# An Assessment of Ground Water Quality in Yatta Plateau in Kitui County, Kenya

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## DECLARATION

I understand that plagiarism is an offence and therefore declare that this thesis is my original work and has not been presented to any other institution for any other award

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# LIST OF ABBREVIATIONS

| | |
|---|---|
| AAS | Atomic Absorption Spectrophometry |
| ANOVA | Analysis of Variance |
| APHA | American Public Health Association |
| DEM | Digital Elevation Model |
| $F_C$ | Correlation factor |
| GIS | Geographic Information System |
| GoK | Government of Kenya |
| GPS | Geographic positioning system |
| JICA | Japanese International Corporation Agency |
| KCIDP | Kitui County Integrated Development Plan |
| KCP | Kitui County Profile |
| KNBS | Kenya National Bureau of Statistics |
| MDGs | Millennium Development Goals |
| MEW & NR | Ministry of Environment, Water and Natural Resources |
| MOWI | Ministry of Water and Irrigation |
| NWCPC | National Water Conservation and Pipeline Corporation |
| SDGs | Sustainable Development Goals |
| SEKU | South Eastern Kenya University |
| TAWSB | Tanathi Water Services Board |
| TDS | Total Dissolved Solids |
| UN | United Nations |
| UNEP | United Nations Environmental Program |
| UV | Ultra Violet Light |
| WARMA | Water Resources Management Authority |
| WASREB | Water Services Regulatory Board |
| WHO | World Health Organization |
| WSB | Water Services Board |

## ABSTRACT

The study is primarily an assessment of groundwater quality in the Yatta Plateau of Kitui County. The study focused on the spatial temporal distribution of key chemical parameters namely pH, TDS, Colour, Total hardness, Turbidity, Conductivity, Total alkalinity, Fluoride and Iron. Yatta Plateau is a volcanic formation which is characteristically flat at the top thus limiting overland flow and depression storage necessary for other methods of water supply to the community resident on the Plateau. Surface water sources are therefore not readily available as most of the rain water percolates easily owing to the flat nature of the plateau. The development of groundwater sources has therefore taken preference to other sources of water supply in the study area. Reliable and good quality water supply on the Yatta Plateau corridor may be affected by the type of chemicals found in the ground water, concentration of the dissolved minerals or even ground water quality changes over time. The purpose of this study was therefore to determine the variability or changes on ground water quality in Yatta Plateau in relation to rainfall, land use, geology among others and determine how the same influences water utilization. Groundwater samples were collected in boreholes distributed on the plateau and the key physicochemical parameters were measured using standard methods. These were then analyzed in order to determine the variability of groundwater quality on the Yatta plateau, the extent of influences of the groundwater chemical parameters on water utilization and, finally come up with recommendations on the appropriate ways of addressing groundwater quality degradation. The study is also important in that the findings provide a better understanding of possible changes in groundwater quality over time and this will prompt planning for appropriate treatment that is required to address the quality changes. The samples were collected in the period between March 2015 and March 2016 covering two dry seasons and two wet seasons experienced in the study area. Samples were collected four times from each of the six target boreholes. In total, twenty four (24) water samples were collected for analysis. The samples were analyzed at the Water Resources Management Authority (WARMA) Water Quality Testing Laboratory in Nairobi. The data obtained from the laboratory tests was analyzed using Surfer for spatial-temporal analysis, and were also subjected to Statistical analysis using SPSS (Statistical Package for Social Science). A questionnaire was also administered on the users of water derived from the sampled boreholes. The questionnaires were analyzed using various statistical methods including the analysis of variance (ANOVA), correlation analysis, and regression analysis, test of hypothesis, frequency distribution tables, means, percentages and bar charts. The results of the study show that there is no direct relationship between rainfall and variations of groundwater quality in the Yatta plateau. It was however found that there was spatial-temporal variability in different groundwater quality parameters that were analysed. The spatial-temporal variability was attributed to differences in the geologic formations forming the aquifers of individual boreholes that were sampled within the study area. Although the groundwater is generally of good quality, electrical conductivity, TDS and fluoride were found to be increasing drastically and may surpass the WHO and KEBS drinking water standards in future. The increase in the parameters was attributed to the nature of the geological formations common on the plateau. The results of the analysis of

the questionnaires showed that groundwater chemical parameters do not influence water utilization in the Yatta Plateau.The major water quality concern was taste and this was attributed to salinity. The study provides recommendations to governmental and non-governmental institutions that are mandated with the responsibility of ground water development planning and quality monitoring.

# CHAPTER ONE

# INTRODUCTION TO THE STUDY

## 1.0 Introduction

The study is focused on the assessment of ground water quality in the Lower Yatta Plateau. The purpose of this chapter is to introduce the study including the objectives and statement of the problem. In addition to the objectives and the hypothesis of the study, the chapter also provides details on justification and scope of the study.

## 1.1 Background to the study

Groundwater is one of the basic human needs and it is among the prime movers of the socio-economic development in many countries. According to the Constitution of Kenya 2010, Water is a basic human right and Article 43 establishes the right to "reasonable standards of sanitation and clean safe water in adequate quantities." To achieve this right, the water sector players require, not only to increase access to water but also to manage the water quality. Development of groundwater resources will allow the country realize this constitutional reqirement.

According to Mumma et. al., (2011), water resources in Kenya are irregularly distributed in both space and time, a situation exacerbated by considerable climate variability. According to Jones (2005), groundwater is recognized as an important resource that supplements surface water in social economic development in all areas but more in Arid and Semi-Arid areas that comprise nearly 80% of the total landmass in Kenya where it is widely utilized for domestic, agricultural and industrial activities.

According to Appelo and Postma (1993); Zhang et al.,(2011), groundwater quality reflects inputs from the atmosphere, soil and water rock reactions as well as anthropogenic pollutant sources such as mining, land clearance, agriculture, acid precipitation, and domestic and industrial wastes. Mirrabasi et al., (2008) argues that suitability of water for various uses depends on type and concentration of dissolved minerals and groundwater has more mineral composition than surface water.

Among the Millennium Development Goals (MDGS), the seventh goal required governments to adopt sustainable resource management policies to reduce the number of people without access to safe water and sanitation by year 2015 (UN, 2000). This is yet to be achieved in Kenya and in Kitui County in particular. Recurring droughts continue to pose serious challenges to water security, resulting in an increased reliance on ground water (UNEP, 2008). Under a scenario of global warming, increasing temperatures generally result in decreasing precipitation over the central continental areas, causing decreasing recharge and therefore depletion of ground water resources. Ground water, surface water (river, streams and ponds), atmospheric water (rain water, snow and hail) and springs are the main sources of water available to the people in general (Adetundee et al., 2011). The available sources of water determine the type of water system to be implemented for a particular community. The method of delivery, the quantity and the quality are integral components of the systems.

According to Caircross and Feachem (1983), the problem of access to safe water in the developing countries is enormous and therefore to alleviate the problem, governments in these countries have given priorities to implementation of community water projects. The authors further argue that water is essential for life and all human activities must have some kind of water source; it may be dirty, it may be inadequate in volume and it may be several hours walk away but nonetheless some water must be available. Different types of water supply systems are appropriate in different areas. Water supply systems are projects implemented essentially for providing water for either industrial, domestic or animal use or one of the three purposes. They are dependent mainly on the available sources. In general water projects can be grouped into three main classifications which includes classification by location thus urban and rural water project, classification by ownership thus private or community water project, or classification by the source of water thus rain water harvesting, surface water, or ground water project. The quality of water supply to rural communities is critical in developing countries including Kenya. According to the Water Supply and Collaboration Council (2010), almost 900 million people worldwide use water from unimproved sources, a threat to their health and productivity. The Council further observes that the majority of those people live in rural areas. The water supply in rural areas derives from different sources such as surface water, springs, ground water or even rain water catchment. The degree of water quality in a particular water basin depends on the present sources of pollution and kinds of contaminants. Land use is related to many water quality parameters (Tong and Chem, 2011). According to the two, surface runoff from different types of land use may be enriched with different kinds of contaminants and consequently the quantity of water available for runoff, stream flow and ground water flow as well as physical, chemical and biological process in the receiving water bodies can be affected.

The quality of drinking water may be controlled through a combined protection of water source, control of treatment process and management of the distribution and handling of the water (WHO, 2006). For instance effective catchment management has many benefits. Water that percolates deep and stored in aquifers as ground water is generally microbial safe and contamination is usually from dissolved minerals.

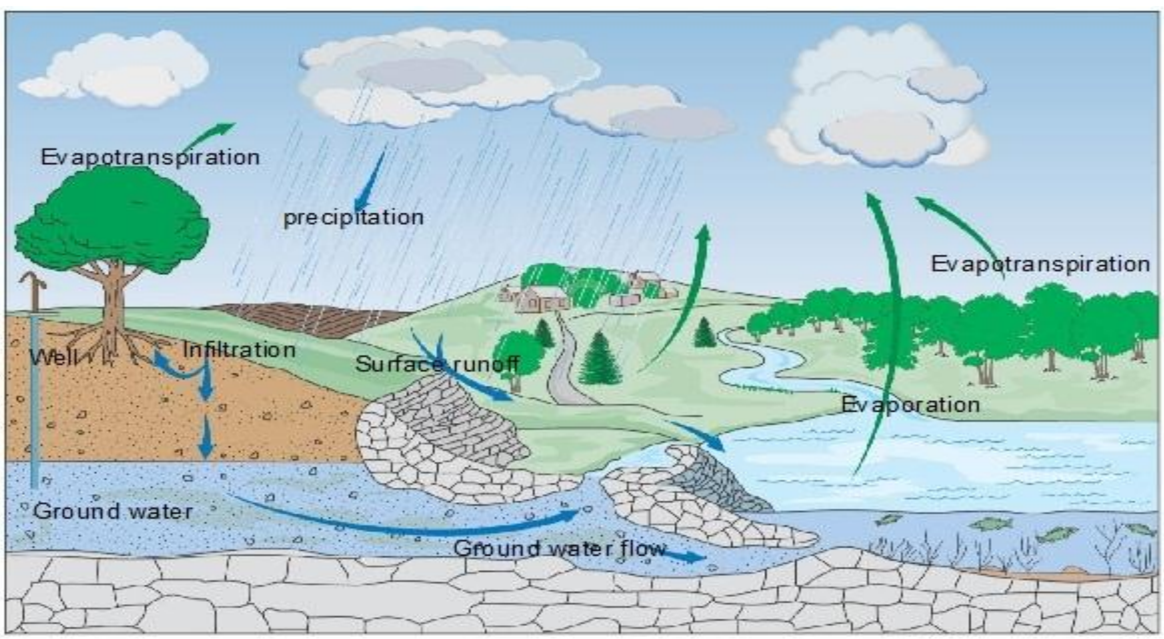


Figure 1.1: Groundwater component in a typical hydrological cycle (Source: Pearson Prentice Hall inc. 2005)

Ground water is water that principally infiltrated and or percolates through the various geological formations as component of the hydrological cycle (Figure1.1 above). Perhaps, as many as two billion people depend directly upon aquifers for drinking water and 40 percent of the world's food is produced by irrigated agriculture that relies largely on ground water (UNEP 2003). UNEP Further argues that recognition of the private role of ground water in human development is relatively recent and still patchy. Generally groundwater is better protected than surface water from the pathogen contamination. This is because before it is stored in either confined or unconfined aquifers, it passes (Infiltration and percolation) through various geological formations that strain and retain much of the microorganisms. However, according to WHO (2005), groundwater is not always available of suitable quality because of various chemical contents. Raghunath (1995) observes that the chemical composition of groundwater is related to the soluble products of rock weathering and decomposition and changes with respect to time and space.

This study is primarily an assessment of ground water quality in the Yatta Plateau of the Lower Yatta Sub-County, Kitui County, Kenya. The Yatta Plateau is characteristically flat and this limits the methods of water supply to the community resident on the Plateau. For instance, surface water sources are not readily available as most of the rain water percolates easily rather than flow into streams or even accumulate in ponds. Ground water sources have therefore taken preference to other sources of water supply in the study area. Most chemicals arising in drinking water are of health concern only after extended exposure of years rather than months, the principal exception being nitrates (WHO, 2006). Increasing population, unplanned development activities and land use change are also threat to sustainable groundwater development. It is also noted that there has been very limited studies on ground water especially on ground water quality. Studies are therefore required to provide data and information on the status of ground water quality in the Yatta plateau. This is important for the sustainable management of the meager ground water resources. The purpose of this study therefore was to determine the variability or changes on ground water quality in Yatta Plateau and how the same influence water utilization.

### 1.2 Statement of the problem

Water is the basis of life on earth (UNEP, 2010).The quality of life directly depends on water quality. Good water quality sustains healthy ecosystems thereby leading to improved human wellbeing. Safe drinking water that is fresh and free from harmful chemicals and disease-causing organisms therefore is a preliquisite for a healthy population. Access to safe drinking water is important as a health and development issue at national, regional and local levels (WHO, 2006).

The health concerns associated with chemical constituents of drinking water differ from those associated with microbial contamination and arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure (WHO, 2006). There are many chemicals that may occur in drinking water, however, only a few are of immediate health concern in any given circumstance. According to Alberta Environment (2009), groundwater quality can be linked to the type of aquifer that water originates from. The chemicals in groundwater derive substantially from the rocks and soil through which water percolates and therefore naturally occurring chemicals may affect deep ground water quality. (WHO, 2006) further stresses that in some regions, it has been shown that investments in water supply and sanitation can yield a net economic benefit, since reductions in adverse health effects and healthcare costs outweigh the costs of undertaking the interventions.

The general geomorphology of the Yatta plateau is such that the top section is flat but the slopes are normally steep and this limits the methods of water supply to the communities' found on the plateau. For instance surface water sources are not readily available as most of the rain water percolate rather than flow in streams or even accumulate in ponds. This means that majority of the local community depend on groundwater for their domestic water supply. Reliable and good quality water supply in the Yatta Plateau corridor may be affected by the type of chemicals found in the ground water, the concentration of the dissolved minerals or even ground water quality variations and changes overtime. Population increase is likely to cause land use changes and increased water abstraction that may also affect ground water quality. Very little research has been done on the same. Based on the Drought Intervention Programme report by the GoK (2009), groundwater provision in the Yatta plateau has taken preference to other sources of water.

This therefore means that incase of any deterioration of ground water quality in the study area, major negative impacts on both health and socio-economic status of the community within the study area will be experienced. The need for sustainable ground water development cannot therefore be over emphasized. It is important that the groundwater chemical parameters be established, analyzed and any changes overtime determined. It is against this background that this study seeks to assess the deep ground water quality in the Yatta plateau corridor of Lower Yatta Sub County, Kitui County, Kenya.

## 1.3 Objectives of the study

### 1.3.1 **General objective**

The general objective of this study was to determine the status and the variability of ground water quality in Yatta plateau and the extent to which the same influence the uses of water.

### 1.3.2 **Specific objectives**

The specific objectives of the study are as follows:

(i) Determine the spatial variations of ground water chemical parameters in the Yatta plateau corridor in Kitui County.

(ii) Determine the short and long-term changes in groundwater chemical parameters in the Yatta plateau corridor in Kitui County.

(iii) Determine the causes of variations in groundwater quality in the Yatta plateau corridor in Kitui County.

(iv) Establish the extent to which ground water quality affects water utilization in the Lower Yatta Sub-County and provide recommendations for sustainable development of ground water resources in the area.

## 1.4 Research questions

(i) Do spatial variations of ground water chemical parameters exist in the Yatta plateau corridor in Kitui County?

(ii) Are there short and long-term changes in groundwater chemical parameters within the Yatta plateau corridor in Kitui County?

(iii) What are the causes of groundwater quality variations in the Yatta plateau corridor in Kitui County?

(iv) To what extent do ground water chemical parameters affect water utilization in the Lower Yatta Sub-County?

## 1.5 **Hypotheses**

The study has the following hypotheses.

1.5.1 $H_0$: There are no spatial variations in ground water chemical parameters in the Yatta plateau, in Kitui County.

$H_1$: Alternative

1.5.2 $H_0$: There are no short and long-term changes of groundwater quality in the Yatta plateau, in Kitui County.

$H_1$: Alternative.

1.5.3 $H_0$: There is no relationship between ground water chemical quality and rainfall in the Yatta plateau in Kitui County.

$H_1$: Alternative.

1.5.2 $H_0$: There is no significant influence of groundwater quality on water utilization in the Yatta plateau in Kitui County.

$H_1$: Alternative.

## 1.6 Justification of the study

Groundwater quality assessment is important for ensuring sustainable use of water as well as access to safe drinking water. Yatta plateau in Kitui County is water stressed and residents along the Yatta plateau have to walk on average more than 5 Km to access water from the rivers (Athi River on the eastern side and Mwitasyano and Tiva River on the western side of the plateau). The availability of and access to water supply strongly influences economic growth and social development patterns (Allan, 2000). Based on the Drought Intervention Program report by the Gok (2009) groundwater provision in the Yatta plateau has taken preference to other sources of water and therefore it is important that the groundwater chemical parameters be established, analyzed and any changes overtime determined. WHO (2006), argues that most chemicals arising in drinking water are of health concern only after extended exposure of years rather than months, the principal exception being nitrates. Various parameters such as pH, TDS, Color, Turbidity, Conductivity, Total hardness, Total alkalinity, Fluoride and Iron were subject of this study. The parameters are some of the most useful and are commonly measured and therefore any significant change in them can be used as an early indicator of change in a water system (Langland and Cronin, 2003).

The findings of the study can be used to recommend appropriate uses regarding ground water in Yatta plateau corridor in Kitui County. The study is also intended to provide a better understanding of short and long-term changes in ground water quality. This can prompt appropriate treatment that may be required thereby influencing management of groundwater resources in the study area. The latter is lacking at the moment. Additionally, the study provides data and information for use in ground water resources management and planning. The study also provides recommendations on general water resources development in the area. Finally, the study will be of use to other researchers interested in establishing other factors influencing ground water quality in the Yatta plateau.

### 1.7 Scope of the study

This study was focused on the assessment of ground water in boreholes found in the Yatta plateau in Kitui County. The study relied on six boreholes located within the area defined by latitudes $-1.50^0$ and $-1.85^0$ and longitudes $37.75^0$ and $37.95^0$.

The Yatta plateau was chosen for the study as it presents a unique hydrogeological unit that incorporates both surface water and ground water taking into account different components of the hydrological cycle. It has to be noted that there is no river which flows on the Yatta plateau. The key focus in this study was boreholes drilled through different programmes and private initiatives on the plateau on different periods in order to address the issue of water scarcity in the area. The programmes included; (i) a GoK/Egyptian Kenya Arid Programme that funded the drilling and equipping of Kanyangi borehole in the year 1997, (ii) Rural Water Programme in Kitui and Mwingi districts funded by JICA, which drilled Muselele and Kanyongonyo boreholes in the year 2007, (iii) a GoK-National Water Conservation and Pipeline Corporation Programme that funded Nthongoni borehole in the year 2014, and finally (iv) two privately initiated borehole drilling projects that drilled Kwa Kilui (Paul Makosa) in the year 2013 and Kalulini (David Mwongela) borehole in the year 2011.

The study was carried out in two dry and two wet seasons during which water samples were collected for testing. It covered chemical water quality parameters particularly pH, TDS, Electrical conductivity, Turbidity, Iron, Total alkalinity, Total hardness and Fluoride. The parameters are some of the most useful and any significant change in them can be used as an early indicator of change in a water system (Langland and Cronin, 2003). The study also covered physical parameters namely color, taste and odor. The study did not cover the biological water quality aspect as this was way beyond the scope.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

Literature review is a critical step in any scientific research (Baker, 2000). This chapter involved the review of published literature on factors influencing groundwater quality. The chapter also establishes the theoretical framework of the study and presents the gaps that this research sought to fill. Literature review was achieved by reviewing published and unpublished information from global, regional and local scholarly scientific journals and technical reports. As is the case in most areas in Kenya, it was difficult to obtain data and information on groundwater.

## 2.2 Drinking Water Quality in relation to Health

The quality of life directly depends on water quality as water is the basis of life on earth (UNEP, 2010). Good water quality sustains healthy ecosystems thereby leading to improved human wellbeing. According to Thirupathaiah et al., (2012), the quality of water in any ecosystem provides significant information about the available resources for supporting life in that ecosystem. They further argue that good quality of water resources depends on a large number of physico-chemical parameters and biological characteristics. However poor water quality affects the environment and human wellbeing. Safe drinking water that is fresh and free from harmful chemicals and disease-causing organisms therefore is a preliquisite for a healthy population. Access to safe drinking water is important as a health and development issue at a national, regional and local level (WHO, 2006). WHO further stresses that in some regions, it has been shown that investments in water supply and sanitation can yield a net economic benefit, since reductions in adverse health effects and healthcare costs outweigh the costs of undertaking the interventions. Human’s development activities among them agriculture, urban settlement and industry interfere with the quality of water from the various sources. Water is finite and therefore can easily be contaminated or depleted by human activities thereby causing water stress in particular regions of the world. Inadequate drinking water supply, quality and poor sanitation are among the world's major causes of preventable morbidity and mortality (WHO, 2005). They further argue that the problem is not limited to developing countries and that beyond the reported waterborne outbreaks, there's unrecognized background knowledge of disease. Water-related issues are therefore high on the international policy agenda.

Water demands outstrip available freshwater resources in many countries. Countries or regions in which such conditions limit development are said to experience water stress. The degree to which the system is susceptible to or unable to cope with adverse effects of environmental change defines its vulnerability (UNEP, 2008). The annual renewable freshwater availability of less than 1000 Cubic meters per person is defined by hydrologists as water scarcity.

Regarding the quality of drinking water, microbiological contamination is a primary concern of developing countries. In addition, inorganic contaminants, concerning both health and aesthetic aspects, can be present in the waters. Fluoride and arsenic are a great health problem worldwide. The public health burden of these two chemicals far exceeds that of other chemical contaminants in drinking-water, but globally it is masked by the public health impact of microbial contamination (WHO, 2013). The source of iron in water may be from the corrosion of iron, steel pipes or borehole casings where the acidity of water measured as pH is below 6.5 (http://www.idph.state.il.us). However iron is not hazardous to health but is considered a secondary contaminant and it helps in transportation of oxygen in blood (http://www.idhp.state.il.us.) The quality of water supply to rural communities is critical in developing countries including Kenya. According to the Water Supply and Collaboration Council (2010), almost 900 million people worldwide use water from unimproved sources, a threat to their health and productivity. The council further observes that the majority of those people live in rural areas. The water supply in rural areas derives from different sources such as surface water, springs, ground water or even rain water catchment. The degree of water quality in a particular water basin depends on the present sources of pollution and kinds of contaminants. Land use is related to many water quality parameters (Tong and Chem, 2011). According to the two, surface runoff from different types of land use may be enriched with different kinds of contaminants and consequently the quantity of water available for runoff, stream flow and ground water flow as well as physical, chemical and biological process in the receiving water bodies can be affected.

The quality of drinking water may be controlled through a combined protection of water source, control of treatment process and management of the distribution and handling of the water (WHO, 2006). For instance effective catchment management has many benefits. Water that percolates deep and stored in aquifers as ground water is generally microbial safe and contamination is usually from dissolved minerals.

Table 2.1: WHO Guidelines for Drinking Water Quality (Source: WHO, (1993))

| **Element/ substance** | **Symbol/ formula** | **Normally found in fresh water/surface water/ground water** | **Health based guideline by the WHO** |
|---|---|---|---|
| Aluminium | Al | | 0.2 mg/l |
| Ammonia | $NH_4$ | < 0.2 mg/l (up to 0.3 mg/l in anaerobic waters) | No guideline |
| Antimony | Sb | < 4 μg/l | 0.005 mg/l |
| Arsenic | As | | 0.01 mg/l |
| Asbestos | | | No guideline |
| Barium | Ba | | 0.3 mg/l |
| Berillium | Be | < 1 μg/l | No guideline |
| Boron | B | < 1 mg/l | 0.3 mg/l |
| Cadmium | Cd | < 1 μg/l | 0.003 mg/l |
| Chloride | Cl | | 250 mg/l |
| Chromium | $Cr^{+3}$, $Cr^{+6}$ | < 2 μg/l | 0.05 mg/l |
| Colour | | | Not mentioned |
| Copper | Cu | | 2 mg/l |
| Cyanide | $CN^-$ | | 0.07 mg/l |
| Dissolvedoxygen | $O_2$ | | No guideline |
| Fluoride | F | < 1.5 mg/l (up to 10) | 1.5 mg/l |

| | | | |
|---|---|---|---|
| Hardness | mg/l$CaCO_3$ | | No guideline |
| Hydrogen sulfide | $H_2S$ | | No guideline |
| Iron | Fe | 0.5 - 50 mg/l | No guideline |
| Lead | Pb | | 0.01 mg/l |
| Manganese | Mn | | 0.5 mg/l |
| Mercury | Hg | < 0.5 μg/l | 0.001 mg/l |
| Molybdenum | Mb | < 0.01 mg/l | 0.07 mg/l |
| Nickel | Ni | < 0.02 mg/l | 0.02 mg/l |
| Nitrate and nitrite | $NO_3$, $NO_2$ | | 50 mg/l total nitrogen |
| Turbidity | | | Not mentioned |
| pH | | | No guideline |
| Selenium | Se | < < 0.01 mg/l | 0.01 mg/l |
| Silver | Ag | 5 – 50 μg/l | No guideline |
| Sodium | Na | < 20 mg/l | 200 mg/l |
| Sulfate | $SO_4$ | | 500 mg/l |
| Inorganic tin | Sn | | No guideline |
| TDS | | | No guideline |
| Uranium | U | | 1.4 mg/l |
| Zinc | Zn | | 3 mg/l |

The chemical and bacteriological quality of surface water is seasonal dependent. The natural ground water quality varies from region to region depending on climate and geology. Boreholes in high rainfall areas produce relatively fresh water compared to those that are found in areas with low rainfall. Some of the boreholes in semi-arid areas produce highly mineralized and saline water (GoK, 2009). The WHO guidelines for drinking water quality are shown in Table 2.1 above;

## 2.3 Ground water quality in relation to geology

Ground water infiltrates and or percolates through the various geological formations as component of the hydrological cycle (Raghunath, 2006). It is regarded as the largest source of fresh water on the planet excluding polar icebergs and glaciers and according to Raghunath (2006), the amount of the ground water within 800meters from the ground surface is over 30 times the amount in stream channels at any one time. Perhaps as many as two billion people depend directly upon aquifers for drinking water and 40 percent of the world's food is produced by irrigated agriculture that relies largely on ground water (UNEP, 2003). UNEP further argues that recognition of the private role of ground water in human development is relatively recent and still patchy. Probably that is why ground water quality and quality monitoring is not of significance to many rural population that depend on the groundwater resource.

According to Alberta Environment (2009), groundwater quality can be linked to the type of aquifer that water originates in. Unconfined aquifers have hard water with higher iron concentrations because they are exposed to the atmosphere through spaces in the soil that are primarily composed of sand or gravel. Many practices with domestic waste water and livestock manure may lead to contamination of groundwater (WHO, 2005). Septic tanks, cesspools, latrines and other on-site systems are widely used for waste water storage and treatment. The water percolating from these facilities contain viruses, bacteria and parasites and many contaminate ground water (WHO, 2005). In countries with limited supplies of fresh water, waste water is used for irrigation either by spray irrigation, overland flow or subsurface infiltration. Groundwater pollution is likely to occur in such a process. Generally groundwater is better protected than surface water from pathogen contamination. This is because before it is stored in either confined or unconfined aquifers, it passes (Infiltration and percolation) through various geological formations that strain and retain much of the microorganisms (Alberta Environment, 2009). As groundwater flows through an aquifer it is naturally filtered. This natural filtering process creates water that is usually free from disease causing bacteria and lower in suspended solids than surface water. Deep groundwater from confined or unconfined aquifers is therefore a preferred source of drinking water production. Shallower groundwater sources or groundwater that can be influenced by surface water will be more vulnerable to fecal contamination. However, according to WHO (2005), groundwater is not always available of suitable quality because of various chemical contents. Raghunath (1995) observes that the chemical composition of groundwater is related to the soluble products of rock weathering and decomposition and changes with respect to time and space. Most chemicals arising in drinking water are of health concern only after extended exposure of years rather than months (WHO, 2006). This underscores the importance of programmed groundwater quality assessment to discount the possibility of extended yet unrealized negative effects to the ground water users (WHO, 2006).

Ground water is an important resource in the Lower Yatta sub-county of the Kitui County. Ground water is used for various purposes among them domestic water needs and small scale irrigation. The kinds and concentration rates of different materials in groundwater are dependent on rocks which are in contact with water (Tavassoli and Khaksar, 2002). They further argue that sedimentary formation with respect to igneous and metamorphic rocks plays a major role in water quality. Therefore geological formation is one of the most important and effective agents on the quality of water. For instance, miocene and marl formation affect the groundwater quality and increases its electrical conductivity. According to the kind of petrology of each formation, water may affect different geological formations and dissolve different cations and anions, which in turn affect the quality of water in these aquifers (Tavassoli and Khaksar, 2002). Therefore the sedimentology of quaternary rock formations can determine the hydrology and hydrogeology of water of the aquifer. In a study conducted by Tavassoli and Khaksar, (2002) in Iran, the two found out that the quality of groundwater was changed by the underlying geologic formations.

Petalas et al., (2006), argues that volcanic rocks are considerably altered where they are in contact with hydrothermal solutions and that aquifers are formed within these formations. Surface and ground waters are strongly metalliferous and their hydro-chemical appearances present similar but complex water types. The chemical types generally found include the following: Ca-Mg-$HCO_3$-$SO_4$, Ca-Mg-$SO_4$-$HCO_3$. Ca-$SO_4$, Ca-Mg-$SO_4$. Ca-Na-Cl-$HCO_3$, Na-Cl (Petalas et al., 2006). The most pronounced property of groundwater is its acidic characteristic, and the high metal concentrations are related to water with low pH values. Sulfide minerals control the low pH values of waters which is an important control factor for the evolution of the groundwater chemical composition (Tavassoli and Khaksar, 2002). The abundance of sulfates in ground is mainly attributed to the dissolution of pyrite ($FeS_2$) and alunite ($KAl_3(SO_4)_2(OH)_6$ minerals (Petalas et al., 2006). Further the water–mineral interactions are responsible for the chemical composition of groundwater. Volcanic rocks have the potential to produce acid drainage (Tavassoli and Khaksar, 2002).

According to Petalas et al., (2006) Volcanics (andesite, dacitic-andesite or tuffs) hydrologic properties have not been defined as extensively as those of other lithologies, probably because their hydrologic variability has discouraged their investigation and further their hydraulic properties differ greatly, and collectively they constitute a complex, heterogeneous, and anisotropic ground-water system. Their permeability is mainly secondary and is attributed to the tectonic activity, as indicated by their petrographic types. The occurrence of the aquifer system resulting from the combined effects of fracture system, topography, and weathering, modifies both transimissivity and storage characteristics.

### 2.4 Groundwater Chemical Parameters in relation to Health

The health concerns associated with chemical constituents of drinking water differ from those associated with microbial contamination and arise primarily from the ability of chemical constituents to cause adverse health effects after prolonged periods of exposure (WHO, 2006). They further argue that there are many chemicals that may occur in drinking water, however, only a few are of immediate health concern in any given circumstance. For instance exposure to high levels of fluoride can lead to mottling of teeth and in severe cases, crippling skeletal fluorosis. Similarly excess exposure to arsenic in drinking water may result in a significant risk of cancer and skin lesions (WHO, 2006).

WHO (2006), Also contents that in most countries, whether developing or industrialized, water sector professionals are likely to be aware of a number of chemicals that are present in significant concentrations in drinking-water supplies. Some key parameters that may be associated with groundwater quality include pH, Color, Turbidity, Conductivity, Iron, Total hardness, Total Alkalinity, Fluoride, and Total dissolved solids. Rainfall does not only affect the groundwater quality but it also influences the quality of groundwater. Water recharge during an arid period may have a higher concentration of salts and hence higher TDS, while during the wet period the converse may occur (Sukhija et al., 1998). Dragoni and Sukhija (2008) observe that to appreciate such changes, long term monitoring of rainfall and groundwater quality is required. They further argue that it is also possible to link occurrence of certain ions in groundwater to particular water-rock processes that occurred during specific past climatic periods. During rainy season, silt, clay and other suspended particles contribute to high turbidity values while in dry season the same particles settle resulting to low values in turbidity.

Total hardness in water may be due to magnesium and/ or calcium salts. During his study in India, Thirupathaiah et al., (2012), observed that increase in total hardness in surface water can be attributed to the decrease in the rate of evaporation at high temperature. Adetunde et al., (2011) argues that excess chloride in water impacts bad taste and may indicate contamination from urine and sewerage while excess iron residue may cause taste and odor problem in water. They further argue that there are no adverse health effects specifically attributed to calcium and magnesium in drinking water but the presence of the ions in drinking water cause hardness of the water.

Groundwater salinity is an important groundwater quality indicator, which is controlled by the factors such as precipitation, evapotranspiration, mineralogy, type of aquifers and sea water intrusion (Yan et al., 2015). In their study of seasonal variations in groundwater level and salinity in coastal plain of eastern china influenced by climate, Shao, (2015) and others observed that the groundwater salinity increased during the dry season where no precipitation event occurred.

**Table 2.2:** WHO and KEBS Drinking Water Quality standards (KS 459-1:2007)

| Element | Units | WHO Standards | KEBS Standards |
|---|---|---|---|
| pH | pH Scale | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | Max 15 | Max 15 |
| Turbidity | N.T.U | Max 5 | Max 5 |
| Conductivity | (25DegC) uS/cm | Max 2500 | - |
| Iron | mg/l | Max 0.3 | Max 0.3 |
| Manganese | mg/l | Max 0.1 | Max 0.5 |
| Calcium | mg/l | Max 100 | Max 150 |
| magnesium | mg/l | Max 100 | Max 100 |
| Sodium | mg/l | Max 200 | Max 200 |
| Pottasium | mg/l | Max 50 | - |
| TotalHardness | mgCaCO3/l | Max 500 | Max 300 |
| TotalAlkalinity | mgCaCO3/l | Max 500 | - |
| Chloride | mg/l | Max 250 | Max 250 |
| Flouride | mg/l | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | Max 10 | - |
| nitrite | mgN/l | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | Max 450 | Max 400 |
| FreeCarbonDioxide | mg/l | - | - |
| TotalDissolvedSolids | mg/l | Max 1500 | Max 1000 |
| Arsenic | ug/l | Max 10 | Max 10 |

(Source: KEBS, 2007)

This study therefore focused on the key chemical parameters specifically pH, TDS, Color, Turbidity, Conductivity, Total hardness, Total alkalinity, Fluoride and Iron since ground water is the preference in the study area. The chemical content standards for ground water are as illustrated in table 2.2 above.

Biological Content: The water should be free from any disease-causing microbes as well as any harmful microbial organisms.

### 2.5 Conceptual Model

Groundwater quality influences sustainable water utilization as well as safe water availability. Figure 2.1 shows the variable relationship between the groundwater quality in the Yatta plateau and the various factors that affect it among them climate, geology, hydrology, water abstraction and land use.

