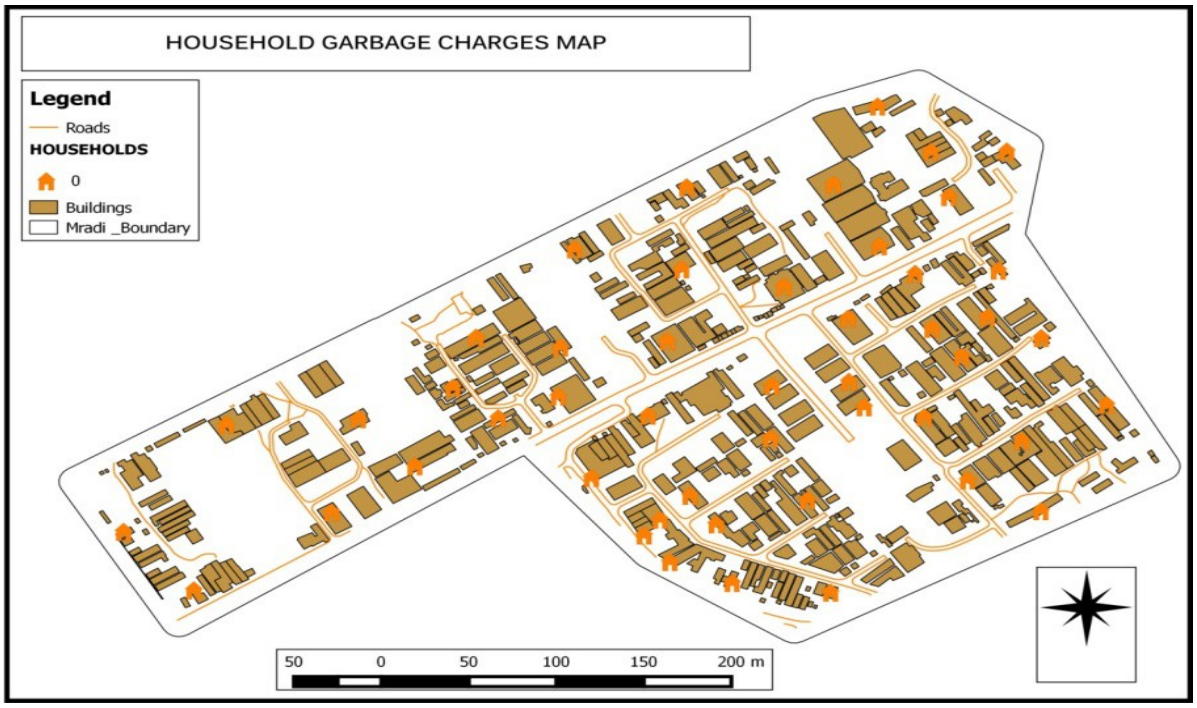


Figure 4.13 Household garbage charges Map

From figure 4.13 all the households are shown in the map is symbolized in one color depicting that residents did not pay for garbage, and this explains why main waste management and disposal is wanting as shown in plate 4.5.

Plate 4.5 waste disposal situation in mradi

4.2WaterPoint Spatial Distribution

Mradi area is an informal settlement within Embakasi village. Figure 4.14 shows distribution of water points, a total of 4 water points were mapped. From the map the location of the water points is random.

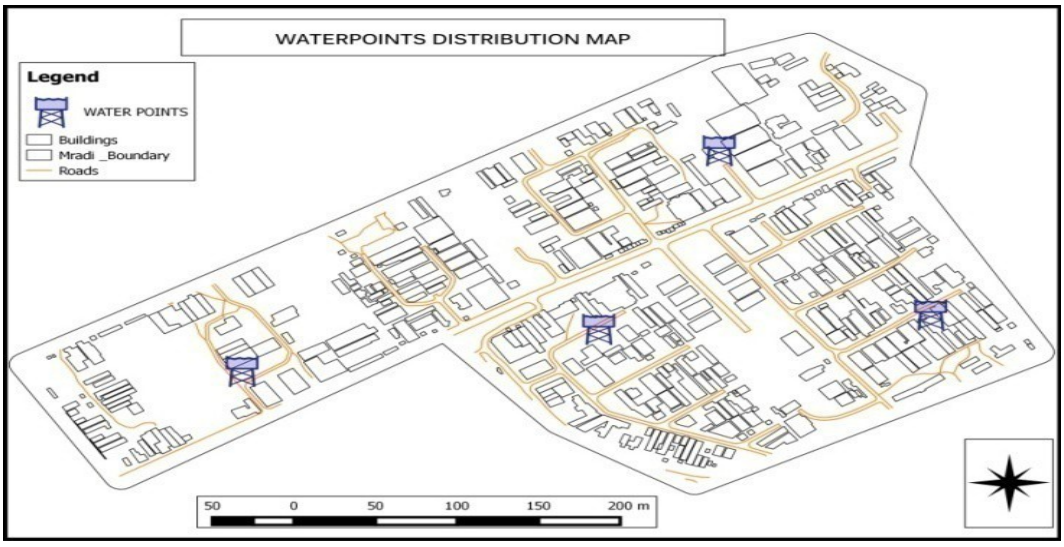


Figure 4.14 distribution of water point

4.2.1 Water sources results

From table 4.7 below it was found out that 2 of total water points which is 50%water points were unprotected sources while other two which is 50% of the total were protected sources.

Table 4.9 water sources type

Water source type	Nom of Water points
protected sources/tap	2
vendor/unprotected source	2
Grand Total	4

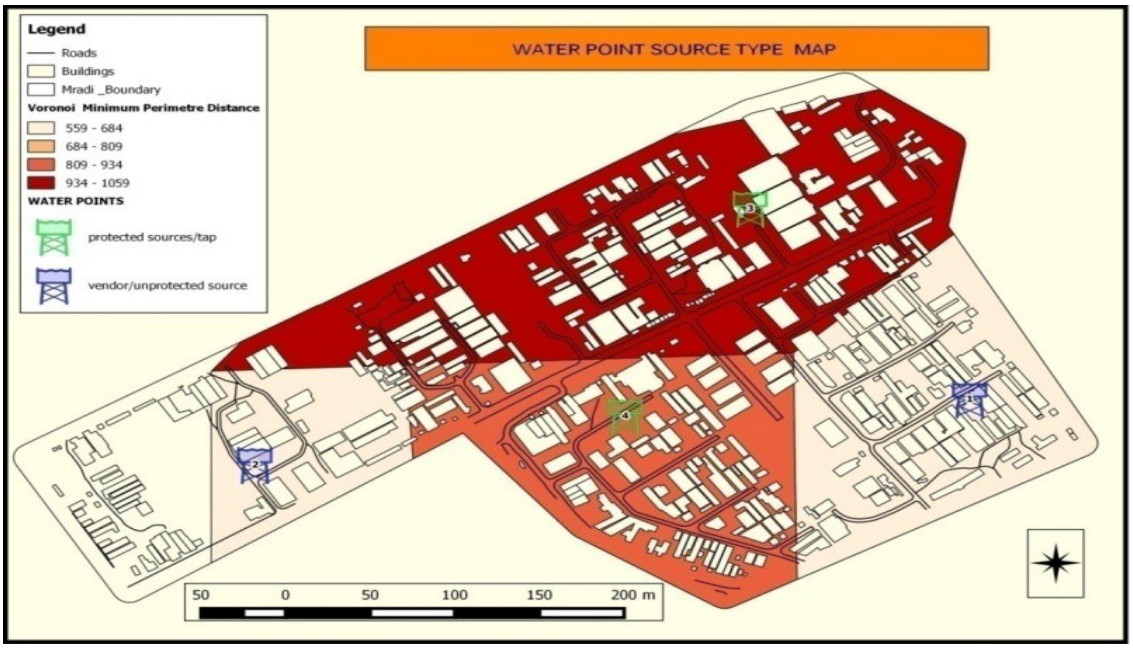


Figure 4.15 Water source area coverage

Figure 4.15 shows the area coverage of each water point, the protected water sources 3 and 4 served majority of household compared to the unprotected sources depicted by the brown color on the map covering a perimeter of 934m-1059m. Water point 3 serves the highest number of households in terms of coverage. Water point 2 and 1 had the smallest covering a perimeter of 559m.

4.2.2 Water points Functionality

From the table 4.10 and figure 4.16 below it was found that 3 of the water points were functional at the time of data collection. As shown by plate 4.6 which is 75%of the total while 25% equals to 1 water points were not operational since it had run out of water.

