EFFECT OF SALT HARVESTING ON GROUND WATER QUALITY IN GONGONI, KILIFI COUNTY

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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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ABBREVIATIONS AND ACRONYMS

CDA	**:**	Coast Development Authority
CDC	**:**	Center for Disease Control
CWSB	**:**	Coast Water and Services Board
EA	**:**	Environmental Audit
EDTA	**:**	Ethylenediaminetetraacetic Acid
ESIA	**:**	Environmental and Social Impact Assessment
EMCA	**:**	Environmental Management and Coordination Act, 1999
FAO	**:**	Food and Agriculture Organization
FCA	**:**	Full Chemical Analysis
GDWQ	**:**	Guidelines for Drinking-Water Quality
GoK	**:**	Government of Kenya
KNHRC	**:**	Kenya National Human Rights Commission
MBA	**:**	Microbiological Analysis
MDG	**:**	Millennium Development Goals
NEMA	**:**	National Environment Management Authority
NWMP	**:**	National Water Master Plan
OSHA	**:**	Occupational Safety and Health Act
SEKU	**:**	South Eastern Kenya University
TDS	**:**	Total Dissolved Solids
UNDP	**:**	United Nation Development Program
UNEP	**:**	United Nation Environmental Program
UNESCO	**:**	United Nations Education, Scientific and Cultural Organization
USGS	**:**	United States Geological Services
WHO	**:**	World Health Organization
WRMA	**:**	Water Resource Management Authority

DEFINATION OF TERMS

Alkalinity:	The quantity of an acid necessary in lowering the pH of a given sample to the point where all bicarbonate [HCO_3^-] and carbonate [CO_3^{2-}] is converted to carbonic acid [H_2CO_3].
Aquifer:	Body of saturated rock through which water can easily move
Brine:	Saturated water that contains huge salt amount especially sodium chloride.
Chemical analysis:	The process in which the physical or chemical composition of a sample of matter is determined
Crystallization:	The forming of salt crystals from ocean water vapor.
Ferre:	To bear or carry water
Ground water:	Collected water flowing under the earth's surface, that fills porous spaces in soil, sediment, and rocks.
Microbiological analysis:	A method of analyzing water to estimate the numbers of bacteria present and, if needed, to find out what sort of bacteria they are.
Mother liquor:	The resultant residual liquid that remains after crystallization.
Salinity:	Is a description of the amount of salts dissolved in water measured in per thousand.
Saltwater intrusion:	The movement of saline water into freshwater Aquifers.

Upconing: Groundwater extraction leading to well contamination by causing upwelling, or upcoming, of saltwater from the depths of the aquifer.

ABSTRACT

Fresh water is essential for the existence and development of any community. In Gongoni, Kilifi County, groundwater forms the primary source of fresh water. The presence of salt harvesting activities in the area and the concentration of pit latrines within their vicinity pose major pollution risks to these water sources. Salt harvesting ponds, which play a key role in concentrating sea water during the salt harvesting process, have a potential of affecting the quality of ground water. It is with this background that this study investigated the activities affecting the quality of ground water sources in Gongoni. The study examined the effect of the high concentration of the seawater in the salt harvesting ponds and the subsequent discharge of the mother liquor after the crystallization process. This was done by analyzing the chemical content of water collected from different ground water sources from the area. The study also involved a survey through snowball sampling that relied on referral networks, mostly the public health officers in the locality. Through this sampling technique, 16 ground water sources were identified and samples collected for chemical and microbiological analysis. Ground water sources in neighboring areas with no salt harvesting activities were sampled for comparative laboratory analysis. Microbiological analysis was also carried out to lessen the possibility of bias from considering salinity levels only. The data from the analysis was collated and analyzed using the Statistical Package for Social Science (SPSS) independent samples to test and Spearman's correlation coefficients. The sampled Gongoni water sources recorded higher levels of the measured parameters (TDS, Salinity, Chloride, and Sodium) than those from Mambrui, Ngomeni and selected secondary data from Mombasa County wells without salt harvesting activities. They had a mean of one thousand nine hundred and sixty nine mg/l compared to that of Mambrui and Ngomeni with a mean of one thousand and fifty mg/l. The secondary data from Mombasa County had a mean of one thousand five hundred mg/l. Similarly, *E. coli* and total coliform levels were also above the permissible Kenyan and WHO standard limit of 0 MPN/100ml for treated water and 10 MPN/100mls for untreated water. *E colli* had the highest levels recorded at two thousand four hundred MPN/100mls and lowest value was five hundred and thirty eight MPN/100mls. The highest coliform values were recorded at two thousand and thirty nine MPN/100mls and the lowest was two thousand four hundred MPN/100mls. In spite of this, the differences were not statistically significance when compared to the samples from Mambrui and Ngomeni where salt harvesting activities take place. The existence of higher levels of tested parameters in Gongoni water sources compared to those in neighboring communities could be attributed to both salt harvesting activities and salt water intrusion. The study recommends that water from these sources should be pretreated to make it suitable for human use. This can be done through filtration or chemical treatment such as chlorination.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of study

Salt harvesting from brine in Kenya is the oldest source of sodium chloride. It is a major source of income for the people of Magarini Sub-County where it provides employment for residents. In spite of this, the sub-county has a very high poverty index that currently stands at 66%. This basically ranks it among the poorest constituencies in the county - position 189 out of 210 (Ocholla et al., 2013). Salt harvesting activities in Gongoni were started by Mombasa Salt Works Limited (a German company) in 1928. The Company was given a leasehold title for about 1017 ha of land to operate its activities (KNCHR 2006). Six salt harvesting companies are located in the area. They include, KEMU salt company limited, Krystalline Salt Company Limited, Kurawa Industries, Malindi Salt Packers, Kensalt and Mombasa Salt Works. They all use solar evaporation method which is the commonest method in warm climate regions of the world.

The process of salt harvesting entails accumulation of sea water in shallow ponds where it then evaporates by the help of solar radiation (Gordon Ocholla et al., 2013. This exercise strongly increases the concentration of the sea water. The salt commodity finally crystalizes from the resultant saturated brine solution that remains after the evaporation (Morton, 2012). However, the process can result in the pollution of marine and freshwater ecosystems. The increase in the total dissolved solids (TDS) of the aquifer caused by natural or anthropogenic factors results to the salinization process. Chloride, which is the natural dominant form of the element chlorine, which actually constitutes many salts in the environment. Once this process is complete, the resultant hypersaline water is discharged directly into the environment and estuary without prior treatment (UNHCR, 2006). This can easily lead to an increase in salt concentration in the sea and can negatively impact marine life and more so juvenile fishes, fish eggs and mangroves. In addition, when the discharge of the mother liquor is done on land it can lead to pollution of soil and groundwater which will further impact peoples livelihoods such as food security by its impact on agricultural productivity and safe drinking water which are key Millennium Development Goals (MDG). Similarly, the lack of safe drinking water and sanitation facilities has been a major source of concern that have led to proliferation of water borne diseases, a major cause of morbidity and mortality in specifically the developing world (WHO, 1996; Gazioğlu et al., 2010; Esetlili et al., 2018; Makokha, (2019).

As salt harvesting activities in the area intensified the impact on the local environment also increased, which generated complaints from the local community. Their sources of drinking water have been contaminated by the salt seepages and other salt mining activities. This scenario was also evidenced in India's little Rann of Kutch in a study involving 1549 salt workers from different mining sites and 555 control individuals selected from nearby villages (ICMR 2005/6). In this study, there was an elevated urinary sodium and serum pH in the urine of salt production workers. Other medical conditions observed included higher skin and eye irritations among the salt workers (ICMR 2005/6).

The scenario in Gongoni somehow was considered an abuse of the local residents' rights necessitating an inquiry after a petition by locals of violation of their rights by the various salt mining firms in the area to the Kenya National Commission on Human Rights (KNCHR) and other governmental and non-governmental agencies (KNCHR, 2006). The petitioners were responding to environmental related issues emanating from the salt manufacturing in Gongoni, Marereni and Kurawa. KNCHR carried out their enquiry in July 2015. The accusations ranged from salinization of freshwater wells and springs to the flooding resulting from the haphazard construction of dykes, coastal and marine environment pollution and soil degradation; activities that negatively impact production of the ecosystems (KNCHR, 2006).

1.1.1 Geography and climate

Kilifi County terrain consist of majorly low-lying hilly sand-stone areas tha slopes towards the ocean. The rocks in the county are characterized by sedimentary rocks that include the Permo-Triassic Duruma rocks found in Taru, Maji ya chumvi, Mariakani; and the Mazeras sandstones. Further, there is the Jurassic Cretaceous rocks that include the Kambe limestones; the Tertiary rocks of Beratumu, Marafa and Magarini that basically consist of sandstones intercalated with limestone and shale beds (Ndege et al., 2002). The County has

21 forests that cover an area of 246 square km. There is a prominent river that traverses across the county by the name River Sabaki that supports both human and livestock water requirements. There are also other seasonal rivers and streams too. The rainfall ranges between 300 mm and 1,300 mm annually.

Gongoni area is characterized by clays sandwiched by Pleistocene sands towards the west and sand dunes on the east (Opiyo et al., 2002). Because the area is more or less at sea level, its lagoonal depression experiences several incursions of sea water during high tides (Opiyo et al., 2002). The area is known for salt harvesting which is done by creating a series of shallow ponds exposed to the actions of wind and sand that causes the water to evaporate leaving behind salt crystals.

1.1.2 Water Scarcity

Kenya is a water-scarce country where less than 647 m^3 of water is available per capita against 1000 m^3 recommended international benchmark ((UN-WATER/WWAP, 2006). Kenya's renewable freshwater is estimated to be 20.2 cubic kilometers each year. This translates to 647 cubic meters per person each year. In 2007, Kenya' National Water Services Strategy reported a poor water sanitation situation in the country characterized by a situation where only 57% of households used water from safe sources. This accounted for 60% in the urban areas which decrease to as low of 20% in the urban poor settlements that account for the majority of urban residents (Moraa et al., 2012).

It is because of this challenge of water distribution, safety and accessibility that the Government initiated reforms to the water sector in line with the national Water Policy – Session Paper No. 1 of 1999. The policy led to the creation of the Water Act of 2002, and subsequent strategies for example; National Poverty Reduction Strategy Paper, and the Economic Strategy for Wealth and Employment Creation

These reforms started in 1986 after public outcry resulting from the deteriorating service provision in the water sector caused by non-functional water infrastructure together with declined water quality and quantity. To address these issues, an initial assessment program was initiated aimed at documenting the water status to propose specific actions to remedy the challenges. This led to formation of the National Water Master Plan (NWMP) in 1992 recommending a change in the water policy to separate the provision of water services from its management. This recommendation resulted in the formulation and publishing of a Kenya water policy in the year 1992 culminated in the water act enactment in the year 2002.

All these activities resulted in the creation of the Water Resources Management Authority with six regional offices to manage water resources in Kenya. The Authority was operationalized in 2005 and has been executing its functions to date effectively. In spite of the work of this authority, there is a call for further actions especially on the challenges resulting from the environmental changes impacting the water resource, demand and provision. The most recent initiative in this sector is the development of the NWMP 2030. The master plan formulated an action plan for activities of WARMA to strengthen their capability and capacity through transfer of technology in monitoring water availability, reliability, quality and vulnerability. It is evident that the changing global temperature from global warming affects people and the ecosystems' health, people's livelihoods, agricultural production, water resource availability and affordability, and the overall security of the people concerned. The effects that are easily detected on water resources include: drought, floods, rainfall distribution changes, rivers drying up, glacier melt-ups, and recession of water bodies among others (Bhavna, 2014). According to a field survey by Ocholla et al., (2013), acidic rains from evaporating concentrated brine has led to corrosion of building iron sheets in Gongoni. Barlow (2003) identified two mechanisms by which saltwater intrudes into coastal aquifers: encroaching laterally from the sea because of excessive aquifer withdrawals and moving vertically (upward) from deeper saline zones.