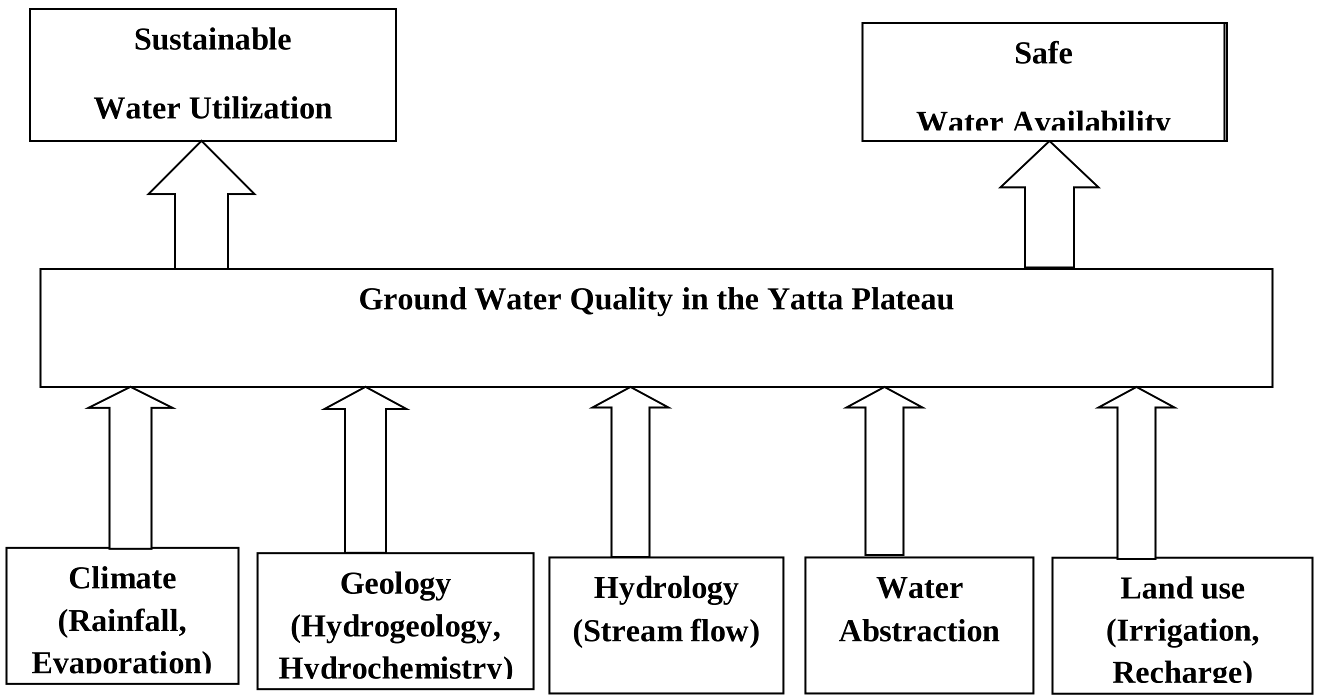


**Figure 1.1: Schematic diagram showing variable relationship**

(Source: Author, 2016.)

# CHAPTER THREE

# DESCRIPTION OF THE STUDY AREA

## 3.1 Introduction

Description of the study area allows for clear understanding of the various hydrological, geological, cultural, socio-economic and population dynamics in the study area. This chapter therefore provides details on the location, topography, geology, climate, land use, vegetation, population dynamics and socio-economic activities of the study area. The chapter was prepared using data and information derived from various published and unpublished sources.

## 3.2 Location of the study area

The Study area is the Yatta plateau found in the Lower Yatta Sub county of Kitui in Eastern Kenya. The location of the study area in relation to Kenya is also shown (Figures 3.1 and 3.2).

The Yatta plateau in Kenya traverses parts of Kitui County occupying most parts of Lower Yatta Sub County (Figure 5). The Sub County is situated in the western part of Kitui County defined by latitudes $-1.50^0$ and – $1.85^0$ and longitudes $37.75^0$ and $37.95^0$. The area falls within medium potential areas of Kitui and it experiences poor rainfall distribution which leads to low agricultural production and low income levels (GOK, 2002). The study area covers a surface area of 1176.8 $Km^2$. Athi river runs parallel to the Sub County on the western side. The plateau is therefore sandwiched between two rivers (Tiva River and Athi River) which are approximately 15km apart on average. Apart from ground water sources, the two rivers therefore are the main alternative water sources for the communities living on the plateau. However the distances to the water sources (the two rivers) are prohibitive.

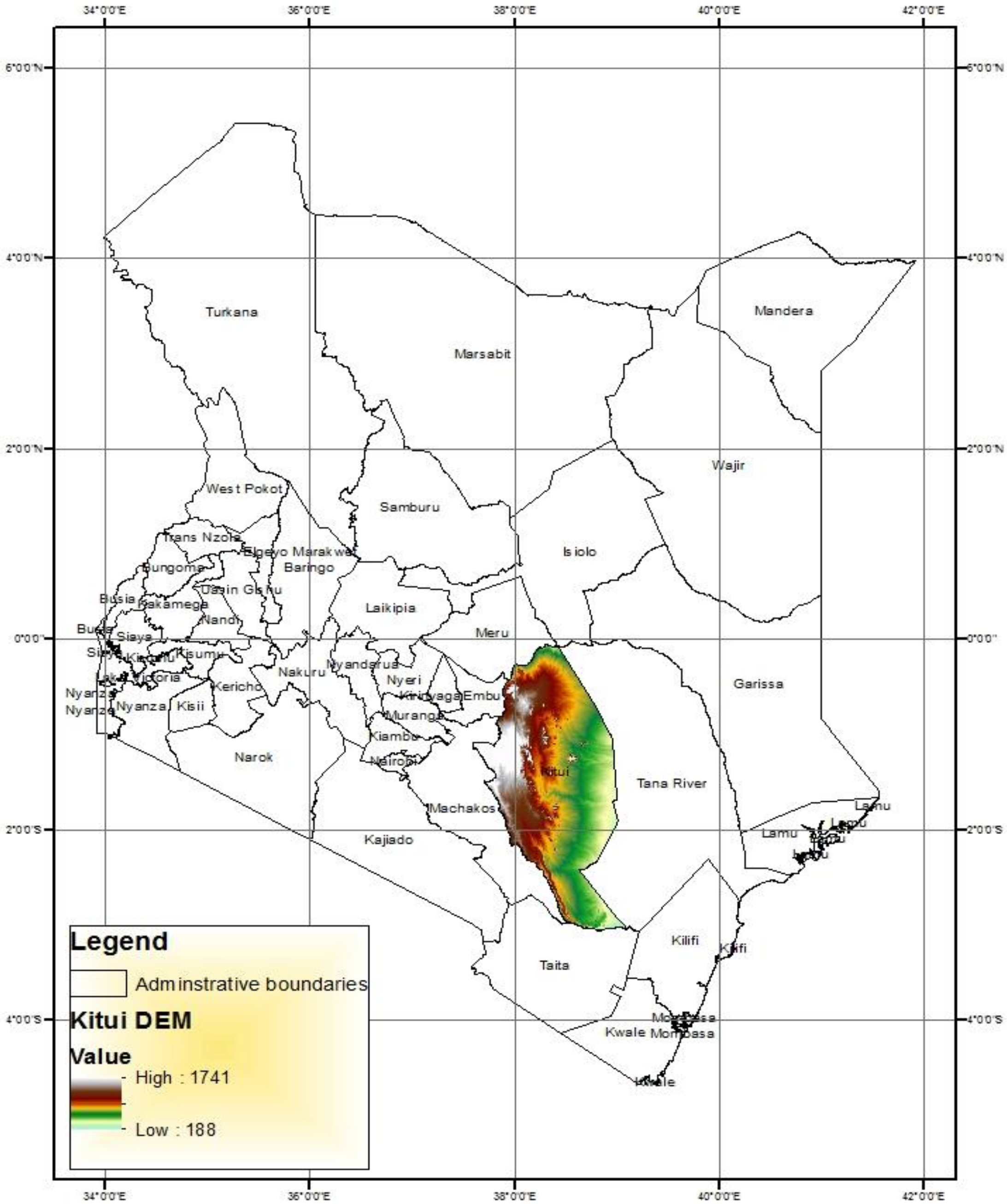


**Figure 2.1: The Location of the study area in Kenya.**

(Source: Author, 2016)

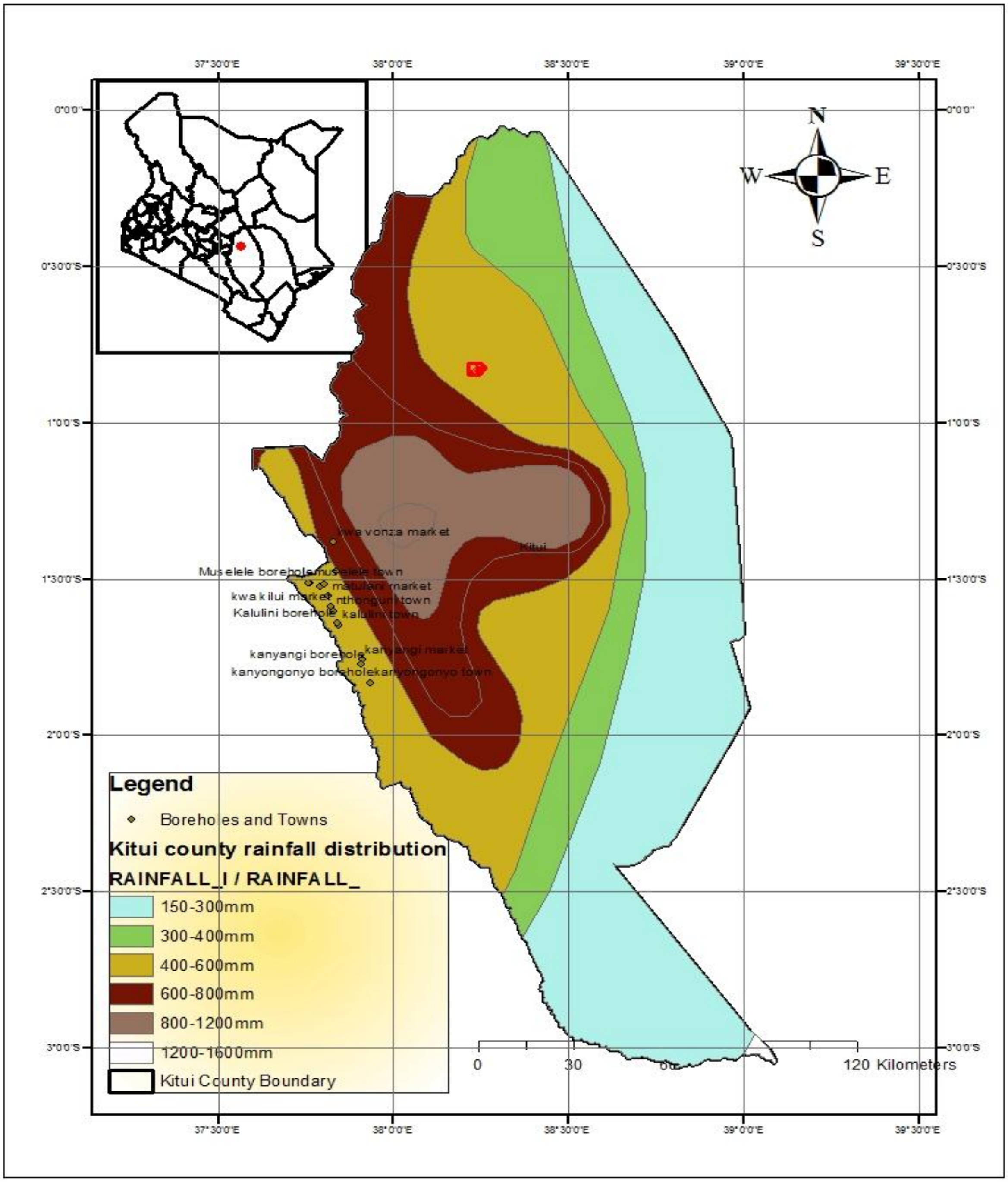


Figure 3.2: The Location of the Yatta Plateau-the study area in Kenya.

(Source: Author, 2016)

### 3.3 Topography

The attitude of the Yatta Plateau in Kitui County ranges between 1100m and 1200m above sea level (Wichura, 2011). According to KICDP (2014), the study area is characterised by wide shallow spaced valleys. It slopes gently towards Tiva River while steep slopes are witnessed westwards towards Athi River. The thickness of the Yatta phonolites from the basement contact to the flow-top remnants ranges from 12 to 25m (Wichura, 2011). Wichura further argues that the average width of the plateau is estimated to be 3km and along the eroded top of the flow, there is an average gradient of 2.8m/km. Figure 3.3 shows the topography of the Yatta plateau.

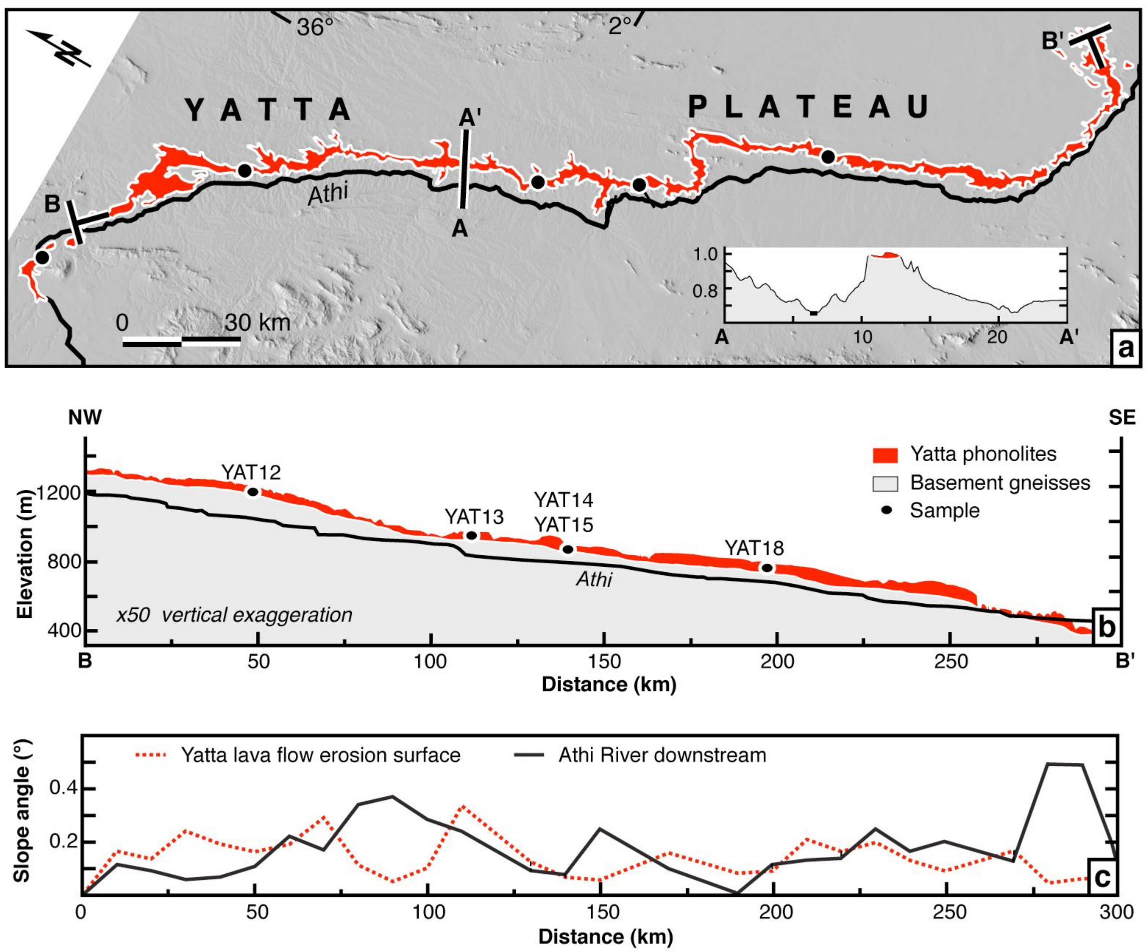


Figure 3.3: Topography of the Yatta Plateau

(Source: Wichura, 2011)

### 3.4 Hydrology and drainage

The Yatta plateau is drained by one perennial river and two seasonal rivers namely Athi, Tiva and Mwitasyano respectively. Athi river is fed by tributaries emanating from the Aberdare ranges in Central Kenya. Tiva river is fed by Mwitasyano among other small tributaries generated accumulation of water surpluses in the upland regions. Mwitasyano River originates from the overflow of the Yatta canal. There are only six boreholes presently located on the study area. Figure 3.4 shows the hydrology and drainage pattern of the study area.

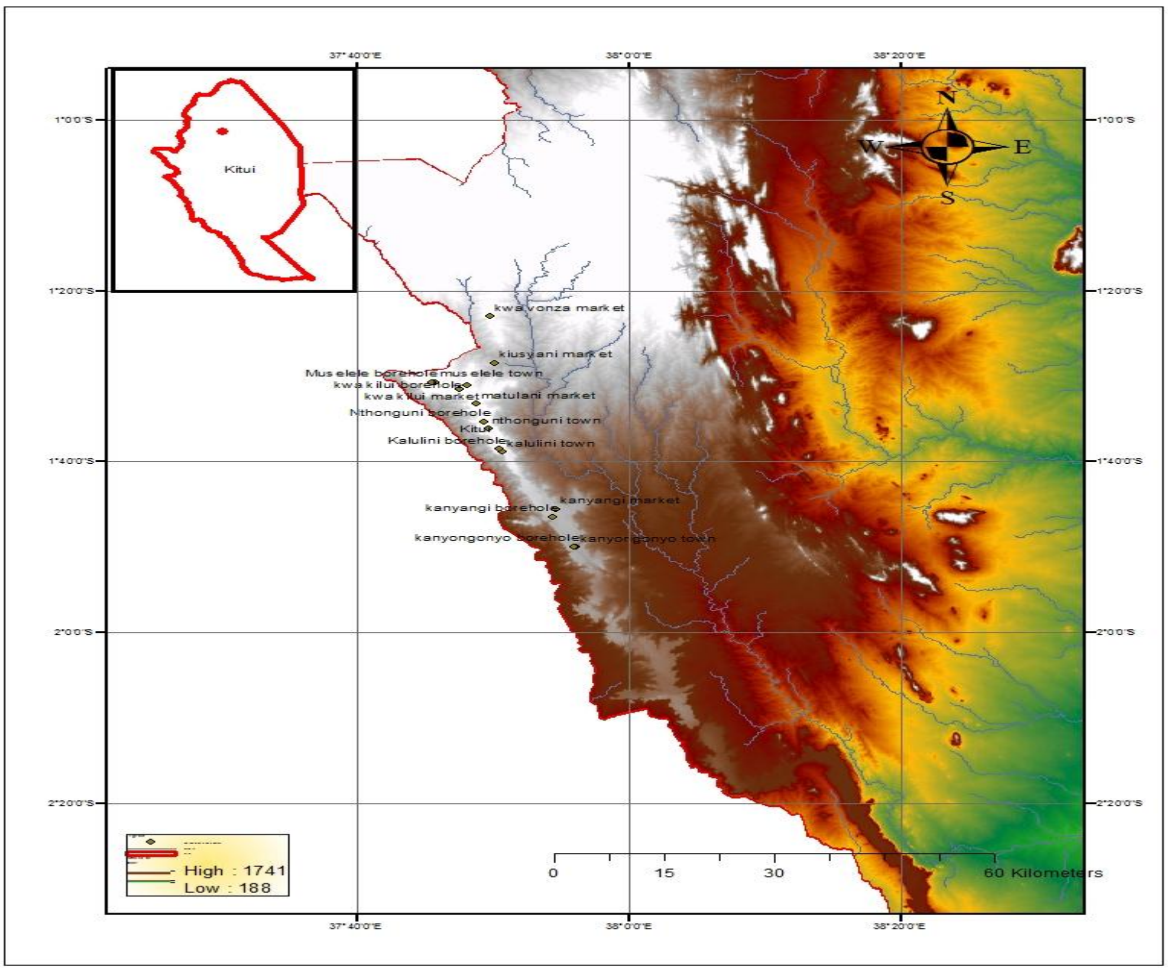


Figure 3.4: Drainage of the Yatta plateau

(Source: Author, 2016)

## 3.5 Geology

The Yatta plateau was formed 11-13.6 million years ago by a stream of lava flow of phonolite finding its way into an ancient river valley (web Kenya, 2003). The surrounding land was lowered by erosion leaving the lava standing up as a small escarpment of approximately 300km long with an average width of 10km. Geodynamic and magmatic activity in the East African Rift System initiated between 45 and 35 million years ago by the buoyancy and melt generation of an asthenospheric plume beneath the present EAP (Ebinger et al., 1993). This resulted in widespread phonolites, basalts, and trachytes erupting over Proterozoic basement rocks since 20 million years ago (Smith, 1994).

The Yatta lava flow was the most prominent manifestation of the major phonolitic eruption at 13.51 million years ago (Veldkamp et al., 2007). Likely, it originated in a region that now corresponds to the eastern Kenya Rift flank and flowed 300 km through the ancient Athi River valley toward the southeast. In contrast to other important volcanics, the Yatta Plateau flow was channelized and is regarded as one of the longest lava flows on Earth. Subsequent down wearing of the basement rocks confining the flow and the low erodibility of the phonolites have caused relief inversion and thus formed the Yatta Plateau. Early estimates of the slope of the Yatta lava flow based on field mapping and simple topographic considerations suggested a minimum slope angle of 0.16° (Saggerson, 1963). The presently observable thickness of the Yatta Plateau phonolites from the basement contact to flow-top remnants is 12-25 m. Individual volcanoes display three principal magmatic suites: (i) nephelinitic; (ii) alkali basaltic; (iii) transitional basaltic. However, some large volcanoes contain more than one of these suites implying that parental magmas of variable alkalinity were available at certain times and places.

The plateau is flat topped thereby posing challenges in surface water storage. Figure 3.5 shows the geology of the Lower Yatta plateau where the study was conducted.

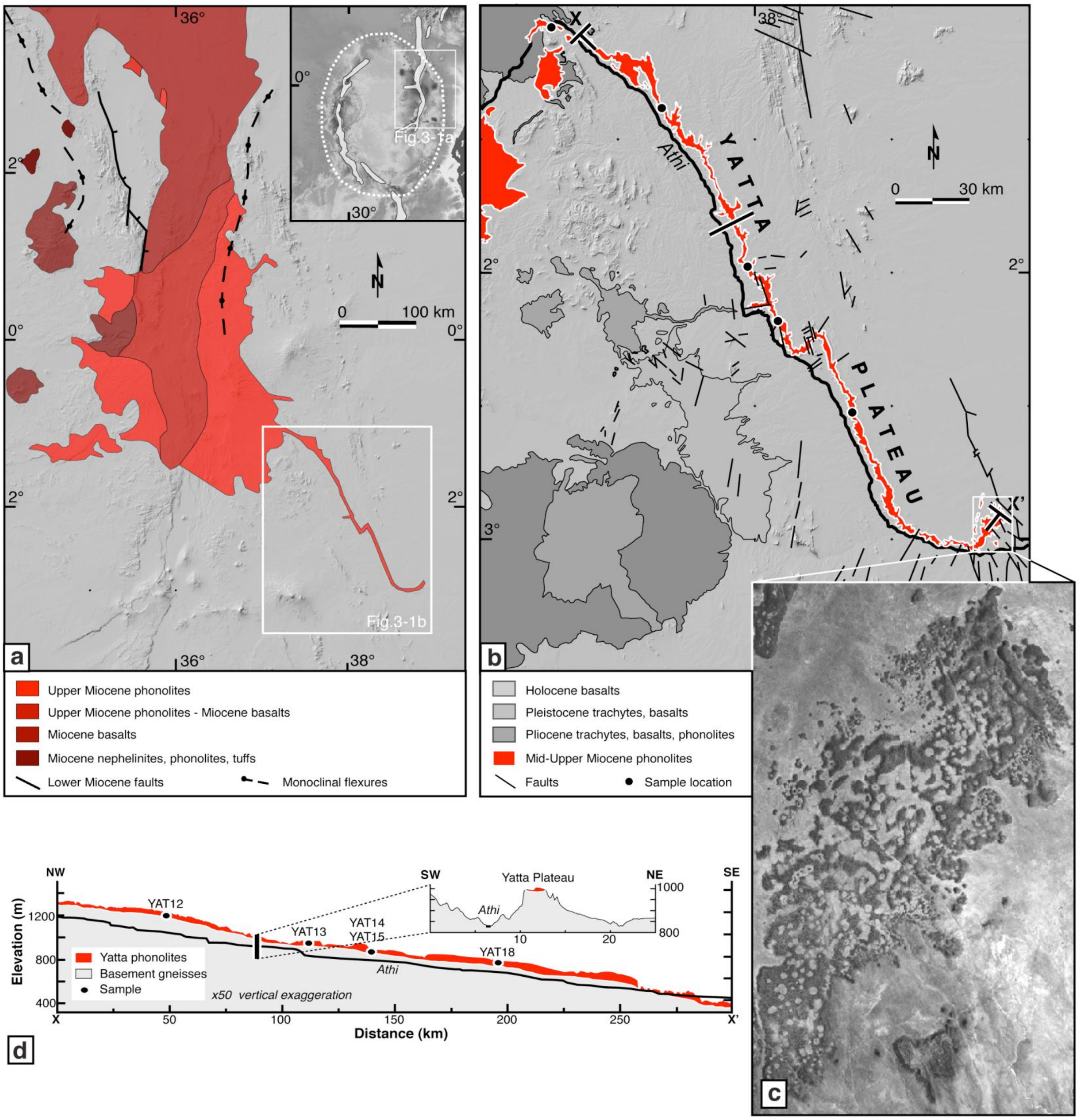


Figure 3.5: Map showing the extent and geology of the Yatta plateau.

(Source: Wichura, 2011)

### 3.6 Climate

The climate of Yatta plateau in Kitui County is hot and dry with unreliable rainfall (Kitui CIDP Report, 2014). The plateau experiences temperatures ranging from 14°C to 34°C throughout the year. The hot months are between September and October and from January to February. The maximum mean annual temperature ranges between 26°C and 34°C whereas the minimum mean annual temperature ranges between 14°C and 22°C (Kitui CIDP Report, 2014). July is the coldest month with temperatures falling to a low of 14°C while the month of September is normally the hottest with temperature rising to a high of 34°C (Kitui CIDP Report, 2014). The climate, therefore, falls under two climatic zones, arid and semi-arid, with most of the plateau being classified as arid. Figures 3.6, 3.7 and 3.8 show the rainfall distribution for Kitui county, location of the rainfall stations in Kitui County and finally the rainfall distribution for the Yatta plateau respectively.

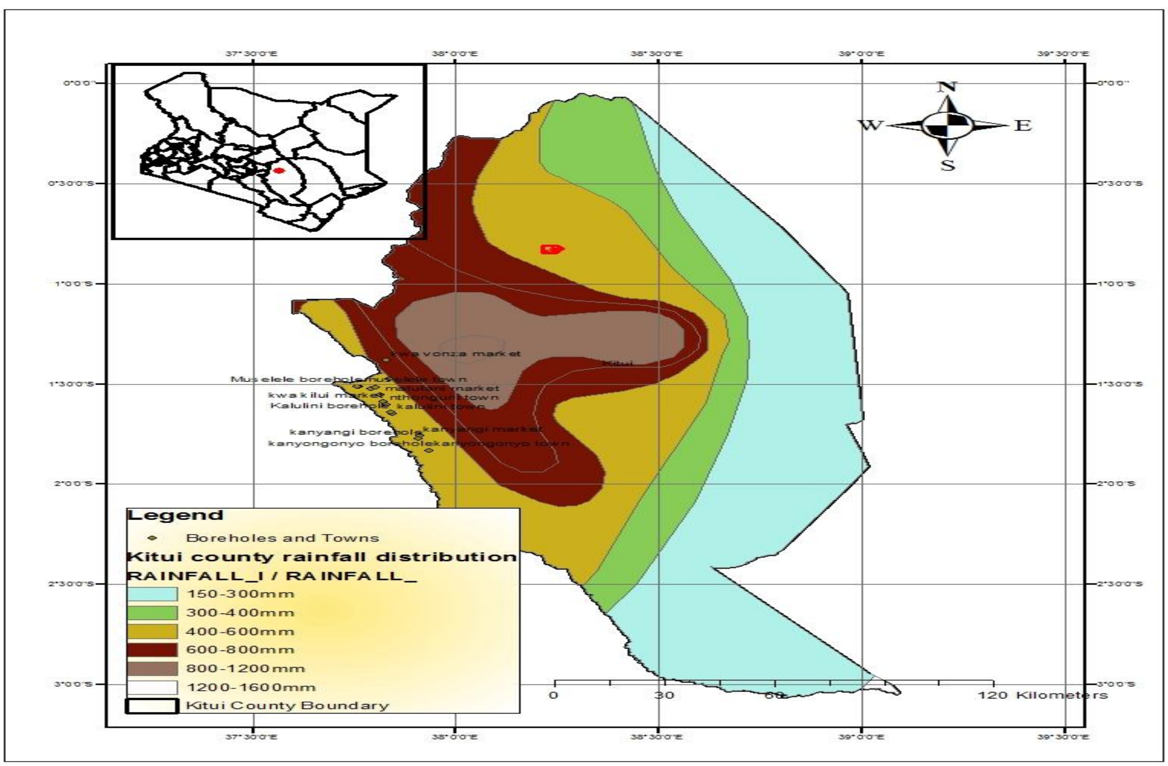


Figure 3.6: Rainfall distribution in Kitui County. **Source: (Author, 2016)**

Due to the high temperatures experienced in the Yatta plateau throughout the year, the rate of evaporation is high with a mean annual potential evaporation in the plateau ranging between 1800 to 2400mm per annum. The rainfall pattern is bi-modal with two rainy seasons annually. The long rains fall in the months of March to May. These are usually very erratic and unreliable. The short rains which form the second rainy season fall between October and December and are more reliable (Kitui CIDP Report, 2014). The rest of the year is dry and the annual rainfall ranges between 250mm-1050 mm per annum with 40% reliability for the long rains and 66% reliability for the short rains. Rainfall is highly unpredictable from year to year.

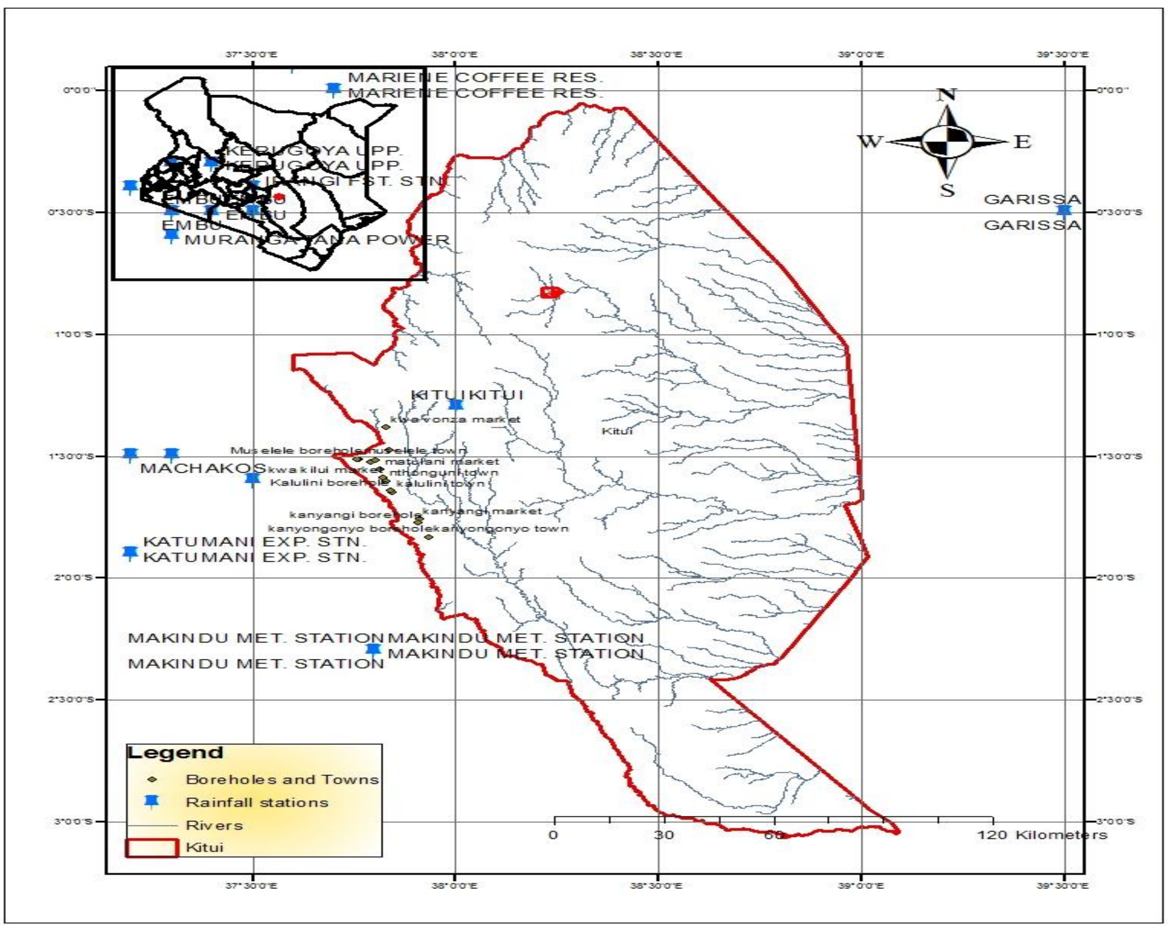


Figure 3.7: Rainfall stations in Kitui County. Source: (Author, 2016)

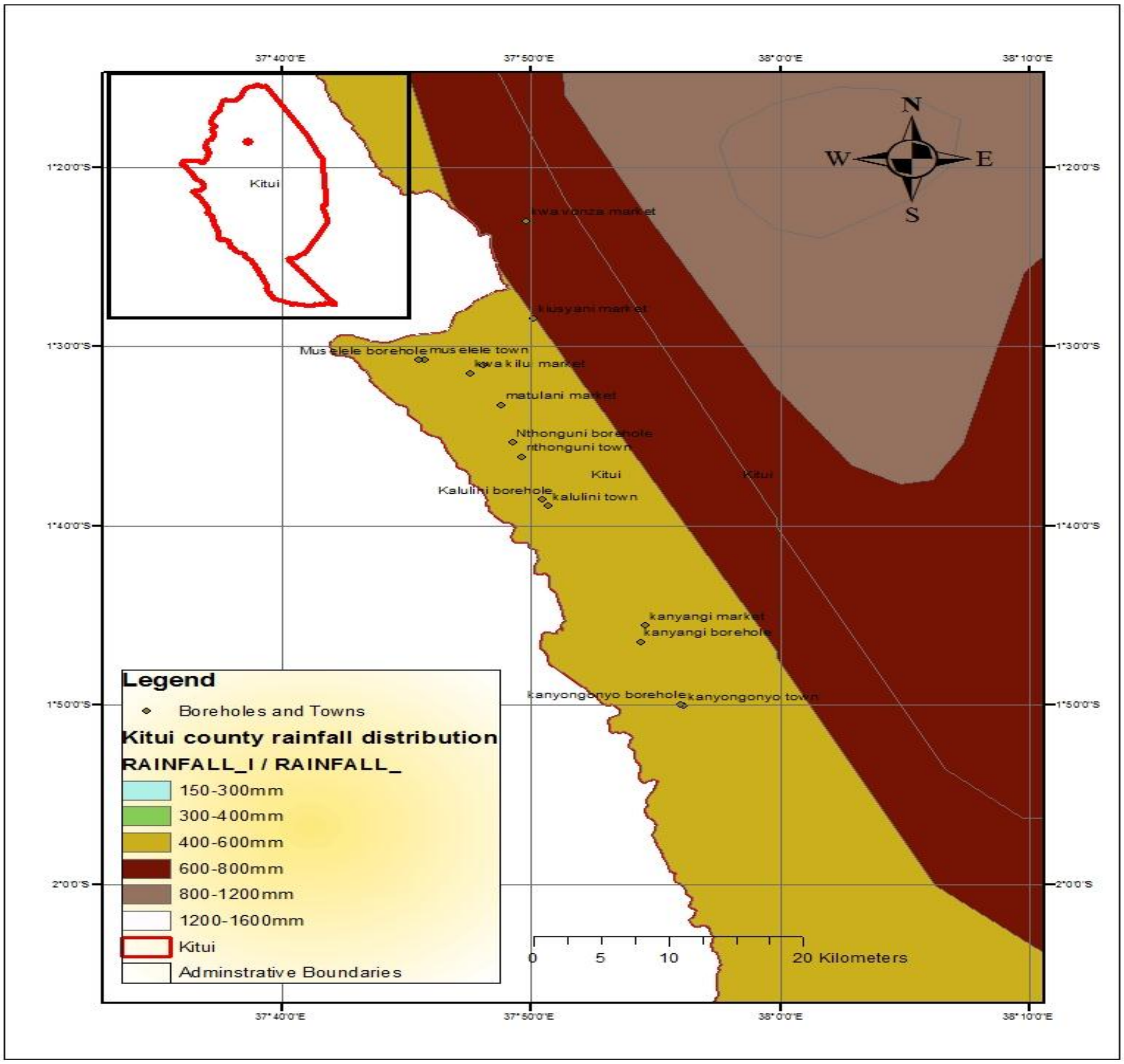


Figure 3.8: Rainfall distribution of the Yatta plateau.