Table 4.10 Functionality of the water point functionality

Functionality	Nom of functional water points
No	1
Yes	3
Grand Total	4

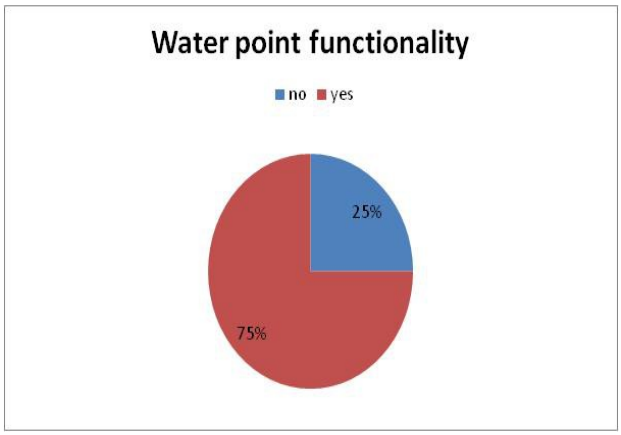


Figure 4.16 proportions of water

Plate 4.6 functional water point

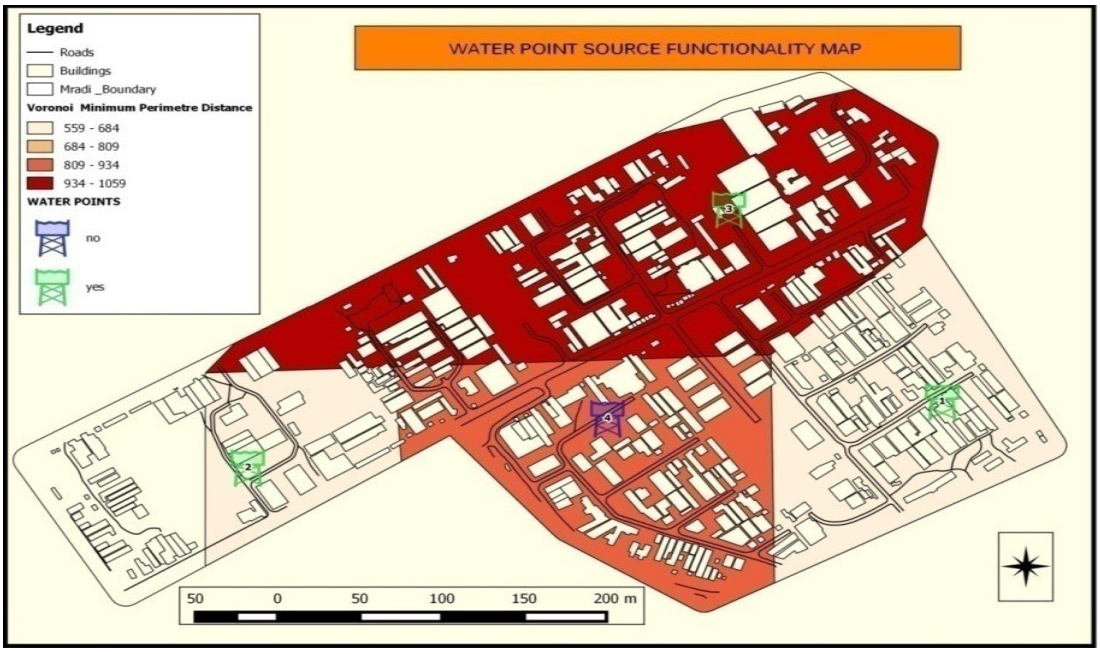


Figure 4.17 water point functionality

Again from the figure 4.17, blue color symbol represents the not functioning water points while the green color symbol representing the functioning water points. From the map water points 1, 2, 3, were functional at the time of data collection while 4 was not functioning meaning that the closest functioning water point of this households was water points either 1 or 3.

4.2.3Water Point Household Capacity

From table 4.11 and figure 4.18 below, one water points could hold a capacity of less than 100 households which is 25% household per day while 3 were found to serve more than 100 household per day

Table 4.11 Water point household capacity

Water point household capacity	Frequency of household Capacity
< 100	1
> 100	3

Grand Total	4

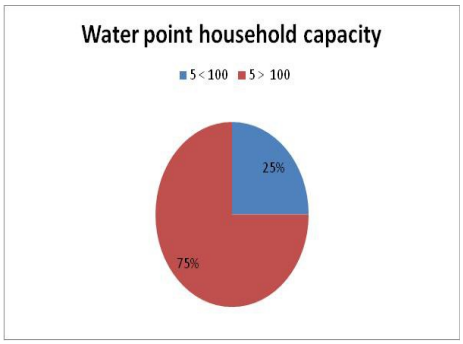


Figure4.18 Water point household percentage percentages

From the figure 4.19 its clear most of the water points 2, 3, 4 support more than 100 household. The green symbolizes less than 100 household while the blue symbolizes more than 100 household. Water point 1 serves less capacity 100.

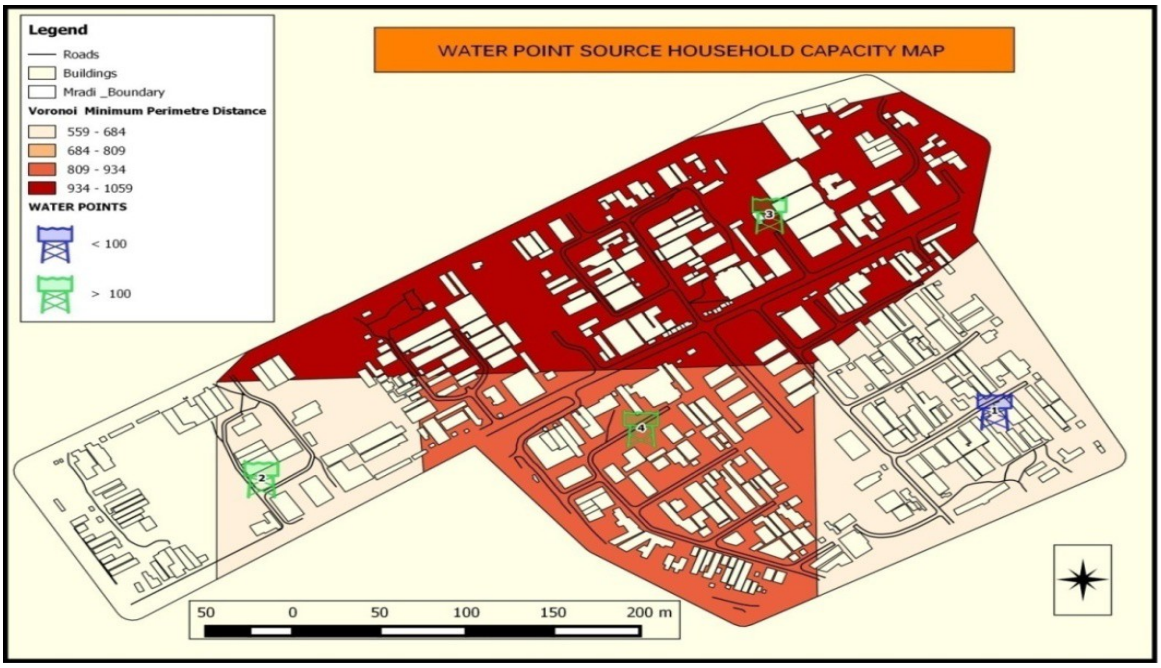


Figure 4.19 water source household capacity

Plate 4.7 a big tank which supports over 100 household

4.2.4 Water Point Contamination

From table 4.12 and figure 4.20 below 2 water points were found to be sited on a ground at risk of contamination due to their proximity to sewerage and the surrounding environment while just 2 were found to be located inside a compound on a raised ground. From the mapped water points 50 % were found to be contaminated while 50 %were not at a risk of contamination.

Table 4. 12 Contaminated water points

Contaminated Water point	Frequency
No	2
Yes	2
Grand Total	4

From the below 4.20 figure the green symbolizes water point in risk of contamination and the blue symbolizes points not at risk of contamination. Water points 4 and 3 which were not at risk

of contamination covered the largest area in terms of household proximity. While the water points 1 and 2 covered a small area and were found at risk of contamination plate 4.8.