Intrusion has been detected in coastal areas especially in areas where water levels have been lowered following the construction and development of drainage canals (Barlow, 2003). There is need to develop groundwater resources to ensure adequate water availability in Kenya especially in the Arid and Semi-Arid Lands (ASALs). Gongoni area falls under the coastal aquifer which is faced with pollution of water resources from both point and non-point sources. This includes seawater intrusion affecting the quality of groundwater and the possible contamination of ground water sources from the salt harvesting activities in the area. The Water Resources Management Authority (WARMA) is the agency that manages and develops water resources in Kenya by ensuring rational and equitable access and distribution amongst the various competing interests and needs. It has a role to play in addressing the water pollution complaints of the residents of Gongoni. The responsibilities of WARMA include: regulation and protection of water resources from negative environmental impacts; regulation of water infrastructure; usage and discharge of effluent and to collect, analyze, collate and disseminate water resources information so as to mitigate any impacts on water resources.

1.2 Statement of the problem

Kenya is a water scarce country based on the annual limited supply of 647 m^3 per individual (Moraa et al., 2012). Activities suspected to be affecting the available ground water resources need to be investigated and solved. Salt harvesting in Gongoni has been let to adverse environmental and social issues at Kenya's coastal area despite being the major employment generating venture to the local residents. It is therefore prudent to document these specific issues. These will go a long way towards developing integrated sustainable development plans for the mining activities that will benefit the local people while preserving and maintain the ecological, social and human health integrity of the people (Gordon O. Ocholla et al, 2013). The effect of the discharged mother liquor from the salt harvesting ponds on the possible pollution of soil and groundwater sources need to be investigated and the consequences on water quality, food security and livelihoods of the people be recorded. Previous research reviews on this area have concentrated on both the effects of sand harvesting and salt harvesting with few touching on the impact of the salt harvesting as a single source of possible contamination of the ground water sources. Gongoni residents have in the past raised concern on the deteriorating quality of their ground water resource. In a report from an inquiry conducted by the Kenya National Commission for Human Rights, gross violations were noted including contamination of ground water sources. The construction of drainage canals in coastal zones easily result to intrusion since it leads to reduction of coastal water levels (Barlow, 2003).

The question on whether the existing salt harvesting activities could be exacerbating the problem by increasing the salinity of the groundwater through release of highly concentrated mother liquor after the crystallization process needs to be investigated. The health of those working at the salt mines and using the polluted groundwater could also be at risk of suffering diseases. The water situation is aggravated by the intermittent supply of piped tap water and the over reliance on groundwater.

In Sub-Saharan Africa, only a small percentage (less than half) of people have access to safe drinking water as opposed to those in first world countries (United Nations, 2005). Disease occurrence from contaminated water sources stretches the health care budget of the Kilifi County thereby compromising the quality of health care services. This can be prevented by instituting water quality monitoring mechanisms. The finding of this study will add to the existing knowledge and bridge the gap of developing and enforcing water quality monitoring mechanisms to ensure constant supply of clean water. It will provide tools for policy makers to manage budgetary allocation for the provision of safe water and relevant health services.

1.3 Objective of study

1.3.1 General Objective

The general objective of this study was to determine the effects of salt harvesting activities on the quality of ground water sources in Gongoni area of Kilifi County.

1.32 Specific objectives

i. To assess the level of ground water sources contamination emanating from salt harvesting activities in Gongoni.
ii. To determine the effect of salt harvesting on *E Colli* and total coliform contamination of ground water sources in Gongoni.
iii. To establish the effect of distance between ground water source and salt harvesting site on the contamination of groundwater sources in Gongoni.

1.4 Research questions

i. What are the contamination levels of the key chemical parameters in the groundwater sources of Gongoni area?
ii. What are the E Colli and total coliform levels of ground water sources in Gongoni?
iii. How does the proximity to the salt harvesting ponds affect the ground water sources?

1.5 Justification of the study

Salt harvesting is a major industrial activity in Gongoni and also contributes to Kenya's endeavor to achieve Vision 2030, a development blueprint whose aim is to make Kenya a middle income economy by the year 2030 through industrialization and other related activities. Salt harvesting (mining) is the main economic activity of the region and has attracted more people to work in the salt firms. However, salt harvesting has not only led to ecological degradation and stress within the area, but also increased the social concerns of the local people. There is need to ensure environmental sustainability and to also address social welfare of the residents if sustainable development has to be achieved.

Industrial development and establishment in developing countries has been haphazard and unregulated leading to situations where industrial effluent is released to water bodies without prior treatment. This is the case mostly in Sub-Saharan Africa. The hypersaline brine is the waste product discharged into the streams after salt crystallization and its resultant effect on the water bodies should be examined. This has increased the need and urgency to establish a quality monitoring system for the local groundwater. This study is actually trying to establish and provide baseline information of the quality of the groundwater of the area by examining the quality of the ground water in this area. Contaminated water sources expose the population to various occupational health risks and poor economic output due to diseases. A previous study by Opiyo et al, (2000) showed high levels of total dissolved solids in a well in Timboni wells of Gongoni ward occasioned by sand and salt harvesting. Other studies by Makokha (2003) generated resulting that reported high percentages of dissolved ions in ground water. This was particularly the case in Magarini Magarini; a salt mining area in Kilifi County.

A five-day inquiry carried out by the Kenyan National Commission for Human Rights reported on the contamination of fresh water sources that the surrounding community traditionally depended on the provision of their water. This contamination was linked to the salt seepage to the groundwater blamed on the salt mining actions carried out in the area (KNCHR 2006). It is against this background that the study intended to assess the composition (microbiological and chemical) of the ground water sources at Gongoni ward of Kilifi County. The goal was to establish the facts from the ground, and come up with suggestion that can sustainably manage the problem.

1.6 Scope of Study

This study was carried out at the Gongoni ward of Kilifi County. It involved sampling of groundwater sources for chemical and microbiological analysis to determine the trends of contamination and to identify the frequency of occurrence for major contaminants. Assessing both microbiological and chemical contamination widened the analysis thereby lessening the possibility of bias from considering salinity levels only.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This chapter is presented in three sub-sections. The first sub-section reviews literature related to the assessment of the quality of groundwater in coastal aquifers where salt water intrusion into ground water sources occur. The second sub-section reviews literature on possible sources of contamination that render groundwater unfit for human consumption and on the impacts of concentrated salt water ponds used for salt harvesting on the potability of ground water sources. The final sub-section reviews literature on the potability of water as the distance from the salt harvesting site is varied. Official Methods of Analysis from AOAC were used for analysis of samples for chemical and microbiological contaminants.

2.2 Saltwater Intrusion

All coastal aquifers experience seawater intrusion to some degree. This is a natural phenomenon that is sometimes accelerated or retarded by human activities and other external factors. Such factors include; decreased ground water pumping activities, nearby irrigation practices, recharge activities, land management activities and global warming and climate change impacts among others (Sefelnasr and Sherif, 2014).

Coastal aquifers are bordered by an extensive salt water body from at least one edge such as a salt water lagoon or a sea or an ocean. However, the flow of the fresh water towards the sea limits the land-ward intrusion of sea water (Sherif and Singh, 1996). These aquifers form a wedge between freshwater and saltwater that is maintained along the coastline or under the land surface (USGS, 1999). This interfaces where freshwater mixes with saltwater are referred to as zones of dispersion or transition zones (Figure 2.1). Productive wells in the coastal zones may pump from freshwater strata underlain by saline water strata. Once water pumping starts, the water table decreases thereby forming a structure referred to as the cone of depression. Similarly, the horizontal interface located between fresh water and salt water rises and forms a mound toward the pumping well. In a situation where the well is close to the saline water strata, the saltwater cone reaches the pumping well where it will cause a brackish discharge (Sherif and Singh, 1996) In an aquifer where fresh groundwater is present above a saline layer, the interface between fresh and saline groundwater can rise in case of extraction from the wells (Gualbert, 1999). This explain cases where high concentrations of chemical parameters are found in wells with higher extraction rates as a result in up coning of saline water causing the water to be brackish. This was observed to happen in some of the samples wells in Gongoni.

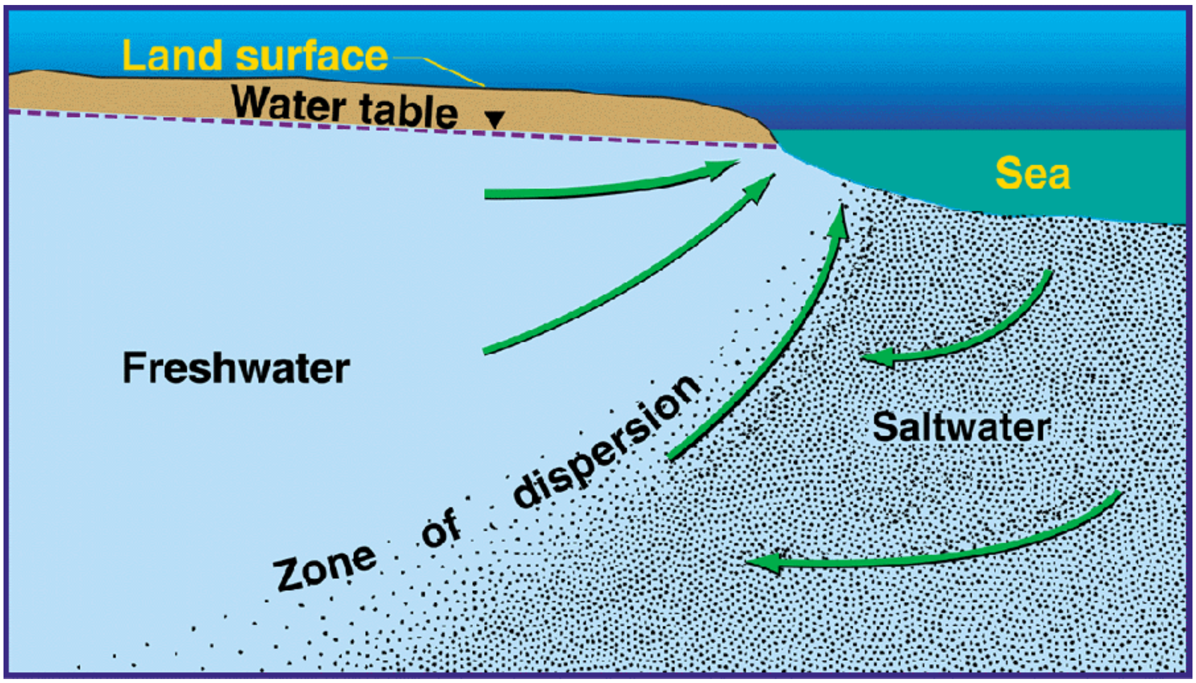


Figure 2.1 Patterns of groundwater flow that illustrates the dispersion zone in a homogenous coastal aquifer (Adopted from Cooper, 1964).

It is through the process of diffusion and mechanical diffusion that freshwater and saltwater mix. This happens at the zone of dispersion. This involves a process where saltwater from the sea circulates to the zone of dispersion and then moves back to the sea; an activity that is induced zone mixing (USGS, 1999).

2.3 Common contaminants and their frequency

The main pollutants of groundwater contamination are the disposed wastes that are directly deposited onto land surfaces such as animal wastes used as manure, sludge, industrial waste products and ordinary garbage. If these deposited wastes contain soluble products, they can easily infiltrate into the land result in the pollution of the ground water (Singh et al, 2003) Waste water from local sewage disposal options such as septic tanks, pit latrines, etc. can cause contamination of groundwater sources. This makes groundwater assessment very crucial in safeguarding not only safeguarding the environment but also public health (Lin et al., 2010), and to ensure that drinking water doesn't have excess chemical contaminants or infectious microorganisms. There is a high risk of groundwater pollution areas where pit latrines are in close proximity with groundwater sources (Hancher, 1991). In fact, fecal and chemical contamination coupled with inadequate treatment of drinking are responsible for many waterborne disease epidemics (Bridgman et al., 1995). For example, 1450 people became ill as a result of a pathogen in well water in Ohio, USA (Fong et al., 2007). Climatic conditions, vegetative cover, land use pattern, local soils and geology and the condition of the well are some of the factors that affect the transport and contamination of well water from pit latrines (Bourne, 2001).