(Source: Author, 2016)

### 3.7 Land Use

Most of households in the Yatta Plateau practice mixed farming and free range livestock rearing. According to KCP (2016), large scale farming is practiced in the study area. In crop farming most farmers apply organic manure on farms; application of fertilizers is limited to few farmers who practice horticulture along river beds (GoK, 2014). The resident communities on the plateau therefore, practice traditional farming and rarely use chemical fertilizers on their farms. Figure 3.9 shows the different types of land use within the study area. The major part of the study area is characterized by bush land. The area also has small trading centers such as Muselele, Kwa Kilui, Nthongoni, Kanyagi and Kanyongonyo near where the respective boreholes are located.

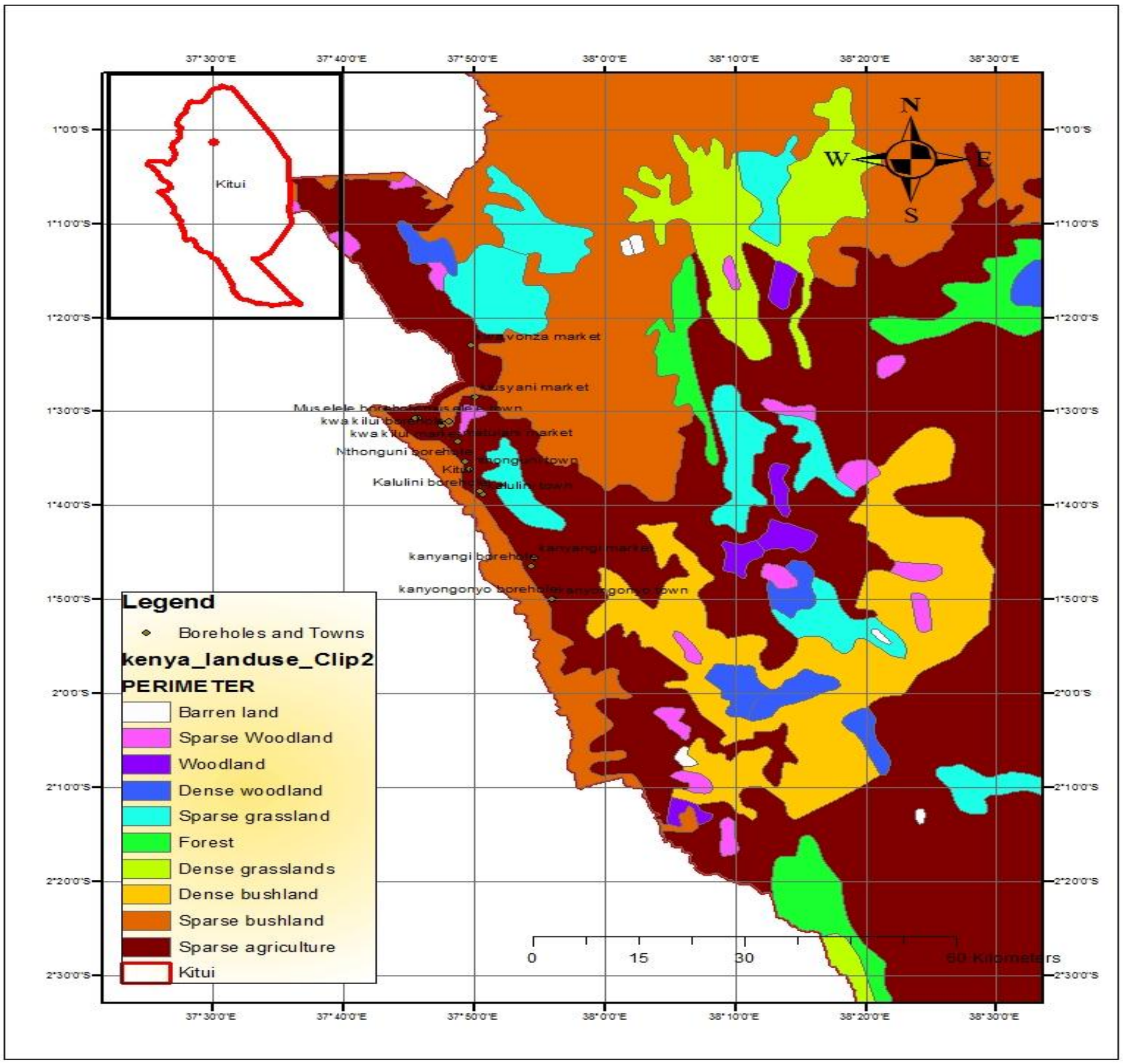


Figure 3.9: Different types of Land use in the Yatta plateau

(Source: Author, 2016)

### 3.8 Vegetation

The Yatta plateau covered by dense and sparse bush land in places where there is no cultivation and areas occupied by settlements. The few forests in the plateau produce a variety of products such as poles, timber, fuel wood, wood posts, charcoal, herbal products, wood for carvings, animal fodder and honey. However, the exploitation of some of these products have had adverse impacts on the environment. Good example is in the case of charcoal burning which should be regulated to avoid destruction of vegetation and consequently drought (Kitui CIDP Report, 2014). The clearing of existing forest cover due to increasing population to create space for settlement and crop production, in Yatta plateau has contributed to sparse bush land (Figure 3.9).

### 3.9 Population

Lower Yatta is sparsely populated with a total population of 30,732 persons which is made up of 15,046 males and 15,686 females. This number is located within an area of 757.40 Km$^2$ and is comprised of 6,674 households (Table 3.1). The Population in the study area is characterized by a mean population density of 41 persons per square kilometer. According to Maguma, (2014), the most densely populated area in Kitui County is Kitui town with an average density of 208 persons per km$^2$ while other parts of the county have low density of 25 persons per km$^2$. The mean population density in the study area is therefore low compared to that of Kitui town. Population dynamics forms an integral part of socio-economic and cultural development in Kitui County (KCP, 2016).

**Table 3.1: Population for Lower Yatta Sub-county**

| LOCATION | SUB LOCATION | MALE | FEMALE | 2009 POPULATION | HHs | Area in Sq Km | Density |
|---|---|---|---|---|---|---|---|
| | | **15,046** | **15,686** | **30,732** | **6,674** | **757.40** | **41.00** |
| Kwa Vonza | | 5,789 | 5,537 | 11,326 | 2,780 | 457.40 | 25.00 |

| LOCATION | SUB LOCATION | MALE | FEMALE | 2009 POPULATION | HHs | Area in Sq Km | Density |
|---|---|---|---|---|---|---|---|
| | Kanyoonyoo | 2,115 | 1,723 | 3,838 | 1,070 | 309.30 | 12.00 |
| | Mikuyuni | 3,674 | 3,814 | 7,488 | 1,710 | 148.10 | 51.00 |
| Yatta | | 5,856 | 6,354 | 12,210 | 2,509 | 188.80 | 65.00 |
| | Makusya | 2,110 | 2,122 | 4,232 | 901 | 65.40 | 65.00 |
| | Ilika | 1,603 | 1,909 | 3,512 | 663 | 58.90 | 60.00 |
| | Ndunguni | 978 | 1,090 | 2,068 | 444 | 31.40 | 66.00 |
| | Nyaanyaa | 1,165 | 1,233 | 2,398 | 501 | 33.10 | 72.00 |
| Nthongoni | | 3,401 | 3,795 | 7,196 | 1,385 | 111.20 | 65.00 |
| | Kawongo/ Kathome | 2,178 | 2,399 | 4,577 | 863 | 74.40 | 62.00 |
| | Muvitha/ Kathemboni | 1,223 | 1,396 | 2,619 | 522 | 36.80 | 71.00 |
| | | **10,804** | **11,290** | **22,094** | **4,328** | **418.70** | **53.00** |
| Kanyongonyo | | 2,432 | 2,466 | 4,898 | 902 | 96.30 | 51.00 |
| | Nzambia | 1,016 | 1,080 | 2,096 | 401 | 31.30 | 67.00 |
| | Kanyongonyo | 1,416 | 1,386 | 2,802 | 501 | 65.00 | 43.00 |
| Kanyangi | | 6,870 | 7,335 | 14,205 | 2,903 | 214.20 | 66.00 |
| | Mandongoi | 2,254 | 2,509 | 4,763 | 981 | 59.90 | 80.00 |

| LOCATION | SUB LOCATION | MALE | FEMALE | 2009 POPULATION | HHs | Area in Sq Km | Density |
|---|---|---|---|---|---|---|---|
| | Syomunyu | 2,758 | 2,898 | 5,656 | 1,137 | 88.20 | 64.00 |
| | Masimba | 1,858 | 1,928 | 3,786 | 785 | 66.10 | 57.00 |
| Kiseuni | | 1,502 | 1,489 | 2,991 | 523 | 108.20 | 28.00 |
| | Kiseuni | 973 | 977 | 1,950 | 341 | 57.30 | 34.00 |
| | Kathiani | 529 | 512 | 1,041 | 182 | 50.90 | 20.00 |

(Source: KNBS Kitui Regional Office, 2016)

### 3.10 Socio-Economic Activities

Yatta plateau is one of the highlands of Kitui County that receive relatively higher rainfall as compared to other parts of Kitui. This therefore influences the socio-economic activities in the area. The local community practice agriculture for subsistence and some commercial farming. The main crops include maize, beans, green grams and to a lesser extend fruits. However, apart from the agricultural activities, the local community also practices other types of commercial activities such as small scale business including hotels and local poultry keeping (KCP, 2016). Limited livestock keeping is also practiced. Those living near the two rivers (Tiva and Athi) that run on either sides of the plateau practice some horticultural farming. The plateau surface is characterized by the presence of loose phonolitic rocks that form high quality construction ballast. The ballast is used in construction activities in the market centers found in the study area and Kitui town.

# CHAPTER FOUR

# RESEARCH METHODOLOGY

## 4.1 Introduction

This chapter presents the methodology that was applied in the study. This includes the data collection and water sampling methods, the frequency of sampling and the data analysis methods applied in the study. The formulation of the methodology of the study was based on similar methods applied elsewhere. The methods are described in the following sections.

## 4.2 Research Design

The study involved a field survey of six (6) boreholes located on the Yatta plateau in Lower Yatta Sub County of Kitui County. It covered key groundwater parameters specifically pH, TDS, Colour, Turbidity, Conductivity, Total hardness, Total alkalinity, Fluoride, and Iron. These parameters were used to define the ground water quality. The parameters are commonly measured and can be used as indicators of water quality in a water system (Langland and Cronin, 2003). Water samples were collected from each borehole during two dry and two wet seasons for laboratory tests.

A Questionnaire was also administered to respondents in each of the 6 boreholes to supplement water quality data. The sample size dictated the number of persons that were to be interviewed in the study area. The sample size used in the questionnaires was found through the use of the following formula (John, 2003):

$$n = \frac{z2pq}{d2} \text{ ……………………………………… Equation 1}$$

Where;

n= is research minimum desired sample size

z= is standard normal deviate at required confidence level. Correspond to (1.96)

p= 30%, is the proportion of the target population estimated to be aware of ground water quality in the Lower Yatta plateau.

q= is 1-p

d= margin of error (0.09)

$$n = \frac{1.96(1.96)\times 0.3(1-0.3)}{0.09(0.09)}$$

$$n = \frac{0.806736}{0.0081} = 99.597$$

$\approx$ 100 Persons

The sample size chosen was 100 persons and this was based on the above mentioned equation by John (2003). The formula is used based on some conditions which range from (1) the level of accuracy desired by the researcher, (2) when the research work is guided by a certain predetermined confidence interval and finally (3) if the actual population of the people in the area is unknown or not certain. However, for the results to be statistically significant, the sample size has to be more than 30 persons (Mugenda, 1999). The respondents for the study were identified from water users of the Boreholes along the Lower Yatta plateau. The questionnaire covered certain indicators of water quality, notably; colour, odour and taste of the water.

## 4.3 Data collection

### 4.3.1 Primary Data

Field Surveys were carried out in the study area particularly at the borehole sites in order to gather primary data. An observation of the activities which included opening and closing times, frequency of visits by water users and seasonal demands for the borehole water was undertaken on the sampling sites. The data collected during the field survey were recorded in notebooks. The target boreholes were located using GPS. The GPS coordinates were used to ascertain the spacing and spread of boreholes within the study area.

### 4.3.2 Secondary Data.

This is data that was obtained from existing records mainly from Governmental Institutions. Of essence was data from the water sector institutions including Tanathi Water Services Board (TAWSB) who have been implementing water projects in the area of study. Existing information from both WARMA and TANATHI WSB concerning the groundwater projects, their yields and Borehole profiles assisted in understanding the groundwater availability, quality and rock material encountered in the study area. Rainfall Data during the entire period of study was of essence in this study. This data was sourced from The Kenya Meteorological Department (KMD). Information pertaining to the population and population increase in the target area was also obtained from the Kenya National Bureau of Statistics Offices in Kitui. Data on ground water abstraction rates were obtained from records of various water supply projects established in the area.

## 4.4 Water sampling

Water Samples were collected during dry and rainy season. The samples were analyzed at WARMA Laboratory in Nairobi. A total of 24 samples were collected from the six boreholes in the Yatta plateau (Figure 4.1).


Figure 4.1: Location of the sampling sites in the study area. Source: (Author, 2016)

The Groundwater Samples were collected in 5-litre containers cleaned with water from same bore holes. In order to ensure correct representative samples are obtained, each sample was collected only after water has been pumped from the bore hole for at least 20 minutes. The samples were transported within the same day and not later than six hours for physicochemical Water Quality Assessment at the WARMA water testing laboratory using appropriate certified and acceptable international standard methods (APHA, 1998).

### 4.5 Frequency of Sampling

The ground water samples were collected between February 2015 and February 2016 covering two dry seasons and two wet seasons. The dry seasons are experienced during the months of January to March and June to September while the wet seasons occur during the long rains of April to May and the short rains of October to December. The samples were collected four times from each of the six respective boreholes translating to a total of 24 samples. Each collection comprised of 6 samples which were transported within the same day for testing in WARMA Laboratory in Nairobi. This avoided change in quality of collected samples. The GPS coordinates, depths of the boreholes, number of samples collected from each borehole and the distances of the boreholes with respect to Muselele borehole are shown in Table 4.1.

**Table 4.1: The Location characteristics of the Boreholes that were Sampled in the Yatta Plateau**

| Name of the borehole | GPS Co-ordinates | | Date Drilled | Depth (m) | No. of Samples collected | Distance (Km) |
|---|---|---|---|---|---|---|
| | Longitudes | Latitudes | | | | |
| Muselele | 37.75816 | -1.51297 | 31/08/2007 | 150 | 4 | 0 |
| Kwa- Kilui | 37.80107 | - | 12/08/2013 | 165 | 4 | 4.35 |

| | | | | | | |
|---|---|---|---|---|---|---|
| (Paul Makosa) | | 1.51782 | | | | |
| Nthongoni | 37.8209 | -1.58964 | 16/05/2014 | 182 | 4 | 13.05 |
| Kalulini (David Mwongela) | 37.84097 | -1.64295 | 12/09/2011 | 230 | 4 | 19.34 |
| Kanyangi | 37.90672 | -1.77496 | 21/10/1997 | 133 | 4 | 35.67 |
| Kanyongonyo | 37.93284 | -1.83288 | 09/07/2007 | 172 | 4 | 42.70 |
| **TOTALS** | | | | | 24 | |

Source: (Author, 2016)

## 4.6 Analysis of the Water Samples

### 4.6.1 Water Sample Tests

The methods adopted for Physico-chemical analysis in this study have been applied in various previous studies (e.g Thirupathaiah, et al., 2012 and Adetunde et al., 2011).

***(a)Physical Parameters***

The physical parameters were determined using certified international standard methods.

- Turbidity was determined using Nephelometric method (APHA, 1998) in which the sample were shaken vigorously and transferred into a sample cell to at least two thirds full. The sample cell was then placed in a turbidimeter for determination.
- Total Dissolved Solids (APHA, 1998). The TDS were measured directly using a TDS meter.

***(b) Chemical parameters***

Various methods were applied to analyze the chemical parameters in the laboratory among them (APHA, 1998) and (WHO, 2006). The methods included;

**(i)** Volumetric titration method (WHO, 2006).

Chemicals were analyzed by titration with a standardized titrant. The titration endpoint was identified by the development of color resulting from the reaction with an indicator, by the change of electrical potential or by the change of PH value.

**(ii)** Colorimetric method (WHO, 2006)

The intensity of colour of the coloured target chemical were measured .The optical absorbance were measured using light of suitable wavelength. The concentration was determined by means of calibration curve obtained using known concentrations of determinants. For ionic materials, the ion concentration was measured using an ion-selective electrode. The measured potential was proportional to the logarithm of the ion concentration.

**(iii)** The UV method (WHO, 2006).

This method is similar to colorimetric method except that UV light was used. Some organic compounds absorb UV light (wavelength 190-380nm) in proportion to their concentration. UV absorption is useful for qualitative estimation of organic substance, because a strong correlation may exist between UV absorption and organic carbon content.

**(iv)** Atomic absorption spectrophotometry (AAS) method (WHO, 2006)

This method was used to determine metals. It is based on the phenomenon that the atom on the ground state absorbs the light of wavelengths that are characteristic to each element when light is passed through the atoms in the vapor state. Because this absorption of light depends on the concentration of the atoms in the vapor, the concentration of target element in the water sample is determined from the measured absorbance. The Beer-Lambert Law describes the relationship between concentration and absorbance.

In this study, the following chemical parameters were therefore analyzed thus;

- The total alkalinity, total hardness and chloride concentrations were determined using titrimetric methods. Alkalinity was determined by titration of the 50mls water sample with 0.1m hydrochloric acid to PH 4.5 using methyl orange indicator.
- Total hardness was analyzed by titration of 50mls water sample with standard EDTA at PH 10 using Erichrome black T indicator.
- The Chloride content was determined using argentometric method where the sample will be titrated with standard silver nitrate using potassium chloride indicator.
- Iron, manganese and lead concentrations were determined using Unicam 969 Atomic Absorption Spectrophotometry (ASS).
- Calcium ions concentrations were determined using EDTA trimetric method.
- Sulphate ions concentration was analyzed using colorimetric method (APHA, 1998).

### 4.6.2 Statistical Data Analysis Methods

Various statistical data analysis methods were also used in the analysis of data. These included Measures of Central tendency, Regression Analysis, Correlation analysis, Analysis of variable (ANOVA) and Test of Hypothesis. These methods are described in more details in the following sections;

***(a) Measures of Central Tendency***

These measures are also referred to as statistical average, most popular being mean, median and mode. This method was used in Data Analysis from questionnaires.

**(i) Mean**

According to Kothari and Garg (2014), Mean is the common measure of central tendency and is obtained by dividing the total of the values of various items in a series by the total number of items as given by the following equation;

$$\bar{x} = \frac{\sum x_i}{n} = \frac{x_1 + x_2 + ....x_n}{n} \text{ ......................................Equation 2}$$

Where;

$\bar{x}$ is the arithmetic mean

$\sum$ is the arithmetic summation

$n$ is the total number of items

$X_i$ is value of the $i^{th}$ item

x, i = 1, 2,…$\boldsymbol{n}$

***(b) Regression Analysis***

The objective of regression analysis model is to study those changes in the values of dependent variable that are due to the changes in the value of independent variable. In this study Regression analysis was applied on the key physico-chemical parameters such as Total Hardness, total Alkalinity, Conductivity and TDS against abstraction rates and rainfall. The Regression Equation is presented as $Y = a + bx + e$…………………………………………...................Equation 3

Where;

Y = the value of the dependent variable (What was being predicted or explained)

$x$= the value independent variable (What is predicting or explaining the value of Y)

$\mathrm{a} = \mathrm{a\ constant\ that\ equals\ the\ value\ of\ Y\ when\ X\ is\ zero\ (0)}$

$\mathrm{b} = \mathrm{the\ coefficient\ of\ X\ \ (the\ slope\ of\ the\ regression\ line\ i.e. How\ much\ Y\ changes\ for\ each\ one-unit\ change\ in\ X)}$

$e = \mathrm{\ the\ error\ term\ predicting\ the\ value\ of\ Y\ given\ the\ value\ of\ X}$

***(c) Correlation Analysis***

The techniques associated with Correlation analysis are essentially those of predicting trends or of showing that no trend exists. It is a unit free measure of relationship between two variables and takes values [-1, +1] **(**Kothari and Garg, 2014). The Karl Pearson's coefficient of correlation (r) is not affected by change of scale or by change in location. When r is close to +1 (-1), there is a strong positive (Negative) relationship. In this study, Correlation analysis was used to determine whether there were relationships between particular key water quality parameters under investigation. It was also used to determine the relationship between the selected water quality parameters, rainfall and water abstraction rates.

The Karl Pearson's Coefficient of correlation between Variables X and Y is given by:

$$r = \frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

…………..……………………Equation 4

Where;

r = Karl Pearson's coefficient of correlation which shows the relation between different variables being tested.

x and y are random variables

***(d) Analysis of Variance (ANOVA)***

ANOVA was used in data analysis for questionnaires which were administered to the water users. Odor, color and taste were considered in the analysis and their means were tested. The basic principle of ANOVA is to test for differences among the means of the populations by examining the amount of variation within each of the samples, relative to the amount of variation between the samples (Kothari and Garg, 2014). While using ANOVA, it is assumed that each of the samples is drawn from a normal population and that each of the populations has the same variance. Using the two variances, the test statistic is defined as:

$$F_c = \frac{between\ samples\ mean}{within\ samples\ mean} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 5}$$

Where; Fc = the correlation factor.

***(c) Hypotheses Testing***

There were four hypotheses in this study which were objectively verified and tested. A hypothesis is a proposition or a set proposition set forth as an explanation for the occurrence of some special group of phenomena either asserted merely as a provisional conjunctive to guide some investigation or accepted as highly probable in the light of established facts (Kothari, 2014). The predictive statement, capable of being tested by scientific methods that relate to an independent variable to some dependent variable is considered as the Null Hypothesis. A conclusion rejecting the null hypothesis is known as alternative hypothesis.

In hypothesis testing, given a hypothesis $H_0$ and an alternative hypothesis $H_1$, we make a rule which is known as decision rule according to which we do not reject $H_0$ (reject $H_1$) or reject $H_0$ (do not reject $H_1$). There are three types of hypothesis given by;

i. $H_0 : \mu = \mu_0$ Against H1 :$\mu = \mu_0$ ……………………………………………Equation 6

ii. $H_0 : \mu = \mu_0$ Against Ha : $\mu > \mu_0$ Or $H_0 : u \leq \mu_0$ Against H1 : $\mu > \mu_0$… Equation 7

iii. $H_0 : \mu = \mu_0$ Against Ha : $\mu < \mu_0$ Or $H_0 : \geq \mu_0$ Against H1: $\mu < \mu_0$…… Equation 8

Where;

$\mu$= Population mean

$\mu_0$= Hypothesis mean

Based on the sign in alternative hypothesis **(±,>** or **<)** there are three different tests (i.e.) two tailed test, right-tailed test and left tailed test (Kothari, 2014).

The first hypothesis on spatial variation in ground water chemical parameters in the Yatta Plateau was verified through the use of Surfer models which were supported by key chemical parameter - time series graphs. The second hypothesis on whether there were short and long-term changes of ground water quality in the Yatta Plateau was tested using the ANOVA tool in SPSS which was supported by the chemical parameters – time series graphs. The third hypothesis on whether there exists a relationship between ground water chemical quality and rainfall in the Yatta Plateau was tested using the ANOVA tool in SPSS and supported by mean plots of the chemical parameters against rainfall. Finally in the fourth hypothesis on whether there was significant influence of ground water quality on water utilization in the Yatta Plateau, ANOVA tool in SPSS was used on the results from the administered questionnaire in regard to color, odor and taste.

# CHAPTER FIVE

# RESULTS OF THE STUDY

## 5.1 Introduction

This chapter presents the results of the study. The presentation of the results is focused on establishing the relationship between rainfall variability within the area of study and ground water quality among other factors. Presented also is the spatial temporal variability in water quality in the six boreholes that were studied. Finally the chapter presents the results of the analysis of the effects of groundwater chemical parameters on water utilization in the study area.

## 5.2 Rainfall variability

Rainfall is one of the most important factors that may influence ground water quality. The influence may occur through infiltration and subsequent percolation of rain water into the ground water aquifers. Figure 5.1 shows combined time series graphs for rainfall and other water quality parameters for the period between March 2015 and March 2016.

During the period of this study there were two wet seasons and two dry seasons. The wet seasons occurred in the period between April and May 2015 and also in the period between October and December 2015. On the other hand the dry seasons occurred in the period between June and September 2015 and from January to February 2016. During the wet season months of April to May 2015, the area received a maximum rainfall of 177.9mm while the mean monthly for the period was 134.45mm. During the wet season of October to November 2015 the area received a maximum rainfall of 313.7mm while the mean monthly for the period was 119.4mm. During the dry season months from June to September 2015 the maximum rainfall for the period was 6.7mm while the mean monthly rainfall for the period was 3.02mm. The time series (Figure 5.1a-c) shows the relationship between rainfall and water quality parameters which include TDS Electrical conductivity and, pH.

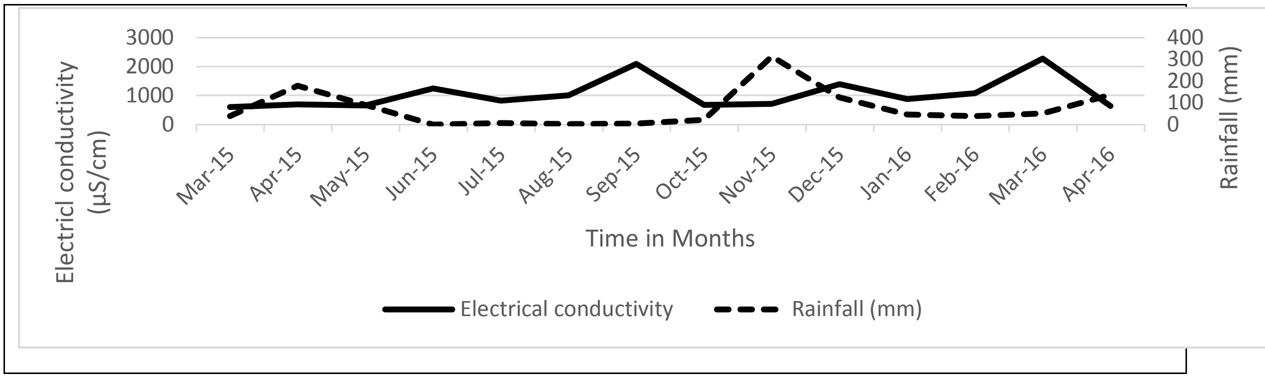


Figure 5.1 (a): The variations of groundwater electrical conductivity as a function of rainfall in the period between March 2015 and March 2016

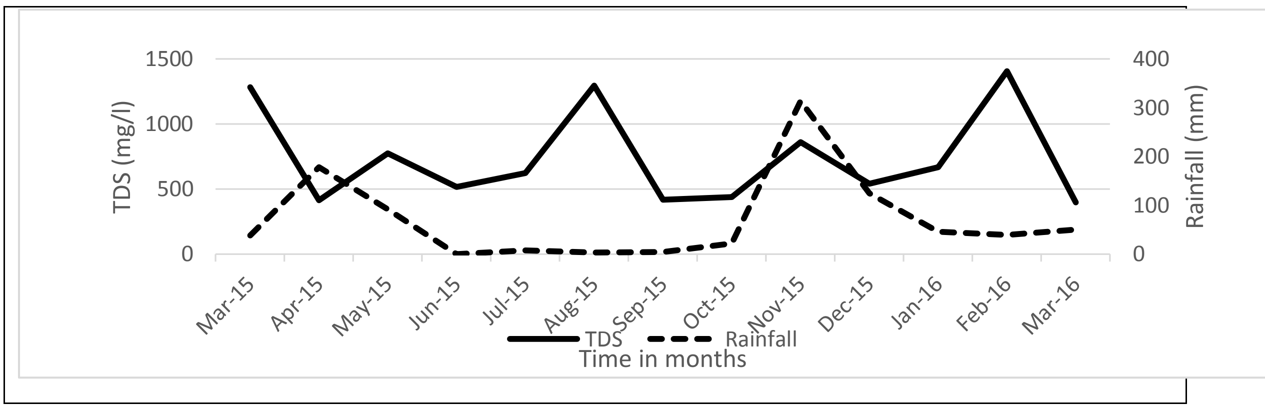


Figure 5.1 (b): The variations of groundwater TDS as a function of rainfall in the period between March 2015 and March 2016

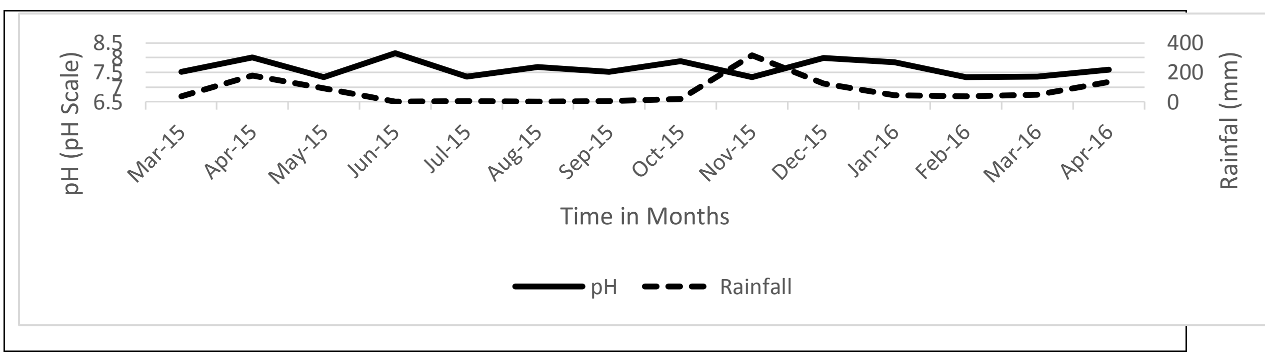


Figure 5.1(c): The variations of groundwater pH as a function of rainfall in the period between March 2015 and March 2016

Figure 5.13: Ground water variations as function of rainfall

## 5.3 Water abstraction

The abstraction of ground water was characterised by significant seasonal variations. The great abstraction rates reaching 150 $m^3$/day were recorded during the dry season at Kanyangi borehole. The wet seasons were generally characterised by relatively low abstraction rates ranging from 8 to 65 $m^3$/day at Kalulini and Kanyangi boreholes respectively. The highest yielding wells were found in the southern and central parts of the plateau while the northern parts yielded relatively lower volumes of ground water ranging from 2.5 to 2.8 $m^3$/hr. There was evidence of over abstraction of water at Kanyangi, Nthongoni and Kanyongonyo boreholes. The total water demand in the study area is 730 $m^3$/day while the ground water supply is 413 $m^3$/day which accounts for 57% of the demand.

The results in table 5.1 show the regression and correlation for selected water quality parameters against water abstraction rates during the sampling period. The table shows correlation values of 0.427, 0.375, 0.085 and 0.555 for turbidity, iron, fluoride and pH respectively. The graphs in figures 5.2 to 5.5 show the regression results for the selected water quality parameters against daily water abstraction during the sampling periods.

Table 4.1: Model summaries of regressions for different water quality parameters against water abstraction

**Model Summary for Turbidity**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .427 | .182 | .101 | 9.488 |

The independent variable is Water abstraction.

**Model Summary for Fluoride**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .085 | .007 | -.092 | .124 |

The independent variable is Water abstraction.

**Model Summary for pH**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .555 | .308 | .239 | .262 |

The independent variable is Water abstraction.

**Model Summary for Iron**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .375 | .141 | .055 | .118 |

The independent variable is Water abstraction.

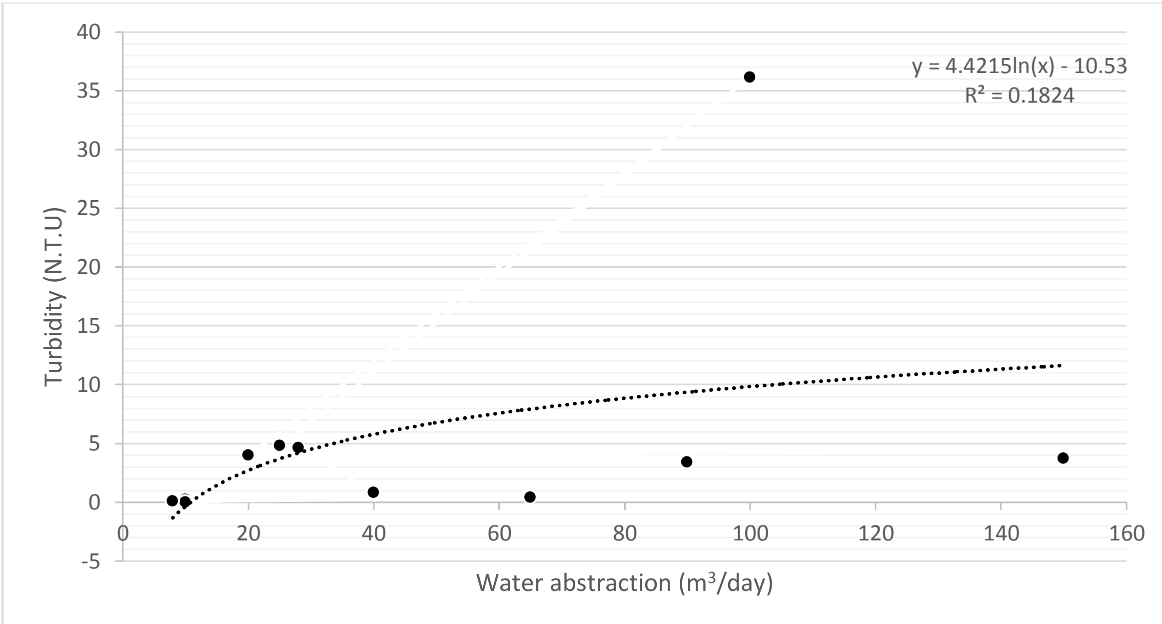


Figure 5.2: The relationship between groundwater turbidity and groundwater abstraction at the Yatta plateau.