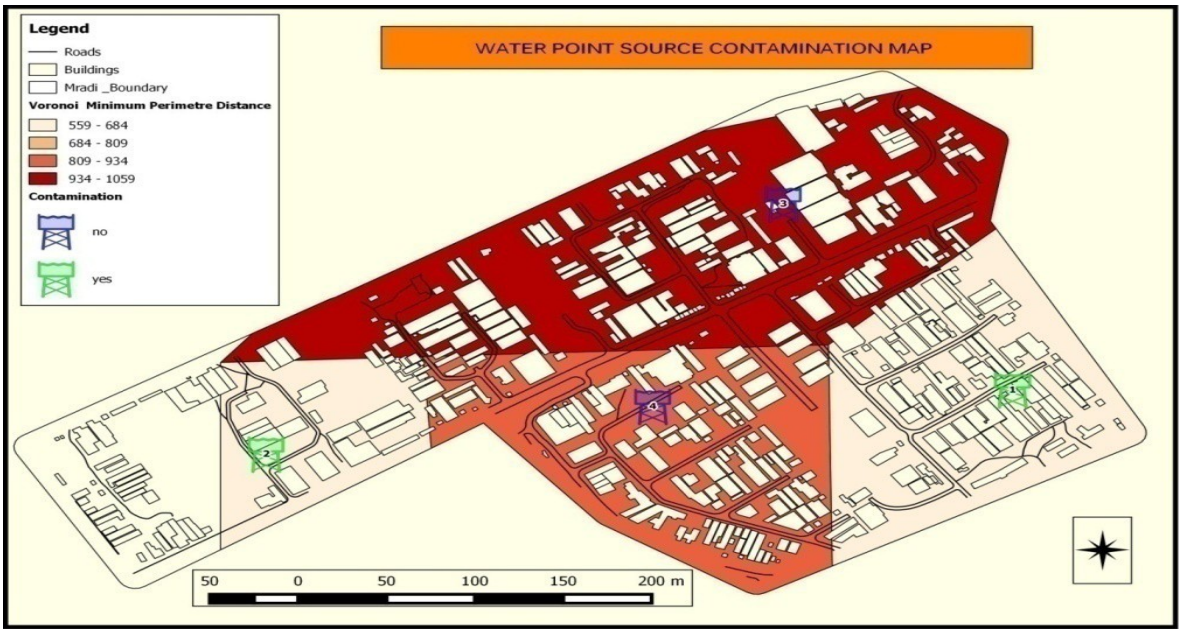


Figure 4.20 Water point contamination

Plate 4.8 water point risk of contamination

4.2.5 Water Point Charges

From the analysis in table 4.13 and figure 4.14 it was found out that all water points vendors charged 5 shilling per 20litres of water. This was regardless of if the water point was privately operated or not or the type was protected or unprotected.

Table 4.13 Water point charges

Water cost per 20 liter jerry can	Nom of water points
5	4
Grand Total	4

One color blue symbol in figure 4.14 symbolizes that all water points charged 5 shilling

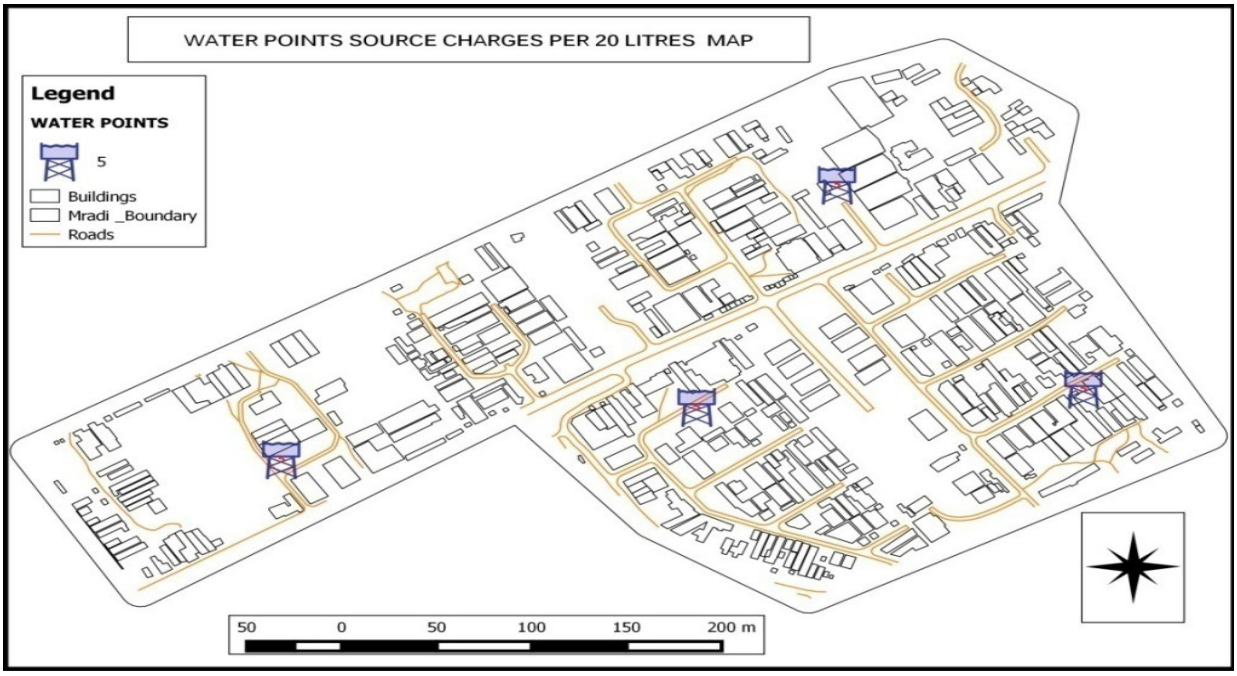


Figure 4.21 water charges map

4.2.6Water Point Operator

From the table 4.21 below the research found out all the 4 water points in Mradi were all privately operated by water reseller's plate 4.9 charging five shilling per 20litre jerrican.

Table 4.14 water point operator

Water point operator	Number of water points
Private	4
Grand Total	4

Plate 4.9 Water point operator

4.2 Sanitation/Hygiene Results

4.3.1Toilets

In regards to sanitation facilities 49 toilets/latrines were mapped in the entire study area which covered a total number of 429 residential buildings, all toilets were located inside the plots and were communal. Figure 4.22 heatmap shows some gaps in coverage of toilet with some having many toilets clustered in an area depicted by black while the white section shows areas with low or no toilets coverage.

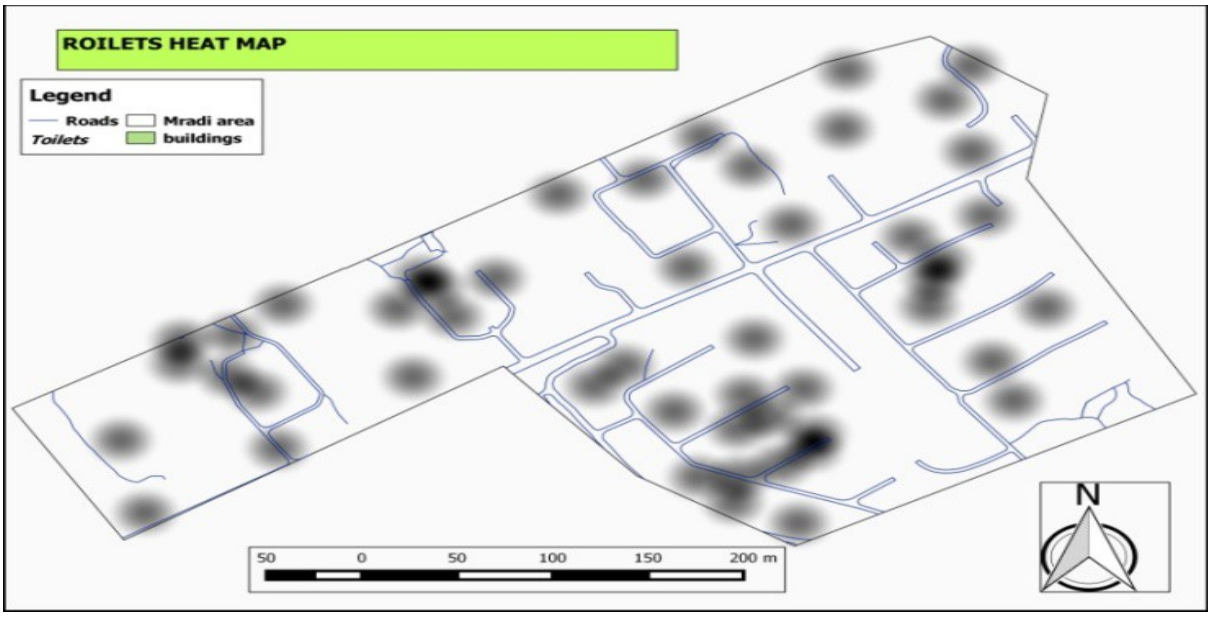


Figure 4 .22 Toilet coverage heat map

From the study, a minimum of 8 households shared one toilet, it was found that this was the main reason why the toilets were dirty, in areas with less coverage, which is households far from the toilets traces open defecation in the mini dumping sites was more noticeable during transect walk as it was less accessible for children.