Nitrogen and Phosphorus are the potential indicators of groundwater contamination from pit latrines. In places with shallow bedrock, removing the contaminants is difficult because of the little interaction between the water and contaminants (Conboy and Goss, 2000). When properly sited e.g. in sparsely populated areas with good drained soils above the water table, pit latrines pose little hazard but may still eventually pollute the groundwater. However, an improperly sited, designed, installed or operated pit latrine can pollute drinking and surface water by contaminating wells in the area or move to the land surface, or both.

Once these hazardous materials that include pathogenic micro-organisms and chemical contaminants comes into contact with drinking-water and enters into the distribution systems, they negatively impact on the quality of the water and in turn adversely affect human health (WHO, 2014). This scenario can lead to diarrhea and other enteric infections among victims whose manifestation will be stunted growth, nutrition shortfalls, and long term cognitive impairment in children (Copeland et al., 2003). This can also have demonstrable physical deformities (Copeland et al., 2003). A common cause of infectious fecal microbial contamination is naturally occurring microbes in the gust of humans and other (Copeland et al., 2003). *Escherichia coli* is recognized by the World Health Organization Guidelines for Drinking-water Quality (WHO, 2011) as the indicator of choice. It should however be noted that thermo tolerant *Escherichia coli* species are alternatively used.

Drinking water quality has a direct effect to all the social aspects of all the individuals of a community. This was demonstrated by a study by Copeland et al. (2003), which established that drinking water quality accounted for 4.0% of all deaths through the emergent water related diseases. He also accounted the same to 5.7% of the global disease burden attributed to poor water quality, hygiene and sanitation. Dumpsites, application of fertilizers and pesticides are hazards that pose threats to groundwater quality (Copeland et al., 2003). It is the activities that happen on the ground that release these hazards which end up contaminating the ground water.

2.4. Groundwater vulnerability

Because of their high permeability together with their viable hydrologic conductance, the limestone and sandy zones along Kenya's coastline provide an important service to the local water supply Munga et al. (2004). This is because they are located in the higher water table areas that comprise of the main recharge areas to the water aquifers. Unfortunately, all these factors make these areas more vulnerability t contamination once contaminants are released on or below the surface, such as soak pits, pit latrines or from other anthropogenic activities where they rapidly enter the ground water system. Microbial contamination from septic tanks contributes the greatest chunk of rural water quality issues. This is more so in those areas that lack sewage treatment infrastructural facilities (USGS 1999). Agricultural fertilizer and pesticide applications coupled with poor waste management activities exuberates this problem.

Salt harvesting is an anthropogenic activity occurring at the surface and it involves increasing the concentration of sea water through evaporation to crystallize out the salt. This can lead to permeation to the groundwater sources and increase the salinity of this source. Sinking of boreholes is currently uncontrolled and many households operate boreholes in close proximity to pit latrines.

2.4.1 Status of Groundwater Quality

Groundwater depletion and quality can result from high water demand from human activities lead to overexploitation of water resources, encroaching recharge areas, devoid of groundwater potential know how, poor groundwater monitoring activities among others (WWAP, 2006). Engaging in these activities has a potential of causing other unintended consequences such as the reduction of water tables, intrusion of seawater into coastal aquifers and the contamination of groundwater (WWAP, 2006).

Due to lack of functioning sewerage infrastructure, many county sewerage and waste water plants release either partially or wholly untreated effluents containing high levels of organic amounts, metals and other toxins directly into surface watercourses (WWAP, 2006). The lack of effective regulatory mechanisms to control pollution also compromises the quality of water. This is a major source of concern since it poses many health hazards thereby increasing water treatment and maintenance costs of the coastal aquatic ecosystems. Once the water has been polluted, it limits the availability of the water which further increases the cost for treatment on downstream water users.

Salt extraction process can lead to the pollution of marine and freshwater ecosystems mainly through the discharge into the environment and estuary of mother liquor (UNHCR, 2006, Ocholla et al,2013) which mainly consists of sodium chloride together with other salts like calcium carbonate, potassium sulphate, potassium chloride, sodium carbonate among others (Davis 2006)

2.4.2 Microbiological contamination of water sources

Though the implementation of the sustainable development goals have greatly improved the provision of safe drinking water and sanitation facilities to a wider area, it is still estimated that 783 million people most in Sub-Saharan Africa and South East Asia are not supplied by safe water sources (Bain et al, 2013). In these countries, fecal contamination of drinking-water is a major challenge that negatively impacts drinking water quality surveillance (Copeland et al., 2013). This surveillance is limited to large urban centers where enforcement regulations are lacking. In rural areas, where "improved source" are non-existent, contamination risks are extremely high (Copeland et al., 2013) and it is necessary to focus surveillance activities in these areas (Bain et al., 2014).

By December 2003 Kenya had about 14000 wells (WWAP, 2006) used for various uses ranging from agriculture, public water supply, domestic use amongst others. Some of the wells are adjacent to pit latrines which make them vulnerable to contamination since harmful microorganisms can travel from the pit latrines to the wells (Marshall, 2011). Therefore, wells should be located in elevated areas of at least 2 meters higher than the water table to avoid pit latrine contamination (Marshall, 2011). This recommendation often does not apply in most overcrowded urban slums of developing countries.

When contaminated water is drunk by local citizens, it can cause diseases. This has actually contributed to the public health burden of many developing countries with the greatest risk arising from microorganisms in human and animal excreta (WHO, 2011). This can strain the health budget of the county government. An early intervention through monitoring and surveillance can save the situation. Currently, there is either no surveillance of the microbiological groundwater quality in the county or if it exists then there are flaws in communicating the adverse effects of the contamination. Open sources as captured in plate 1 below are common in Gongoni and are prone to microbiological contamination.

Plate 1 An open well in Gongoni area of Kilifi County (photograph taken by author)

2.4.3 Total dissolved solids

Another indicator of polluted water that determines the palatability and acceptability of water is Total dissolved solid (TDS). These indicate the quantity of dissolved inorganic salts and in some extend organic matter in water (Makokha, M, 2019). This is an important indicator in salt harvesting since by the start of the process, the sea water involved is at about 3% while at the end it goes up at about 25% salinity (Christensen, 2011). When the salt crystalizes, it is shoveled into heaps and carried to a processing place. Rapid proliferation of industries, increasing urbanization and new age agricultural activities during the last few decades have badly affected surface as well as groundwater quality with industrial and municipal solid waste regarded as a leading cause of pollution (Lamma O.A, et al, 2018). Other human activities such as application of agricultural pesticides and fertilizers, irrigation return flow, urban runoff, leakage from underground storage tanks amongst others also may affect quality of ground water (California Department of Water Resources southern district, 2002).

Acceptable water contains concentrations of below 1000 mg/L TDS (WHO 2013). The presence of high values of Total Dissolved Solids in certain locations may be due human activities e.g. disposal of effluent, waste dumping, farming activities among others (Sarala C, Ravi Babu P, 2012)

When the water contains high concentrations of these total dissolved solids, it can negatively impact animals and plants. A good example is boron; a plant nutrient mineral when in low quantities but becomes toxic when concentrations are slightly increased (USGS, 2013).

2.5 Literature gaps

Previous studies have not conclusively established the levels of salinity of the groundwater sources resulting from the proximity to the salt harvesting ponds. This notion is shared by both the Coast Water Board and the local residents of Gongoni. There is need for an information dissemination strategy that will ensure ground water usage without the fear of outbreaks of diseases from heavily contaminated ground water. Gongoni area is in close proximity to the sea and has salt harvesting activities but there are no documented results of salinity levels at the water board.

Most published results in Gongoni, Kilifi County were on the impacts of salt and sand harvesting on the geology and salt water intrusion to the water aquifers in the area (Ocholla et al., 2013, and Opiyo et al., 2002). This necessitates further research on effects caused by the salt harvesting as a single entity on the ground water, especially from the concentrated water ponds used for crystalizing salt from the sea water. Other gaps noted include

- Safe water and sanitation provision issues for Gongoni area and sharing it with concerned stakeholders.
- Measures for the improvement of sanitation infrastructure and policies.
- Inadequate data on the groundwater quality status.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

In order to achieve the study objectives, both primary and secondary data collection techniques were utilized. These included capturing information from earlier surveys, use of sample collection information forms and laboratory analytical data. The use of these techniques was aimed at examining the groundwater quality in Gongoni area as affected by salt harvesting activities. The goal was to determine whether the highly concentrated ponds from which salt is harvested have any effect on the salinity of the ground water to levels higher than normal salt water intrusion. The contents of this section include:

i. Description of study area
ii. Data requirements and sources
iii. Data collection and sampling
iv. Data analysis

3.2 Study area

3.2.1 Location

Gongoni Ward is located in Magarini Sub-County within Kilifi County and comprises Shomela, Fundissa, Ngomeni and Gongoni sub-locations (Figure 3.1 and Table 3.1). It lies between 2° 58' 32'' S and __3° 16' 8'' S_S/N and between 40° 1' 29'' E and 40° 30' 0'' E/W. It has a population of about 34,597 and covers an area of approximately 232.00 km². Gongoni Ward is located about 420 km south-east of Nairobi, 60km north of Mombasa and 25 km from Malindi town.

Gongoni area of Kilifi County is characterized by sand dunes that border the Indian Ocean lagoon towards the east. These sand dunes are believed to have originated from the organic matter transported into the area from inland areas into the coastline by the River Sabaki (Opiyo et al., 2002). As, noted earlier, the area is endowed by sandy and limestone zones that aid in the water supply because they are highly permeable and hydraulically conductible. These sandy and limestone areas comprise the focal recharge areas to the unconfined aquifers but their characteristics make them highly vulnerable to contamination.

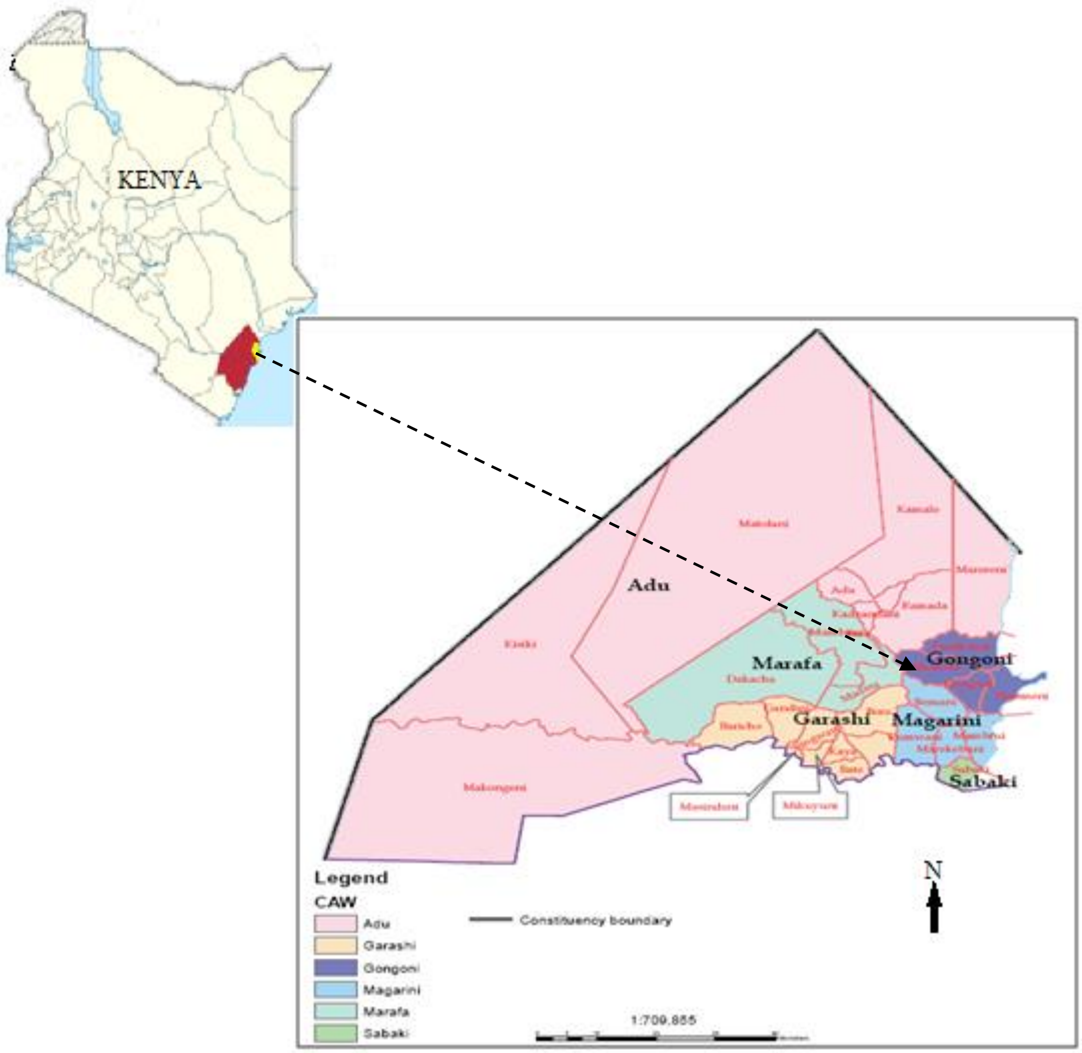


Figure 3.1 Map showing the location of the study area in Kenya and Kilifi County (Source; GIS Field Survey).