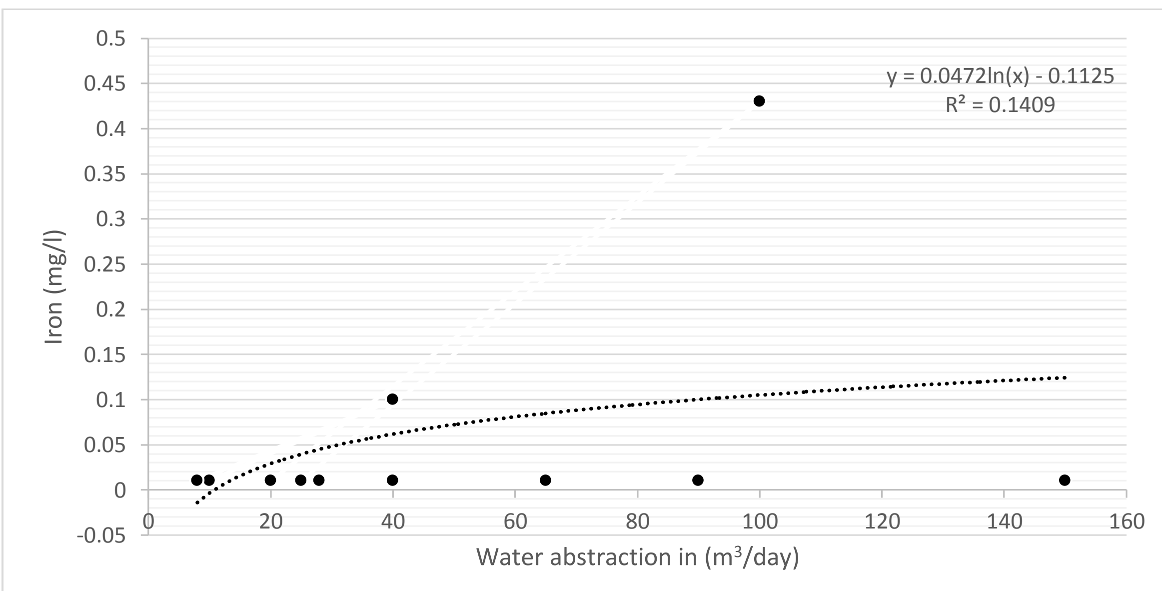


Figure 5.3: The relationship between groundwater iron concentration and groundwater abstraction at the Yatta Plateau

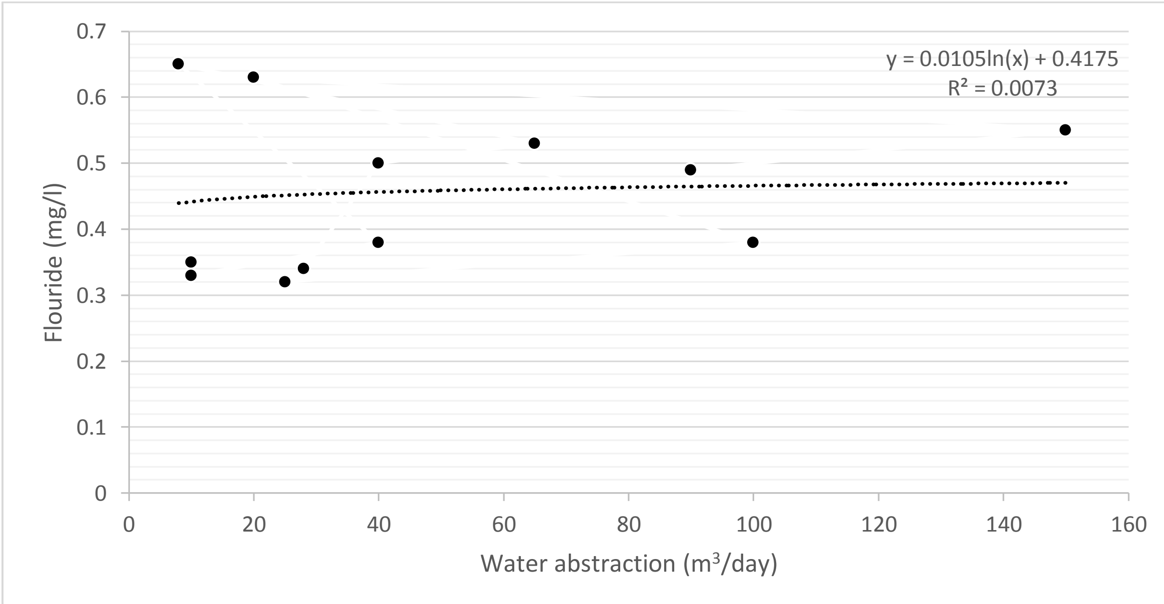


Figure 5.4: The relationship between groundwater Flouride concentration and groundwater abstraction at the Yatta Plateau

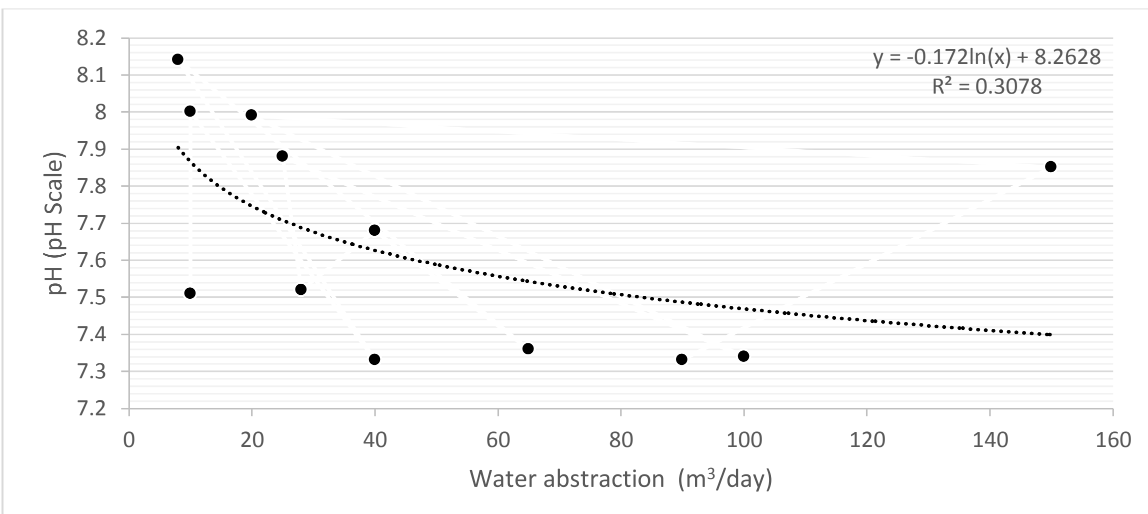


Figure 5.5: The relationship between pH and groundwater abstraction at the Yatta Plateau

## 5.4 Water quality variability

The key physical chemical parameters in the Yatta plateau were analysed in order to determine spatial and temporal variations. The analysed water quality parameters included pH, Electrical conductivity, Iron, Total alkalinity, TDS, Turbidity, Fluoride, Total hardness, Colour, Taste and Odour.

### 5.4.1 Spatial variability

#### 5.4.1.1 pH

The pH of ground water in the sampled boreholes was analyzed in order to determine spatial variation and results presented. Figures 5.6 and 5.7 show the spatial variation of pH at Muselele, Kwa Kilui, Nthongoni, Kalulini, Kanyangi and Kanyongonyo boreholes. The data from the figures were sampled in May 2015 and Agust 2016. In the Figures, the red color signifies the highest value for pH while the purple color signifies the lowest value. During the sampling period the highest value of pH occurred at Kalulini area during both wet and dry seasons as shown in figures. The lowest occurred at Nthongoni and Kanyongonyo areas for both wet and dry seasons. During the sampling period, the highest levels of pH ranging between 7.7 to 8 were recorded at Kalulini borehole while the lowest values ranging between 7.18 to 7.3 were recorded at Nthongoni and Kanyongonyo boreholes. The differences were attributed to the geological formations found in each specific aquifer of the boreholes.

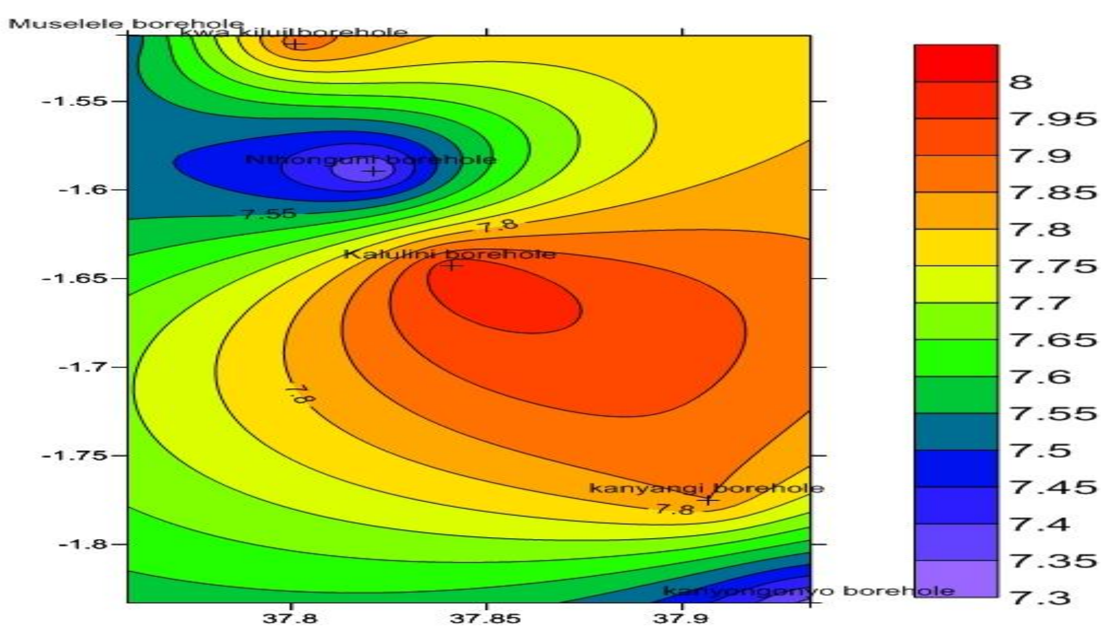


Figure 5.6: Spatial variations for pH during the wet period in May, 2015

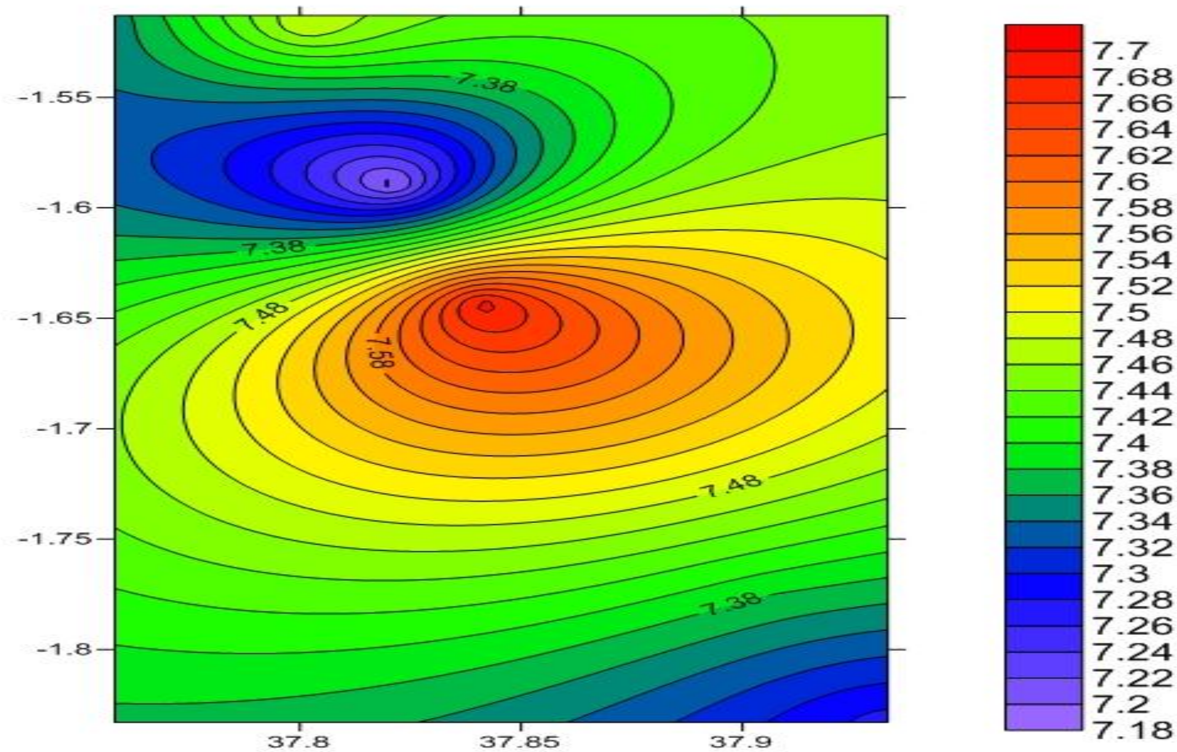


Figure 5.7: Spatial variations of pH during the dry period in August, 2015

#### 5.4.1.2 Electrical conductivity

Spatial variation in electrical conductivity in Yatta plateau is presented in Figures 5.8 and 5.9. The Figures show water quality data for electrical conductivity that was sampled from Muselele, Kwa Kilui, Nthongoni, Kalulini, and Kanyongonyo boreholes. The highest concentration of the electrical conductivity in the comparisons was recorded in Kanyongonyo borehole while the lowest concentrations were observed around Nthongoni borehole during both wet and dry periods. The difference in the electrical conductivity in the boreholes was attributed to the underlying geology where different chemical composition may dissolve the various anions and cations which in turn may affect the conductivity levels.

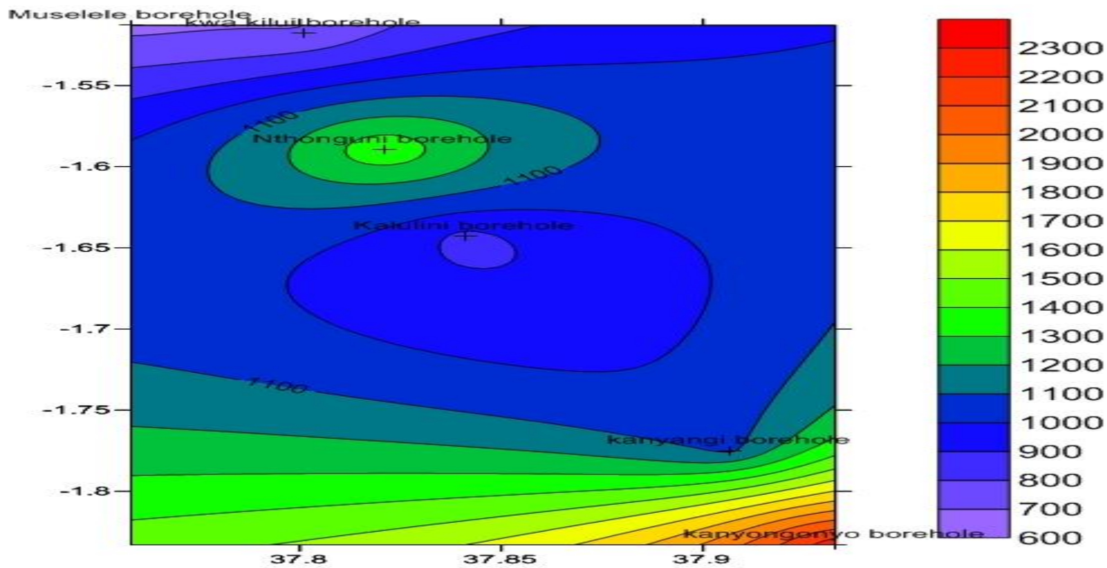


Figure 5.8: Spatial variation of Electrical Conductivity during the wet season of May, 2015

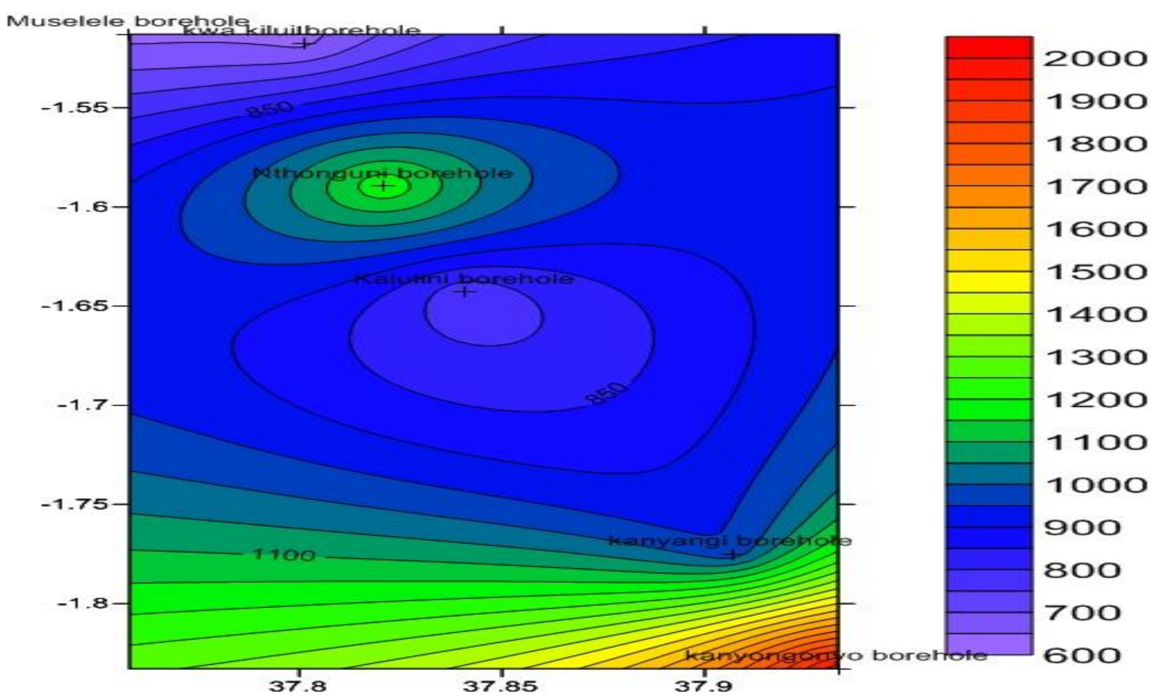


Figure 5.9: Spatial variation of Electrical Conductivity during the dry season of August 2015

### 5.4.1.3 Iron

Spatial variation for Iron is shown in Figures 5.10 and 5.11 for data sampled from the six boreholes in the study area. During the sampling period, it was noted that the highest values of Iron were at Nthongoni and decreased southwards with the lowest values of less than 0.01mg/l at Kanyongonyo borehole in both wet and dry seasons.

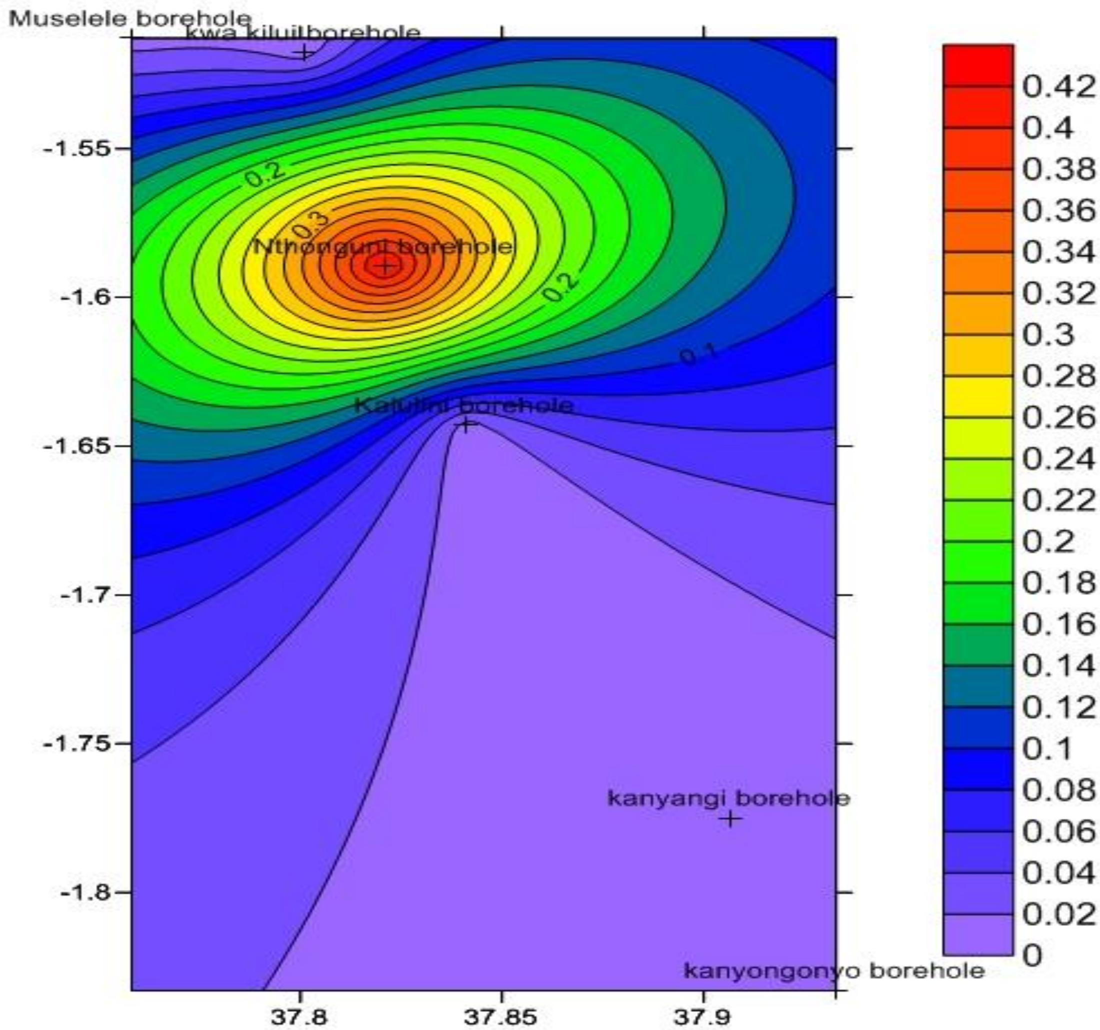


Figure 5.10: Spatial variations of Iron during the wet season in May, 2015

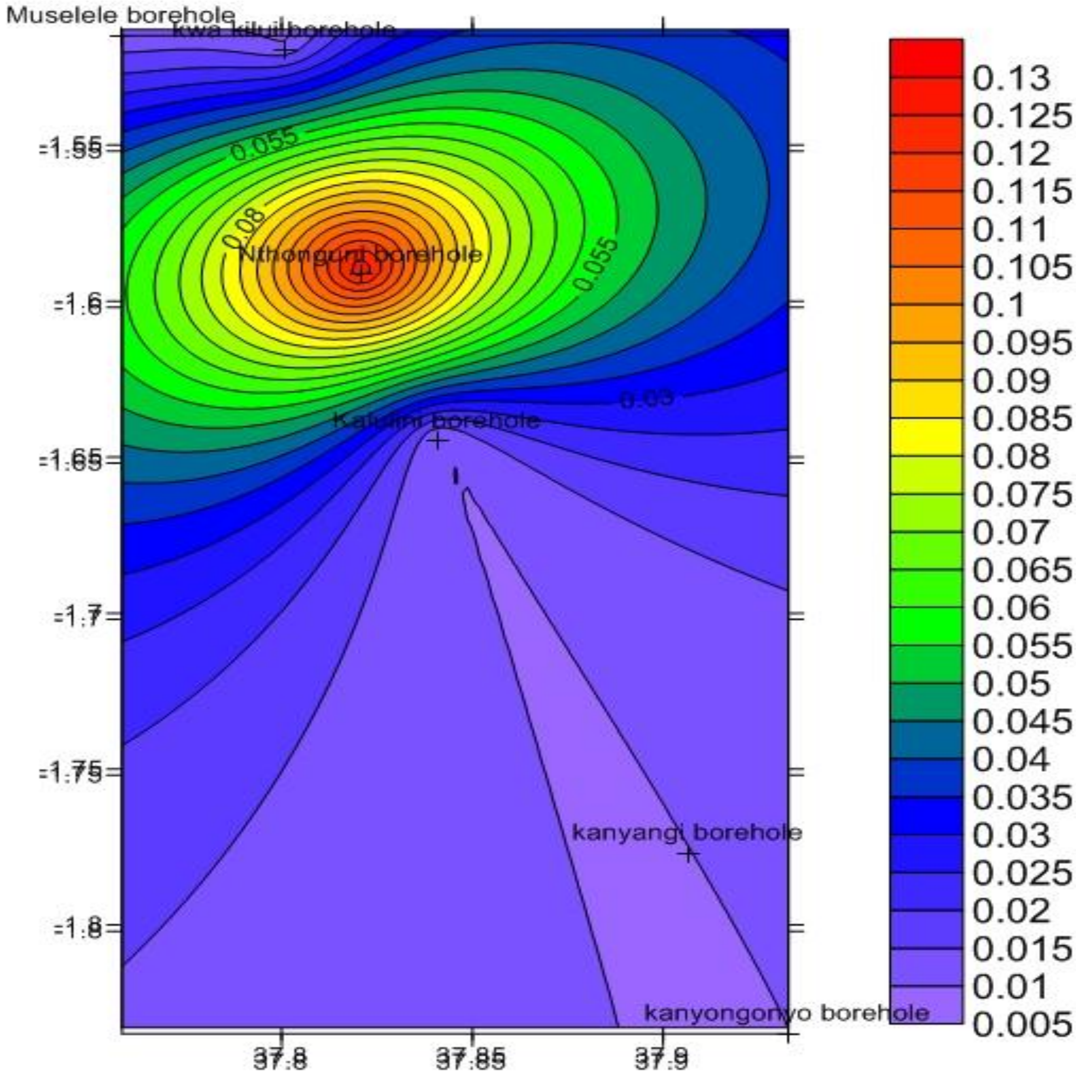


Figure 5.11: Spatial variations of Iron during the dry season in August, 2015

### 5.4.1.4 Total Alkalinity

The water quality data sampled from Muselele, Kwa Kilui, Nthongoni, Kalulini, Kanyangi and Kanyongonyo boreholes was analyzed for spatial variations of Total Alkalinity in both dry and wet periods. The results of the Total Alkalinity values for both wet and dry period are shown in Figure 5.12 and 5.13 respectively. The alkalinity is lowest northwards and increases southwards in both seasons.

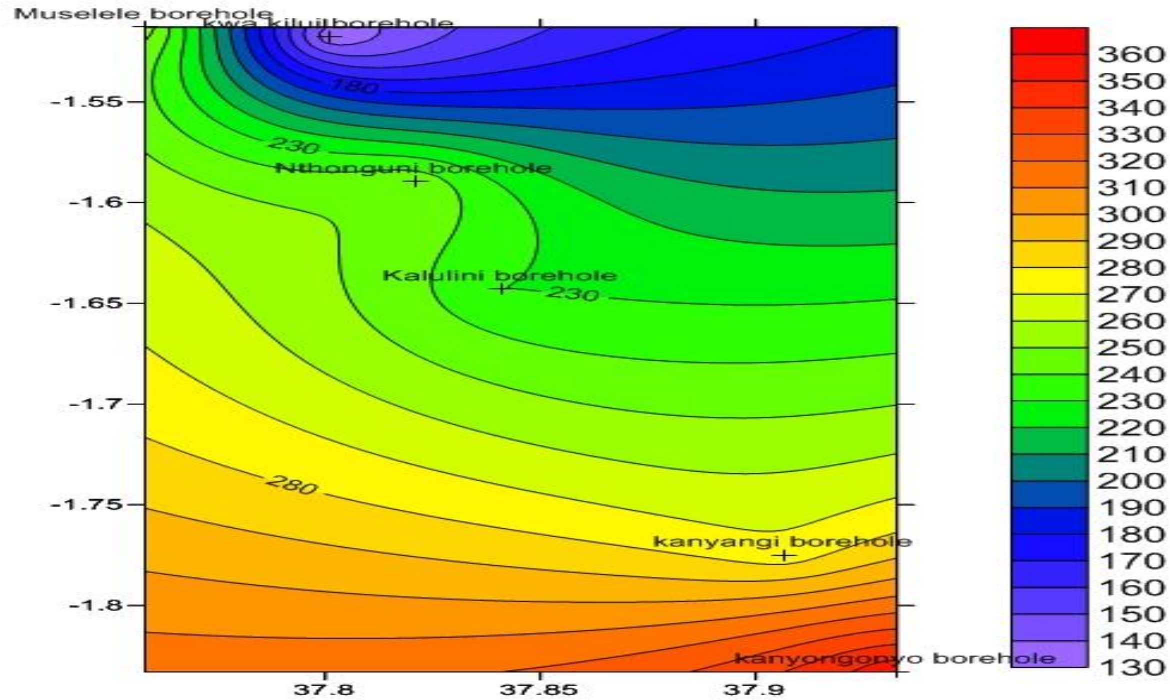


Figure 5.12: Spatial variation of Total Alkalinity during the wet season in May, 2015

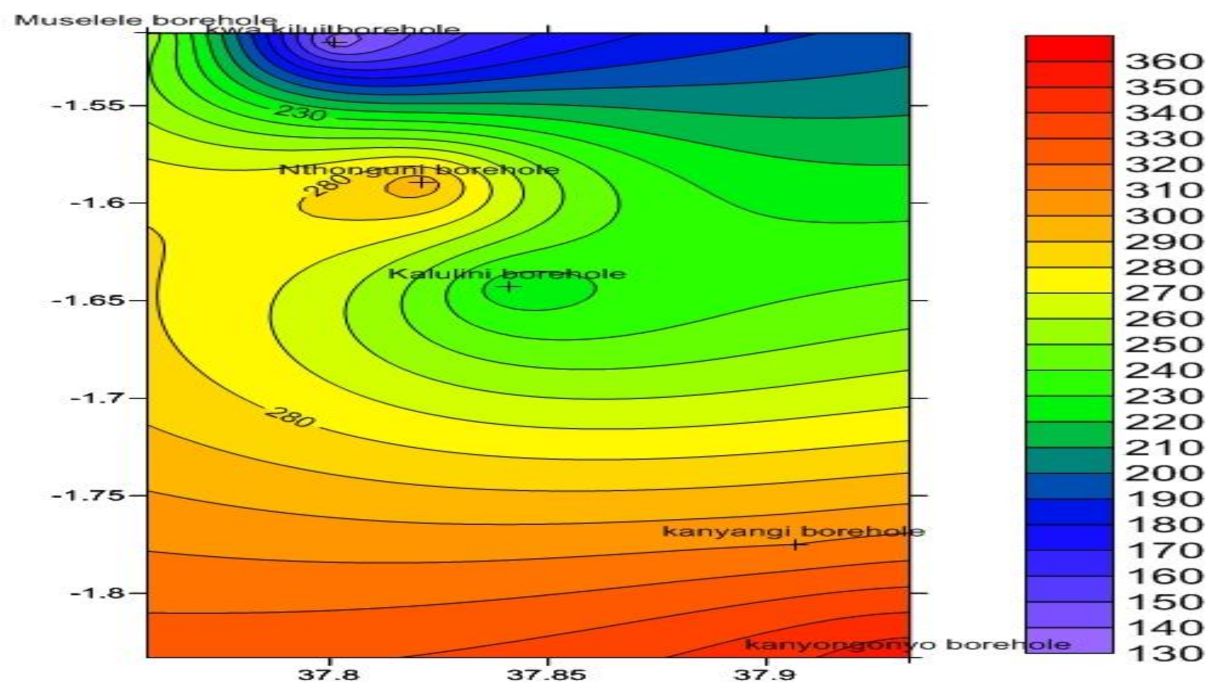


Figure 5.13: Spatial variation of Total Alkalinity during the wet season in August, 2015

### 5.4.1.5 TDS

The spatial variation models of water quality data for TDS that was sampled from the boreholes under study are shown in Figures 5.14 and 5.15. The figures show that the highest values of TDS were recorded at Kanyongonyo borehole and decreased northwards towards Kwa kilui borehole irrespective of the seasons.

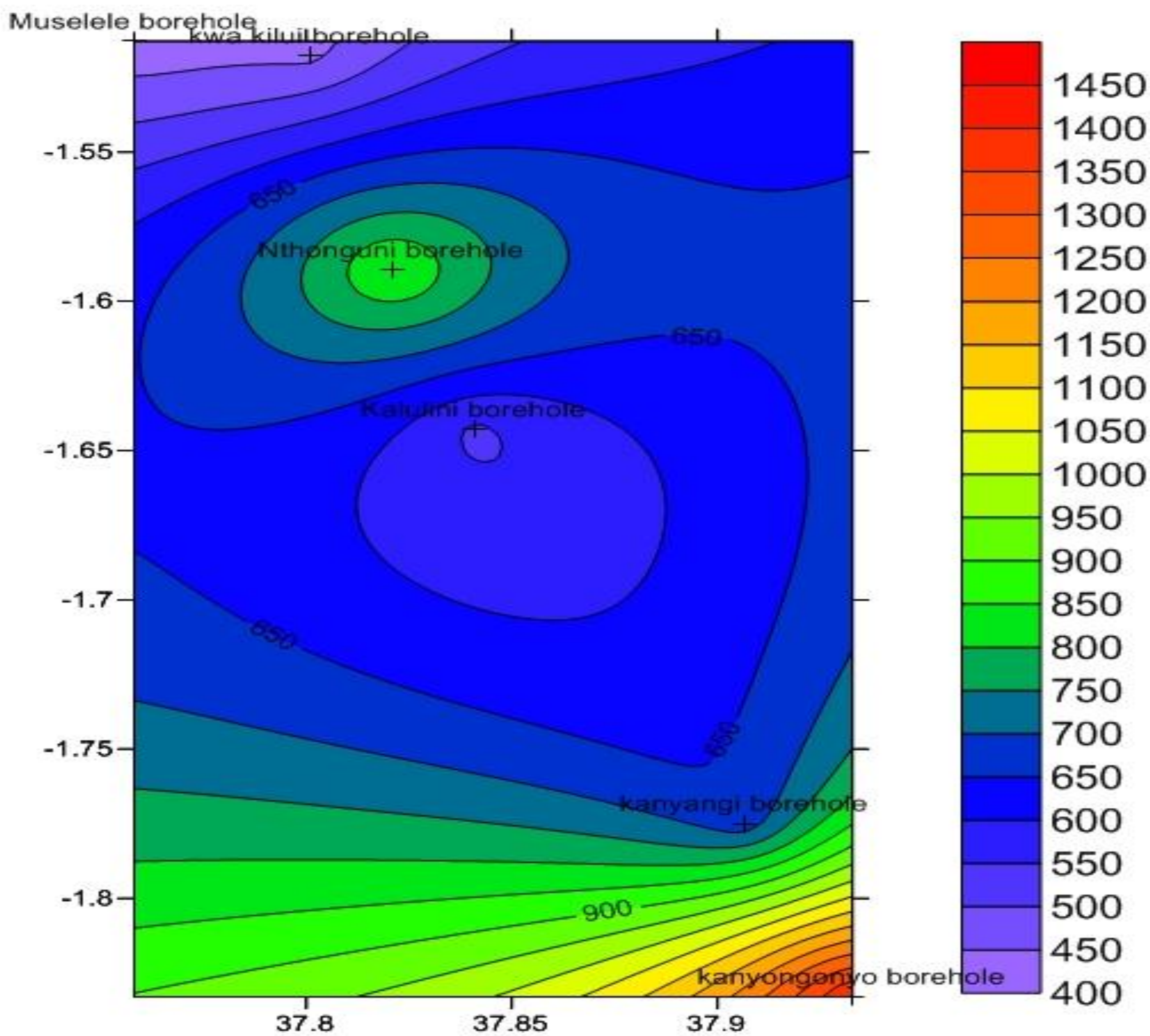


Figure 5.14: Spatial variation of TDS during the wet season in May, 2015

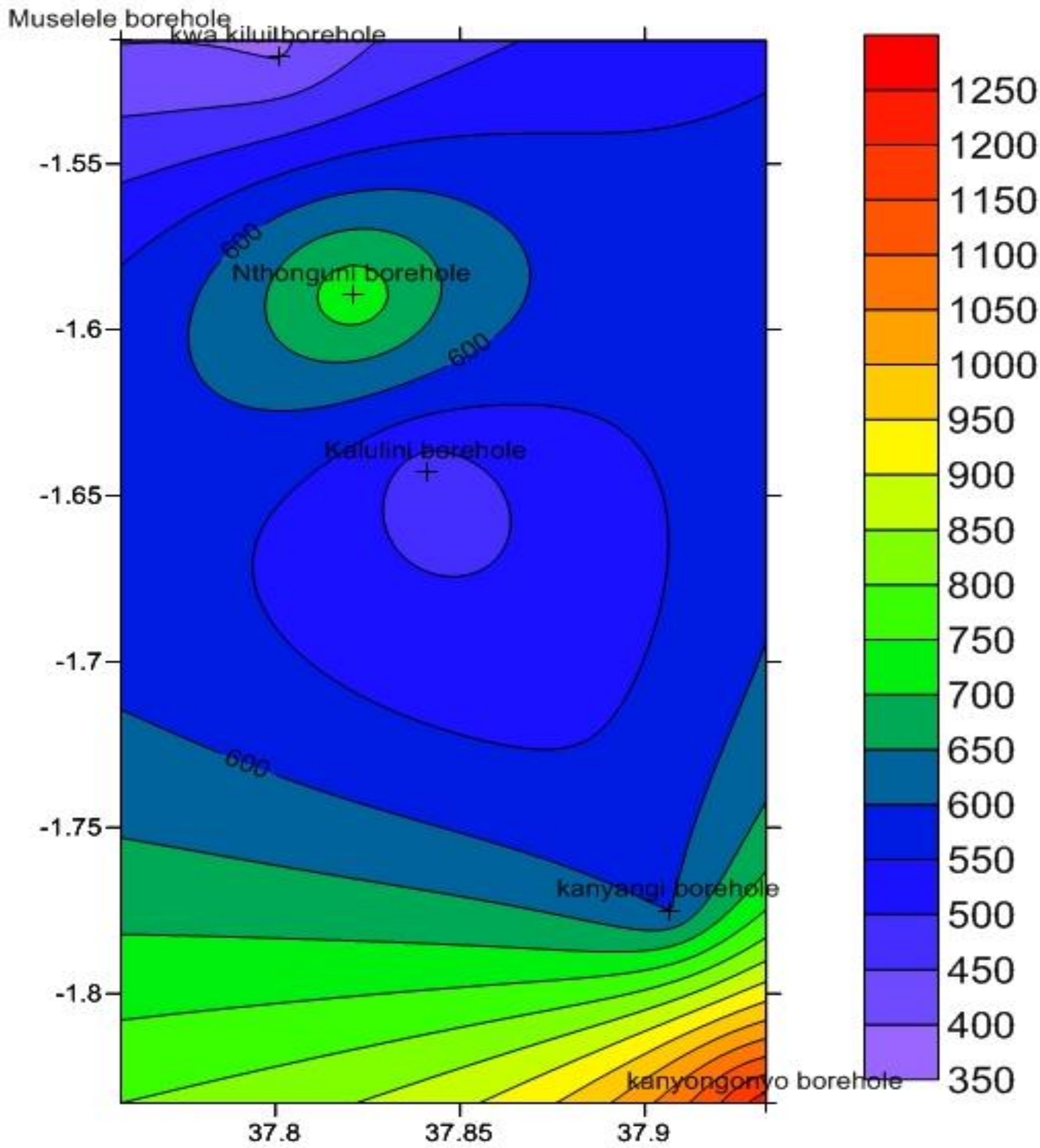


Figure 5.15: Spatial variation of TDS during the dry season in August, 2015

### 5.4.1.6 Turbidity

Figures 5.16 and 5.17 show results of data that was sampled during the wet season in May, 2015 and the dry season in August, 2015. The trend in the figures is that Nthongoni borehole has the highest turbidity regardless of the season and the turbidity decreases in all directions.