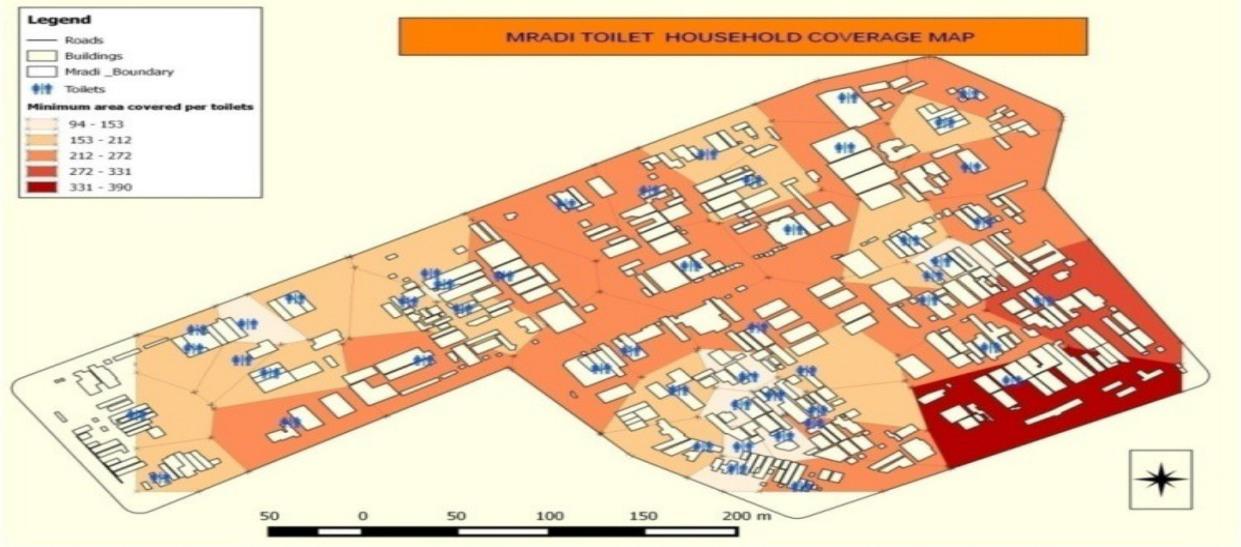


Figure 4.23 toilets coverage map

From figure 4.23 above the area symbolized by more brown were found to have less toilets covering an area of 390 square meters while the area with lighter brown had more toilets as each toilet covered 153 square meters.

Table 4.7 Total toilet per household capacity map

Average of nom of toilets	Average of households
1	1
1	3
3	4
1	5
2	6
2	7
2	8
2	9
1.	10
1.	11
1	12
1	13
1	17
2	21
8	32
1	8.

From Table 4.15 it was found that 1 toilet in Mradi was used by an average of 8 households .The study found out that there existed no physical hand wash facility in the entire area, outside of any toilet mapped or anal cleansing material. the conditions of this facilities are wanting plate 4.10 shows a full toilet which is still being used and plate 4.11 shows falling walls of the toilets.

Plate 4.10 toilet which is full and in use

Odor and flies nuisance are very scenario in mradi with pit latrines likely to pose danger of groundwater contamination in boreholes.

Plate 4.1 toilets that needs repair but still in use

On the issues of the belief concerning disposal of excreta for children by women remained the traditional method. Through the key informant it was found that women in mradi still dispose child waste into the dustbin and young children still defecate on the open as women belief their waste is less harmful as shown in plate 4.12 . Through transect walk practices of defecation were evident especially close to the garbage site and in the open space.

4.3.2 Waste Disposal Results

Households living close to dumpsite and open sewage are at a higher risk of suffering from cholera outbreak .From table 4.16 and figure 4.24 below 8 main garbage points were mapped and they were randomly located over the study area. From figure 4.24 below the area with dark shade of symbolizes

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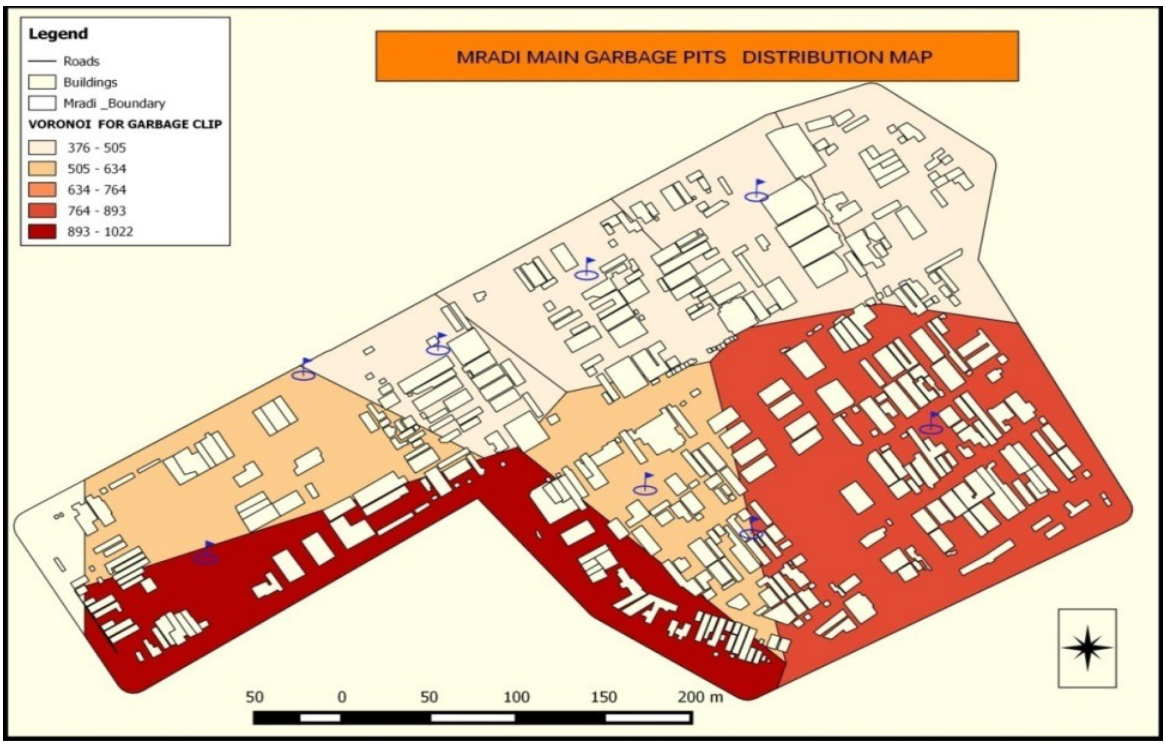

Figure 4:24 Garbage pits distribution Map

From figure 4.24 above the area shaded with dark shades of brown indicates main garbage sites which serves majority of the area households as they cover between 893-1022 meter squred.While the lighter shade symbolizes area with main garbage sites serving less households covering an area of 376-505 square meters.

Table 4.0.8 Summary of Garbage points' general characteristics

Garbage Id	Garbage type	waste type
1	Open	Mixed
2	Open	Mixed
3	Open	Mixed
4	Open	Mixed
5	Open	Mixed
6	Open	Mixed
7	Open	Mixed
8	Open	Mixed
Grand Total	8	8

4.4 WASH Accessibility

Figure 4.25 shows distribution of WASH in the study area.