Table 3.1 Population of Kilifi County by constituency

Constituencies	Population in 2009 census	Area (km^2)	Wards
Kilifi North	207,587	405	Tezo, Sokoni, Kibarani, Dabaso, Matsangoni, Watamu, Mnarani
Kilifi south	171,607	401	Junju, Mwarakaya, Shimo la Tewa, Chasimba,Mtepeni
Kaloloeni	139,302	651	Mariakani, Kayafungo, Kaloleni, Mwanamwinga
Rabai	113,622	241	Mwawesa, Ruruma, Jibana, Rabai/Kisurutuni
Ganze	137,664	2,942	Dungicha,Bamba, Jaribuni, Sokoke
Malindi	162,712	627	Jilore, Kakuyuni, Ganda, Malindi Town, Shella
Magarini	177,241	6,979	aarafa, Magarini, Gongoni, Adu, Garashi,Sabaki
Total	**1,109,735**	**12,245.90**	

3.2.2 Determination of sampling wells

In order to assess the quality of the groundwater in Gongoni area of Kilifi County, all the functional wells were sampled as shown in Table 3.2 below. Four wells from the neighboring area where salt harvesting is not done were also sampled to provide control samples.

Table 3.2 List of wells sampled, their location and distance from salt harvesting sites

S/No	Sampled at	Facility	Covered	Est. dist. from salt firm(s) (KM) & GPS codes
1	Ken-Salt-Kadzuhoni	Tank	Yes	<0.5 (3°2'5.0''S – 40°8'16.8''E)
2	Krystalline salt firm-Madukani	Tap	Yes	<0.5 (3°2'8.0''S – 40°8'13.6''E)
3	Krysatalline salt firm-Inside	Well	No	<0.5 (3°2'5.0''S – 40°8'16.8''E)
4	Gongoni- Mapimo village	Well	No	<0.5 (3°2'20.2''S–40°8'12.4''E)
5	Timboni (A)- Timboni	Well	No	5.0 (2°59'56.1''S 40°11'15.1''E)
6	Timboni (B)-Timboni	Well	No	5.0 (2°59'53.0''S-40°11'35.6''E)
7	Ngomeni(A)- Ngomeni	Well	No	8.0 (3°3'55.8''S-40°8'56.4''E)
8	Ngomeni (B)-Ngomeni	Well	No	8.0 3°3'57.0''S – 40°8'49.8''E)
9	Mjanaheri (A)-Gongoni	Well	Yes	3.0 (3°4'18.8''S – 40°8'48.2''E)
10	Mjanaheri (B)-Gongoni	Well	Yes	3.0 (3°4'33.1''S – 40°8'34.2''E)
11	Gongoni (A)-Gongoni	Well	No	1.0 (3°2'8.5''S – 40°7'59.4''E)
12	Gongoni (B)-Gongoni	Well	No	1.0 (3°2'11.0''S – 40°8'.5''E)
13	Mambrui-Secondary	Well	Yes	15 (3°7'20.2"S-40°9'33.6''E)
14	Mambrui-Dispensary	Well	No	15 (3°7'4.1''S - 40°9'25.4''E)
15	Gongoni-Fundisha village	Well	No	3.0 (2°55'47.0"S - 40°5'41.6''E)
16	Gongoni-Fundisha village	Well	Yes	3.0 (2°59'40.0''S –40°8'30.1''E)

Table 3.2 shows location and proximity of the ground water sources to the salt harvesting ponds. Wells 7, 8, 13, 14 are situated in the area with no salt harvesting activities. The rest of the wells are located within the salt harvesting area. The conditions under which the water sources are operated is also tabulated, whether covered or open wells. Some of the wells are operated using water pumps while others are operated manually by the villagers.

3.3 Data Requirements and Sources

In order to obtain data that addressed the research objectives, both primary and secondary data collection techniques were utilized. Data collection techniques broadly engaged surveys of earlier studies, sample collection forms and laboratory analytical data. Primary data comprised of analytical results of samples collected from identified wells in Gongoni area and those outside the salt harvesting areas as control.

3.4 Data collection and sampling

The study relied on both primary and secondary data collected from the groundwater sources in Gongoni area with wells in areas neighboring Gongoni included as controls.

3.4.1 Secondary Data Collection

Secondary data was collected from public health office for comparison with the data that was collected during the sampling and analysis of the ground water. The secondary data was useful for selecting indicators to be analyzed in assessing the salinity of the groundwater sources. The secondary data was extracted from studies on coastal aquifers by Munga et al (2006) where the highest value of total dissolved solids was 1500mg/L. N. Opiyo Akech et al (2000) on his study on investigation of the impact of salt and sand harvesting on Timboni well, Gongoni captured chemical parameters including TDS of up to 3640mg/L.

3.4.2 Primary Data Collection

Primary data was collected through sample collection forms and through observations made during collection of the water samples. These forms gathered information from the source at which the samples were collected. They documented the distance from the salt harvesting ponds, the location of the wells and whether they were covered or not. The collected information included whether the water source was treated or otherwise.

Primary data involved sampling for the chemical and microbial water quality parameters. Sampling for chemical analysis was done using clean two and half liter plastic bottles purchased specifically for sampling purposes. Two samples per well were collected, filled to the brim and properly sealed before submission to the laboratory within 24 hours. 100 ml sterile glasses were used to collect samples for microbial parameters. The samples were then stored under ice in cooler boxes and delivered to the laboratory within 24 hours, where analysis was done immediately. The bottles for collecting microbiological samples were autoclaved at 121 degrees Celsius for thirty minutes.

Sampling was done between June and July 2015 from the identified 16 wells. 75% of the wells were from Gongoni area while 25% were from neighboring parts of Gongoni, such as Mambrui and Ngomeni where no salt harvesting activities took place. This implies that only four of the wells sampled in the study were not within the region of salt mining. Areas close to Gongoni, such as Mambrui 15 km and Ngomeni 8 km away from the salt harvesting ponds were sampled for comparative analysis to check the effect of salt water contamination.

Plate 2 Collection of water samples at Fundisha Village (Source; Author, 2020)

Sampling for full chemical analysis was done using clean two and half liter plastic bottles (plate 2) purchased specifically for sampling purposes. Open wells are common in Gongoni and are susceptible to microbiological contamination by both human and animals. The sampling was done using snowballing method where sampling points were referred to by the public health officer in charge of Gongoni area. The distance from the harvesting ponds was identified as the independent variable. A total of sixteen wells were sampled and two samples collected per well for the chemical analysis. All chemical analysis of the collected samples was done at Government Chemists laboratories using Atomic Absorption Spectrometer and titrimetric methods.

The increased human and animal population in Gongoni ward necessitated the examination of microbiological quality of the ground water sources. The study analyzed two coliform indicators of fecal water contamination; i.e. total coliform bacteria and *Escherichia coli*. were analyzed. Samples for microbiological analysis were collected using 100 ml sterile bottles and the samples were kept under ice in cooler boxes and delivered to the laboratory within 24 hours, where analysis was done immediately.

The team that collected the samples was accompanied by the Gongoni public health officer for identification of the wells and to provide relevant information when need arose.

3.4.3 Laboratory Analysis

Chemical analysis

In the laboratory, a chemical analysis was carried out on the samples targeting the common ions and cations associated with hardness and salinity of the ground water sources. The cations and anions analyzed included Sodium (Na^+), Calcium (Ca^{2+}) Magnesium Mg^{2+} and Chloride (Cl) Sulfate (SO_4^{2-}), Carbonate (CO_3^{2-}), Bicarbonate (HCO_3^-), Nitrates (NO_3^-) and Phosphates (PO_4^{3-}). Other parameters tested included pH, electrical conductivity, total dissolved solids, total hardness (Carbonate plus non Carbonate hardness) and total alkalinity. The levels of chloride were determined by taking a sample of 50mls and making it to 100mls. 1 ml of potassium chromate (K2CrO4) indicator solution was added to the sample and titrated with standard silver nitrate AgNo3 until a pinkish yellow end point was observed. The samples were titrated at a pH range of between 7 to 10. A blank run was done by titrating 50mls of distilled water against the standard AgNO3.

Sodium (Na^{+}), Potassium (K^{+}) Calcium (Ca^{2+}) and Magnesium (Mg^{2}+) cations were analyzed using Atomic Absorption Spectrometer (AAS), model analytikjena Contra AA 700. The instrument uses a single lamp with a wide range of wavelength for detection of specific cations of interest. Standard stock solutions of 1000 ppm for Sodium, Potassium, Calcium and Magnesium were diluted in distilled water to various concentrations and run in the AAS to develop calibration curves. The test samples were then prepared and the absorbance measured. The samples were diluted where the absorbance was too large and the dilution factor taken in to account during calculation.

Carbonate hardness was analyzed using titrimetric methods with methyl orange as the indicator and hydrochloric acid until end point. A few drops of methyl orange were added to a water sample in a beaker and hydrochloric acid added until the color of solution changes from yellow to orange. Total carbonate hardness was analyzed using the titrimetric ethylenediaminetetraacetic acid (EDTA) method and end point was achieved when the color changed from purple red to blue.

Total dissolved solid levels were determined by stirring a sample using a magnetic stirrer to have a uniform sample. A glass fiber filter was used to filter 100mls of the water sample under vacuum pressure for three minutes. The filter was then washed using de-ionized water and the process repeated for another three minutes. The filtrate evaporated to dryness in an oven at a temperature of 180 ± 2°C for an hour using an evaporating dish whose weight was pre-determined. The evaporating dish was then cooled in a desiccator and later weighed. The drying and weighing was repeated until a constant weight was obtained. The total dissolved solids were calculated using the formula below:

$$TDS\ (mg/L) = (A-B) * 1000 / \text{Sample volume(ml)}$$

where: A = weight of dried residue + dish (mg), B = weight of dish (mg)

Microbiological analysis

For microbiological analysis, indicators for water contaminated with fecal matter (total coliform and fecal bacteria and *Escherichia coli)*, samples were analyzed using multiple tube test method. The equipment used were an autoclave for sterilizing the culture media, an incubator capable of maintaining uniform temperature during the analysis and a weighing balance with an accuracy of 0.05g for weighing the powdered culture medium. Others were culture medium (MacConkey), sodium thiosulfate, distilled water, test tubes and rack, a scoop and pipettes. The sodium thiosulfate was used to neutralize any chlorine present during sample collection.

MacConkey medium was inoculated with portions of the well water samples and incubated at a temperature of 36 degrees Celsius for 48 hours. The tubes showing gas formation were regarded as presumptive positive for coliform. Confirmatory tests were done using samples collected from the presumptive positive tubes and inoculated into a selected culture broth and incubated for 24 hours. The most probable number (MPN) of bacteria present was then estimated from the number of tubes inoculated and the number of positive tubes obtained in the confirmatory test using specially designed statistical tables (WHO, 2013).

3.5 Data analysis

The concentrations of the parameters in the ground water sources were plotted against the distance from the salt harvesting ponds to determine the relationship between the two variables.