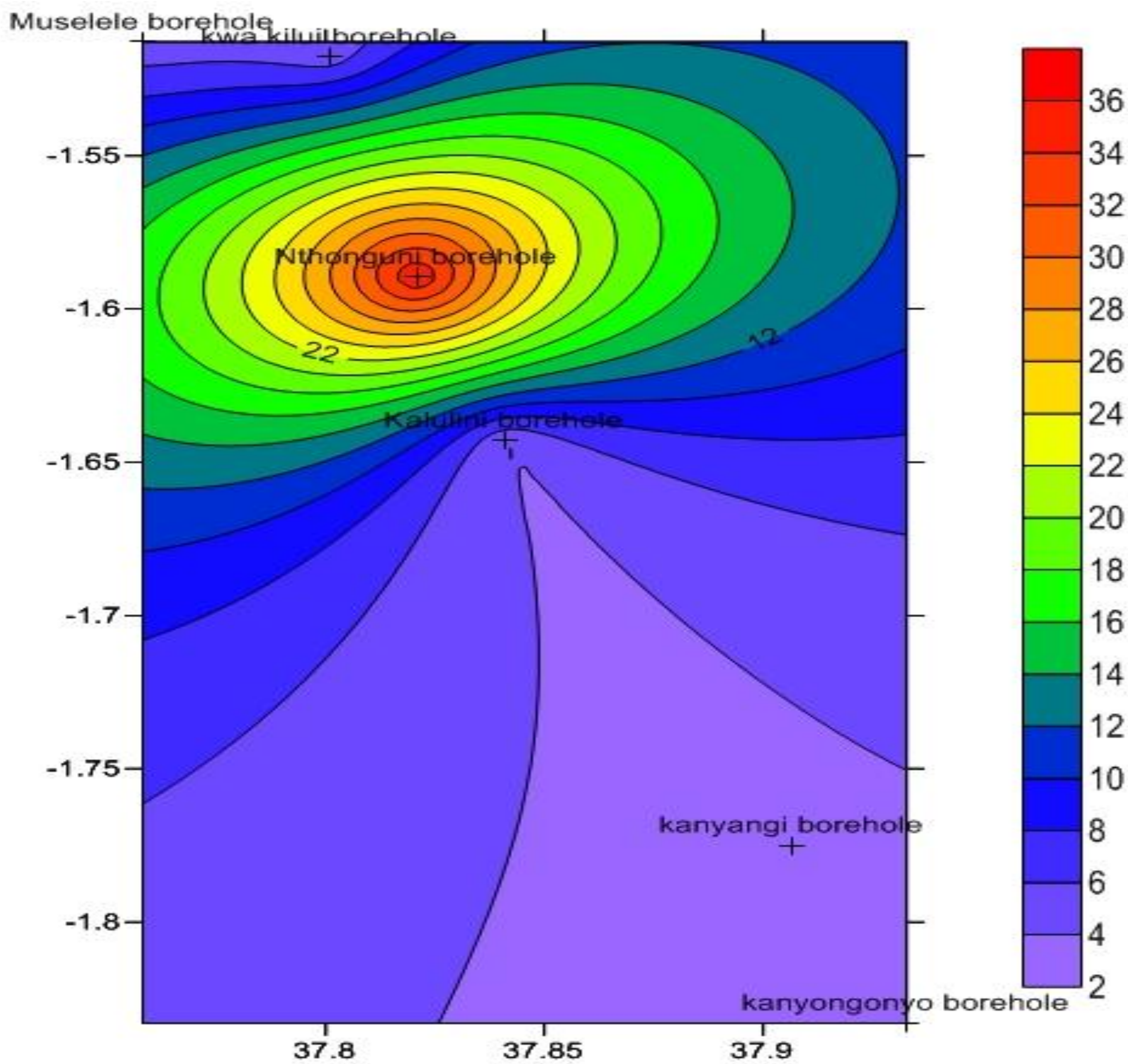


Figure 5.16: Spatial variation of Turbidity during the wet season in May, 2015

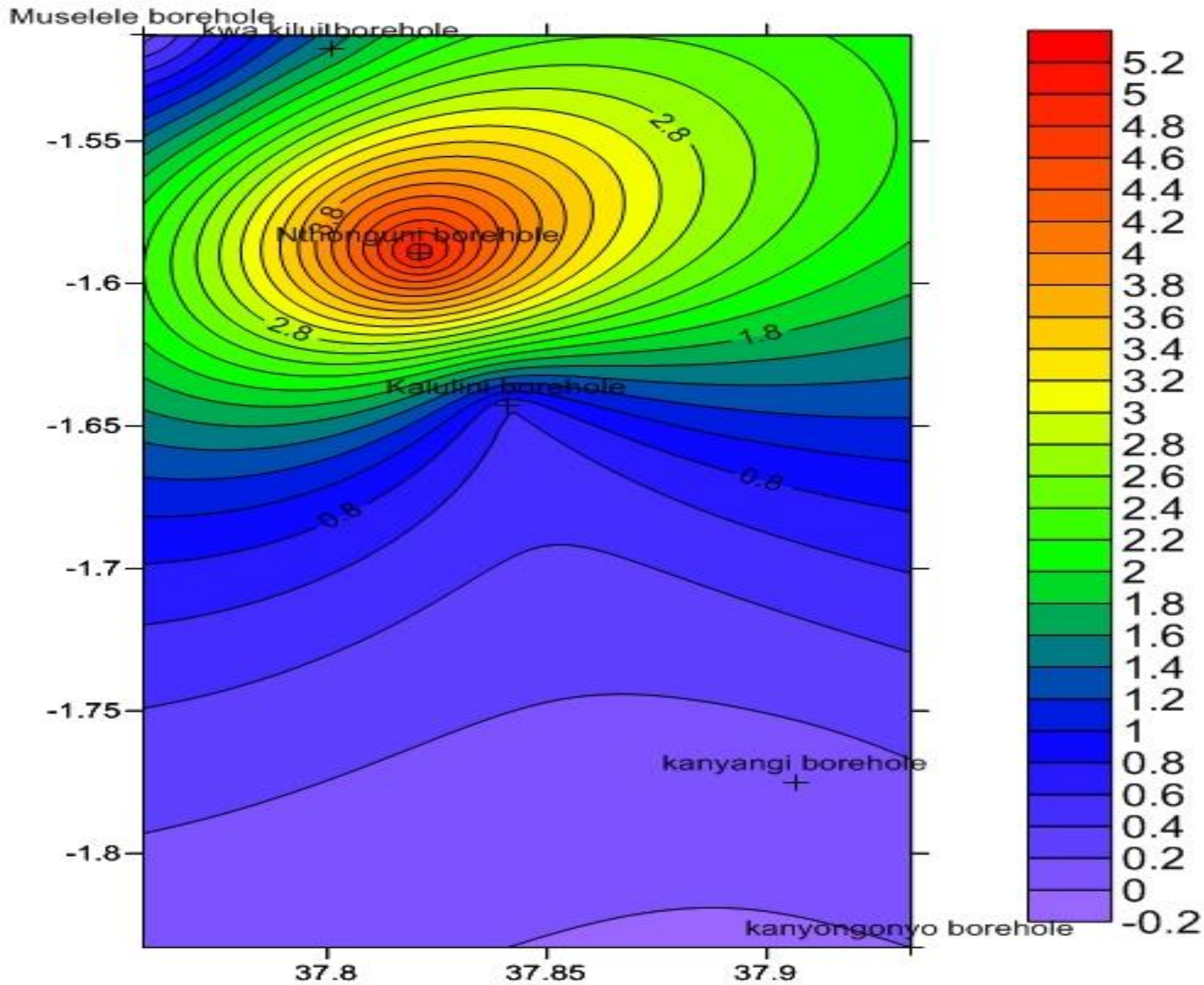


Figure 5.17: Spatial variations of Turbidity during the dry season in August, 2015

### 5.4.1.7 Fluoride

As one of the selected key parameters, fluoride was also subjected to surfer modeling for spatial variation. The results are shown in Figures 5.18 and 5.19. The spatial variations in the Figures were from samples obtained in May, 2015 and August 2015. During the sampling period, the highest Flouride levels were noted in Kalulini borehole and decreased radiating in all directions irrespective of the sampling seasons.

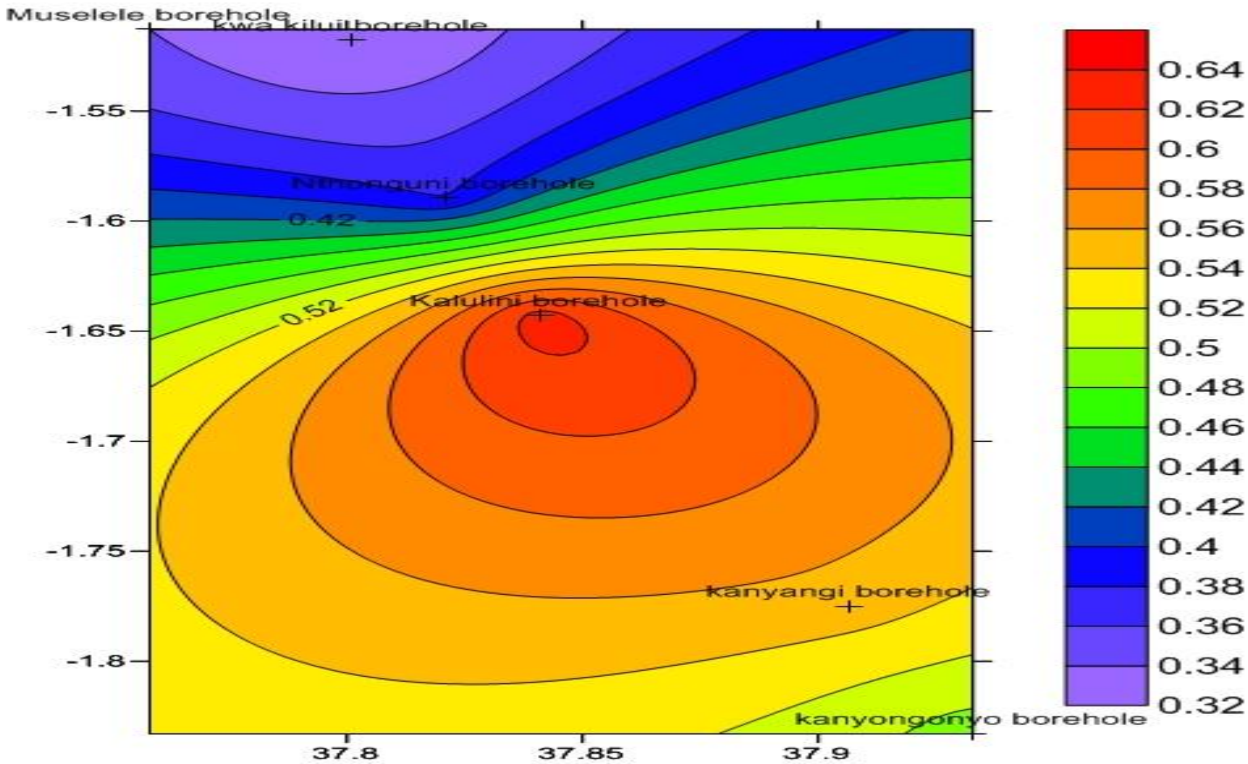


Figure 5.18: Spatial variation of Flouride during the wet season in May, 2015

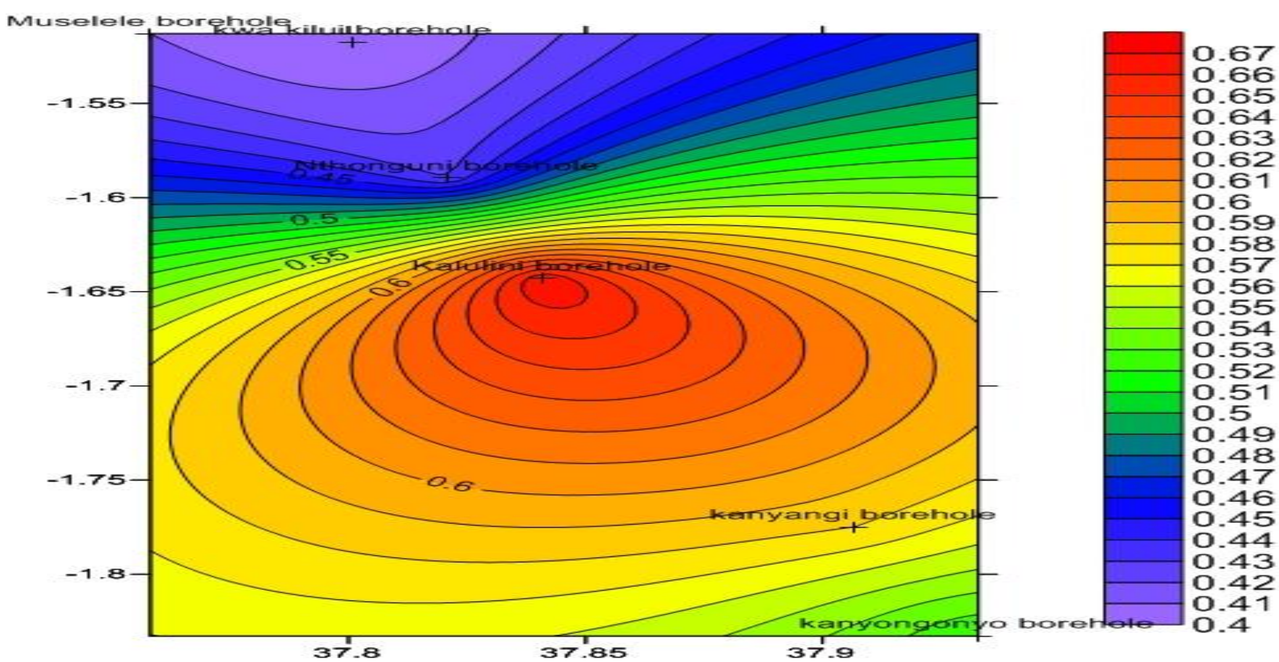


Figure 5.19: Spatial variation of Flouride during the dry season in August, 2015

#### 5.4.1.8 Total hardness

Total hardness was also one of the key parameters selected for spatial variation analysis. Figures 5.20 and 5.21 show the spatial variation models of water quality data for the Total hardness. The data from figures was sampled on May 2015 and August, 2015. In the models the red color signifies the highest value for Total hardness while the purple color signifies the lowest value. Kanyongonyo borehole had the highest levels of total hardness while Kalulini borehole had the lowest.

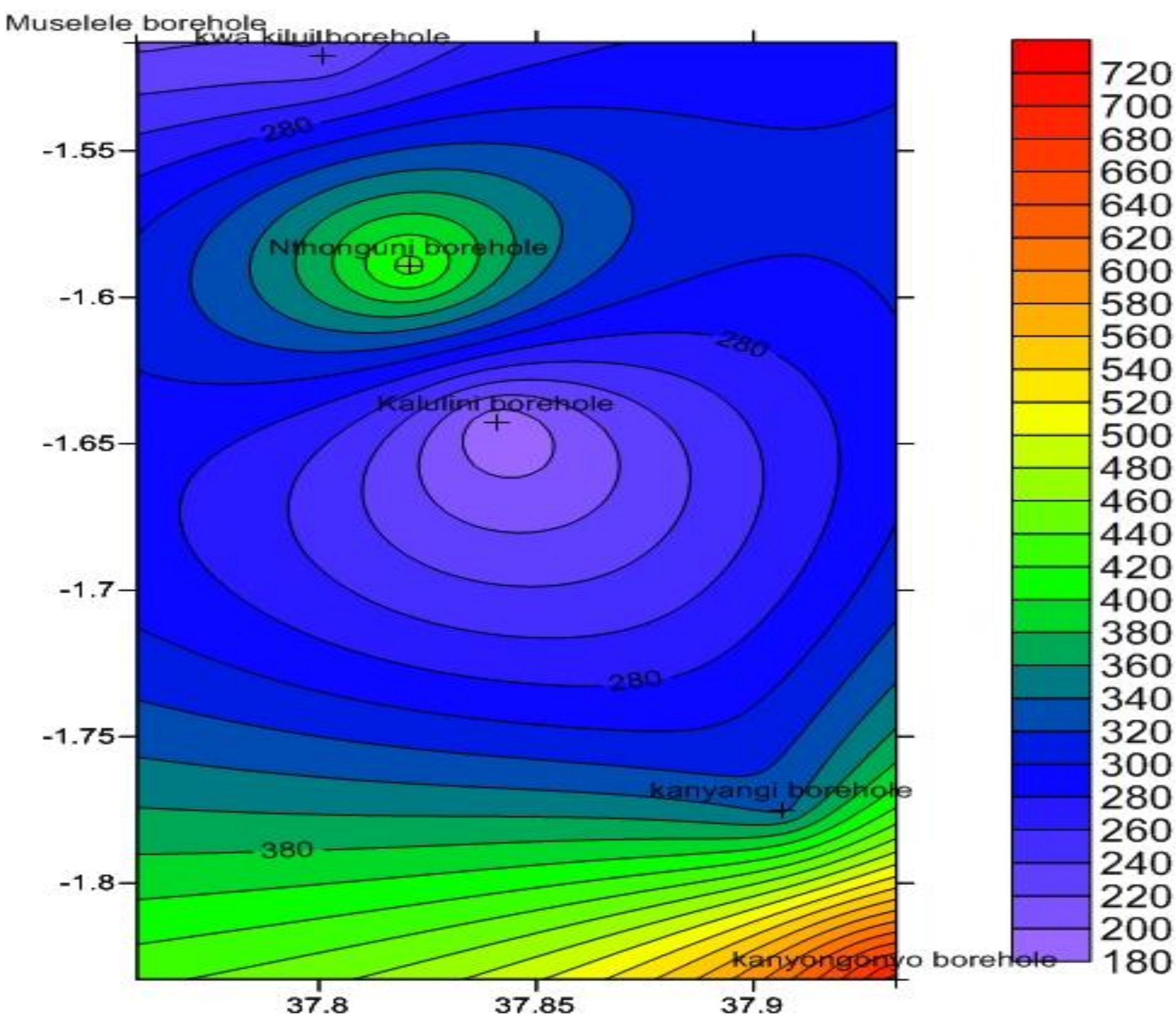


Figure 5.20: Spatial variation of Total Hardness during the wet season in May, 2015

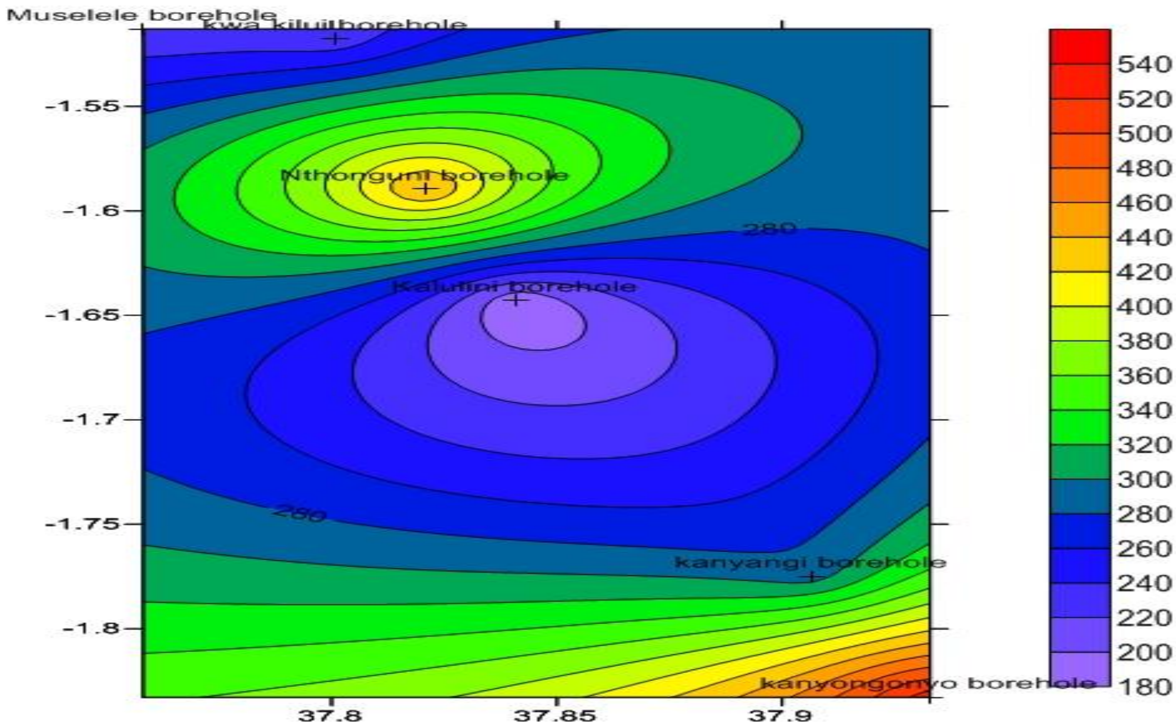


Figure 5.21: Spatial variation of Total Hardness during the dry period in August, 2015

### 5.4.2 Temporal Variability in water quality

The temporal variability in water quality for boreholes on the Yatta plateau was analyzed through the use of clustered bar graphs as shown in Figures 5.22 to 5.25. This was done with an aim to investigate whether there were any temporal variations in each of the boreholes. Figure 5.22 shows the temporal variation in electrical conductivity for the boreholes within the Yatta plateau. The electrical conductivity for each of the boreholes is plotted against time in seasons and the WHO standard for the parameter (2500 µS/cm). The lowest value for electrical conductivity was 184µS/cm which was found at Muselele borehole during the drilling period. The highest was 2270µS/cm found at Kanyongonyo borehole during the wet season of May 2015. The baseline data in the figure is for different drilling periods as shown in Table 4.1.

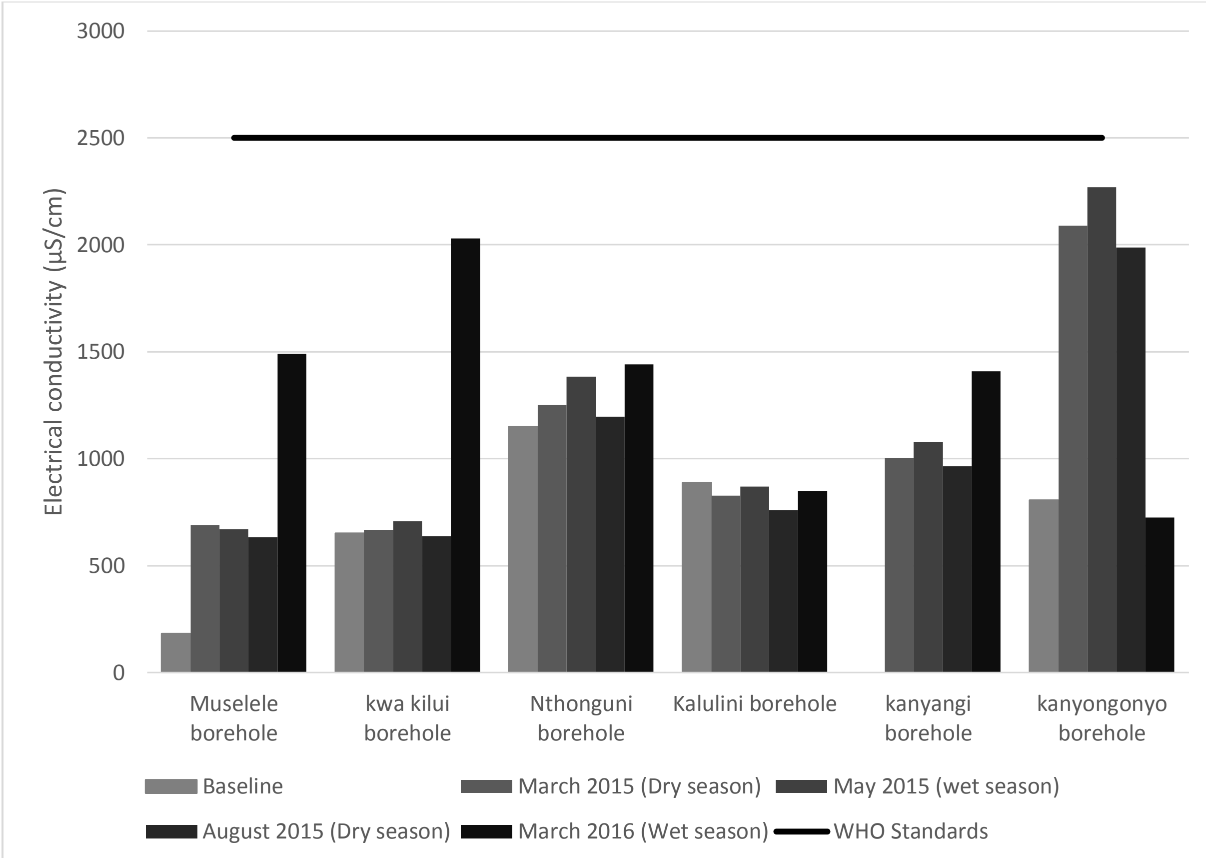


Figure 5.22: The temporal variations of groundwater electrical conductivity for boreholes located in the Yatta Plateau

Temporal variations for Iron in different boreholes within the Lower Yatta plateau are shown Figure 5.23. Iron is plotted against time in seasons. The highest value for Iron was 1.63 mg/l measured at Kwa Kilui borehole during the drilling period while the lowest value was 0.01 measured at all the boreholes in both dry and wet seasons. Some of the measured values in Kwa Kilui, Nthongoni and Kalulini boreholes surpassed the KEBS and WHO standards for Iron of 0.3 mg/l. The drilling periods when the baseline data was measured is shown in Table 4.1.

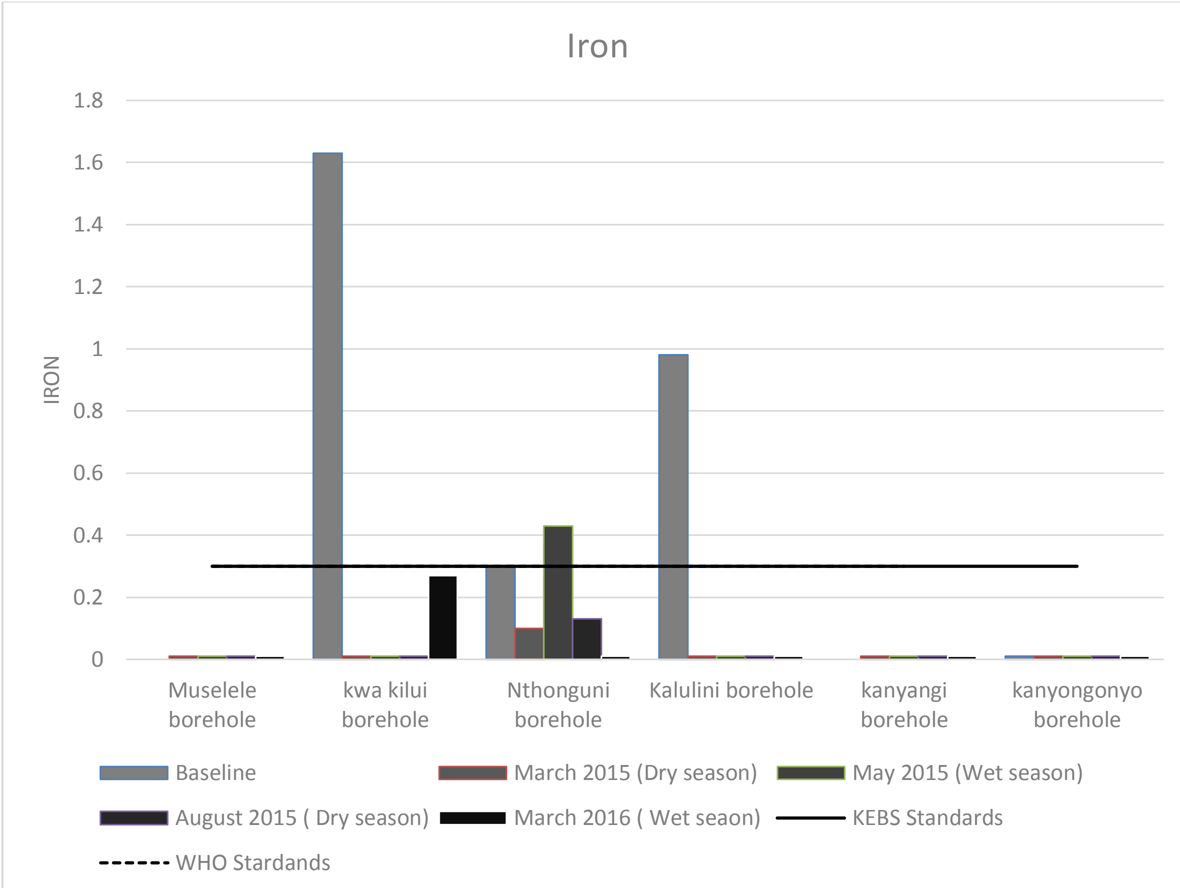


Figure 5.23: The temporal variations of groundwater iron concentration for boreholes located in the Yatta Plateau

TDS for the different boreholes was plotted as shown in Figure 5.24 for temporal variations. From the figure, WHO and KEBS standards differ for the parameter where KEBS has a lower value of 1000 mg/l while that of WHO is 1500 mg/l. All the values measured were found to be within the WHO standards but values measured in Muselele, Kwa Kilui and Kanyongonyo boreholes were found to surpass the KEBS standards. The highest value was 1407 mg/l measured at Kanyongonyo borehole during the wet season of May 2015 while the lowest was 114 mg/l measured at Muselele borehole during the drilling period shown in Table 4.1.

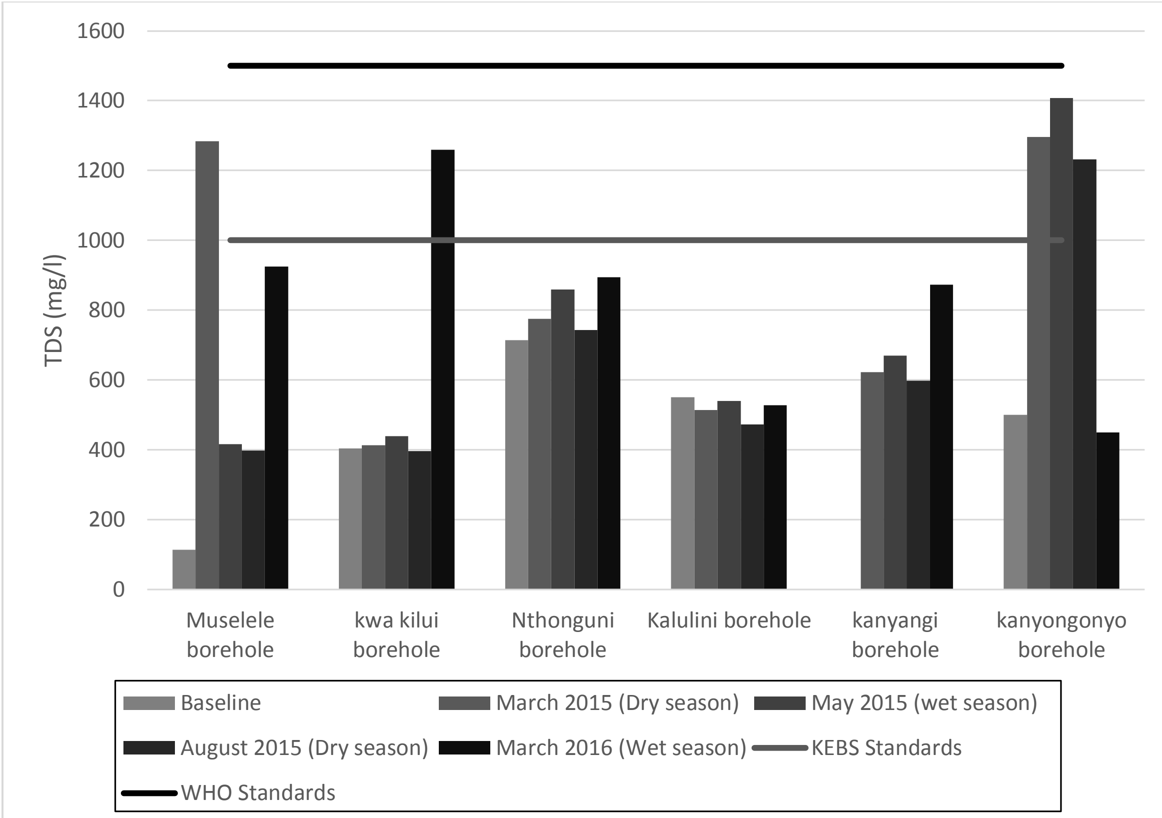


Figure 5.24: The temporal variations of the total dissolved solids (TDS) for boreholes located in the Yatta Plateau

The temporal variation in Fluoride for the boreholes in the Lower Yatta plateau is shown in Figure 5.25. Fluoride is plotted against time in seasons for each of the boreholes. Values measured for Muselele and Kanyongonyo boreholes were found to surpass both the WHO and KEBS standards of 1.5 mg/l while that of Kalulini borehole, was found to equal the limit of the standards during the drilling periods shown in table 4. The highest value was 2.4 mg/l measured during the drilling period at Kanyongonyo borehole while the lowest value was 0.3 mg/l, measured at Kwa Kilui borehole during the drilling period in Table 4.1.