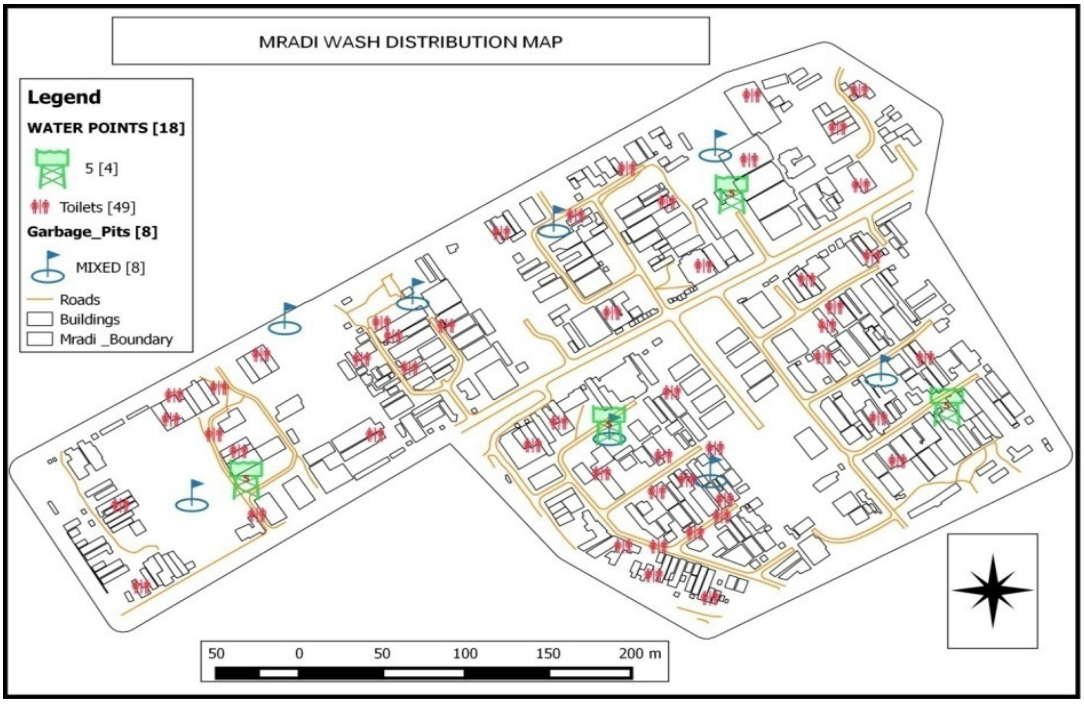

Figure 4.6 WASH distribution Map

4.4.1 Water accessibility

This means the distance of water points to the household**.**

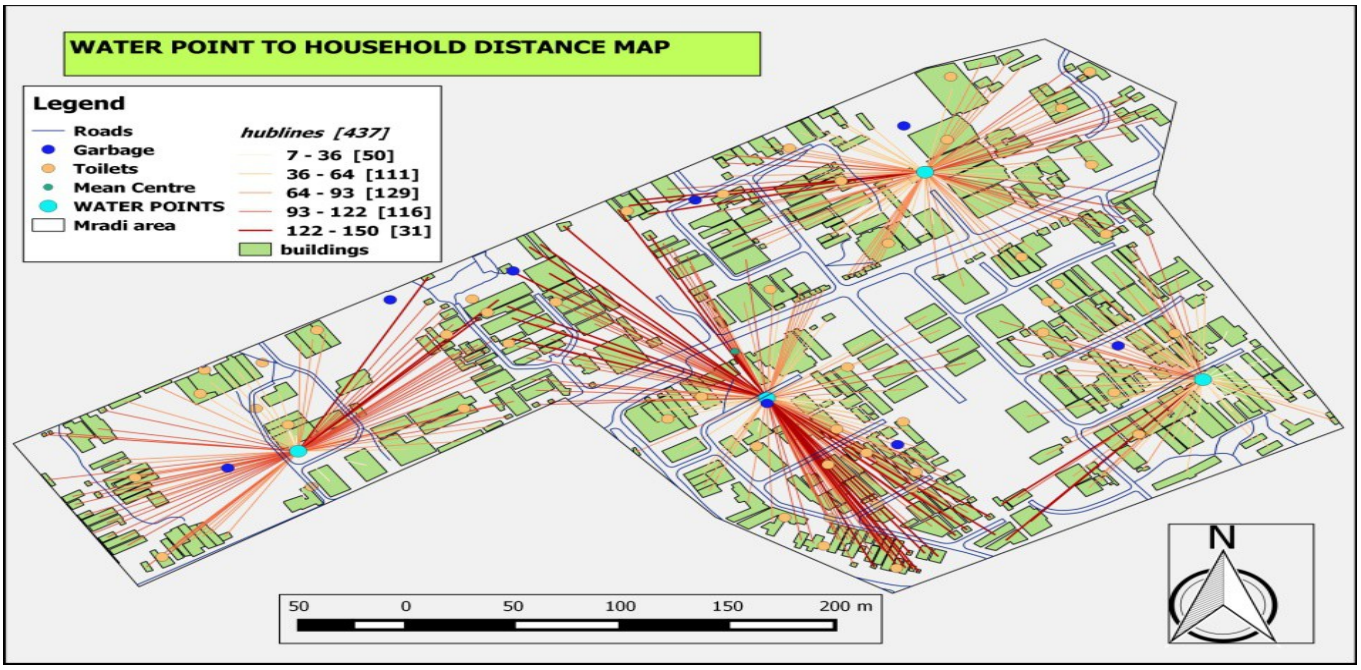

Figure 4.26 distance of water points to the households map

From figure 4.26 above the hub lines distances shows that the households that are very close to water point is 7m and the farthest water point from the households is 150m. Majority of the people live between 63-93m from all water points. From figure 4.27 water point 3 served highest number of households, with water point 2 serving the least.

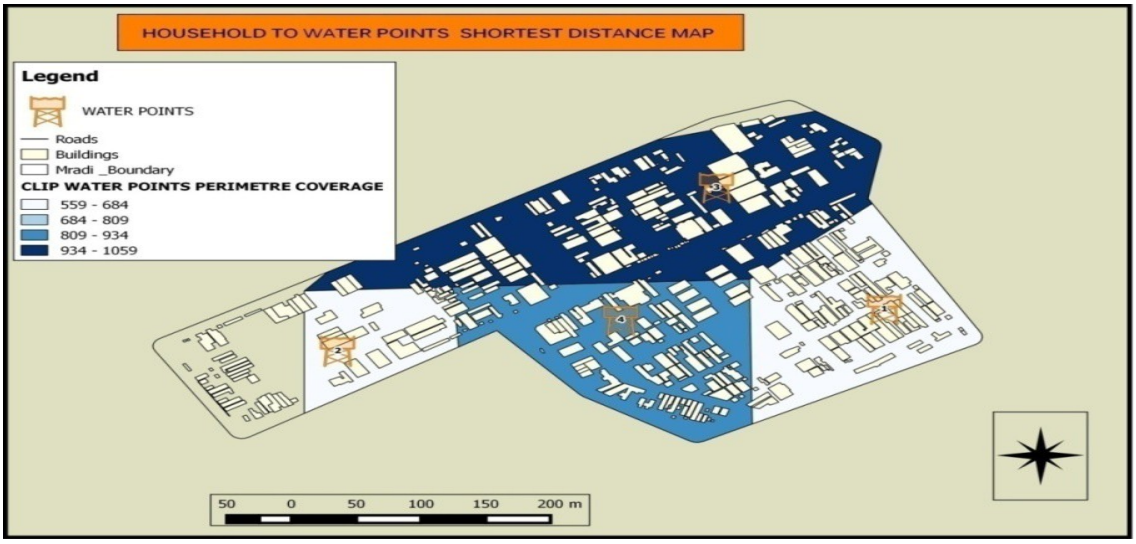

Figure 4.27 Water point area shortest distance

Figure 4.28 shows 100 meter buffer of water points and the area the cover

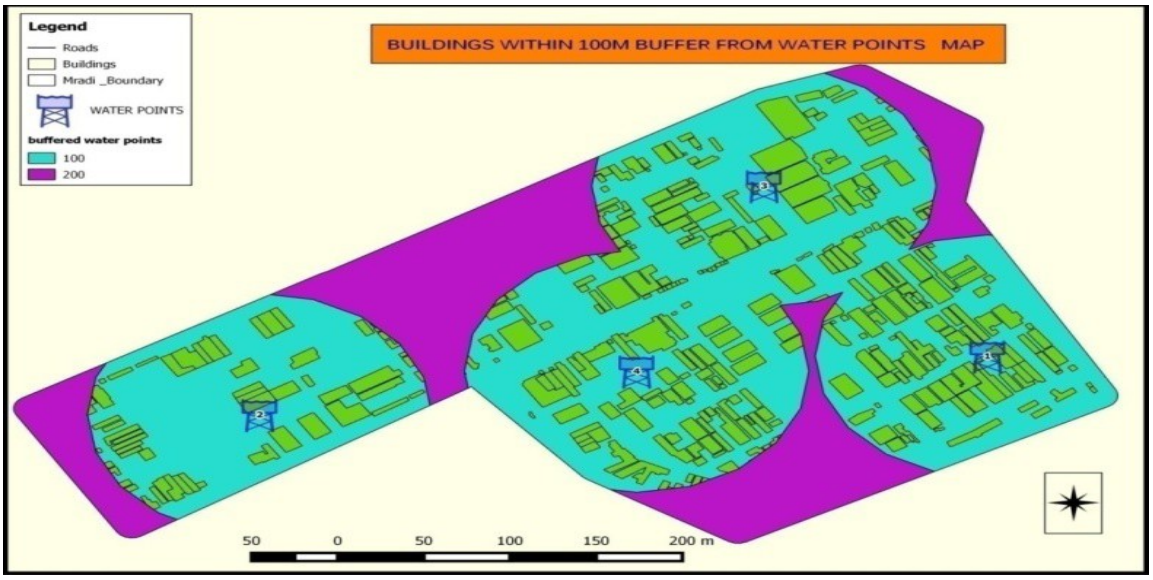

Figure 4.28 100 m water point buffer

From the figure 4.28 above the research found there was 353 buildings within the 100M buffer.

Figure 4.29 200m water point buffer

From the figure 4.29 above considerable 142 dwellings were found to be within 200 buffers and outside 100m buffer from water points. The study found that 78% of households reported that they still did not have enough water for all house members which according to WASH standards 1 person should be able to access 20 liters of water per day WHO (2004).

4.4.2New water sites

Figure 4.30 4 new water points were suggested at the edge of the area symbolized by the brown color. Green symbolized areas were found to be the least suitable. This was after creating buffer around toilets, garbage points and then rasterizing reclassification and then running the weighted overlay where roads were given a weight of 20 percent importance garbage site as they affect the water quality were given 40% toilets 30% and close to other water points was assigned 20%importance.