Qualitative data was analyzed using both descriptive and inferential statistics SPSS statistical package and Microsoft Excel. The distances of the ground water sources from the salt harvesting ponds plotted against the concentrations of the various parameters. To test salt intrusion into the groundwater sources cation and anion concentration data was subjected to the analysis of variance (one ANOVA, SNK - test) at 95% confidence levels to determine the effect of the independent variable (distance from the salt harvesting ponds) have on the dependent variable. The dependent variable is the concentrations of chemical contaminants in the ground water sources in Gongoni area and the neighboring area further away from the salt harvesting ponds.

The mean of the contaminants which were found to be ≤ 0.05 were considered significant at 95 % confidence levels, while those found to be >0.05 were considered statistically insignificant as causes of contamination or salinity of the ground water sources in Gongoni.

The levels of salinity causing parameters and microbiological contaminants in the ground water sources were plotted against the distance from salt harvesting ponds and inferences in the relationship to the distance of the sources from the salt harvesting ponds were done. Basically, measures of central tendency, measures of dispersion and inferential statistics were employed to establish substances responsible for the contamination of ground water in Gongoni ward. Graphs, tables and charts have been used to display the findings as shown in Chapter 4.

3.6 Quality assurance

The measured parameters were analyzed in triplicate to yield a mean that showed the trueness of the observed values (Valcarel, 2000). Analytical quality control was ensured by blanks and standard solutions which ensured the accuracy and reproducibility of the observed results (Akpoveta et al., 2011).

Further, the quality of the samples and analysis was observed at every stage. For example, to ensure that water samples were free from contamination from sampling containers, the sample containers were sterilized prior to use. Similarly, to prevent microbial activity during transportation of water samples, the samples were kept on ice to ensure that the temperature was kept low.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

The results of the chemical and biological analysis were collected and tabulated in the tables in this chapter and in the appendices

4.2 Chemical contamination levels of ground water sources in Gongoni area

Table 4.1 below captures the values of the chemical means of individual well water samples collected in duplicate and how they relate to the WHO and Kenya Bureau of Standards. All the water samples from the sources met the water standards for pH. Samples from source 1 at Kensalt firm, 6500±0.mg/L, well source 2 at Gongoni A1650±1061 mg/L, well source 3 at Mjanaheri A, 2367±753 mg/L and well source at Mambrui dispensary, 1050±350 mg/L had high TDS values above the 1000mg/L standard. For salinity levels samples from source 1, Kensalt firm, 3600±0 mg/L, well source 3, Mjanaheri A 1238±819 mg/L had higher levels than the WHO/KEBS permitted standard of 900mg/L. Both sources were in the salt harvesting area of Gongoni. However, two other sources, Timbon A, 386±205 mg/L and Gongoni A, 271±115 mg/L, from the same area had salinity levels which conform with the standard.

Table 4.1 Chemical composition of groundwater sources and comparison with KEBS/WHO standards

SNo	Parameter	Source 1 Kensalt firm	Source 2 Gongoni (A	Source 3 Mjanaheri (A)	Source 4 Timboni (A)	Source 5 Ngomeni (A)	Source 6 Mambrui-Dispensary	KEBS/WHO Standard (mg/l)
1	TDS	6500±0	1650±106	2367±753	807±167	460±40	1050±350	1000
2	Salinity as NaCl	3600±0	271±115	1238±819	386±205	69±0	579±442	900
3	Ph	7.3±0	7.6±0.1	7.4±0.2	7.6±0.1	7.6±0	8.5±0.2	6.2—8.5
4	Chloride	2500±43	67±12.5	883±0	275±42	45±34	485±0	250
5	Sodium	1100±0	203±127	255±90	111±65	24±0	94±27	200

Table 4.2 below shows the means of the chemical parameters in Gongoni and the adjacent areas of Mambrui and Ngomeni where no salt harvesting takes place. Total Dissolved solids presented the highest level with a mean of 1969.33±527.13mg/l for Gongoni area and 1050±350 mg/l for the area neighboring Gongni. Similarly; chloride ions means were 662.00±250.44 mg/l and 485.800±415 mg/l respectively, Total Alkalinity means were 252.85±38.52mg/l and 185.75±109.25mg/l. Salinity as Sodium Salinity expressed as NaCl had means of 965.87±328.54mg/l for Gongoni and 578.50±441.50 mg/l for the neighboring area. The pH of the water sources had a mean of 8.5±0.20 and 7.54±0.06 for the area neighboring Gongoni. The means were taken for samples taken from twelve wells in Gongoni area and four wells from Mambrui and Ngomeni area where no activities of salt harvesting take place. The data was analyzed for equality of means for the two compared groups and the p values generated to show the significance at 95% confidence levels. Regressions were plotted to show the coefficient of determination for the various contaminants. The coefficient of determination shows percentage variance of the dependent variable predicted by the independent variable.

Table 1.2 Comparison of means for ground water sources at Gongoni and neighboring areas

Parameter	Mambrui & Ngomeni Mean±SE	Gongoni Mean±SE	p-value
PhosphatePO_3^{4-}	0.17±0.15	0.31±0.08	0.527
Fluorides	0.07±0.02	0.66±0.07	0.009*
Chloride	485.00±415.00	662.00±250.44	0.808
Sodium	93.50±26.50	283.87±90.98	0.469
Total Dissolved solids Residue dried at180^{o}C	1050.00±350.00	1969.33±527.13	0.546
PH	8.50±0.20	7.54±0.06	<0.001*
Salinity as NaCl	578.50±441.50	965.87±328.54	0.684
Total Alkalinity	185.75±109.25	252.85±38.52	0.560

*parameters show significant difference between the control and Gongoni samples (independent t-test, 95% CL)

4.3 Biological contamination levels of ground water sources in Gongoni area

The study also intended to establish the extent to which biological contaminants contaminated ground water in Gongoni area. These sources were explored by examining the presence of coliform bacteria and *Escherichia coli* in the collected water samples. The results are displayed in Table 4.3.

Table 4.3 Effect of distance from salt mining site on microbial parameters

Parameter (MPN/100ml)	1 km		5 km		10 km		15 km		p-value
	≈ value	± error	≈ value	± error	≈ value	± error	≈ value	± error	
E. coli count	2400	438	571	426	538	421	539	473	0.079
Total coliform count	2400	345	2400	327	2497	363	2539	347	0.254

The study found that the coliform bacteria and *E. coli* were almost equally concentrated in the ground water of Gongoni area. Of the 16 well water samples tested none of the well samples met the potability standards. This implies that, apart from chemical contamination discussed above, ground water in Gongoni area also had high levels of coliform and *E. coli*. Human and animal sources of fecal contamination present the highest likelihood that their waste contains pathogenic E. coli.

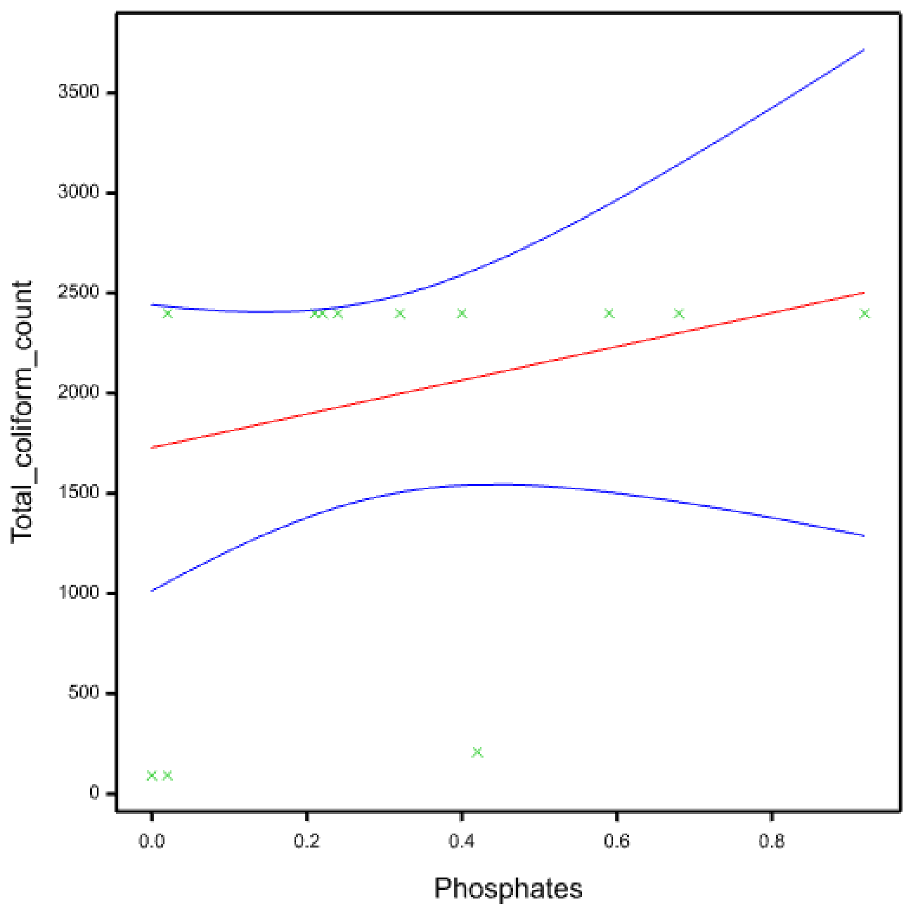
4.4 Correlation between water quality parameters and biological measurements in Gongoni

There was a significant positive relationship between biological parameters (total coliform count and *E. coli* count) and Phosphates and E. coli count and water pH (Table 4.4). However, there was no significant correlation with other measurements.

Table 4.4 Spearman's rank correlation coefficients - correlation matrix (adjusted for ties).

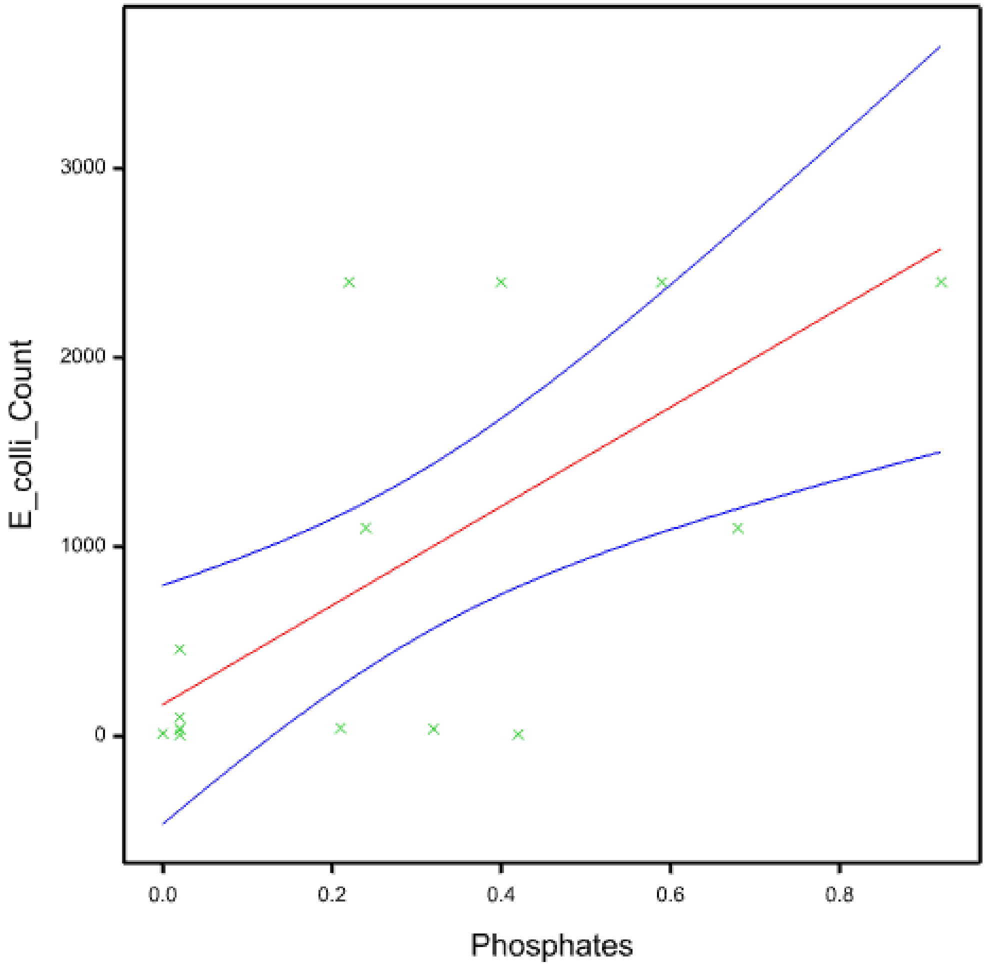
	E. coli	Fluorides	Phosphates	Sodium	TDS	Total coliform
Fluorides	0.134					
Phosphates	**0.623**	-0.126				
Sodium	0.154	0.303	-0.004			
TDS	-0.093	-0.070	-0.096	0.679		
Total coliform	**0.685**	-0.063	**0.340**	0.102	0.001	
Ph	**0.685**	**-0.469**	-0.162	**-0.661**	-0.248	-0.034

There was positive correlation between *E. coli* count and total coliform count; between total coliform count and phosphates (Figure 4.1); and between *E coli* and phosphates (Figure 4.2). In contrast, there was a negative correlation between *E. coli* count and pH (Figure 4.3); between fluorides and pH; and between Sodium and pH.