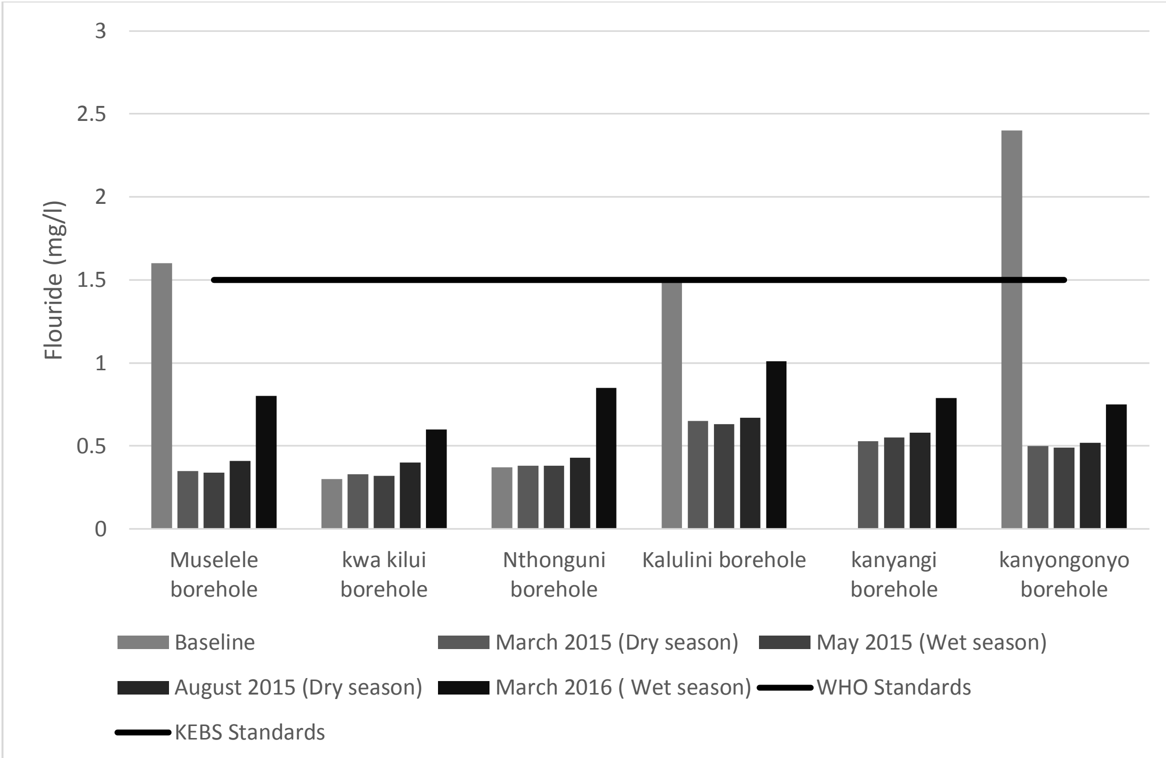


Figure 5.25: The temporal variations of fluoride concentration for boreholes located in the Yatta Plateau

## 5.5 Water Utilization

Questionnaires were administered on local community in order to assess water utilization in the Yatta plateau. The proportion of the local community who depended on the borehole water for their domestic needs was analyzed and the results showed that over 98% depended entirely on the boreholes. The views on different water quality concerns (odor, color and taste) for the people of Lower Yatta plateau were grouped in terms of the different boreholes. Over 90% of the respondents expressed concerns on the taste of the ground water in all the sampled boreholes however there was little concern on odor and color. Over 70% of the respondents who had expressed concerns about color claimed that there was seasonal variation in the different boreholes. Further the occurrence of taste was analyzed for seasonal variations where 100% of the respondents cited that there were seasonal variations. Odor was also assessed for presence and seasonal variation in the different boreholes. More than 85% of the respondents claimed that there was no odor in the different boreholes with only less than 15% suggesting its presence, and from the 15% only 60% suggested that there were seasonal variations.

In order to ascertain whether taste as a key ground water quality parameter affected water utilization in the study area, analysis of its presence in the different boreholes was also taken into account. In the analysis the taste was analyzed for three different types namely salinity, bitterness or any other. Salinity was sighted by over 80% as the major concern in all the boreholes in regard to taste. Further the occurrence of color in different seasons was analyzed with a view of establishing whether the occurrence of color affected water utilization. The water users views on the effect of color on water utilization showed that over 90% were un-confortable while drinking water where according to them color existed.

On the proposed solutions for water quality concerns 60% of the respondents suggested treatment of the water, while only 20% suggested development of other sources.

**5.6 Hypothesis testing**

The hypotheses in this study on the presence of spatial-temporal variation, the relationship between ground water quality parameters and rainfall and, the influence of ground water quality on water utilization in the Yatta plateau were tested using SPSS ANOVA tool. ANOVA seeks to find out whether the means of different groups are equal. There are three assumptions that are used in ANOVA which are; the cases are different from each other, the errors are normally distributed and finally the dependent variable(s) is normally distributed. Like the t-test, ANOVA is a robust analytical tool and is not relatively affected by violations of the above mentioned assumptions.

The ANOVA results for the test concerning the possibility of spatial variation in the study area during the wet and dry seasons are shown in tables 5.2 and 5.3

respectively. The Tables show significance of the results and the corresponding t-values. The results on Table 5.2 show that out of the eight parameters tested during the wet season only the values of Iron at 0.156 were found to have a significance value above the confidence interval of 95%. From Table 5.3, only Iron and Turbidity were found to have significance value above the confidence interval at 0.305 and 0.137 respectively.

Table 5.2: Analysis of variance for spatial variation during the wet season

**ANOVA**

| | Test Value = 0 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| pH | 55.781 | 5 | .000 | 7.67000 | 7.3165 | 8.0235 |
| Turbidity | 2.692 | 5 | .043 | .38333 | .0173 | .7494 |
| Conductivity | 4.968 | 5 | .004 | 1088.50000 | 525.2986 | 1651.7014 |
| Iron | 1.667 | 5 | .156 | .02500 | -.0136 | .0636 |
| Total Hardness | 4.658 | 5 | .006 | 351.00000 | 157.2900 | 544.7100 |
| Total Alkalinity | 7.104 | 5 | .001 | 247.66667 | 158.0528 | 337.2805 |
| Fluoride | 8.960 | 5 | .000 | .45667 | .3256 | .5877 |
| Total Dissolved Solids | 5.200 | 5 | .003 | 817.36000 | 413.2694 | 1221.4506 |

Table 5.3: Analysis of variance for spatial variation of selected water quality parameters during the dry season

**ANOVA**

| | Test Value = 0 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| pH | 64.371 | 5 | .000 | 7.65167 | 7.3461 | 7.9572 |
| Turbidity | 1.767 | 5 | .137 | 9.43333 | -4.2877 | 23.1543 |
| Conductivity | 4.729 | 5 | .005 | 1163.83333 | 531.1970 | 1796.4696 |
| Iron | 1.143 | 5 | .305 | .08000 | -.0999 | .2599 |
| Total Hardness | 4.276 | 5 | .008 | 349.00000 | 139.2105 | 558.7895 |
| Total Alkalinity | 8.384 | 5 | .000 | 249.66667 | 173.1178 | 326.2155 |
| Fluoride | 8.865 | 5 | .000 | .45167 | .3207 | .5826 |
| Total Dissolved Solids | 4.730 | 5 | .005 | 721.51000 | 329.4295 | 1113.5905 |

In the study area, the possibility of existence of temporal variations for different parameters was also tested. Table 5.5 shows the ANOVA results for the test. The results show the level of significance for the analysis of different physical chemical parameters that were tested and the computed t-values. In the test, pH, Turbidity, Electrical conductivity, Iron, Total hardness, Total alkalinity, Fluoride and Total dissolved solids were analyzed for variance at 95% confidence interval. From the results the significance value for Turbidity at 0.06 was found to be slightly above the value for significance of 0.05.

Table 5.4: ANOVA for temporal variations of selected Physical - chemical parameters

**ANOVA**

| | Test Value = 0 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| pH | 16.020 | 29 | .000 | 6.80900 | 5.9397 | 7.6783 |
| Turbidity | 1.960 | 29 | .060 | 7.52000 | -.3288 | 15.3688 |
| Conductivity | 10.648 | 29 | .000 | 1044.10000 | 843.5579 | 1244.6421 |
| Iron | 2.145 | 29 | .040 | .13500 | .0063 | .2637 |
| Total Hardness | 8.172 | 29 | .000 | 312.00000 | 233.9154 | 390.0846 |
| Total Alkalinity | 11.911 | 29 | .000 | 223.26667 | 184.9291 | 261.6042 |
| Flouride | 7.586 | 29 | .000 | .64767 | .4730 | .8223 |
| Total Dissolved Solids | 10.591 | 29 | .000 | 676.00000 | 545.4595 | 806.5405 |

The physical chemical parameters were correlated and the results shown are in Table 5.6 for the entire sampling period. The results show the computed Pearsons' correlation values for the different parameters that were tested in the laboratory. From the results the correlations between pH and Electrical conductivity, pH and Total hardness, pH and TDS, and Total alkalinity and Flouride were found to have correlation values of 0.417, 0.460, 0.423 and -0.381 respectively. The correlations were found to be significant at 95% confidence.

Table 5.5: Correlation results for selected water quality parameters found in boreholes within the Lower Yatta plateau.

**Correlations**

| | | pH | Turbidity | Conductivity | Iron | Total Hardness | Total Alkalinity | Flouride | Total Dissolved Solids |
|---|---|---|---|---|---|---|---|---|---|
| pH | Pearson Correlation | 1 | .112 | .417* | .113 | .460* | .697** | -.475** | .423* |
| | Sig. (2-tailed) | | .555 | .022 | .551 | .011 | .000 | .008 | .020 |
| | Sum of Squares and Cross-products | 157.167 | 159.102 | 15116.923 | 2.635 | 6496.860 | 4833.538 | -14.985 | 9972.937 |
| | Covariance | 5.420 | 5.486 | 521.273 | .091 | 224.030 | 166.674 | -.517 | 343.894 |
| | N | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Turbidity | Pearson Correlation | .112 | 1 | -.083 | .954** | -.041 | -.144 | -.098 | -.109 |
| | Sig. (2-tailed) | .555 | | .663 | .000 | .830 | .449 | .608 | .568 |
| | Sum of Squares and Cross-products | 159.102 | 12812.768 | -27167.560 | 200.444 | -5225.400 | -8991.160 | -27.806 | -23140.036 |
| | Covariance | 5.486 | 441.820 | -936.812 | 6.912 | -180.186 | -310.040 | -.959 | -797.932 |
| | N | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Conductivity | Pearson Correlation | .417* | -.083 | 1 | -.056 | .906** | .675** | -.073 | .897** |
| | Sig. (2-tailed) | .022 | .663 | | .768 | .000 | .000 | .701 | .000 |
| | Sum of Squares and Cross-products | 15116.923 | -27167.560 | 8364618.700 | -301.715 | 2949866.000 | 1078614.200 | -532.823 | 4881646.000 |
| | Covariance | 521.273 | -936.812 | 288435.128 | -10.404 | 101719.517 | 37193.593 | -18.373 | 168332.621 |
| | N | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Iron | Pearson Correlation | .113 | .954** | -.056 | 1 | -.015 | -.185 | .001 | -.084 |
| | Sig. (2-tailed) | .551 | .000 | .768 | | .937 | .327 | .996 | .658 |
| | Sum of Squares and Cross-products | 2.635 | 200.444 | -301.715 | 3.447 | -31.460 | -190.090 | .005 | -294.529 |
| | Covariance | .091 | 6.912 | -10.404 | .119 | -1.085 | -6.555 | .000 | -10.156 |
| | N | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Total Hardness | Pearson Correlation | .460* | -.041 | .906** | -.015 | 1 | .620** | -.334 | .833** |
| | Sig. (2-tailed) | .011 | .830 | .000 | .937 | | .000 | .071 | .000 |
| | Sum of Squares and Cross-products | 6496.860 | -5225.400 | 2949866.000 | -31.460 | 1268136.000 | 386212.000 | -947.560 | 1766682.760 |
| | Covariance | 224.030 | -180.186 | 101719.517 | -1.085 | 43728.828 | 13317.655 | -32.674 | 60920.095 |
| | N | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Total Alkalinity | Pearson Correlation | .697** | -.144 | .675** | -.185 | .620** | 1 | -.381* | .678** |
| | Sig. (2-tailed) | .000 | .449 | .000 | .327 | .000 | | .038 | .000 |
| | Sum of Squares and Cross-products | 4833.538 | -8991.160 | 1078614.200 | -190.090 | 386212.000 | 305691.867 | -530.511 | 705352.680 |
| | Covariance | 166.674 | -310.040 | 37193.593 | -6.555 | 13317.655 | 10541.099 | -18.293 | 24322.506 |
| | N | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Flouride | Pearson Correlation | -.475** | -.098 | -.073 | .001 | -.334 | -.381* | 1 | -.123 |
| | Sig. (2-tailed) | .008 | .608 | .701 | .996 | .071 | .038 | | .516 |
| | Sum of Squares and Cross-products | -14.985 | -27.806 | -532.823 | .005 | -947.560 | -530.511 | 6.342 | -585.501 |
| | Covariance | -.517 | -.959 | -18.373 | .000 | -32.674 | -18.293 | .219 | -20.190 |
| | N | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| Total Dissolved Solids | Pearson Correlation | .423* | -.109 | .897** | -.084 | .833** | .678** | -.123 | 1 |
| | Sig. (2-tailed) | .020 | .568 | .000 | .658 | .000 | .000 | .516 | |
| | Sum of Squares and Cross-products | 9972.937 | -23140.036 | 4881646.000 | -294.529 | 1766682.760 | 705352.680 | -585.501 | 3544259.232 |
| | Covariance | 343.894 | -797.932 | 168332.621 | -10.156 | 60920.095 | 24322.506 | -20.190 | 122215.836 |
| | N | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

The results of the water samples that were analyzed at WARMA laboratory were subjected to ANOVA test to check whether there was relationship between them and the rainfall data collected for the same periods. Table 5.6 shows the model summary results for the ANOVA test. The correlation values for electrical conductivity, total hardness, total alkalinity and TDS were 0.065, 0.016, 0.199 and 0.017 respectively while the regression values were 0.004, 0.000, 0.040 and 0.000 respectively. Figures 5.26 to 5.29 show the regression graphs for electrical conductivity, Total Hardness, Total Alkalinity and TDS against rainfall during the sampling.

Table 5.6: Regression analysis for Electrical Conductivity, Total Hardness, Total Alkalinity and TDS

**Model Summary for Electrical conductivity**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .065 | .004 | -.086 | 562.697 |

The independent variable is Rainfall.

**Model Summary for Total Hardness**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .016 | .000 | -.091 | 187.134 |

The independent variable is Rainfall.

**Model Summary for Total Alkalinity**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .199 | .040 | -.048 | 74.250 |

The independent variable is Rainfall.

**Model Summary for TDS**

| R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|
| .017 | .000 | -.091 | 380.628 |

The independent variable is Rainfall.

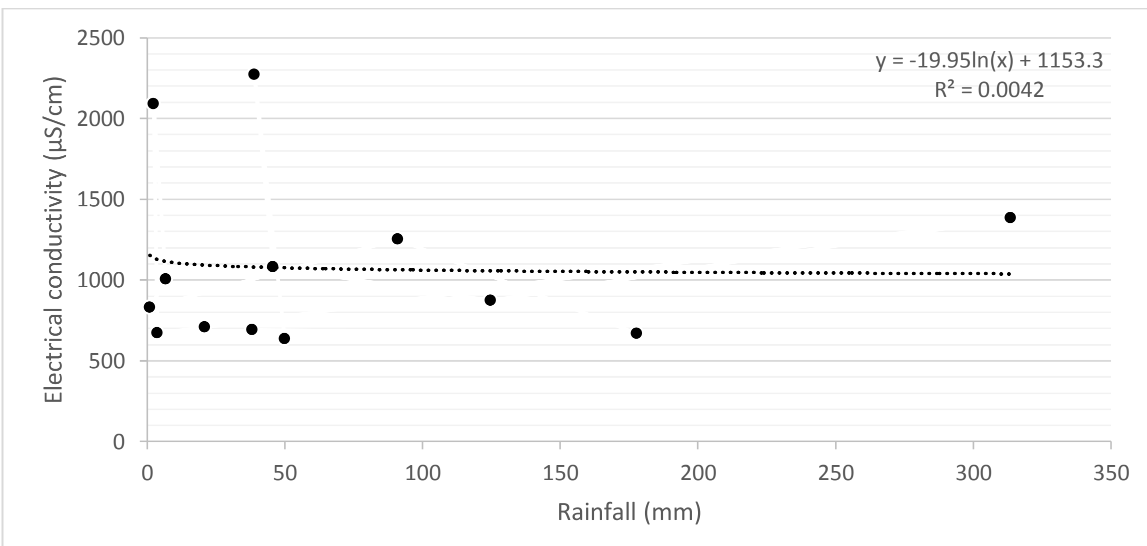


Figure 5.26: Regression curve for Electrical Conductivity against rainfall

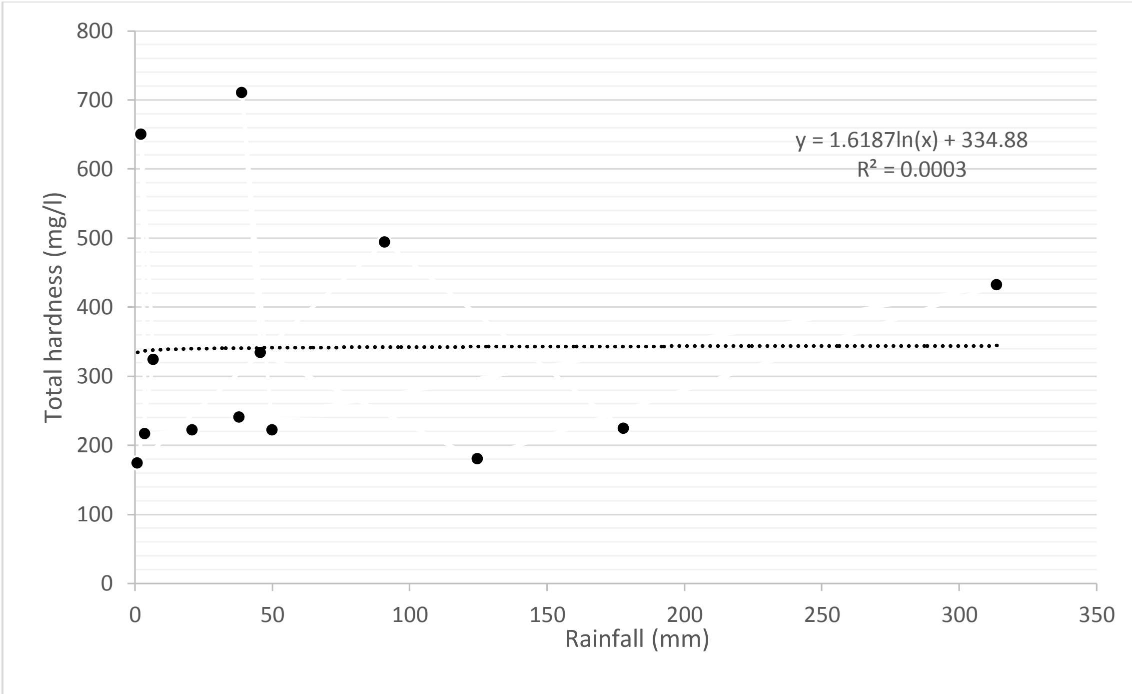


Figure 5.27: Regression curve for Total Hardness against rainfall

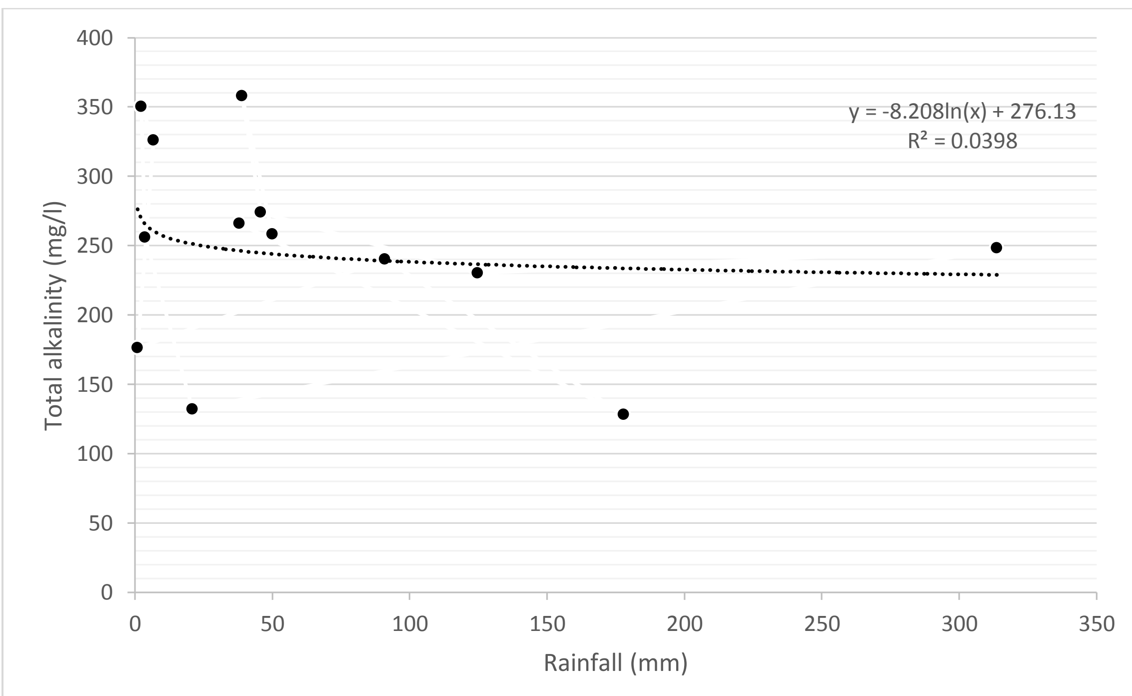


Figure 5.28: Regression curve for Total alkalinity against rainfall

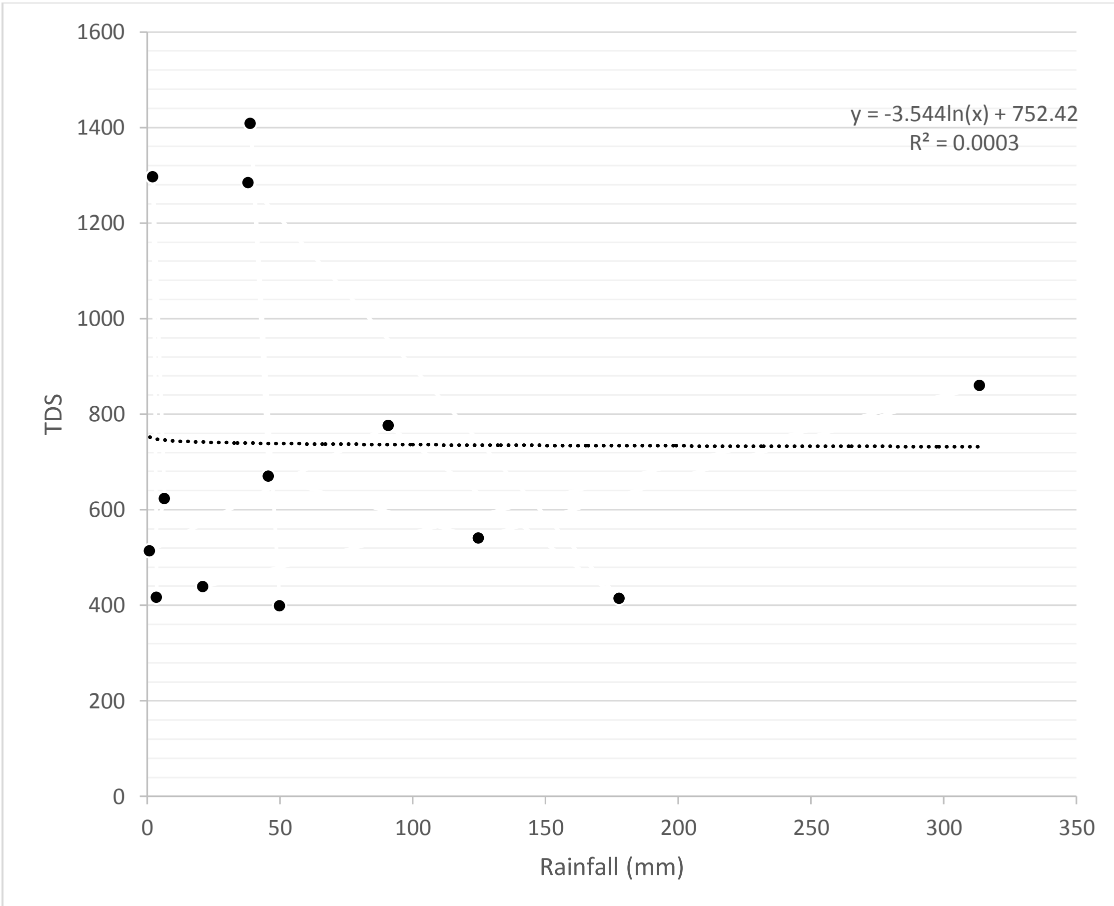


Figure 5.29: Regression curve for TDS against rainfall

Correlation was also conducted for the water quality parameters against rainfall with an aim of establishing whether or not there exists any relationship between the water quality parameters and rainfall during the sampling period. Table 5.7 shows the correlation results for the different water quality parameters against rainfall. The results show the different specific values for significance and Pearson correlation values for each of the relationships. The results range from -0.79 to 1.000 for turbidity and rainfall respectively.

Table 5.7: Correlation analysis for rainfall and water quality parameters

**Correlations**

| | | Rainfall | pH | Turbidity | Conductivity | Iron | Total Hardness | Total Alkalinity | Flouride | Total Dissolved Solids |
|---|---|---|---|---|---|---|---|---|---|---|
| Pearson Correlation | Rainfall | 1.000 | .168 | -.079 | .206 | .008 | .130 | .338 | -.035 | .069 |
| | pH | .168 | 1.000 | .198 | .537 | .197 | .632 | .776 | -.523 | .525 |
| | Turbidity | -.079 | .198 | 1.000 | -.017 | .955 | .022 | -.035 | -.103 | -.084 |
| | Conductivity | .206 | .537 | -.017 | 1.000 | -.005 | .889 | .741 | -.091 | .791 |
| | Iron | .008 | .197 | .955 | -.005 | 1.000 | -.002 | -.074 | .005 | -.075 |
| | Total Hardness | .130 | .632 | .022 | .889 | -.002 | 1.000 | .840 | -.467 | .750 |
| | Total Alkalinity | .338 | .776 | -.035 | .741 | -.074 | .840 | 1.000 | -.501 | .750 |
| | Flouride | -.035 | -.523 | -.103 | -.091 | .005 | -.467 | -.501 | 1.000 | -.158 |
| | Total Dissolved Solids | .069 | .525 | -.084 | .791 | -.075 | .750 | .750 | -.158 | 1.000 |
| Sig. (1-tailed) | Rainfall | . | .260 | .382 | .214 | .488 | .309 | .092 | .448 | .396 |
| | pH | .260 | . | .223 | .013 | .224 | .003 | .000 | .016 | .015 |
| | Turbidity | .382 | .223 | . | .474 | .000 | .467 | .447 | .347 | .375 |
| | Conductivity | .214 | .013 | .474 | . | .493 | .000 | .000 | .363 | .000 |
| | Iron | .488 | .224 | .000 | .493 | . | .497 | .389 | .493 | .388 |
| | Total Hardness | .309 | .003 | .467 | .000 | .497 | . | .000 | .029 | .000 |
| | Total Alkalinity | .092 | .000 | .447 | .000 | .389 | .000 | . | .020 | .000 |
| | Flouride | .448 | .016 | .347 | .363 | .493 | .029 | .020 | . | .273 |
| | Total Dissolved Solids | .396 | .015 | .375 | .000 | .388 | .000 | .000 | .273 | . |
| N | Rainfall | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | pH | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | Turbidity | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | Conductivity | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | Iron | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | Total Hardness | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | Total Alkalinity | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | Flouride | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |
| | Total Dissolved Solids | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 | 17 |

The data from the questionnaires was also subjected to hypothesis testing using SPSS ANOVA tool. Table 5.8 shows the results for key parameters (color, odor and taste). The analysis considered the variability of these parameters in terms of different seasons. The table also shows the degrees of freedom which range from 5 to 94, the mean of squares and finally the significance.

Table 5.8: ANOVA summary results for key parameters and water quality concerns

**ANOVA**

| | Test Value = 0 | | | | | |
|---|---|---|---|---|---|---|
| | t | df | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| Does the water have color | 57.093 | 94 | .000 | 1.884 | 1.82 | 1.95 |
| Does the color affect the utilization of the water | 9.690 | 10 | .000 | 1.182 | .91 | 1.45 |
| Does the color vary with different seasons | 9.037 | 10 | .000 | 1.273 | .96 | 1.59 |
| Does the water have taste | 42.375 | 94 | .000 | 1.063 | 1.01 | 1.11 |
| Does the taste change with seasons | 27.777 | 87 | .000 | 1.489 | 1.38 | 1.60 |
| Does the water have odour | 70.731 | 93 | .000 | 1.926 | 1.87 | 1.98 |
| Does the odour vary with seasons | 7.906 | 5 | .001 | 1.667 | 1.12 | 2.21 |
| What can be done to ease the problem | 20.533 | 93 | .000 | 1.734 | 1.57 | 1.90 |

# CHAPTER SIX

# DISCUSSIONS OF THE RESULTS

## 6.1 Introduction

This chapter presents the discussion of the results of the study. The chapter is aimed at examining the relationship between rainfall variability and water quality variability, including the effect on the water utilization. The discussion on water quality variability involved the analysis of both spatial and temporal variability. The discussions therefore are primarily on the results of the analysis on the spatial-temporal variations on ground water chemical parameters, the long term changes in ground water chemical parameters, the relationship between ground water chemical quality parameters and rainfall and finally, the effects of ground water chemical parameters on water utilization in the study area.

## 6.2 Relationship between rainfall and ground water quality

The results on the relationship between rainfall variability and subsequent variations in ground water quality parameters have shown that there exists no significant relationship. The pH, electrical conductivity and TDS time series shown in Figure 5.1 for boreholes in the study area do not directly relate to the rainfall variability during the sampling period. This is interpreted to mean that there is no direct relationship between the surface runoff caused by the rainfall in the area, and the trends witnessed in the water quality parameters.

The absence of a significant relationship between rainfall and the water quality parameters may be due to time taken for surface water to infiltrate and percolate to deep aquifers as is the case for boreholes in the study area with depths as given in Table 4.1 which range from 133 to 230m. Therefore the geology in the area may be more important in influencing changes in the level of the said water quality parameters. This finding is consistent with the findings of Tavassoli and Khaksar (2002) who reported that in deep aquifers, in volcanic geological formations, water quality parameters are not mainly influenced by surface water.

### 6.3 Spatial-temporal variability

The results of spatial temporal variability on the key ground water parameters in Yatta plateau are discussed in this section. The key parameters include pH, Electrical conductivity, Iron, Total alkalinity, TDS, Turbidity, Fluoride and Total hardness.

### 6.3.1 Spatial variability

#### 6.3.1.1 pH and geology

Spatial variability for pH is shown in Figures 5.6 and 5.7. The figures show that the pH for Nthongoni and Kanyongonyo boreholes is lower compared to the other boreholes while that of Kalulini and Kwa Kilui boreholes is relatively higher.

The presence of acidity in the borehole water may be due to the volcanic rocks that make up the geology of the area. The influence of geology in the chemical parameters of the borehole water concurs with the studies done by Petalas et al., (2006) on the influence of geology on the pH of ground water. The trend of pH in the figure is such that the pH falls' south wards and northwards in reference to Kalulini borehole. Kalulini and Kwa Kilui boreholes tend to appear to be approaching high alkalinity levels while Nthongoni and Kanyongonyo boreholes tend to be approaching neutral pH levels. The pH data for all the boreholes is however noted to be within the standards given by KEBS and WHO as shown in Table 2.2.

#### 6.3.1.2 Electrical conductivity and TDS

Electrical conductivity is the ability of water to transmit electrical current. Figure 5.8 and 5.9 show the trend for electrical conductivity for the boreholes in the study area. The trend in the figures shows that Kanyongonyo borehole had the highest electrical conductivity levels. The trend falls northwards towards Muselele borehole.

The differences in the electrical conductivity may be due to the underlying geology where different chemical materials and formations in individual borehole aquifers that may dissolve the various anions and cations which in turn may be affecting the water quality of the area. This concurs with the results of the study by Tavassoli and Khaksar, (2002) in a study on the effects of geological formations on quaternary aquifers where they found out that the kinds and concentration rates of different materials in groundwater are dependent on rocks which are in conduct with the water. The data in Figures 5.8 and 5.9 is noted to be within the WHO and KEBS standards for drinking water of maximum 2500 uS/cm as shown in Table 2.2.

#### 6.3.1.3 Iron

The variability of Iron in different boreholes is shown in Figures 5.10 and 5.11. The figures show the spatial variability for Iron during wet and dry season. The figures show that Nthongoni had the highest concentration of Iron and this reduces in all directions but mainly southwards towards Kanyongonyo borehole.

The trend witnessed is found to be relating to the pH in the specific boreholes where the lower the level of pH in a borehole the higher was the level of iron in that borehole. This was found to be in line with the findings of Petalas et al., (2006) where they found that high metal concentrations in aquifers were related to water with low pH values. The parameter however is noted to be within the standards given by WHO and KEBS of a maximum of 0.2 mg/l as shown in Table 2.2.

#### 6.3.1.4 Total Alkalinity

Alkalinity is defined as a measure of the capacity of hydrogen ions dissolved in a certain amount of water without a change in the water's pH value and is influenced by the concentration of hydroxide, bicarbonate or carbonate ions. Figure 5.12 and 5.13 show the spatial variability of total alkalinity for the boreholes within the study area during two seasons of the sampling period. The figures show that Kanyongonyo and Kanyangi have the highest concentrations and this reduces northwards towards Kwa Kilui borehole.

The cause of the high alkalinity shown in these boreholes could be as a result of the geo-chemistry of the area which may be causing minerals to dissolve into the specific aquifers. The above is in line with the studies of Petalas et al., (2006), although there is also need to establish the actual geochemistry of the area so as to ascertain the extent of different variables and how each occurs in the different aquifers in the area. The parameter however is noted to be within the standards given by WHO and KEBS of 500 mg CaCO3/l as shown in Table 2.2.

### 6.3.1.5 Total Dissolved Solids (TDS)

TDS is the amount of dissolved substances in a water sample and the higher the concentration the more the ratio of water to contaminant may be. Figures 5.14 and 5.15 show the spatial variability of TDS for the boreholes within the study area for wet and dry period respectively. The TDS reduces northwards from Kanyongonyo Borehole towards Muselele borehole regardless of the seasons.The TDS witnessed in the boreholes may be attributed to the underlying geology in the area of study which may be affecting the ground water quality. The above is in line with the findings of Alberta (2009) and those of Tavassoli and Khaksar, (2002). The parameter is however within the standards given by WHO and KEBS of Maximum 1500 and 1000 mg/l respectively.