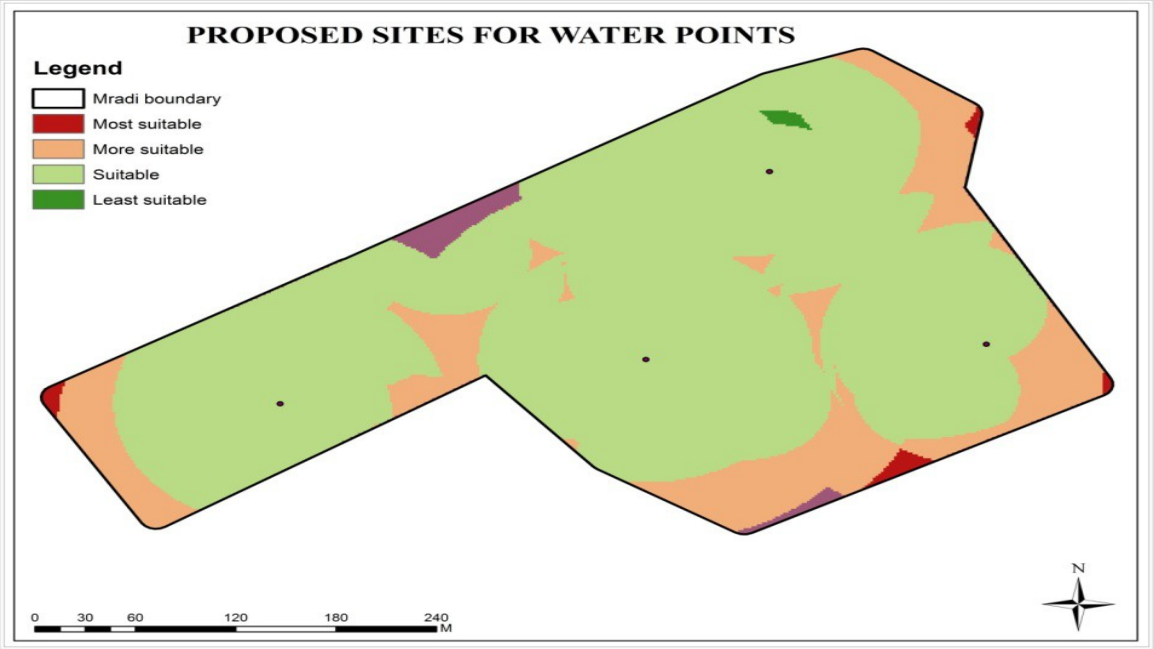

Figure 4.30 Map showing proposed new sites for water point

4.4.3 Sanitation and Hygiene Accessibility

From figure 4.31 below the shortest distance to a toilet was 18 meters from house dwelling. The total number of these dwelling were 215 while the longest distance from household was 91m and this were mostly the business areas which had no toilets.

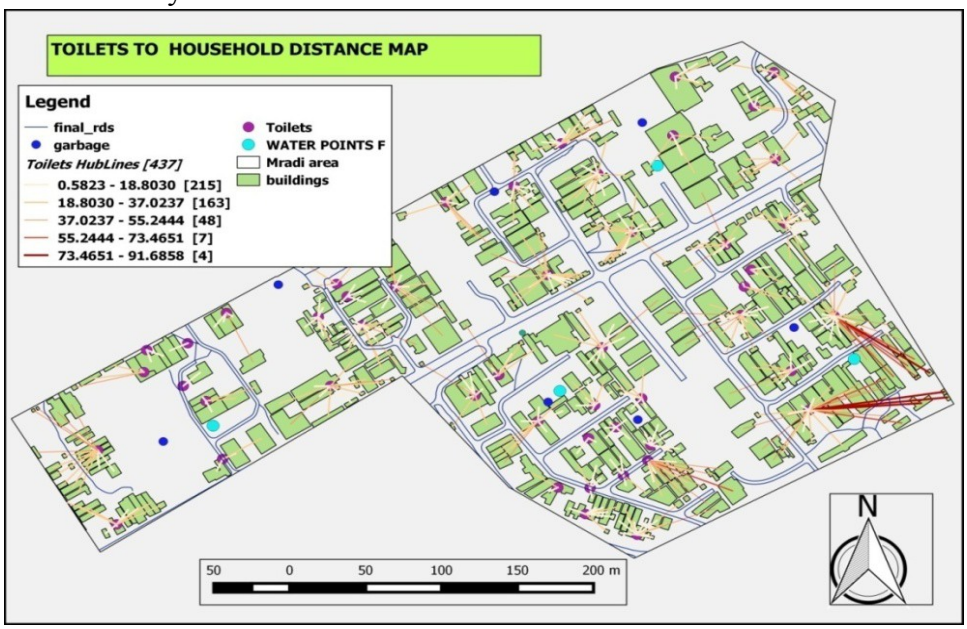

Figure 4.31 Toilets to households distance map

From the study through interview with the key informant and observation it was found that the current facilities in the study area were not friendly to the vulnerable group of the society. Most of toilets/latrines/bathroom was found to be communally shared. Toilets in Mradi were both unisex and therefore this according to the key informant posed a danger to women especially at night. It is inaccessibility that was identified as the reason why there was traces of defecation and flying toilets especially close to the garbage site and in the open. Map showing the clusters on areas with more toilet shaded black meaning there are several areas with less toilet coverage. From the research a total of 49 toilets were mapped. From the figure 4.32 below the lighter shade of green depicts small distance to the nearest toilet neighbor while the dark green color depicts toilets that were far from nearest neighbor. From the map it was found that the area with more household had more toilets than the areas with few households where toilets covered more blocks.

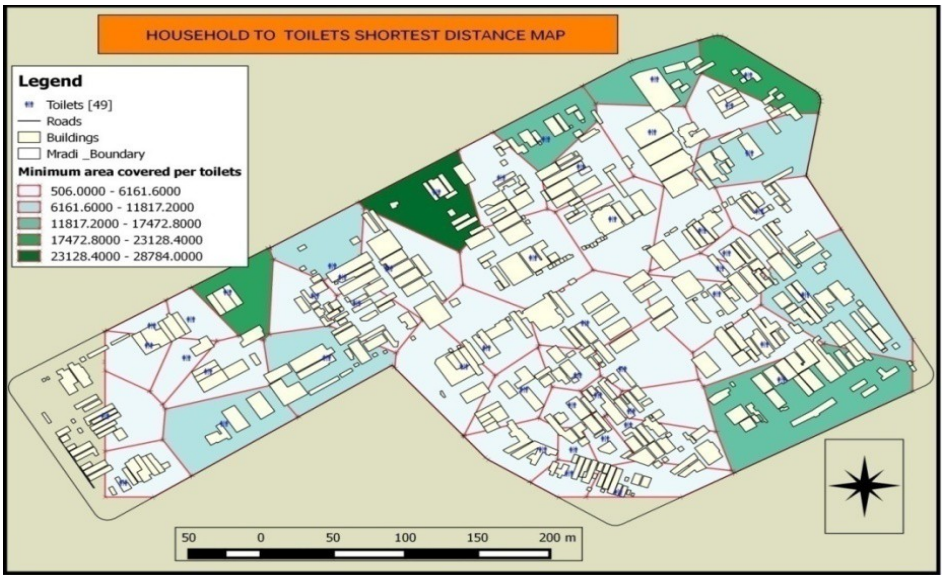

Figure 4.32 Toilets shortest distance map

The toilets were dirty and communally shared and mostly situated at the entrance of a house dwelling. There were no toilets found in the area that was specially made for most at risk population e.g. children and this probably explain the reason there were noticeable flying toilets in the area. Minimum standard – toilets no more than 50m from dwellings or no more than 1 minutes' walk. From the research figure 4.35 it was found out that most of the toilets were inside the households hence less than 50 m from dwelling place .However, the business area there were found to be no public toilet and therefore they walked more than 50 m and more than one minute to reach a toilet.