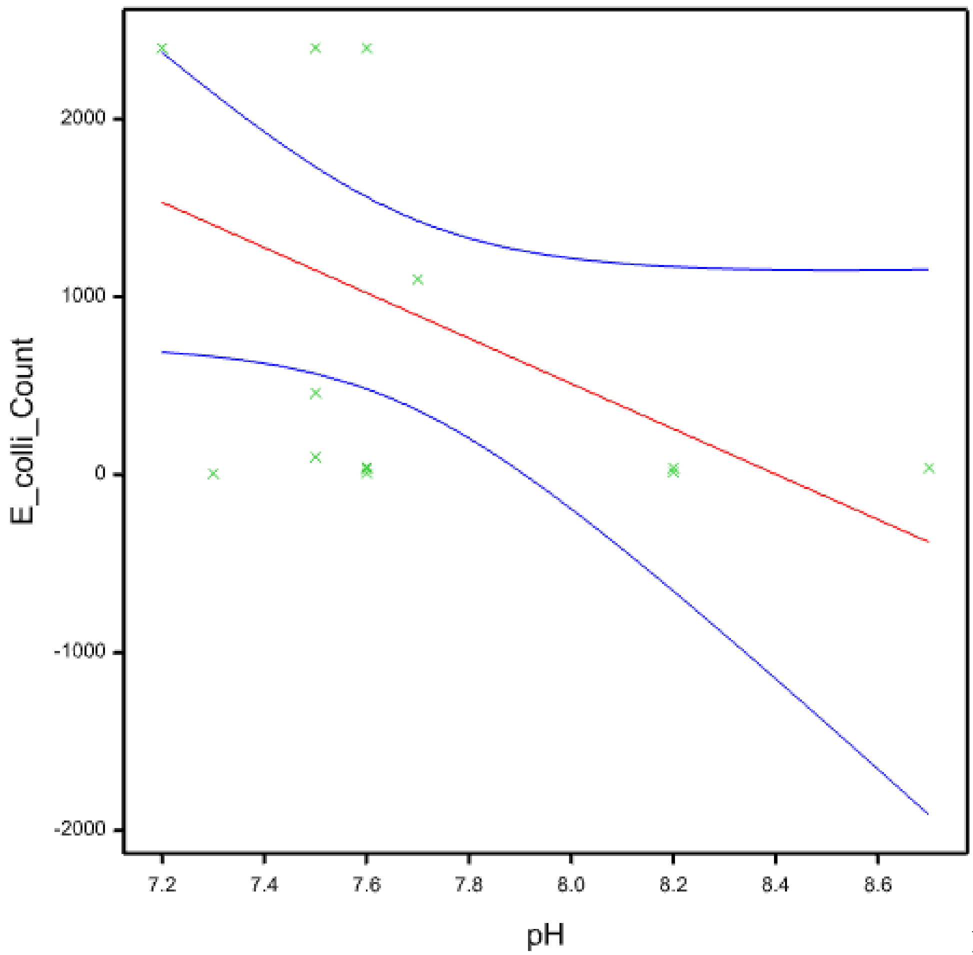
$R^2 = 0.97$

Figure 4.1 Relationship between Total coliform count and Phosphates



R^2=0.98

Figure 4.2 Fitted and observed relationship between *E. coli* count and Phosphates



R^2=0.99

Figure 4.3 Relationship between *E. coli* with pH

4.5 Relationship between the proximity of the groundwater sources and salt harvesting ponds

Table 4.5 shows the means of the various chemical parameters in ground water sources and the distance from the salt harvesting ponds. It captures the significance levels of the means at 95% confidence levels as the distance from the salt harvesting ponds is increased. Figure 4.4 and 4.5 shows the negative correlation that was observed between phosphates and fluorides as distance from the harvesting is increased.

Table 4.5 Comparison of water quality parameters with distance from salt mining sites

Mean±SE followed by the same small letter (s) within the same row do not differ significantly from one another (One-ANOVA, SNK-test, α = 0.05)

Parameter	**Distance in Km**							**r^2 Values**	**P-value**
	<0.5	**0.5**	**1.0**	**3.0**	**5.0**	**8.0**	**15.0**		
Sodium	169±56	1100±0	203±127	255±90	111±65	24±0	94±27	0.215	<0.001
Total Dissolved solids	933±120	6500±0	1650±1061	2367±753	807±167	460±40	1050±350	0.0666	<0.001
PH	7.7±0.2	7.3±0.0	7.6±0.1	7.4±0.2	7.6±0.1	7.6±0.0	8.5±0.2	0.4382	0.007
Salinity as NaCl	579±198	3600±0	271±115	1238±819	386±205	69±0	579±442	0.1548	0.054
Total Alkalinity	132±77	450±0	328±23	265±107	232±94	175±55	186±109	0.0217	0.551
Total hardness	183±61	55±0	275±125	245±90	200±64	145±30	203±103		0.825

The water source situated less than 500 meters from the salt harvesting ponds had lower values for chemical parameters while the source at 500 meters have higher values This could be due to various reasons including rates of extraction and the depth of the well source.

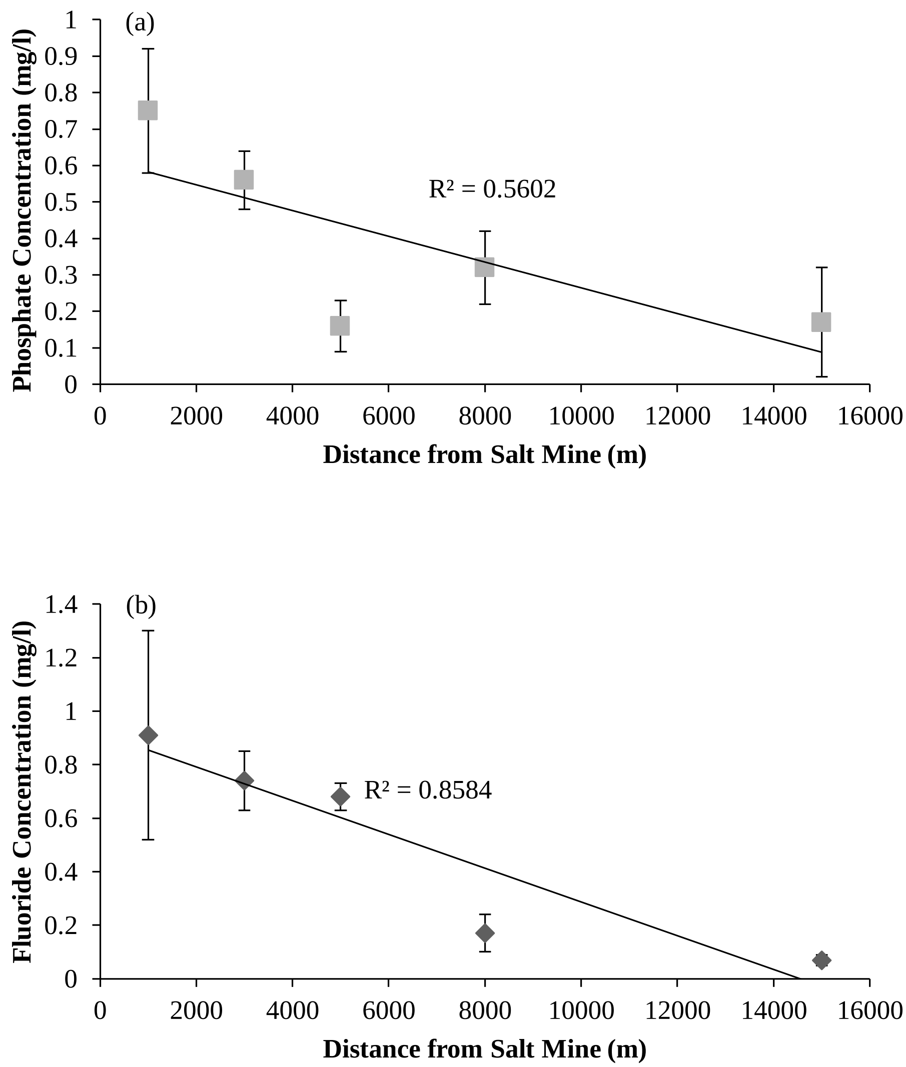


Figure 4.4 Variation of (a) Phosphate concentration and (b) Fluoride concentration with distance from salt mining sites

Effect of distance from the ponds on concentration of contaminants

The study intended to establish whether distance from the salt harvesting ponds affected the concentration of the contaminants. Scatter plots were drawn to ascertain whether such relationships existed. The coefficient of determination, also known as regression was calculated. This formula, $R^2 = \{(1 / N) * \Sigma [(x_i - x) * (y_i - y)] / (\sigma_x * \sigma_y) \}^2$ was used

Here:

N = the number of observations used to fit the model,

Σ = the summation symbol,

x_i = the x value for observation i,

x = the mean x value,

y_i = the y value for observation i,

y = the mean y value,

σ_x = the standard deviation of x, and

σ_y = the standard deviation of y.

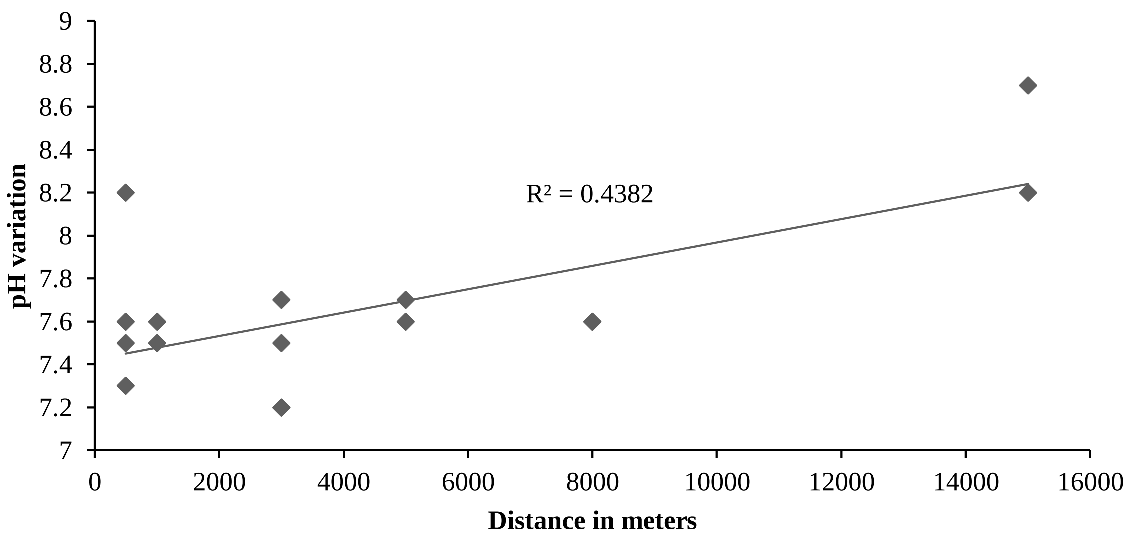


Figure 4.5 Water pH levels with distance from mining sites

From Figure 4.5 above, it can be deduced that there is a slight increase of pH as the distance from the salt mining site increases.