### 6.3.1.6 Turbidity.

Turbidity is a measure of cloudiness of water and is related to total suspended solids (TSS). The turbidity level as shown in Figures 5.16 and 5.17 is relatively higher in Nthongoni and reduces southwards and northwards towards Kanyangi and Muselele boreholes respectively. The high turbidity witnessed in Nthongoni borehole can be related to the high level of electrical conductivity that was earlier noted within the borehole and hence the turbidity can be attributed to the geology of the area. The above is found to be in line with the studies of Tavassoli and Khaksar, (2002), Petalas et al., (2006), Tong and Chem (2011) and those of Raghunath (2006) concerning the effects of geology on the water quality in different aquifers. The highest turbidity values noted at Nthongoni borehole were above WHO standards for drinking water of maximum of 5 N.T.U shown in Table 2.2.

#### 6.3.1.7 Fluoride

The spatial variability models for fluoride for the boreholes within the study are shown in Figures 5.18 and 5.19. Kalulini borehole was found to have relatively higher fluoride levels compared to other boreholes in the area, the concentration reducing in all directions. However, the levels are within the WHO and KEBS standards shown in Table 2.2.

Raghunath (2006) observes that the chemical composition of groundwater is related to soluble products of rock weathering and decomposition and changes with respect to time and space. Therefore the differences witnessed within the boreholes may be due to changes in the fluoride concentrations in the different aquifers or due to the different forms of land use in the area. This is also in line with the findings of Tavassoli and Khaksar, (2002) and those of Petalas et al., (2006) where they both attributed the ground water quality to the different geological formations present within the specific aquifers.

#### 6.3.1.8 Total hardness

Boreholes within the study area were analyzed for spatial variability in total hardness and the results presented in Figures 5.20 and 5.21. From the figures Kanyongonyo had a relatively higher concentration of total hardness while Kalulini had the lowest concentration compared to the other boreholes within the study area.

The fluoride value for Kanyongonyo borehole was noted to be above both WHO and KEBS standards shown in Table 2.2. This could be due to the high levels of TDS noted within the borehole during the sampling period which concurs with a study by Thirupathaiah et al., (2012), where he found that total hardness was due to magnesium and calcium salts in the water. The high levels of total hardness may be also due to the dissolution of minerals present within the aquifer (Tavassoli and Khaksar, 2002).

### 6.3.2 Temporal variability in water quality

The temporal variability of water quality parameters in the Yatta plateau had different trends. This is confirmed by the results of the sampled water quality data that were plotted in graphs in Figures 5.22 to 5.25.

#### 6.3.2.1 Electrical conductivity

Electrical conductivity is the measure of the capability of water to pass electrical current and this is directly related to the concentration of ions in the water (Wetzel, 2001). Figure 5.22 shows the temporal variability in electrical conductivity for the boreholes within the study area. The trend in electrical conductivity in the figure shows a rise in the electrical conductivity between the values from the baseline data and the data from the last sampling period for all the boreholes except for Kalulini borehole. All the values for the parameter were found to be within the WHO and KEBS standards meaning that the water was safe for human consumption. Due to the similarity witnessed in the electrical conductivity trend, it is most likely that the increase could be as a result of dissolution of parent material within the respective aquifers leading to increase of ions in the water. This idea is also supported by the findings of Tavassoli and Khaksar, (2002) and those of Thirupathaiah et al., (2012).

#### 6.3.2.2 Iron

Iron is mainly found into distinct forms namely the insoluble ferric iron and the soluble ferrous iron. Water is normally clear and colorless even when it contains ferrous iron however when exposed to air the water turns cloudy and reddish brown substance begins to form due to oxidation of iron (http://www.idph.state.il.us). Figure 5.23 shows the temporal variability of Iron in the studied boreholes. The figure shows a decrease in iron for three boreholes namely Kwa Kilui, Nthongoni and Kalulini boreholes while that of the remaining three boreholes is constant. The decrease could be due to increase in pH within the water column above pH of 6.5. This is collaborated by the findings published on Environmental Fact Sheet (http://www.idph.state.il.us). The trend could also be due to differences in the composition of the geologic formations at the different aquifer levels.

This is found to be in line with the findings of Tavassoli and Khaksar, (2002) where they found that the geology of an area affected the ground water quality. Conversely the trend is in line with the findings of Petalas et al., (2006) where they found that high metal concentrations in aquifers were related to water with low PH values. Some of values of iron for Kwa Kilui, Nthongoni and Kalulini boreholes were found to be above the WHO and KEBS standards. This meant that the water was un-aesthetically safe.

#### 6.3.2.3 Total Dissolved Solids (TDS)

Total dissolved solids include all the dissociated electrolytes that make up salinity concentrations as well as other compounds such as dissolved organic matter (EPA, 2012). Figure 5.24 shows the temporal variability in TDS for boreholes within the study area. All the values for the parameter were found to be below the WHO standards. However some values for Muselele, Kwa Kilui and Kanyongonyo boreholes were found to surpass the KEBS standards. Generally therefore the water from the studied boreholes is safe for TDS. It is evident from the figure that temporal variation for TDS exists for borehole water in the Yatta plateau. The trend shown in the figure could be as a result of differences in the geological formations and factors such as weathering that may be common within the different aquifers. The above is concurred by the findings of Tavassoli and Khaksar, (2002), Tong and Chem (2011) and those of Alberta Environment (2009).

#### 6.3.2.4 Fluoride

Fluoride is a naturally occurring chemical substance found in water, soil, foods and several other compounds in trace quantities (Harrison, 2005). Figure 5.25 shows the temporal variability for fluoride during different periods. Although the fluoride values for the boreholes during the sampling period were found to be lower than those of the baseline data, there was an increasing trend for data collected during the sampling period. This could be attributed to changes in the geologic formations for the different aquifers. The trend showed in the figure may be also due to differences in the composition of the geologic formations at the different aquifer levels. The changes witnessed in the different boreholes concur with results of Tavassoli and Khaksar, (2002) and those of Petalas et al., (2006) where they both attributed the ground water quality to the different geological formations present within the specific aquifers.

The increases may be a threat to health if the observed trend in the boreholes continues since exposure to high levels of fluoride can lead to mottling of teeth and in severe cases, crippling skeletal fluorosis (WHO, 2006) and therefore extensive and long term monitoring should be conducted in the area in order to better understand the ground water situation within the area.

### 6.4 Water Utilization

The concerns of the respondents, in regard to the suitability of ground water, for various purposes, was determined through questionnaire survey. The ground water in the Lower Yatta plateau is used for various purposes among them domestic, livestock and small scale irrigation. The demand for water has been rising due to increase in population. From the questionnaires administered on the water users of the different boreholes during the sampling period, it was found that the local community was almost entirely dependent on borehole water for their domestic water needs. The data gathered from the questionnaires show the main water quality concern for the water users as taste at over 90%. The water users also suggested that the major taste concern was salinity at over 80%. The taste in the water could be attributed to the underlying rocks which may be causing the minerals in them to dissolve hence causing saline taste in the water. Also the taste can be attributed to iron within the different aquifers in the area. This concurs with findings in the chemical analysis of the water samples which points that the taste may be due to the presence of high levels of total hardness, high levels of turbidity and finally the high levels of electrical conductivity within the boreholes. The water users suggested that the taste in water changed with different seasons although the views were divided however the change was unanimously agreed to occur during the wet season only.

The findings were found to be in line with those of Adetunde et al., (2011) and Yan, et al (2015). Other water quality concerns raised were color and odor. Most of the water users suggested that there was no odor in the borehole water. The small group that complained of odor in the borehole water for Kanyangi, Kalulini, Kanyongonyo and Nthongoni boreholes when asked whether the odor in the water had seasonal variability they gave divided views on the matter. The odor in the water may be due to presence of iron in the water. This case is also supported by a study done by Adetunde et al., (2011).

With regard to water color more than 95% did suggest color as a key concern. The small group that complained of color further suggested that the color varied with different seasons and that the change was mostly during the wet season. The presence of color could be attributed to minerals and turbidity in the water which has also been found in the chemical analysis results which have been discussed earlier in this chapter. These findings appear to be in agreement with those of Tavassoli and Khaksar, (2002) in a study conducted in Iran on the effects of geologic formations on quaternary aquifers.

The presence of color affected the water users such that some of them found the water being unfit for drinking purposes. Based on a study done by WHO (2006), it was found that the main contamination in deep ground water aquifers is mainly from dissolved minerals and the water is usually microbial safe. The views of the water users on the possible water quality solutions showed that most of the water users preferred treatment of the water as an alternative solution. This was closely followed by the alternative to develop other sources.

### 6.5 Influence of water abstraction on ground water quality

The water demand in the Yatta plateau has been increasing due to increasing population. This has been collaborated by the fact that there has been over abstraction in ground water in almost all the boreholes in the study area. Key water quality parameters were analysed to determine whether water abstraction influenced the groundwater quality during the sampling period. The parameters analysed were turbidity, iron, fluoride and pH. The results of the regression analysis in Table 5.1 show that, generally, there was no significant relationship between abstraction rates and water quality parameters. The regression curves in figures 5.2 to 5.5 confirm that the relationship between the water abstraction and the variation of groundwater quality is not significant.

**6.6 Hypothesis Testing**

The four (4) hypotheses in this study were tested using SPSS ANOVA tool and the results presented in chapter 5 of this report. The ANOVA analysis results for the first hypothesis concerning the possibility of existence of spatial variability in the water quality parameters within the study area during both the wet and dry seasons were shown in Tables 5.2 and 5.3 respectively. In the results, during the wet season, only iron had a p-value higher than 0.05 while in the dry season both iron and turbidity had p-values higher than 0.05. This means that out of the eight parameters tested, during the wet season only iron did not have significant spatial variation while during dry season both iron and turbidity did not have significant spatial variation. Given that the rest of the water quality parameters in both dry and wet seasons had significant spatial variation the null hypothesis was rejected. This means that there were significant spatial variations in ground water chemical parameters in the Yatta plateau in Kitui County.

The results on the second hypothesis on existence of temporal variations of ground water quality in the Yatta plateau in Tables 8 show that only turbidity had a p-value (0.06) higher than 0.05. The parameters were also correlated and the results in Table 5.5 showed significant correlations at 95% confidence interval between, pH and Electrical conductivity, pH and Total hardness, pH and TDS, and Total alkalinity and Flouride at correlation values of 0.417, 0.460, 0.423 and -0.381 respectively. The correlation values means that the relationships were weak. From the results in Table 5.4, the second hypothesis is also rejected meaning that there was short and long term changes of ground water changes in the Yatta plateau in Kitui County.

The third hypothesis stated that there was no relationship between ground water chemical quality and rainfall in the Yatta plateau. The correlation results in Table 5.7 show that there was a weak relationship between rainfall and groundwater quality parameters. Table 5.6 shows the individual correlation values for Electrical conductivity, Total hardness, total alkalinity and TDS as 0.065, 0.016, 0.199 and 0.017 respectively while the regression values are 0.004, 0.000, 0.040 and 0.000 respectively. From the results in the table, therefore, the relationships between rainfall and the water quality parameters can be termed as generally weak. The null hypothesis was not rejected meaning that there was no significant relationship between the ground water quality and rainfall at 0.05 alpha level.

Finally in the fourth (4) hypotheses, the null hypothesis was not rejected based on the results in Table 5.8 since all the p-values for the results were below 0.05 level. This means that there is no significant influence of chemical water quality on water utilization in the Yatta plateau in Kitui County.

# CHAPTER SEVEN

# CONCLUSIONS AND RECOMMENDATIONS

## 7.1 Introduction

This chapter provides the conclusion and recommendations of the study on the assessment of the ground water quality in the Lower Yatta Plateau. The conclusions and recommendations are based on the results of the analysis, discussions and hypothesis testing presented in chapters five (5) and six (6). The conclusions and recommendations are deduced specifically from the analysis of the relationship between water abstraction, rainfall variability and the groundwater quality, the spatial-temporal variability in water quality and finally the effects of key ground water parameters on water utilization in the study area.

## 7.2 Key findings

This study came up with a number of key findings that are presented in the following sections:

(i) Spatial variations on water quality.

It was noted that there were significant spatial variations in the groundwater quality parameters in the Yatta plateau. The variations of the different water quality parameters were characterized by increase or decrease in independent directions. The spatial variations do not seem to be interconnected. The causes of the spatial variations were mainly attributed to the nature of geological formations in Yatta plateau.

(ii) Temporal variations of ground water quality parameters.

Both short term and long term changes in the ground water chemical parameters were found to exist in the Yatta plateau. The Electrical conductivity, TDS and fluoride were found to be increasing when baseline conditions are taken into account. The values for TDS in some cases were above the KEBS standards although all the values remained within the WHO standards. The values for iron were found to be either constant in some boreholes or decreasing in other boreholes during the study period. The increases and or decreases were attributed to the nature of the geological materials within the specific aquifers.

(iii) The influence of hydrogeology on ground water quality.

The depths of the boreholes that were studied range between 133 to 230m deep. The ground water quality variations were attributed to the differences in the composition of the geologic formations at the different aquifer levels. The influence of hydrogeology on the ground water quality was found to play a key role in the variations since other factors including rainfall were found not to play a role in the water quality changes.

(iv) The influence of water abstraction and land use.

It was found out that there was no significant influence of the water abstraction on the ground water quality. However, it was noted that there existed a strong relationship between abstraction rates in the dry seasons and ground water quality than is the case during the rain seasons. It was also found out that the residents within the study area generally practice traditional farming and rarely use chemical fertilizers on their farms and therefore land use was not found to influence the ground water quality in the study area.

(v) The levels of key water quality parameters

Most of the ground water quality parameters except for turbidity were found to be within the WHO and KEBS standards (Table 2.2). However, it was also found that some of the parameters notably Electrical conductivity, TDS and fluoride were increasing and are likely to surpass the WHO and KEBS standards in the future.

### 7.3 Conclusions

The main conclusions of this study are presented in the following sections:

(i) Spatial – Temporal variations and influence of hydrogeology on water quality.

Based on the discussions in chapter 6, there was no direct relationship between rainfall and ground water chemical parameters within the study area. It was also noted that there was spatial variability in different parameters that were analysed in different boreholes during the different sampling periods. The spatial variability may be due to differences in the geologic formations of the aquifers for individual boreholes within the study area that vary from one borehole to another. Long term and short term changes were noted for several chemical parameters.

Based on hypothesis testing, it was concluded that there exists spatial variability in the tested parameters, that there were short term and long term changes in ground water quality parameters within the Lower Yatta plateau, that there is no relationship between rainfall variability and variability of ground water chemical parameters and finally there was no significant influence of chemical water quality on water utilization within the Lower Yatta plateau.

(ii) The influence of water abstraction and land use on the ground water quality.

Although there was no significant influence of the existing water abstraction rates to the ground water quality, it was noted that there existed a stronger relationship between abstraction rates in the dry seasons and ground water quality than is the case in the rain seasons. Therefore increased abstraction rates are likely to influence the ground water quality in the Lower Yatta plateau. Increasing population is likely to cause land use change and therefore influence the ground water quality in the future in the study area.

(iii)Water quality Concerns

Turbidity was found to be above the WHO and KEBS standards shown in Table 2.2. Although the borehole water in the study area is generally of good quality, some parameters were noted be increasing drastically and probably they may surpass the WHO and KEBS standards in future. The parameters that were noted to be increasing included electrical conductivity, TDS and Fluoride.  From the analysis of the questionnaires administered on the water users, it was concluded that the water users in the study area depended almost entirely on the existence of the boreholes for their domestic water supply. The major water quality concern was taste although there were other minor water quality concerns on colour and odour. The main possible water quality solutions suggested by the water users were treatment of the borehole water and the development of other possible water sources.

### 7.4 Recommendations

The provision of recommendations in any study is important in that it allows the findings of the research to be translated into action on the ground. The study came up with recommendations to various governmental and non-governmental institutions and for further studies. The recommendations are presented in the following sections:

#### 7.4.1 Recommendation to County Government of Kitui

(i) The County government of Kitui should consider liaising with other government

institutions (eg.WARMA and TANATHI Water Services Board) in order to make a more informed decision while developing local community water supplies. This is crucial in making decisions on the appropriate water development projects. This will assist in minimizing wastage of financial resources on poor quality ground water projects.

(ii) The County government should consider developing new policies on ground water

quality monitoring and ground water utilization in line with the national policies. This will help the county governments to better monitor the ground water quality in the plateau and also allow for regulation and governance of ground water development projects.

(iii) Ground water quality monitoring programme should be established with support of the County Government.

(iv) There is need for keeping of records for all boreholes developed in the county for future reference and research.

(v) Promote recharge of groundwater system using appropriate technologies and land use management.

(vi) Establish ground water- recharge zones in different parts of Yatta plateau.

### 7.4.2 Recommendations to Government Institutions:

The recommendations are made to specific institutions concerned with water resources management. These include WARMA and Tanathi Water Service Board.

**WARMA**

WARMA is the Institution charged with the responsibility of managing the water quality and exploitation of the water resources in Kenya.

(i) It is recommended that regular and enhanced ground water quality monitoring be

made in oder to establish the existing water quality trends in theYatta plateau. This will enable the Authority to advice Kitui County Government, other government institutions and NGOs implementing water projects in the Yatta plateau.

(ii) WARMA should carry out a detailed ground water quality mapping and share data and information with implementing agencies to avoid implementation of projects with poor water quality which are not viable.

**Tanathi Water Services Board.**

The Water Services Boards are Institutions charged with the responsibility of developing national public water works in specific regions in Kenya. Tanathi Water Services Board covers the study area among others. The following specific recommendations are directed to Tanathi Water Services Board:

(i) The Board should liaise with other government institutions (eg. WARMA) before implementing borehole-drilling programs so as to better determine the existing chemical water quality conditions for different regions. This is important for locating projects in appropriate areas.

(ii) It is further recommended that the Board should also integrate the use of surfer model

maps used in this report when developing new ground water sources on the Yatta plateau so as to avoid developing sources in areas with poor water quality levels. This will ensure that the new water sources developed have safe water that meets WHO and KEBS standards.

(iii) Borehole drilling record keeping, Water quality monitoring, and control of over abstraction to avoid deterioration of ground water is also recommended.

### 7.4.3 Recommendations for further studies:

(i) It is also recommended that a detailed geologic investigation be conducted for the

boreholes in the region so as to ascertain the different causes of the trends witnessed in the different parameters analysed for each of the boreholes.

(ii) It is also recommended that the chemical water quality parameters that have shown signs of degradation be monitored from time to time so as to ensure water quality control and continued supply of safe water from the boreholes within the plateau.

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# ANNEXES

## ANNEX 1: QUESTIONNAIRE FOR ASSESSING WATER UTILIZATION IN YATTA PLATEAU

SECTION A: INTRODUCTION/ GENERAL

Name…………………………………………………………………………

Name of the borehole…………………………………………………………

I. Age:

1. 18-30 [ ]
2. 31-40 [ ]
3. 41-50 [ ]
4. Above 50 [ ]

II. Sex

1. Male [ ]
2. Female [ ]

III. What is the highest education level you have attained?

1. Primary [ ]
2. Secondary [ ]
3. College/university [ ]
4. None [ ]

SECTION C: BOREHOLE COMMUNITY WATER USERS

IV. Where do you draw your water for domestic uses from?

1. River [ ]
2. Dam/pan [ ]
3. Borehole [ ]
4. Roof Catchment [ ]

V. According to you, what are the quality concerns with the Borehole source?

1. Odour [ ]
2. Colour [ ]
3. Taste [ ]

VI. When do you use the Borehole Water?

1. Dry season only [ ]
2. Rain season only [ ]
3. All seasons [ ]

VII. Does the water have color?

1. Yes [ ]
2. No [ ]

VIII. Does the color affect your utilization of the water?

1. Yes [ ]
2. No [ ]

IX. If yes, how

1. It makes me uncomfortable drinking the water
2. It can only be used for other activities but not drinking [ ]

X. Does the color vary with different seasons?

1. Yes [ ]
2. No [ ]

XI. If yes, explain

1. It changes during the wet season [ ]
2. It changes during the dry season [ ]

XII. Does the water have taste?

1. Yes [ ]
2. No [ ]

XIII. If yes, what is the taste?

1. Saline [ ]

2. Bitter [ ]
3. Any other [ ]

XIV. Does the taste change with seasons?

1. Yes [ ]
2. No [ ]

XV. If yes, Explain

1. It changes in the rainy season [ ]
2. It changes in the dry season [ ]

XVI. Does the water have odor?

1. Yes [ ]
2. No [ ]

XVII. Does the odor vary with seasons?

1. Yes [ ]
2. No [ ]

XVIII. What can be done to ease the problem if any?

1. Treatment of the water [ ]
2. Nothing [ ]
3. Develop other sources [ ]

**ANNEX 2: RAINFALL DATA COLLECTED BETWEEN JANUARY 2015 AND MAY 2016**

| Jan-15 | **Feb-15** | **Mar-15** | **Apr-15** | **May-15** | **Jun-15** | **Jul-15** | **Aug-15** | **Sep-15** | **Oct-15** | **Nov-15** | **Dec-15** |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3.5 | 8.7 | 38.1 | 177.9 | 91 | 0 | 6.7 | 2.3 | 3.6 | 21 | 313.7 | 124.8 |

| **Jan-16** | **Feb-16** | **Mar-16** | **Apr-16** | **May-16** | **Jun-16** |
|---|---|---|---|---|---|
| 45.7 | 39 | 50 | 136.4 | 14.3 | |

(Source: KMD, Kanyangi Yard Station)

## ANNEX 3: BASELINE DATA FOR WATER QUALITY FOR BOREHOLES IN YATTA PLATEAU

### 1. NTHONGONI BOREHOLE BASELINE DATA

Baseline: Nthongoni B/HOLE

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| TITLE: Water Sample Analytical Certificate – Physical Chemical Results | REF. NO : F/9/1/3 |
| | ISSUE NO : 04 |
| DEPARTMENT: Technical | REV. NO : 03 |
| ISSUED BY: DTCM | DATE OF ISSUE: 15th April 2013 |
| AUTHORISED BY : TCM | Page : 1 of 2 |

Serial No: ..................

Sample No: 2398

Name of Customer: NWCPC

Address: ..................

Purpose of Sampling: DOMESTIC.

County: KITUI

Date Sampled 16/05/14

Date Received 23/05/14

Source: NTHONGONI B/H

Date Compiled: 11/06/14

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 6.73 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 9.0 | Max 5 | Max 5 |
| Conductivity ($25^0$C) | µS/cm | 1151 | Max 2500 | - |
| Iron | mg/l | 0.30 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 120 | Max 100 | Max 150 |
| Magnesium | mg/l | 28.74 | Max 100 | Max 100 |
| Sodium | mg/l | 66.3 | Max 200 | Max 200 |
| Potassium | mg/l | 9.04 | Max 50 | - |
| Total Hardness | mg$CaCO_3$/l | 418 | Max 500 | Max 300 |
| Total Alkalinity | mg$CaCO_3$/l | 244 | Max 500 | - |
| Chloride | mg/l | 179 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.37 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 12.56 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 29.2 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 94 | - | - |
| Total Dissolved Solids | mg/l | 713.6 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst CELLINE A. OBUYA Signature

## 2. MUSELELE AND KANYONGONYO BOREHOLES BASELINE DATA

THE PROJECT FOR RURAL WATER SUPPLY IN KITUI AND MWINGI DISTRICT ; THE MINISTRY OF WATER AND IRRIGATION, THE REPUBLIC OF KENYA

Progress & Summary of Drilling Works

| Progress No. | Well No. | District | Village | State of Well Completion | Drilling team | Drilling work: Date (Commencement / Completion) | Depth (m) (Drilling / Casing) | Casing length (m) (Plain PVC / Screen PVC) | Screen position (m) | Packed gravel volume ($m^3$) | Development works: Date (Commencement / Completion) | Water level (m) (Static W.L. / After developing) | Water discharge of airlifting during drillinging ($m^3/h$) | Water discharge of airlifting during developing ($m^3/h$) | Developing hours | to become clean water | Water Quality Analysis at the site: Temperature (°C) | EC ($\mu S/cm$) | TDS (mg/l) 2000 | Fluoride (mg/l) 2.0 | Fe (mg/l) 1.00 | Mn (mg/l) 0.50 | Information: Planning drilling depth / W.S.Facilities | Remarks (Successful well Number) Blue: Submersible pump (Total Number) Black: Hand pump |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 17 | 59 | Mwingi | Ibumbi | Tentative Successful | Spare(2) | 06/08/07 / 07/08/09 | 70.00 / 65.50 | 50.50 / 15.00 | 47.50-62.50 | 1.08 | 06/08/07 / 06/08/07 | 31.00 / 18.85 | 21.60 | 21.60 | 3.0 | clear | 26.60 | 2100 | 1302 | 2.80 | 0.06 | <0.01 | 123 m. / S-Pump | 14 (11/30) |
| 18 | 61 | Mwingi | Kavaini | Dry well | Spare(1) | 06/10/07 / 06/10/07 | 94.00 / None | Non | Non | Non | Non | Non / Non | Non | Non | – | – | – | – | – | – | – | – | 60 m. / S-Pump | Dry well 4 |
| 19 | 61A | Mwingi | Thitani | Tentative Successful | Spare(1) | 06/22/07 / 06/24/07 | 86.70 / 62.50 | 47.50 / 15.00 | 29.5-41.5, 56.5-62.5 | 1.23 | 06/23/07 / 06/23/07 | 18.13 / 12.87 | 20.00 | 21.00 | 4.0 | clear | 27.6 | 1481 | 918 | 0.5 | 0.18 | <0.01 | 110 m. / S-Pump | 15 (12/30) |
| 20 | 56 | Mwingi | Katuyu | Tentative Successful | Spare(1) | 06/24/07 / 06/26/07 | 80.00 / 74.00 | 47.00 / 27.00 | 20.0-23.0, 29.0-35.0, 44.0-53.0, 59.0-62.0 | 1.80 | 06/26/07 / 06/26/07 | 3.00 / 4.88 | 5.00 | 5.10 | 4.0 | clear | 26.50 | 2360 | 1492 | 2.80 | <0.01 | <0.01 | 145 m. / Handpump with Iron filter | 16 |
| 21 | 55A | Mwingi | Wikivuvwa | Dry well | Spare(1) | 06/26/07 / 06/28/07 | 100.00 / 0.00 | Non | Non | Non | Non | Non / Non | Non | Non | – | – | – | – | – | – | – | – | 100 m. / S-Pump | Dry well 5 |
| 22 | 55 | Mwingi | Ndaluni | Tentative Successful | Spare(1) | 06/29/07 / 06/31/07 | 100.00 / 96.00 | 68.00 / 30.00 | 24.0-33.0, 51.0-64.0, 66.0-69.0, 75.0-87.0, 90.0-93.0 | 1.87 | 06/30/07 / 06/30/07 | 7.90 / 8.95 | 1.60 | 1.80 | 4.0 | clear | 27.00 | 975 | 605 | 0.40 | 0.00 | 0.00 | 51 m. / S-Pump | 17 (13/30) |
| 23 | 39 | Kitui | Kunikila | Tentative Successful | Spare(1) | 06/08/07 / 06/08/07 | 155.00 / 155.00 | 110.00 / 45.00 | 102.0-152.0, | 2.31 | 06/10/07 / 06/10/07 | 7.80 / 8.95 | 30.00 | 20.57 | 4.0 | clear | 26.3 | 802 | 497 | 1.74 | <0.01 | <0.01 | 154 m. / S-Pump | 18 (14/30) |
| 24 | 10 | Kitui | Kaluva secondary school | Tentative Successful | Spare(1) | 06/10/07 / 06/14/07 | 100.00 / 96.50 | 77.50 / 21.00 | 65.5-71.5, 80.5-95.5 | 1.43 | 06/13/07 / 06/13/07 | 21.00 / 19.50 | 5.00 | 6.00 | 4.0 | clear | 28.2 | 973 | 655 | 0.69 | 0.17 | 0.69 | 154 m. / S-Pump | 19 (15/30) |
| 25 | 8 | Kitui | Kanzaamu | Tentative Successful | Spare(1) | 06/15/07 / 06/18/08 | 100.00 / 96.50 | 68.50 / 30.00 | 50.5-62.5, 74.5-77.5, 90.5-95.5 | 1.32 | 06/13/07 / 06/13/07 | 33.00 / 32.10 | 2.40 | 2.40 | 4.0 | clear | 24.6 | 704 | 437 | 1.70 | 0.29 | 0.04 | 48 m. / S-Pump | 20 (16/30) |
| 26 | 4 | Kitui | Ngwani | Dry well | Spare(1) | 06/21/07 / 06/22/07 | 120.00 / 0.00 | Non | Non | Non | Non | Non / Non | Non | Non | - | - | - | - | - | - | - | - | 70 m. / S-Pump | Dry well 6 |
| 27 | 50 | Kitui | Mwala | Dry well | Spare(1) | 06/23/07 / 06/27/07 | 170.00 / 0.00 | Non | Non | Non | Non | Non / Non | Non | Non | - | - | - | - | - | - | - | - | 45 m. / Handpump | Dry well 7 |
| 28 | 51 | Kitui | Kyatune | Tentative Successful | Spare(1) | 06/29/07 / 07/01/07 | 125.00 / 119.00 | 70.00 / 36.00 | 53.5-59.5, 68.5-88.5, 88.5-92.5, 101.5-110.5 | 1.95 | 07/01/07 / 07/01/07 | 4.40 / 4.40 | 10.30 | 10.33 | 4.0 | clear | 23.9 | 434 | 269 | 0.14 | 0.00 | 0.00 | 155 m. / Handpump | 21 (17/30) |
| 29 | 20 | Kitui | Kanyongonyo | Tentative Successful | Spare(1) | 07/05/07 / 07/09/07 | 172.00 / 170.00 | 121.00 / 51.00 | 83.5-89.5, 95.0-110.0, 122.0-137.0, 140.0-152.0, 161.0-167.0 | 3.00 | 07/09/07 / 07/09/07 | 45.00 / 41.87 | 15.60 | 10.28 | 4.0 | clear | 23.1 | 808 | 500 | 2.4 | <0.01 | <0.01 | 175 m. / S-Pump | 22 (18/30) |
| 30 | 32 | Kitui | Kakilini | Dry well | Spare(1) | 07/08/07 / 07/15/07 | 138.00 / 0.00 | Non | Non | Non | Non | Non / Non | Non | Non | - | - | - | - | - | - | - | - | 77 m. / Handpump | Dry well 8 |
| 31 | 69 | Mwingi | Yumbu | Tentative Successful | UT-1 | 07/08/07 / 07/13/07 | 120.00 / 119.00 | 92.00 / 27.00 | 83.0-86.0, 98.0-119.0 | 1.56 | 07/13/07 / 07/13/07 | 27.20 / 27.20 | 27.00 | 27.00 | 4.0 | clear | 22.3 | 598 | 398 | 1.8 | 0.11 | <0.01 | 94 m. / S-Pump | 23 (19/30) |
| 32 | 74 | Mwingi | Miambani | Tentative Successful | UT-1 | 07/14/07 / 07/21/07 | 211.00 / 66.50 | 44.50 / 24.00 | 21.5-33.5, 39.5-48.5, 63.5-66.5 | 6.11 | 07/20/07 / 07/20/07 | 6.50 / 19.80 | 0.00 | 4.00 | 16.0 | clear | 22.6 | 2500 | 1609 | 0.0 | 0.20 | 0.00 | 130 m. / S-Pump | 24 (20/30) |
| 33 | 33 | Kitui | Muselele | Tentative Successful | Spare(1) | 07/16/07 / 07/19/07 | 153.00 / 145.00 | 100.00 / 45.00 | 85.0-94.0, 103.0-139.0 | 2.30 | 07/18/07 / 07/18/07 | 19.70 / 19.10 | 5.10 | 4.10 | 4.0 | clear | 25.8 | 194 | 114 | 1.8 | 0.00 | 0.00 | 182 m. / S-Pump | 25 (21/30) |

2/5

## 3. KANYANGI BOREHOLE BASELINE DATA

Baseline: Kanyangi B/Hole

M.W.D. 90
W.A.B. 28 (Revised 1976)

Entered
Recorded Plotted

REPUBLIC OF KENYA

MINISTRY OF WATER DEVELOPMENT

**BOREHOLE COMPLETION RECORD**

Borehole No. ~~27~~ C-11818

Borehole Name Kanyangi

**To be filled in TRIPLICATE**

Formation Volcanics

1. *Location:* Kanyangi ... KITUI District.
Map Sheet: 163/4 . Scale: 1:50,000 Coordinates: 01° 46' 22" S
Area: 37 54' 29" E

(*See* sketch page 4) Elevation: ... m. above msl.

2. *Owner:* MLRRW ; Address: 3051 Nairobi

Locality/Estate: ... ; L.R. No.: ...

Intended Use:—Public W.S.; Irrig.; Indust.; Domestic; Stock; Other...

3. *Contractor:* Regwa Co. of Egypt ; Address: Box 40076 Nai'b
Licence No.: ... ; Gazetted on ... (*Date*) ; Drilling Supervisor: ...

4. *Type of Borehole:*—Drilled; Driven; Bored; Jetted; Other Drilled
Type and Make of Drill Rig: S.S. 135

5. *Borehole Construction* (also *see* sketch page 3)
Drilling started: 17.10.97 (*Date*); Drilling completed 18.10.97 (*Date*) All work completed: 21.10.97 (*Date*)
Total Depth: Reported 133 m.; Measured 133 m.; Final (back-filled) Depth: ... m.
Hole Diameter: 311.15 mm. from 0 m. to 6 m.
225.4 mm. from 6 m. to 133 m.
/ mm. from / m. to / m.
Permanent Casing:
Plain:
Type steel ; Diam. 254 mm.; Length 6 m., from 0 m. to 6 m.
Type steel ; Diam. 152 mm.; Length 97.5m., from +0.5 m. to 66 m.
Slotted or Perforated: 78–96, 108–120m
Size and Description of Openings ... ;
Type ... ; Diam. ... mm.; Length ... m., from ... m. to ... m.
Screen:
Type and Make machine slotted, steel ;
Diameter 152 mm., Length 36 m., set from 66 m. to 78 m.
Gravel Pack: 96–108 and 120–132m
Size of grains 2–4 mm., Roundness (good, fair, poor), Volume inserted in to annular space ... cu. m., from ... m. to ... m.
Open Hole: Diameter ... mm., from ... m. to ... m.

6. *Aquifer:* 1st Water Struck at 60 m.; Water rest level ... m.
Main Aquifer Struck at ... m.; Water rest level ... m.
Water-bearing material: weathered phonolite from ... m. to ... m.

# 4. KWA KILUI BOREHOLE BASELINE DATA

MANAGEMENT AUTHORITY

| | |
|---|---|
| TITLE: Water Sample Analytical Certificate – Physical Chemical Results | REF. NO : F/9/1/3 |
| | ISSUE NO : 04 |
| DEPARTMENT: Technical | REV. NO : 03 |
| ISSUED BY: DTCM | DATE OF ISSUE: 15th April 2013 |
| AUTHORISED BY : TCM | Page : 1 of 2 |

Serial No: ..........

Sample No: 0397

Name of Customer: ALMAK AQUA DRILLERS

Address: ..........

Purpose of Sampling DOMESTIC

County: MACHAKOS

Date Sampled: 12.08.2013

Date Received: 21.08.2013

Source: PAUL MAKOSA B/H KYUSYANI, YATTA.

Date Compiled: 30.08.2013

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.59 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | 50 | Max 15 | Max 15 |
| Turbidity | N.T.U | 109 | Max 5 | Max 5 |
| Conductivity (25°C) | µS/cm | 651 | Max 2500 | - |
| Iron | mg/l | 1.63 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | 0.3 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 68 | Max 100 | Max 150 |
| Magnesium | mg/l | 13.65 | Max 100 | Max 100 |
| Sodium | mg/l | 44.2 | Max 200 | Max 200 |
| Potassium | mg/l | 2 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 226 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 156 | Max 500 | - |
| Chloride | mg/l | 72 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.3 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 5.0 | Max 50 | Max 50 |
| Nitrite | mgN/l | 0.14 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 65.1 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 82 | - | - |
| Total Dissolved Solids | mg/l | 403.6 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst PETER M. MWIRIGI Signature ..........