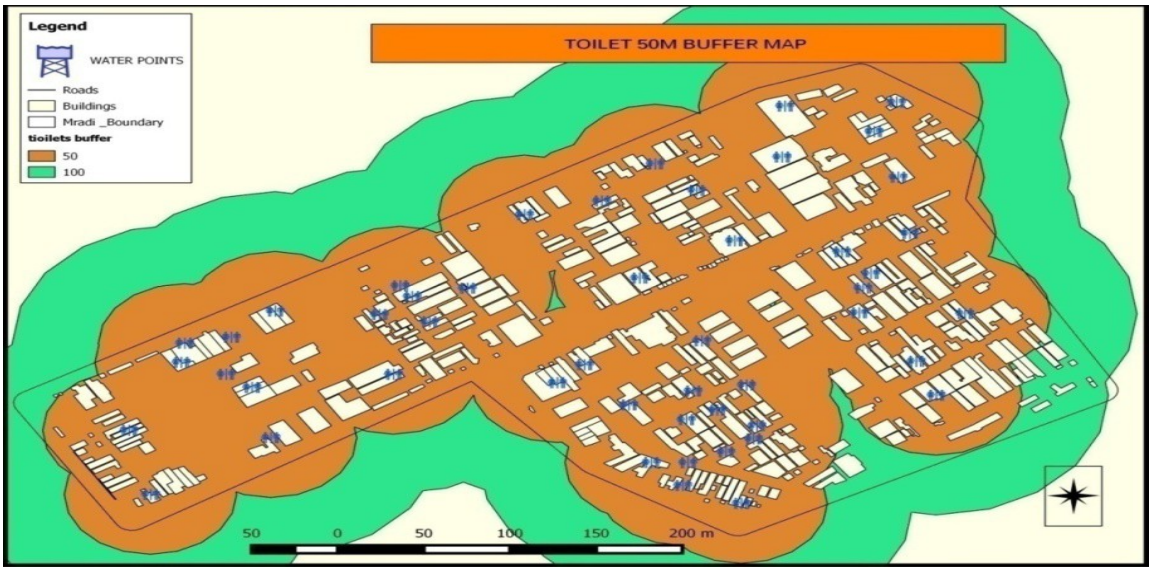

Figure 4.33 50m Toilets buffer

4.4.4 Dumping Sites accessibility

From figure 4.33 a total of 8 dumping sites were mapped. All of them were open and almost full with all kind of trash mixed. Only the main dumping sites were mapped as the rest were small and were mostly situated outside the household dwelling plate 4.13 and plate 4.14. Most residents reported that they walked less than 50m to the dumping site which explained why there were mini dumping sites in the area. From the figure 4.36 below the minimum distance to the main dumping site from households was found to be 26mand the highest distance was 118m from the dumping site. This therefore explains why they were more small scattered dumping sites all over as depicted by plate 4.13.

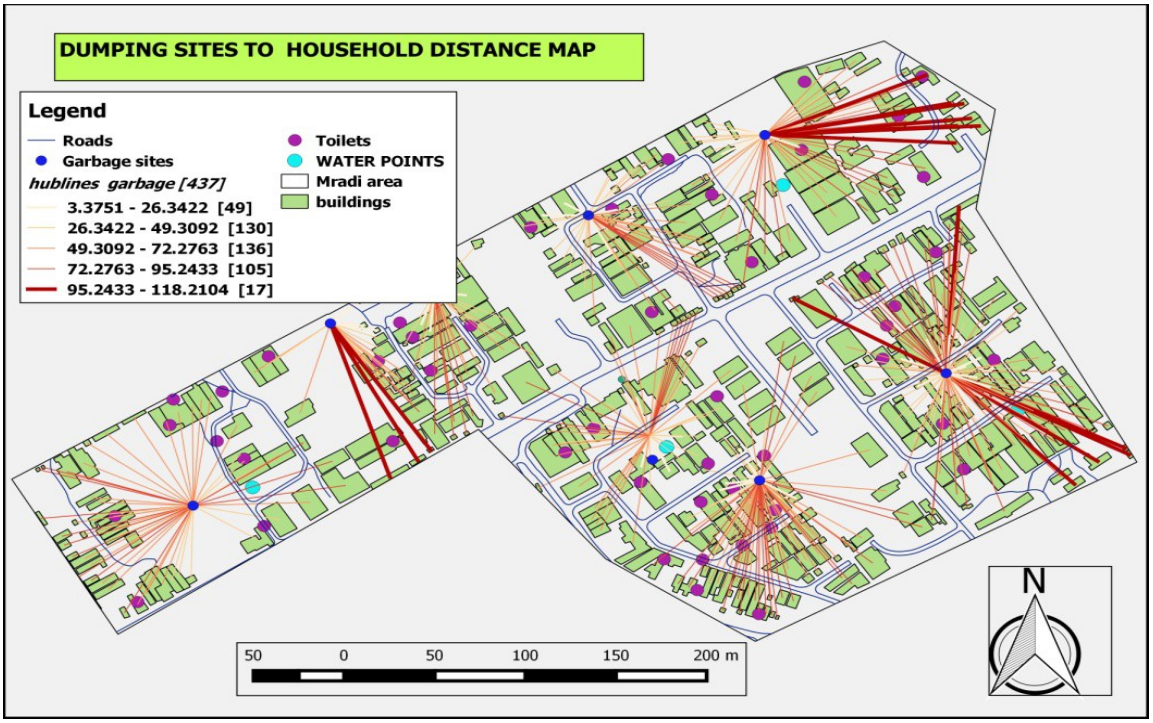

Figure 4.34 Dumping sites household distance map

Plate 4.13 show the general surrounding of Mradi area.

Plate 4. 2 Littered garbage photograph

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Plate 4.14 Poor drainage system with open sewer photograph

In Mradi plate 4.14 the waste discharges directly into open drains which in itself it's a health hazard. The sewage is in close proximity to many vegetable vendors which can pose real dangers to resident's plate 4.15 show sewage running outside an eatery.

Plate 4.3 Hotel next to an open sewerage system

4.5 Discussion of the Results

The overall purpose of this project was to assess and analyse distribution of water, sanitation and hygiene services in Mradi, this would help in understanding geographic inequalities in coverage of drinking-water supply and sanitation and hygiene practices and at the long run help to track progress towards universal coverage of water and sanitation by identifying marginalized populations, thus helping to increase life expectancy and reduce infant mortality among the urban poor. The objectives of this study were achieved.This study had four specific objectives: .To Collect data relating to WASH within the supply area analyze accessibility of WASH within the supply area and suggest new sites, Assess levels of awareness and practice on sanitation and hygiene and finally identify water supply and sanitation and hygiene problems within the study Area. Objective one was achieved through collection of WASH facilities in the study area. This was achieved through the use of a mobile phone which was GPS enabled and which used the Open Data Kit (ODK) as an application. All the existing water collection points were mapped with associated attribute information, all the toilets and bathrooms in the area were also mapped and the attribute associated with them were collected too. The garbage sites were also mapped. The key findings from this objective was 4 water points were found and mapped .2 were protected and 2 were unprotected sources ,at the time of research 1 water point was not

operational. All water points were privately operated and located to possible areas of contamination from waste water.3 of the Water point had enough water to support over 100 households in a day while one could serve less than 100 household .The water charges from the water point were found 5shillings per 20litres jerry can depending on water availability. On sanitation and hygiene 49 toilets were mapped and all of them were functional at the time of research. Each toilet served a minimum of 8 household and they were located inside the plot. Toilets were constructed from iron sheet and they were communally shared. All toilets mapped were functional in that they were being used regardless of the status ,The toilet were dirty as a result of being communal and the fact that most households could not afford extra water for use to clean the toilets .

8 main dumping sites were mapped and it was found that these sites were full and open and contained all manner of trash an indication that garbage emptying was not regular. Animals were found feeding from the garbage indication that households threw biological waste. Most garbage site were in front of the residential dwelling and the smell coming from them was found overwhelming ,open sewer was found to run in front of residential areas even close to food eating points. To achieve objective two and three a household survey was carried out and a sample of 50 responded to the questionnaire. The key finding from this objective was that the average household size for mradi was 4.4 people which are slightly below the average household size of a Kenyan urban slum which is five people. The household was found to spend an average of 5shillings to 15 shillings for water which is an equivalent of minimum 20litres and maximum 60 litres.All water points in mradi were found to be within 200 m buffer, toilets were found to be within 50m from their dwelling with some areas having fewer toilets. Household water source was found to be from unprotected sources and it cost 5 shillings per 20litre. The residents did not pay for garbage and that's why waste management which includes collection was not Available. The main problems identified in regards from WASH were found to be residents did not have enough water for use for all house members and this in itself compromised on hygiene standards in the household e.g. hand washing after Toilets. Lack of access to water has direct implication to the health of entire household members. The water sources were unprotected and at high risk of contamination and this has direct impact on the quality of water for use by household. Communally shared toilets was found to be a big problem since it posed security threats to children and women at night .The toilet design and was found not favorable for vulnerable

groups like children and this was found to be the biggest reason contributing to the practice of open defecation by young children. Waste disposal was found to be a big problem in the study area with open sewer system flowing on resident door point and even at eating places. Not separating waste before disposal by resident was identified as another problem since the resident are at higher risk of being exposed to hazardous waste, the foul smell was also identified as health hazard contributed by lack of garbage emptying by Nairobi City Council .During this study it was found out that resident of study area did not have a refuse container to throw their waste. Most waste was dumped outside the residential area in an open dustbin where the city council comes to carry away the waste. The open garbage sites were found to be full an indication that it was not emptied on regular basis. From observation the garbage site smelled an indication that waste had taken long before being Emptied. Objective four was achieved through the use of three key informants that which explained deeply on the problems relating to WASH in the study area. The major finding was that the key informant mentioned to us that generally women had problems in disposing used sanitary towel and that it was mixed with the rest of the waste .The women too disposed used pampers to the garbage site which its self is a real health hazard. The lack of sanitation facilities is considered a big problem by the women in Mradi , but it is very difficult to improve the situation because of several related issues. First, there is hardly any space for latrines, the compounds are built up to capacity and available empty spaces are becoming encroached and are privately owned. Secondly, latrines are considered the responsibility of the landlord in this area, and because the landlord usually does not live in the area, s/he is not interested in improving the latrine situation. It was also found out that Observing sanitation is the duty of women in comparison to the man as the women are mostly at home doing the household chores. The water challenge experienced in the area made it difficult for the toilets to be cleaned regularly therefore the practice of open defecation among children was found to be very common especially in the garbage area.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1CONCLUSIONS