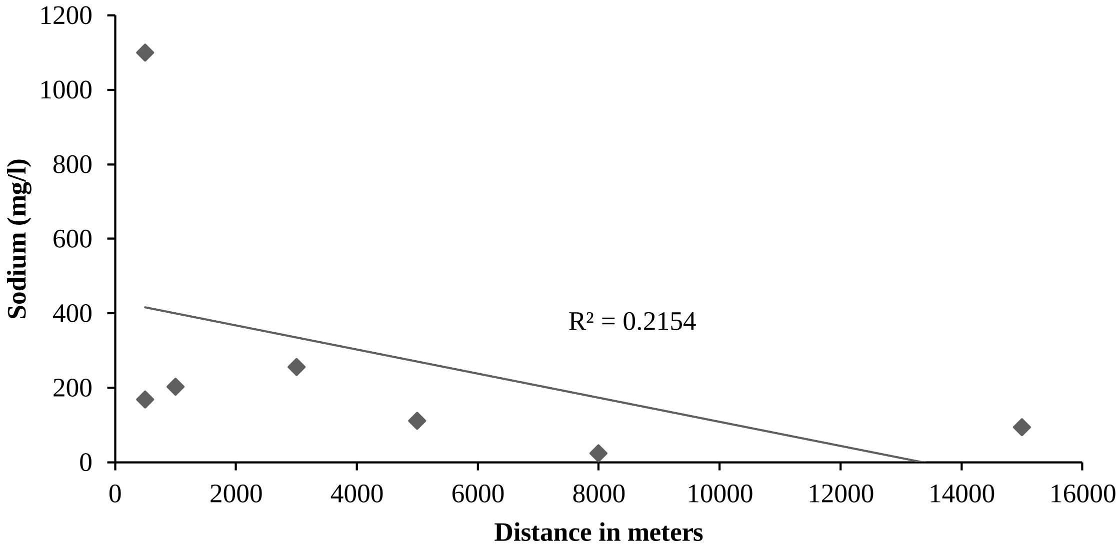


Figure 4.6 Sodium concentrations plotted against distance from salt harvesting

Concentration of Sodium ions in ground water sources decreased with increase in distance from the salt harvesting ponds (Figure 4.6). The regression shows that 2.1% of the variance in the Sodium concentration is predictable from the distance variable.

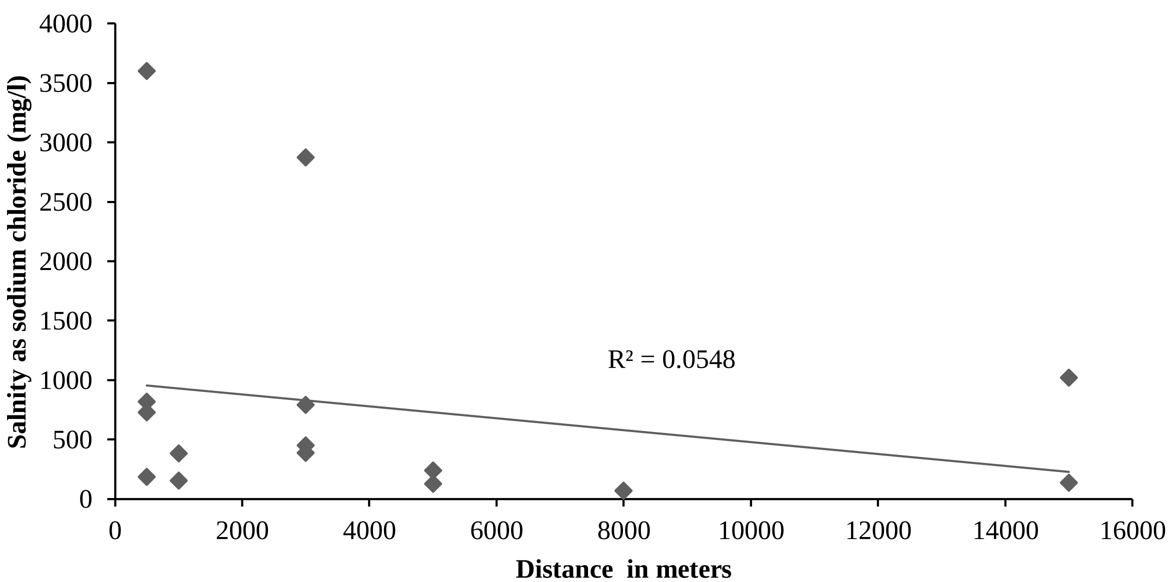


Figure 4.7 Salinity as sodium chloride concentration plotted against distance from salt harvesting ponds

Sodium Chloride used as a measure of the salinity caused by the presence of Sodium chloride ions. The concentration of sodium chloride ions in ground water decreased with increase in distance from the salt harvesting ponds (Figure 4.7). The regression shows that only 5.4% of the variance in the dependent variable (concentration of the sodium chloride ions) arises as a result of the independent variable. The p value for the sodium concentration is below 0.01 and shows a strong significance at 95% confidence level

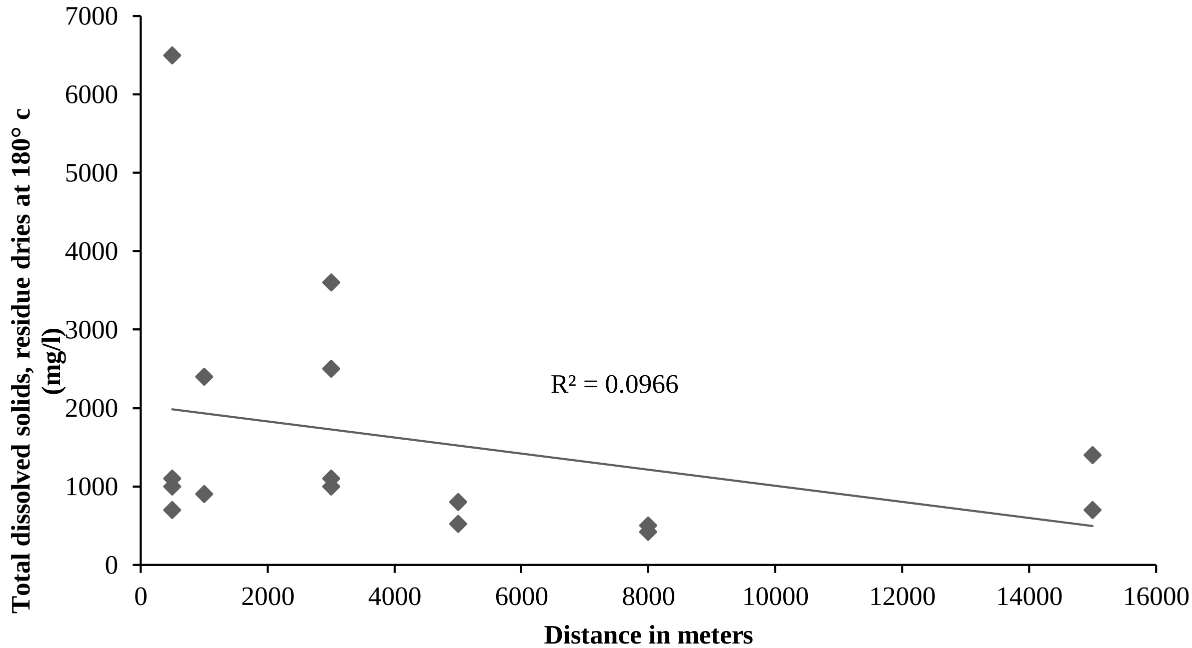


Figure 4.8 Total dissolved solids plotted against distance from salt harvesting ponds

Total dissolved solids (TDS) reduced gradually with increase in distance from the salt harvesting ponds (Figure 4.8). TDS measures the quantity of all the dissolved inorganic salts and organic substances in water. These substances may originate from agricultural activities, residential waste water runoff; discharge from discharged polluted water from industrial or sewage plants among other sources. The regression shows that only 9.6% of the variability of the dependent variable is caused by variation of the independent variable.

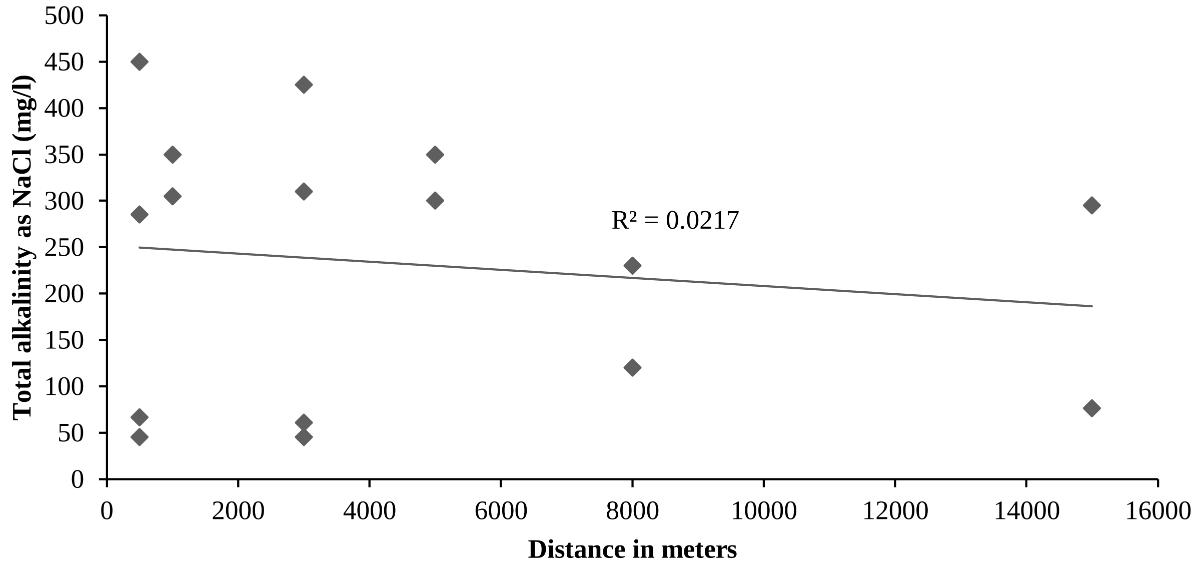


Figure 4.9 Total alkalinity plotted against distance from salt harvesting ponds

Total alkalinity represents the ability of sea water to resist pH change upon addition of acid. This was obtained by adding the results of methyl orange indicator and that of phenolphthalein indicator. The regression shows that 2.1% of the variance in the total alkalinity is predictable from the variation in the distance from the salt water harvesting ponds (Figure 4.9). Sea water absorbs atmospheric carbon dioxide forming weak carbonic acid which dissociates to bicarbonate anions and subsequently to carbonate anions and hydrogen ions. The dilution as the seawater percolates in to the aquifer reduces the alkalinity levels.

CHAPTER FIVE

5.0 DISCUSSION

5.1 Chemical contamination levels of ground water sources in Gongoni

The chemical parameters for ground water sources in Gongoni area are captured in Table 4.1. The results show the levels for various parameters at measured distances from the salt firms. The p value for sodium in the means of the samples is <0.001 which is less than 0.05 and therefore statistically significant at 95% confidence levels.

The total dissolved solids (TDS) show a p value of <0.01 which is significant at 95% confidence levels as captured in Table 4.1. However, in the comparisons of the means in the two groups the p value becomes insignificant as it rises to above 0.05. Gongoni water sources have a mean of 1969.00±527.13mg/L and the control shows 1050.00±350 mg/L. Water with TDS value above 1000 mg/L is unfit for human consumption. Opiyo et al, (2000) analysed and found TDS values in Timboni water sources in Gongoni as high as 3600mg/L The reasons cited for enhanced total dissolved solids in ground water sources closer to the ocean include salt water intrusion (Sefelnasr and Sherif, 2014). Previously, the Government Chemist had done an analysis which developed in the vicinity beach hotels along the coastline and the low density residential areas in the coast yielded blackish water with TDS values higher than 1500 ml/L (Munga, 2000). This provided evidence of intrusion of saltwater into the coastal aquifers.

Percolations emanating from discharged mother liquor from the ponds into the streams contribute to the enhanced salinity of the water sources (Ocholla et al, 2013). The implication is that presence of total dissolved solids in ground water of Gongoni area can be partly attributed to salt harvesting activities in the area. The source which is less than 500 meters from the salt harvesting ponds and showing a lower TDS could be due to low water extraction rates and depth of the well.