## 5. KALULINI BOREHOLE BASELINE DATA

# REPUBLIC OF KENYA

## MINISTRY OF WATER AND IRRIGATION

**Central Water Testing Laboratories**

Tel. No. (020) 553834, 553957
P.O. Box 30521-00100,
NAIROBI.

PHYSICAL/CHEMICAL WATER ANALYSIS REPORT

Sample No...........787.......................................
Source..David Mwongela B/H, Lower Yatta – MKS..
Purpose of Sampling.....Domestic........................

Date of Sampling...12 – 09 – 11 ...........
Date Received......13 – 09 – 11 ............
Submitted by ...Almak Aqua Drillers Ltd...
Address.................................................

| PARAMETERS | UNIT | RESULTS | REMARKS |
|---|---|---|---|
| pH | pH Scale | 7.57 | |
| Colour | mgPt/l | 70 | |
| Turbidity | N.T.U. | 33 | |
| Permanganate Value (20 min. boiling) | $mgO_2/l$ | 15.8 | |
| Conductivity ($25^0$ C) | µS/cm | 888 | |
| Iron | mg/l | 0.98 | |
| Manganese | mg/l | 0.18 | |
| Calcium | mg/l | 36 | |
| Magnesium | mg/l | 10.7 | |
| Sodium | mg/l | 142 | |
| Potassium | mg/l | 1.4 | |
| Total Hardness | $mgCaCO_3/l$ | 134 | |
| Total Alkalinity | $mgCaCO_3/l$ | 120 | |
| Chloride | mg/l | 27 | |
| Fluoride | mg/l | 1.5 | |
| Nitrate | mgN/l | 0.6 | |
| Nitrite | mgN/l | 0.09 | |
| Ammonia | mgN/l | - | |
| Total Nitrogen | mgN/l | - | |
| Sulphate | mg/l | 270 | |
| Orthophosphate | mgP/l | - | |
| Total Suspended Solids | mg/l | - | |
| Free Carbon Dioxide | mg/l | 72 | |
| Dissolved Oxygen | mg/l | - | |
| Total Dissolved Solids | mg/l | 550.6 | |
| Others | | | |

**COMMENTS:**

**Slightly turbid, coloured water with high Iron and Manganese contents. However, the clarity is expected to improve with time. The other chemical characteristics are satisfactory.**

Oi/c ....**J. N. MUASYA**............
CENTRAL WATER TESTING LABORATORIES

WATER QUALITY LABORATORY
P.O. BOX 30521, NAIROBI

## ANNEX 4: SAMPLED DATA BETWEEN MARCH 2015 AND MARCH 2016

### 1. KWA KILUI BOREHOLE MARCH 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO :** F/9/1/3 |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:** ..........

**Name of Customer:** FREDRICK TITO MWAMATI

**Purpose of Sampling:** RESEARCH

**Date Sampled:** 24/3/15

**Source:** KWA KILUI BOREHOLE, YATTA.

**Sample No:** 2522

**Address:** ..........

**County:** KITUI

**Date Received:** 26/3/15

**Date Compiled:** 7/04/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 8.00 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | NIL | Max 5 | Max 5 |
| Conductivity (25° C) | μS/cm | 667 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 62.4 | Max 100 | Max 150 |
| Magnesium | mg/l | 16.56 | Max 100 | Max 100 |
| Sodium | mg/l | 46 | Max 200 | Max 200 |
| Potassium | mg/l | 6.9 | Max 50 | - |
| Total Hardness | mg$CaCO_3$/l | 224 | Max 500 | Max 300 |
| Total Alkalinity | mg$CaCO_3$/l | 128 | Max 500 | - |
| Chloride | mg/l | 83 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.33 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 12.46 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 38.4 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 6 | - | - |
| Total Dissolved Solids | mg/l | 413.5 | Max 1500 | Max 1000 |
| Arsenic | μg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst CELLINE OBUYA Signature

## 2. MUSELELE BOREHOLE MARCH 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:** ............

**Sample No:** 2521

**Name of Customer:** FREDRICK TITO MWAMATI

**Address:** ............

**Purpose of Sampling:** RESEARCH

**County:** KITUI

**Date Sampled:** 24/3/15

**Date Received:** 26/3/15

**Source:** MUSELELA BOREHOLE, YATTA.

**Date Compiled:** 7/04/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.51 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.2 | Max 5 | Max 5 |
| Conductivity ($25^0$ C) | µS/cm | 691 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 64 | Max 100 | Max 150 |
| Magnesium | mg/l | 19.48 | Max 100 | Max 100 |
| Sodium | mg/l | 44 | Max 200 | Max 200 |
| Potassium | mg/l | 6.7 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 240 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 266 | Max 500 | - |
| Chloride | mg/l | 55 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.35 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 6.41 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 4.7 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 16 | - | - |
| Total Dissolved Solids | mg/l | 1283.4 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst **CELLINE OBUYA** Signature ............

## 3. KANYONGONYO BOREHOLE MARCH 2016 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO :** F/9/1/3 |
| | **ISSUE NO :** 04 |
| **DEPARTMENT:** Technical | **REV. NO :** 03 |
| **ISSUED BY:** DTCM | **DATE OF ISSUE:** 15th April 2013 |
| **AUTHORISED BY :** TCM | **Page :** 1 of 2 |

**Serial No:** ........

**Sample No:** 2119

**Name of Customer:** FREDRICK TITO MWAMATI

**Address:** ........

**Purpose of Sampling:** DOMESTIC

**County:** KITUI

**Date Sampled:** 16/03/2016

**Date Received:** 18/03/2016

**Source:** KANYONGONYO BOREHOLE, KANYANGI.

**Date Compiled:** 29/03/2016

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.58 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.3 | Max 5 | Max 5 |
| Conductivity ($25^{0}$C) | µS/cm | 726 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 25.6 | Max 100 | Max 150 |
| Magnesium | mg/l | 32.08 | Max 100 | Max 100 |
| Sodium | mg/l | 72 | Max 200 | Max 200 |
| Potassium | mg/l | 6.4 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 196 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 266 | Max 500 | - |
| Chloride | mg/l | 57 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.75 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 3.91 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 1.17 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 18 | - | - |
| Total Dissolved Solids | mg/l | 450.12 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst **RACHEL OLONGA** Signature ........

## 4. KANYANGI BOREHOLE MARCH 2016 PHYSICAL-CHEMICAL RESULTS

| | | |
|---|---|---|
| WATER RESOURCES MANAGEMENT AUTHORITY | | |
| | TITLE: Water Sample Analytical Certificate – Physical Chemical Results | REF. NO : F/9/1/3 |
| | | ISSUE NO : 04 |
| | DEPARTMENT: Technical | REV. NO : 03 |
| | ISSUED BY: DTCM | DATE OF ISSUE: 15th April 2013 |
| | AUTHORISED BY : TCM | Page : 1 of 2 |

**Serial No:** ..........

**Name of Customer:** FREDRICK TITO MWAMATI

**Purpose of Sampling:** DOMESTIC

**Date Sampled:** 16/03/2016

**Source:** KANYANGI BOREHOLE, KANYANGI.

**Sample No:** 2118

**Address:** ..........

**County:** KITUI

**Date Received:** 18/03/2016

**Date Compiled:** 29/03/2016

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.45 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.6 | Max 5 | Max 5 |
| Conductivity ($25^0$C) | µS/cm | 1408 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | 0.18 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 95.2 | Max 100 | Max 150 |
| Magnesium | mg/l | 47.68 | Max 100 | Max 100 |
| Sodium | mg/l | 115 | Max 200 | Max 200 |
| Potassium | mg/l | 14 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 434 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 312 | Max 500 | - |
| Chloride | mg/l | 235 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.79 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 2.41 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 18 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 22 | - | - |
| Total Dissolved Solids | mg/l | 872.96 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ..........

## 5. KALULINI BOREHOLE MARCH 2016 PHYSICAL-CHEMICAL RESULTS

| | WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|---|
| | **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | | **ISSUE NO : 04** |
| | **DEPARTMENT:** Technical | **REV. NO : 03** |
| | **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| | **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:**

**Name of Customer:** FREDRICK TITO MWAMATI

**Purpose of Sampling:** DOMESTIC

**Date Sampled:** 16/03/2016

**Source:** KALULINI BOREHOLE, KANYANGI.

**Sample No:** 2121

**Address:**

**County:** KITUI

**Date Received:** 18/03/2016

**Date Compiled:** 29/03/2016

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 8.16 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.2 | Max 5 | Max 5 |
| Conductivity ($25^0$C) | µS/cm | 850 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 25.6 | Max 100 | Max 150 |
| Magnesium | mg/l | 25.77 | Max 100 | Max 100 |
| Sodium | mg/l | 112 | Max 200 | Max 200 |
| Potassium | mg/l | 8.6 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 170 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 232 | Max 500 | - |
| Chloride | mg/l | 73 | Max 250 | Max 250 |
| Fluoride | mg/l | 1.01 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 1.96 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 54.7 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 18 | - | - |
| Total Dissolved Solids | mg/l | 527 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature

## 6. NTHONGONI BOREHOLE MARCH 2016 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:** ..................

**Sample No:** 2120

**Name of Customer:** FREDRICK TITO MWAMATI

**Address:** ..................

**Purpose of Sampling:** DOMESTIC

**County:** KITUI

**Date Sampled:** 16/03/2016

**Date Received:** 18/03/2016

**Source:** NTHONGONI BOREHOLE, YATTA.

**Date Compiled:** 29/03/2016

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.42 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.6 | Max 5 | Max 5 |
| Conductivity ($25^0$C) | µS/cm | 1441 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 74.4 | Max 100 | Max 150 |
| Magnesium | mg/l | 48.64 | Max 100 | Max 100 |
| Sodium | mg/l | 143 | Max 200 | Max 200 |
| Potassium | mg/l | 16 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 386 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 334 | Max 500 | - |
| Chloride | mg/l | 229 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.85 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 2.72 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 24.3 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 8 | - | - |
| Total Dissolved Solids | mg/l | 893.42 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ..................

# 7. KWA KILUI BOREHOLE MARCH 2016 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:** ..........

**Sample No:** 2116

**Name of Customer:** FREDRICK TITO MWAMATI

**Address:** ..........

**Purpose of Sampling:** DOMESTIC

**County:** KITUI

**Date Sampled:** 16/03/2016

**Date Received:** 18/03/2016

**Date Compiled:** 29/03/2016

**Source:** KWA - KILUI BOREHOLE YATTA.

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.59 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 6.1 | Max 5 | Max 5 |
| Conductivity (25° C) | μS/cm | 2030 | Max 2500 | - |
| Iron | mg/l | 0.27 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | 0.16 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 292 | Max 100 | Max 150 |
| Magnesium | mg/l | 48.77 | Max 100 | Max 100 |
| Sodium | mg/l | 35 | Max 200 | Max 200 |
| Potassium | mg/l | 3.8 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 930 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 176 | Max 500 | - |
| Chloride | mg/l | 135 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.6 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 1.21 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 850 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 12 | - | - |
| Total Dissolved Solids | mg/l | 1258.6 | Max 1500 | Max 1000 |
| Arsenic | μg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst **RACHEL OLONGA** Signature ..........

# 8. MUSELELE BOREHOLE MARCH 2016 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
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**Serial No:** ..................

**Sample No:** 2117

**Name of Customer:** FREDRICK TITO MWAMATI

**Address:** ..................

**Purpose of Sampling:** DOMESTIC

**County:** KITUI

**Date Sampled:** 16/03/2016

**Date Received:** 18/03/2016

**Source:** MUSELELE BOREHOLE, YATTA.

**Date Compiled:** 29/03/2016

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.89 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.3 | Max 5 | Max 5 |
| Conductivity ($25^0$ C) | µS/cm | 1492 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 61.6 | Max 100 | Max 150 |
| Magnesium | mg/l | 52.03 | Max 100 | Max 100 |
| Sodium | mg/l | 162 | Max 200 | Max 200 |
| Potassium | mg/l | 18 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 368 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 294 | Max 500 | - |
| Chloride | mg/l | 253 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.8 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 3.79 | Max 10 | - |
| Nitrite | mgN/l | 0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 116.9 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 10 | - | - |
| Total Dissolved Solids | mg/l | 925.04 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ..................

# 9. KANYONGONYO BOREHOLE AUGUST 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
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**Serial No:** ..........

**Sample No:** 0331

**Name of Customer:** TITO FREDRICK MWAMATI

**Address:** ..........

**Purpose of Sampling:** STUDY

**County:** KITUI

**Date Sampled:** 12/08/2015

**Date Received:** 14/08/2015

**Source:** KANYONGONYO BOREHOLE, KANYANGI,

**Date Compiled:** 20/08/2015

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.27 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | NIL | Max 5 | Max 5 |
| Conductivity (25$^0$ C) | µS/cm | 1987 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 74.4 | Max 100 | Max 150 |
| Magnesium | mg/l | 84.11 | Max 100 | Max 100 |
| Sodium | mg/l | 147.5 | Max 200 | Max 200 |
| Potassium | mg/l | 20 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 532 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 358 | Max 500 | - |
| Chloride | mg/l | 464 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.52 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 5.41 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 63.71 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 42 | - | - |
| Total Dissolved Solids | mg/l | 1231.94 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature

## 10. KANYANGI BOREHOLE AUGUST 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| TITLE: Water Sample Analytical Certificate – Physical Chemical Results | REF. NO : F/9/1/3 |
| | ISSUE NO : 04 |
| DEPARTMENT: Technical | REV. NO : 03 |
| ISSUED BY: DTCM | DATE OF ISSUE: 15th April 2013 |
| AUTHORISED BY : TCM | Page : 1 of 2 |

Serial No: ..........

Sample No: 0332

Name of Customer: TITO FREDRICK MWAMATI

Address: ..........

Purpose of Sampling: STUDY

County: KITUI

Date Sampled: 12/08/2015

Date Received: 14/08/2015

Source: KANYANGI BOREHOLE, KANYANGI.

Date Compiled: 20/08/2015

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.38 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.1 | Max 5 | Max 5 |
| Conductivity (25° C) | μS/cm | 964 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 40 | Max 100 | Max 150 |
| Magnesium | mg/l | 46.19 | Max 100 | Max 100 |
| Sodium | mg/l | 74 | Max 200 | Max 200 |
| Potassium | mg/l | 9.0 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 290 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 310 | Max 500 | - |
| Chloride | mg/l | 124 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.58 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 6.16 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 22.06 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 28 | - | - |
| Total Dissolved Solids | mg/l | 597.68 | Max 1500 | Max 1000 |
| Arsenic | μg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ..........

## 11. KALULINI BOREHOLE AUGUST 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3**<br>**ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
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**Serial No:** ........................

**Sample No:** 0330

**Name of Customer:** TITO FREDRICK MWAMATI

**Address:** ........................

**Purpose of Sampling:** STUDY

**County:** KITUI

**Date Sampled:** 12/08/2015

**Date Received:** 14/08/2015

**Source:** KALULINI BOREHOLE, KANYANGI.

**Date Compiled:** 20/08/2015

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.69 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.6 | Max 5 | Max 5 |
| Conductivity (25$^0$ C) | µS/cm | 761 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 23.2 | Max 100 | Max 150 |
| Magnesium | mg/l | 30.14 | Max 100 | Max 100 |
| Sodium | mg/l | 84 | Max 200 | Max 200 |
| Potassium | mg/l | 6.5 | Max 50 | - |
| Total Hardness | mg$CaCO_3$/l | 182 | Max 500 | Max 300 |
| Total Alkalinity | mg$CaCO_3$/l | 222 | Max 500 | - |
| Chloride | mg/l | 76 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.67 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 2.56 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 106.86 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 10 | - | - |
| Total Dissolved Solids | mg/l | 471.82 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ........................

# 12. NTHONGONI BOREHOLE AUGUST 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
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**Serial No:** ..................

**Sample No:** 0327

**Name of Customer:** TITO FREDRICK MWAMATI

**Address:** ..................

**Purpose of Sampling:** STUDY

**County:** KITUI

**Date Sampled:** 12/08/2015

**Date Received:** 14/08/2015

**Source:** NTHONGONI BOREHOLE, YATTA.

**Date Compiled:** 20/08/2015

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.19 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 5.2 | Max 5 | Max 5 |
| Conductivity (25$^0$ C) | µS/cm | 1197 | Max 2500 | - |
| Iron | mg/l | 0.13 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 94.4 | Max 100 | Max 150 |
| Magnesium | mg/l | 51.08 | Max 100 | Max 100 |
| Sodium | mg/l | 72.5 | Max 200 | Max 200 |
| Potassium | mg/l | 9.3 | Max 50 | - |
| Total Hardness | mg$CaCO_3$/l | 446 | Max 500 | Max 300 |
| Total Alkalinity | mg$CaCO_3$/l | 298 | Max 500 | - |
| Chloride | mg/l | 207 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.43 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 2.38 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 66 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 36 | - | - |
| Total Dissolved Solids | mg/l | 742.14 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ..................

**13. KWA KILUI BOREHOLE AUGUST 2015 PHYSICAL-CHEMICAL RESULTS**

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
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**Serial No:**

**Sample No:** 0329

**Name of Customer:** TITO FREDRICK MWAMATI

**Address:**

**Purpose of Sampling:** STUDY

**County:** KITUI

**Date Sampled:** 12/08/2015

**Date Received:** 14/08/2015

**Source:** KWA KILUI BOREHOLE, YATTA.

**Date Compiled:** 20/08/2015

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.48 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 1.6 | Max 5 | Max 5 |
| Conductivity (25$^0$ C) | µS/cm | 639 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 61.6 | Max 100 | Max 150 |
| Magnesium | mg/l | 17.53 | Max 100 | Max 100 |
| Sodium | mg/l | 55 | Max 200 | Max 200 |
| Potassium | mg/l | 5.6 | Max 50 | - |
| Total Hardness | mg$CaCO_3$/l | 226 | Max 500 | Max 300 |
| Total Alkalinity | mg$CaCO_3$/l | 134 | Max 500 | - |
| Chloride | mg/l | 84 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.40 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 7.69 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 56.31 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 12 | - | - |
| Total Dissolved Solids | mg/l | 396.18 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature

## 14. MUSELELE BOREHOLE AUGUST 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:** ..............

**Name of Customer:** TITO FREDRICK MWAMATI

**Purpose of Sampling:** STUDY

**Date Sampled:** 12/08/2015

**Source:** MUSELELE BOREHOLE, YATTA.

**Sample No:** 0328

**Address:** ..............

**County:** KITUI

**Date Received:** 14/08/2015

**Date Compiled:** 20/08/2015

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.35 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.1 | Max 5 | Max 5 |
| Conductivity (25°C) | µS/cm | 634 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 41.6 | Max 100 | Max 150 |
| Magnesium | mg/l | 28.69 | Max 100 | Max 100 |
| Sodium | mg/l | 55 | Max 200 | Max 200 |
| Potassium | mg/l | 5.4 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 222 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 258 | Max 500 | - |
| Chloride | mg/l | 56 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.41 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 3.42 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 0.8 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 10 | - | - |
| Total Dissolved Solids | mg/l | 393.08 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ..............

## 15. KANYONGONYO BOREHOLE MAY 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| TITLE: Water Sample Analytical Certificate – Physical Chemical Results | REF. NO : F/9/1/3<br>ISSUE NO : 04 |
| DEPARTMENT: Technical | REV. NO : 03 |
| ISSUED BY: DTCM | DATE OF ISSUE: 15th April 2013 |
| AUTHORISED BY : TCM | Page : 1 of 2 |

Serial No: ..........

Name of Customer: FREDRICK TITO MWAMATI

Purpose of Sampling: STUDY

Date Sampled: 25/5/15

Source: KANYONGONYO BOREHOLE, KANYANGI.

Sample No: 2974

Address: ..........

County: KITUI

Date Received: 26/5/15

Date Compiled: 27/5/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.33 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 3.4 | Max 5 | Max 5 |
| Conductivity (25°C) | µS/cm | 2270 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 148 | Max 100 | Max 150 |
| Magnesium | mg/l | 82.69 | Max 100 | Max 100 |
| Sodium | mg/l | 177.5 | Max 200 | Max 200 |
| Potassium | mg/l | 27 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 710 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 358 | Max 500 | - |
| Chloride | mg/l | 410 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.49 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 18.68 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 102 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 58 | - | - |
| Total Dissolved Solids | mg/l | 1407 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ..........

## 16. KANYANGI BOREHOLE MAY 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:** ..........

**Sample No:** 2971

**Name of Customer:** FREDRICK TITO MWAMATI

**Address:** ..........

**Purpose of Sampling:** STUDY

**County:** KITUI

**Date Sampled:** 25/5/15

**Date Received:** 26/5/15

**Source:** KANYANGI BOREHOLE, KANYANGI.

**Date Compiled:** 27/5/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.85 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 3.7 | Max 5 | Max 5 |
| Conductivity (25°C) | µS/cm | 1079 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 84.8 | Max 100 | Max 150 |
| Magnesium | mg/l | 29.69 | Max 100 | Max 100 |
| Sodium | mg/l | 85.5 | Max 200 | Max 200 |
| Potassium | mg/l | 14 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 334 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 274 | Max 500 | - |
| Chloride | mg/l | 127 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.55 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 15.28 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 26.6 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 18 | - | - |
| Total Dissolved Solids | mg/l | 668.98 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst **RACHEL OLONGA** Signature ..........

## 17. KALULINI BOREHOLE MAY 2015 PHYSICAL-CHEMICAL RESULTS

| | WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|---|
| | TITLE: Water Sample Analytical Certificate – Physical Chemical Results | REF. NO : F/9/1/3 |
| | | ISSUE NO : 04 |
| | DEPARTMENT: Technical | REV. NO : 03 |
| | ISSUED BY: DTCM | DATE OF ISSUE: 15th April 2013 |
| | AUTHORISED BY : TCM | Page : 1 of 2 |

Serial No: ..................

Name of Customer: FREDRICK TITO MWAMATI

Purpose of Sampling: STUDY

Date Sampled: 25/5/15

Source: KALULINI BOREHOLE, KANYANGI.

Sample No: 2972

Address: ..................

County: KITUI

Date Received: 26/5/15

Date Compiled: 27/5/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.99 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 4.0 | Max 5 | Max 5 |
| Conductivity ($25^0$C) | µS/cm | 871 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 36.8 | Max 100 | Max 150 |
| Magnesium | mg/l | 21.40 | Max 100 | Max 100 |
| Sodium | mg/l | 111.3 | Max 200 | Max 200 |
| Potassium | mg/l | 9.7 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 180 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 230 | Max 500 | - |
| Chloride | mg/l | 77 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.63 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 6.21 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 123.7 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 14 | - | - |
| Total Dissolved Solids | mg/l | 540.02 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature

## 18. NTHONGONI MAY 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:** ..................

**Sample No:** 2975

**Name of Customer:** FREDRICK TITO MWAMATI

**Address:** ..................

**Purpose of Sampling:** STUDY

**County:** KITUI

**Date Sampled:** 25/5/15

**Date Received:** 26/5/15

**Source:** NTHONGONI BOREHOLE, YATTA.

**Date Compiled:** 27/5/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.34 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | 20 | Max 15 | Max 15 |
| Turbidity | N.T.U | 36.1 | Max 5 | Max 5 |
| Conductivity (25° C) | µS/cm | 1385 | Max 2500 | - |
| Iron | mg/l | 0.43 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | 0.02 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 122.4 | Max 100 | Max 150 |
| Magnesium | mg/l | 30.69 | Max 100 | Max 100 |
| Sodium | mg/l | 110.7 | Max 200 | Max 200 |
| Potassium | mg/l | 14 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 432 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 248 | Max 500 | - |
| Chloride | mg/l | 221 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.38 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 7.92 | Max 10 | - |
| Nitrite | mgN/l | 0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 95.4 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 50 | - | - |
| Total Dissolved Solids | mg/l | 858.7 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst RACHEL OLONGA Signature ..................

## 19. KWA KILUI BOREHOLE MAY 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| **AUTHORISED BY :** TCM | **Page :** 1 of 2 |

**Serial No:**

**Sample No:** 2973

**Name of Customer:** FREDRICK TITO MWAMATI

**Address:**

**Purpose of Sampling:** STUDY

**County:** KITUI

**Date Sampled:** 25/5/15

**Date Received:** 26/5/15

**Source:** KWA-KILUI BOREHOLE, YATTA.

**Date Compiled:** 27/5/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.88 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 4.8 | Max 5 | Max 5 |
| Conductivity ($25^0$ C) | µS/cm | 707 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 65.6 | Max 100 | Max 150 |
| Magnesium | mg/l | 14.13 | Max 100 | Max 100 |
| Sodium | mg/l | 55.3 | Max 200 | Max 200 |
| Potassium | mg/l | 8.1 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 222 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 132 | Max 500 | - |
| Chloride | mg/l | 81 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.32 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 16.60 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 85.5 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 6 | - | - |
| Total Dissolved Solids | mg/l | 438.34 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst **RACHEL OLONGA** Signature

## 20. MUSELELE BOREHOLE MAY 2015 PHYSICAL-CHEMICAL RESULTS

| | WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|---|
| | **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | | **ISSUE NO : 04** |
| | **DEPARTMENT:** Technical | **REV. NO : 03** |
| | **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| | **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:**

**Name of Customer:** FREDRICK TITO MWAMATI

**Purpose of Sampling:** STUDY

**Date Sampled:** 25/5/15

**Source:** MUSELELE BOREHOLE, YATTA.

**Sample No:** 2970

**Address:**

**County:** KITUI

**Date Received:** 26/5/15

**Date Compiled:** 27/5/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.52 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 4.6 | Max 5 | Max 5 |
| Conductivity (25° C) | μS/cm | 671 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 64.8 | Max 100 | Max 150 |
| Magnesium | mg/l | 13.16 | Max 100 | Max 100 |
| Sodium | mg/l | 50.1 | Max 200 | Max 200 |
| Potassium | mg/l | 7.6 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 216 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 256 | Max 500 | - |
| Chloride | mg/l | 49 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.34 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 8.28 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 4.6 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 36 | - | - |
| Total Dissolved Solids | mg/l | 416.02 | Max 1500 | Max 1000 |
| Arsenic | μg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst **RACHEL OLONGA** Signature

## 21. KANYONGONYO BOREHOLE MARCH 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | **ISSUE NO : 04** |
| **DEPARTMENT:** Technical | **REV. NO : 03** |
| **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
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**Serial No:** ...................... **Sample No:** 2524

**Name of Customer:** FREDRICK TITO MWAMATI **Address:** ......................

**Purpose of Sampling:** RESEARCH **County:** KITUI

**Date Sampled:** 24/3/15 **Date Received:** 26/3/15

**Source:** KANYONGONYO BOREHOLE **Date Compiled:** 7/04/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.68 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.8 | Max 5 | Max 5 |
| Conductivity ($25^0$ C) | µS/cm | 2090 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 144 | Max 100 | Max 150 |
| Magnesium | mg/l | 70.54 | Max 100 | Max 100 |
| Sodium | mg/l | 153 | Max 200 | Max 200 |
| Potassium | mg/l | 46 | Max 50 | - |
| Total Hardness | $mgCaCO_3/l$ | 650 | Max 500 | Max 300 |
| Total Alkalinity | $mgCaCO_3/l$ | 350 | Max 500 | - |
| Chloride | mg/l | 435 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.50 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 13.40 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 47.1 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 10 | - | - |
| Total Dissolved Solids | mg/l | 1295.8 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst **CELLINE OBUYA** Signature ......................

## 22. KANYANGI BOREHOLE MARCH 2015 PHYSICAL-CHEMICAL RESULTS

| | | |
|---|---|---|
| | **WATER RESOURCES MANAGEMENT AUTHORITY** | |
| | **TITLE:** Water Sample Analytical Certificate – Physical Chemical Results | **REF. NO : F/9/1/3** |
| | | **ISSUE NO : 04** |
| | **DEPARTMENT:** Technical | **REV. NO : 03** |
| | **ISSUED BY:** DTCM | **DATE OF ISSUE: 15th April 2013** |
| | **AUTHORISED BY :** TCM | **Page** : 1 of 2 |

**Serial No:** ............ **Sample No:** 2525

**Name of Customer:** FREDRICK TITO MWAMATI **Address:** ............

**Purpose of Sampling:** RESEARCH **County:** KITUI

**Date Sampled:** 24/3/15 **Date Received:** 26/3/15

**Source:** KANYANGI BOREHOLE, KANYANGI LOCATION. **Date Compiled:** 7/4/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.36 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.4 | Max 5 | Max 5 |
| Conductivity (25$^0$ C) | µS/cm | 1004 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 76.8 | Max 100 | Max 150 |
| Magnesium | mg/l | 32.12 | Max 100 | Max 100 |
| Sodium | mg/l | 75.4 | Max 200 | Max 200 |
| Potassium | mg/l | 10.2 | Max 50 | - |
| Total Hardness | mg$CaCO_3$/l | 324 | Max 500 | Max 300 |
| Total Alkalinity | mg$CaCO_3$/l | 326 | Max 500 | - |
| Chloride | mg/l | 133 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.53 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 12.01 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 16.5 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 18 | - | - |
| Total Dissolved Solids | mg/l | 622.48 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst CELLINE OBUYA Signature ............

# 23. KALULINI BOREHOLE MARCH 2015 PHYSICAL-CHEMICAL RESULTS

| | WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|---|
| | TITLE: Water Sample Analytical Certificate – Physical Chemical Results | REF. NO : F/9/1/3 |
| | | ISSUE NO : 04 |
| | DEPARTMENT: Technical | REV. NO : 03 |
| | ISSUED BY: DTCM | DATE OF ISSUE: 15th April 2013 |
| | AUTHORISED BY : TCM | Page : 1 of 2 |

Serial No: ..........
Sample No: 2523
Name of Customer: FREDRICK TITO MWAMATI
Address: ..........
Purpose of Sampling: RESEARCH
County: KITUI
Date Sampled: 24/3/15
Date Received: 26/3/15
Source: KALULINI BOREHOLE, KANYANGI
Date Compiled: 7/04/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 8.14 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.1 | Max 5 | Max 5 |
| Conductivity (25$^0$ C) | µS/cm | 828 | Max 2500 | - |
| Iron | mg/l | <0.01 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 36 | Max 100 | Max 150 |
| Magnesium | mg/l | 20.43 | Max 100 | Max 100 |
| Sodium | mg/l | 105 | Max 200 | Max 200 |
| Potassium | mg/l | 8.2 | Max 50 | - |
| Total Hardness | mg$CaCO_3$/l | 174 | Max 500 | Max 300 |
| Total Alkalinity | mg$CaCO_3$/l | 176 | Max 500 | - |
| Chloride | mg/l | 82 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.65 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 4.99 | Max 10 | - |
| Nitrite | mgN/l | 0.13 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 97.7 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 4 | - | - |
| Total Dissolved Solids | mg/l | 513.36 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max 10 |
| Others | | - | | |

Name of Analyst CELLINE OBUYA Signature ..........

## 24. NTHONGONI BOREHOLE MARCH 2015 PHYSICAL-CHEMICAL RESULTS

| WATER RESOURCES MANAGEMENT AUTHORITY | |
|---|---|
| TITLE: Water Sample Analytical Certificate – Physical Chemical Results | REF. NO : F/9/1/3<br>ISSUE NO : 04 |
| DEPARTMENT: Technical | REV. NO : 03 |
| ISSUED BY: DTCM | DATE OF ISSUE: 15th April 2013 |
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Serial No: ............ Sample No: 2520

Name of Customer: FREDRICK TITO MWAMATI Address: ............

Purpose of Sampling: RESEARCH County: KITUI

Date Sampled: 24/3/15 Date Received: 26/3/15

Source: NTHONGONI BOREHOLE, NTHONGONI. Date Compiled: 7/04/15

| PARAMETERS | UNIT | RESULTS | WHO STANDARDS | KEBS(KS 459-1:2007) STANDARDS |
|---|---|---|---|---|
| pH | pH Scale | 7.33 | 6.5-8.5 | 6.5-8.5 |
| Colour | mgPt/l | <5 | Max 15 | Max 15 |
| Turbidity | N.T.U | 0.8 | Max 5 | Max 5 |
| Conductivity (25° C) | µS/cm | 1251 | Max 2500 | - |
| Iron | mg/l | 0.1 | Max 0.3 | Max 0.3 |
| Manganese | mg/l | <0.01 | Max 0.1 | Max 0.5 |
| Calcium | mg/l | 130.4 | Max 100 | Max 150 |
| Magnesium | mg/l | 40.9 | Max 100 | Max 100 |
| Sodium | mg/l | 53 | Max 200 | Max 200 |
| Potassium | mg/l | 10.4 | Max 50 | - |
| Total Hardness | mg$CaCO_3$/l | 494 | Max 500 | Max 300 |
| Total Alkalinity | mg$CaCO_3$/l | 240 | Max 500 | - |
| Chloride | mg/l | 219 | Max 250 | Max 250 |
| Fluoride | mg/l | 0.38 | Max 1.5 | Max 1.5 |
| Nitrate | mgN/l | 6.32 | Max 10 | - |
| Nitrite | mgN/l | <0.01 | Max 0.1 | Max 0.003 |
| Sulphate | mg/l | 66.4 | Max 450 | Max 400 |
| Free Carbon Dioxide | mg/l | 24 | - | - |
| Total Dissolved Solids | mg/l | 775.62 | Max 1500 | Max 1000 |
| Arsenic | µg/l | - | Max 10 | Max10 |
| Others | | - | | |

Name of Analyst CELLINE OBUYA Signature ............

## ANNEX 5: WATER ABSTRACTION RATES, STATIC WATER LEVELS AND MEANS FOR SELECTED WATER QUALITY PARAMETERS FOR BOREHOLES IN THE STUDY AREA.

| S.NO: | Name of bore hole | Static Water Levels | Water abstraction($m^3$/day) | | Selected ground water quality parameters | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Dry season | Wet season | Turbidity | EC | Iron | Fluoride | TDS | Total hardness | Total alkalinity | pH |
| 1 | Muselele | 20 | 28 | 10 | 1.3 | 872 | 0.01 | 0.475 | 755.635 | 261.5 | 268.5 | 7.5675 |
| 2 | Kwa Kilui | 31.75 | 25 | 10 | 3.125 | 1010.75 | 0.075 | 0.4125 | 626.655 | 400.5 | 142.5 | 7.7375 |
| 3 | Nthongoni | 37 | 100 | 40 | 10.675 | 1318.5 | 0.1675 | 0.51 | 817.47 | 439.5 | 280 | 7.32 |
| 4 | Kalulini | 38.1 | 20 | 8 | 1.225 | 827.5 | 0.01 | 0.74 | 513.05 | 176.5 | 215 | 7.995 |
| 5 | Kanyangi | 40 | 150 | 65 | 1.2 | 1113.75 | 0.01 | 0.6125 | 690.525 | 345.5 | 305.5 | 7.51 |
| 6 | Kanyongonyo | 35.4 | 90 | 40 | 1.125 | 1768.25 | 0.01 | 0.565 | 1096.215 | 522 | 333 | 7.465 |
| Mean | | 7.15 | 68.8 | 28.8 | 3.108333 | 1151.792 | 0.047083 | 0.5525 | 749.925 | 357.5833 | 257.4167 | 7.599167 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Max | 40 | 150 | 65 | 10.6 | 1768.25 | 0.1675 | 0.74 | 1096.215 | 522 | 333 | 7.995 |
| Min | 20 | 20 | 8 | 1.12 | 827.5 | 0.01 | 0.4125 | 513.05 | 176.5 | 142.5 | 7.32 |
| Std. Deviation | | 53.429 | 23.497 | 4.01 | 368.833 | 0.067 | 0.123 | 216.229 | 131.124 | 72.80924 | 0.253 |