This study aimed at demonstrating how GIS can be used to assess pro-poor urban WASH programme in Mradi Embakasi village.GIS proved to be a very useful tool in the whole WASH project cycle for pro-poor urban WASH programs mainly for decision making, this will ensure targeted resource allocation for facilities in the study area to ensuring the interventions are targeted at individual in dire need of this basic but important services necessary for human survival. It has also demonstrated that the integration of GIS can be done without spending a large amount of money because the project utilized QGIS, which is an open source GIS software and also ODK which is a free to use application running on android mobile phones . Use of maps to display the result has enabled the reader to have a more conceivable picture of the area and understand the spatial entity distribution in a pro-poor urban. Use of point's analysis techniques in QGIS for the mapped facilities provided the shortest distance of the area covered by each facility. Heatmaps enabled the identification of clusters in the area while buffers quantified the number of household within a certain radius from the facility.

From the household survey the average household size for mradi was 4 per household. The household with bigger sizes were found to lack enough water for domestic use. The main source of water was from unprotected sources mainly from vendors and was located next to an open sewer line or garbage site. The toilets in this area were few because one toilet was shared by a minimum of 8 households which translates to 32 persons. The solid waste management in the area was wanting as evidenced by the surrounding where litter was found all over with piled up emptied dumping sites. Residents are not charged on garbage disposal and this may explain why they are not emptied irregularly. Open defecation was evident especially in the open grounds and in the dumping sites. Toilets in the area had falling side walls and therefore not safe for use by children, elderly and pregnant mothers.

The research found that Water is typically collected by women from observation and Drinking water typically came from two main sources: water vendors (78%), boreholes (12 %.) these water sources were located in the operator plot, 88% of respondent walks for less than 500m and 12% walks for more than 500m, suggesting that most households are investing time in collecting water since there are only 4 major water points in entire area. This suggests that increasing water points and water safety practices in this area could help prevent waterborne diseases.

Residents in this area use the toilets as the bathroom, which in itself it's a health hazard. The business area had no toilets and the entire area lacked public toilets.

Communal latrines and toilets are also not easily accessible to all mradi dwellers especially at night raising security concerns. After darkness, women must risk rape or other gender based violence to use the toilets due to lack of security and the location of toilets. Shared pit latrines and shared bathrooms are often in unhygienic conditions, rarely cleaned, have unbearable smell, and attract insects and other disease vectors. The study revealed that some toilets had been closed down as they had blocked. The research found cases where the toilet was one and was used the bath

From this study therefore water sanitation and hygiene situation in Mradi is wanting, the standard of living is poor and WASH facilities are not accessible to all, therefore the government agencies and other stakeholder should fill in the existing spatial gaps in distribution of these facilities.

5. 2 RECOMMENDATIONS.

The outcome of this study has shown that GIS can successfully be integrated in assessing WASH programs, and can be helpful in identifying the existing gaps in provision of these vital services. Stakeholders in slums programs are encouraged to adopt these techniques in planning WASH projects to ensure target based interventions toward post 2015 development agenda.

Remote sensing imagery data should be explored and integrated in WASH related research especially in site selection. Future studies should utilize high resolution remote sensed data to carry out supervised classification so as to detect the changes before and after programs implementation.

Specific Recommendation:

- Every WASH programme should involve a GIS expert for spatial data collection during baseline and subsequent spatial data analysis to identify the gaps and areas to prioritise new intervention. This is important because Mradi area toilets were found to be concentrated in one area and the water points were just 4 and randomly distributed.
- Landlord should be encouraged to have at least a toilet and a bathroom built separately in the compound. This is because one toilet was shared by a minimum of 8 households and some residential buildings did not have toilets at all and others lacked bathroom.
- More water points should put up. This study found only 4 water points with only 3 being functional at the time of study in an area where they were more than 400 residential buildings
- Campaign on basic hygiene practices should be carried out in the area to sensitize the resident on the need of observing hygiene. No hand wash facility was found during the study despite the toilets being communal. Traces of open defecation was evident especially on the dumping site
- Main dumping points should be made accessible to people and have clear pathway. The study found out a lot of trash on the way to the main dumping site and this has a direct connection with accessibility during emptying of waste.
- Mobile phone data collection should be adopted as an alternative to paper based method of data collection. This research used ODK application to captures for both spatial and non-spatial data collection and eventually exported to GIS software where maps were made. This method proved to be cheap since there is no subsequent data entry.

- The water sources should be situated in a clean environment far from garbage and good drainage system to avoid contamination. This is because clean water collection point has a direct implication to reduced contamination at the source. The study found that half of the water points were located close to an open sewer and very close to dumping site.

- Some latrines should be constructed in an inclusive manner that considers the disabled, old and sick people. This may ensure access to sanitation for all without discrimination. The toilets are in the area are unisex and raised from the ground which makes it difficult for the vulnerable.

- Sanitary bin and anal cleansing materials should be placed in the toilets to enable the women safely dispose their sanitary towel.

- Garbage sites should be regularly emptied and residents should be sensitized on the need to throw waste on designated areas to avoid littering and prevent bad odor.
- There should be at a central and free water collection point where resident can wash their clothes and fetch water sited at the recommended water point location. This would ensure that even those who cannot afford to buy water have access.
- Placement of refuse container close to households to avoid dumping and introducing charges to facilitate the emptying of the containers.
- Construction of a public toilet especially in business areas. From the study this area had the biggest gap in term of accessibility and availability of both water points and toilets.
- Proper measure to be put in place to ensure regular emptying of toilets to make them safe for use

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Appendix 1

Built in form for toilet questionnaire

Toilet Questionnaire

Type	Name	label	hint
Note	**note_section_e**	**Toilets**	
Date	interview date	Date of the interview	
Integer	Id	Identification	
			Make sure
Geoponic	Toilet	Toilet point	meters
Integer	nom_of_toilets	Number of toilets	
Integer	Households	Number of households	
Text	Condition	Condition	
Integer	Bathroom	Number of bathrooms	
Text	Handwash	Handwash	

Garbage Site Questionnaire

Type	Name	label
Note	note_section_c	**Gabbage collection point**
Date	interview_date	Date of the interview
Text	Header	Header
Text	gabbage_name	Name of the gabbage
Text	gabbage_type	Type of the gabbage
Text	waste_type	Type of the waste
Integer	garbagepints	How far is garbage points from where you live?
Integer	garbage_cost	How much do you pay for garbage?
Geopoint	gabbage_point_gps	Collect the GPS coordinates of this gabbage collection point

Key Informant Questionnaire

Type	Name	label
Note	note_section_d	**KEY INFORMANT**
Date	interview_date	Date of the interview
Text	Access	Do vulnerable groups have easy access to the facilities
Text	Awareness	What is the current level of awareness of public health risks?
text	hand_washing	Are there hand washing facilities?
text	Material	What material/water is used for anal cleansing? Is it available
text	menstruation	How do women deal with menstruation? Are there materia

		need for this?
text	Disposal	How do people dispose of their waste?
text	Defeacation	Are still practices of defecation in open areas?

Household Questionnaire

integer	household_id	Enter the household number
integer	water_volume	How much water do you fetch per day?
integer	household_size	How many members are in your household?
text	water_access	Does everyone have equitable access to water?
text	water_source	What is the source of your water?
integer	water_points	How far are water collection points from where you live?
integer	toilet_bathroom	How far is the toilet/bathroom from where you live?
integer	water_cost	How much do you spend on water daily?
integer	toilet_cost	How much do you spend on toilet daily?
text	water_transport	How do you transport your water?
geopoint	household_gps	Collect the GPS coordinates of this household

Water Point Questionnaire

geopoint	water_gps	Collect the GPS coordinates of this water point
text	functionality	Is this water point functional?
text	contamination	Is this contaminated contaminated?
text	Fenced	Is the fenced fenced?
integer	Households	How many households use this water point?
text	Operator	Who is the operator of this water point?
integer	Cost	What is the cost of water for every 20litres?