Chloride concentration was found to show minimal changes in the means of the two groups of wells. Gongoni had a mean of 662.00±250.44 mg/l and the control was 485.00±415 mg/l. The implication is that presence of chloride anions in ground water sources of

Gongoni might not be necessarily attributed to salt harvesting ponds only. The mother liquor released from the salt harvesting ponds into streams increases the chloride concentration of the streams and eventually percolates into the aquifer. This was cited by Ocholla et al. (2013) in his studies. Salt water intrusion is another source for the enhanced chloride levels. This is also captured in Table 4.1 where the p value for the chloride is 0.206 thus showing that it is not statistically significant at 95% confidence levels.

Large standard deviations were established in concentration of dissolved solids, sodium, calcium and chloride ions in Gongoni area. This implies that some wells were highly contaminated while others were less contaminated depending on their distance from salt harvesting ponds. The aquifers located in limestone and sandy zones along the coastline are highly permeable with a hydraulic conductivity. These characteristics make them prone to high risks of contaminations. The fact that they are in high water table areas, exuberates this fact (Munga et al., 2014). The implication of these findings is that salt harvesting activities in Gongoni area has to some extent attributed to increased chemical composition of some parameters such as salinity and concentration of phosphates, total dissolved solids, sodium, calcium salts in some of the ground water sources in Gongoni area. The general trend shows reduction in concentrations of the selected chemical parameters as distance from the salt ponds increases.

To ascertain whether the observed differences between the means of concentrations of different contaminants in Gongoni and those in neighboring Gongoni area were statistically significant, the study employed an independent t-test where equal variances were not assumed. This tested if there is no statistical difference in the concentration of contaminants displayed in Table 4.2. The analysis was done at 95% confidence interval. Statistically significant result is one that is not attributed to chance. Factors like sampling error and probability can affect the result we achieve. If the variability of the concentration of the contaminants is less than or equal to 5% ($\leq$ 05), then the concentrations are significantly different. The results showed that the concentrations are not statistically different.

5.2 Biological contamination levels of ground water sources in Gongoni

For Microbiological contamination, pollution indicator bacteria, (*E. coli* and total coliforms) were present in all the sampled wells. This *E colli* is an indicator for contamination from human waste from pit latrines or/and animal waste from the surrounding areas. The presence of these bacteria exposes the residents to the risk of contracting diseases. Improving drinking water quality, reducing faecal coliform counts and enhancing environmental sanitation would reduce the risk of disease contamination (van Derslice and Briscoe, 1995).

Total and faecal coliform counts in all the sampled wells were higher than the Kenyan and WHO recommended values of 0 MPN/100ml for treated water and 10 MPN/100mls for untreated water. This can be caused by leaving the wells unattended wells. Furthermore, the unsuspecting locals rely on the well water for their domestic water supply. Observation made in relation to distance of well from salt mining sites did not yield any relationship. Nevertheless, there was a positive relationship between the bacterial counts and phosphorus and soil pH. The water quality of Kisauni in Mombasa County is not any better when compared to that of the island (Munga, 2002). This information was corroborated by another study carried out in July 2003 that demonstrated poor water quality with higher amounts of microbiological contaminants that exceed the recommended levels (Ministry of Water Resources Development and Management, 2003).

5.3 Correlation between water chemical contaminants and biological measurements in Gongoni water sources

The significant relationships between microbial and phosphate parameters are very interesting and suggest greater regeneration of the limiting phosphorus element by planktonic food webs that supports the bacterial abundance. The presence of microbial contamination was not affected by well cover. These microbial parameters were also influenced by water pH. Bacteria prefer neutral pH, which was mostly found in the study wells. Correlation analysis between the other chemical properties and total coliform count and *E. coli* counts did not show any correlation.

CHAPTER SIX

6.0 CONCLUSION AND RECOMENDATIONS

The results of the study show that some ground water sources in Gongoni have higher salinity levels than the control areas of Mambrui and selected secondary data with high salinity sources from Mombasa County wells where no salt harvesting occurs. Makokha (2019) observed that most of the boreholes and wells close to the sea exhibited high levels of salinity as compared to those in the hinterland. However, there are exceptions of ground water sources within Gongoni area whose salinity levels are within acceptable range for sources next to the ocean. The existence of these water sources with abnormally high salinity and total dissolved solids could be associated with both the salt harvesting activities and salt water intrusion. Other anthropogenic activities in the area such as sand harvesting expose the aquifer and render it vulnerable to contamination.

Normal sea water intrusion into the ground water sources impacts on the salinity levels as observed in the secondary data from Mombasa County (1500mg/l) and sources from Mambru (1050mg/l) which are far from the salt harvesting ponds. With the salt harvesting activities in Gongoni the levels have been raised to a mean of 1969mg/L showing some impact on the ground water sources. However, despite the elevated parameters from Gongoni water sources, the differences are not statistically significant.

The water sources are also heavily contaminated with coliform and *E. colli* bacteria and should be regularly disinfected using the appropriate chlorination methods. It is important to test the water samples from the wells in reputable laboratories as a way of monitoring the effectiveness of the disinfection.

The water wells with enhanced contamination levels can be treated using reverse osmosis filtration methods to lower the TDS levels to acceptable limits. The other wells with favorable salinity levels can be disinfected for use. Other water sources could be the piped water from Baricho water works which is not very far from the study area.

This study recommends that all salt harvesting projects should be subjected to environmental and social impact assessments more so prior to start. This is actually a requirement of EMCA Act of 1999. Annual audits should also be carried out to ascertain compliance to their operating licenses. If this is implemented, the confidence of the community will be restored.

REFERENCES

Akpoveta O.V., Okoh B.E., and Osakwe S.A. (2011). Quality Assessment of Borehole Water used in the Vicinities of Benin, Edo State and Agbor, Delta State of Nigeria. Current Research in Chemistry, 3: 62-69.

Bain, R., Cronk, R., Wright, J., Yang, H., Slaymaker, T., & Bartram, J. (2014). Fecal contamination of drinking-water in low-and middle-income countries: a systematic review and meta-analysis. *PLoS medicine*, *11*(5), e1001644.

Barlow., (2003). Solinst papers, Groundwater Monitoring, Management and Conservation Keep Saltwater Intrusion Under Controlsource http://www.solinst.com/resources/papers/101c4salt.php Accessed 16/11/14 1.31pm

Bhavna Deonarain, (2014). 8 ways climate change is already affecting Africa Source http://350africa.org/2014/12/12/8-ways-climate-change-is-already-affecting-africa/

Bourne, A. C. (2001). *Assessing the contamination risk of private well water supplies in Virginia* (Doctoral dissertation, Virginia Tech).

Bridgman, S. A., Robertson, R. M. P., Syed, Q., Speed, N., Andrews, N., & Hunter, P. R. (1995). Outbreak of cryptosporidiosis associated with a disinfected groundwater supply. *Epidemiology & Infection*, *115*(3), 555-566.

Christensen Emma (2011). Producer tour From Ocean to Box. How sea salt is Harvested source http://www.thekitchn.com/come-along-on-a-159478

Conboy, M. J., & Goss, M. J. (2000). Natural protection of groundwater against bacteria of fecal origin. *Journal of contaminant hydrology*, *43*(1), 1-24.

Cooper Jr, H. H. (1964). A hypothesis concerning the dynamic balance of fresh water and salt water in a coastal aquifer. *Journal of Geophysical Research*, *64*(4), 461-467.

Copeland, C. C., Beers, B. B., Thompson, M. R., Fitzgerald, R. P., Barrett, L. J., Sevilleja, J. E., ... & Guerrant, R. L. (2009). Faecal contamination of drinking water in a Brazilian shanty town: importance of household storage and new human faecal marker testing. *Journal of water and health*, *7*(2), 324-331.

DeSimone, L. A., Hamilton, P. A., & Gilliom, R. J. (2009). Quality of ground water from private domestic wells. *Water Well Journal*, 33-37.

DWR, southern district report (2002). Water resources of the Arroyo Grande – Nipomo Mesa area

Fong, T. T., Mansfield, L. S., Wilson, D. L., Schwab, D. J., Molloy, S. L., & Rose, J. B. (2007). Massive microbiological groundwater contamination associated with a waterborne outbreak in Lake Erie, South Bass Island, Ohio. *Environmental health perspectives*, *115*(6), 856-864.

Gualbert H. P. Oude Essink, (1999) Saltwater intrusion in coastal aquifers Source: :https://www.researchgate.net/publication/46608750 pg 38

Hanchar, D. Withington. (1991). Effects of Septic tank effluent on groundwater quality in Northern Williamson County and Southern Davidson County, Tennessee, US Geological Survey, Water – Resources Investigation Report 91 – 4011.

Kenya National Commission on Human Rights, (2006). Report of a public inquiry into allegations of humanrights violations in Magarini, Malindi pg 123 Source; https://www.knchr.org/Portals/0/EcosocReports/Malindi_Inquiry.pdf?ver=2013-02-21-141657-360

Kohout, F.A., 1964, The flow of fresh water and salt water in the Biscayne aquifer of the Miami area, Florida: U.S. Geological Survey Water-Supply Paper 1613-C, p. 12-32).

Lamma, O. A., Swamy, A. V. V. S., & Subhashini, V. Ground water quality in the vicinity of industrial locations in Guntur, AP, India.

Lin, C. Y., Abdullah, M. H., Musta, B., Aris, A. Z., & Praveena, S. M. (2010). Assessment of selected chemical and microbial parameters in groundwater of Pulau Tiga, Sabah, Malaysia. *Sains Malaysiana*, *39*(3), 337-345.

Makokha, M. (2019). Groundwater Quality Analyses along Kenyan Coastal Region, Case Study of Kilifi County. *International Journal of Environment and Geoinformatics*, *6*(1), 1-14.

Marshall, S. (2011). The water crisis in Kenya: Causes, effects and solutions. *Global Majority E-Journal*, *2*(1), 31-45

Mombasa water sewerage company ltd, Mowasco, (2011). http://www.mombasawater.co.ke/index.php/services) Accessed on 8/11/2014

Moraa, H., Otieno, A., Salim, A. (2012). Water governance in Kenya:Ensuring Accessibility, Service delivery and Citizen Participation pg 5 source, http://www.ihub.co.ke/ihubresearch/uploads/2012/july/1343052795__537.pdf

Munga, D., Kitheka, J. U., Mwaguni, S. M., Massa, H. S., Mwashote, B. M., Mwangi, S., & Opello, G. (2004). Pollution and Vulnerability of Water Supply Aquifers in Mombasa Kenya: Interim Progress Report.

Munga, D. (2002). Freshwater Shortage and Groundwater Quality in Mombasa. *KMFRI, Mombasa*.

Ocholla, G. O., Bunyasi, M. M., Asoka, G. W., Pacha, O., Mbugua, H. K., Mbuthi, P., ... & Kamau, H. K. W. P. K. (2013). Environmental issues and socio-economic problems emanating from salt mining in Kenya; a case study of Magarini district. *International Journal of Humanities and Social Science*, *3*(3), 213-223.

Opiyo-Akech, N, Olago, D. O., Dindi, E. W., & Ndege, M. M. (2002). Human impact on groundwater quality along the Kenyan coast: A case study on an unconfined aquifer to the north of the coastal town of Malindi, Kilifi District Kenya.

Parihar, V. L., Sharma, M. S., & Sharma, L. L. (2003). Utility of bacteriological parameters for assessing best use and trophic status of seasonal waters: a case study from Udaipur, Rajasthan. *Pollution Research*, *22*(2), 163-167.

Reilly, T.E., (1993) Analysis of ground-water systems in freshwater-saltwater environments, in Alley, W.M., ed., Regional ground-water quality: New York, Van Nostrand Reinhold, 634 p.)

Ruben Geert van den Berg (2014). SPSS T Test Examples. Source http://www.spss-tutorials.com/spss-independent-samples-t-test/Accessed on 17/7/2016

Sarala, C., & Ravi Babu, P. (2012). Assessment of groundwater quality parameters in and around Jawaharnagar, Hyderabad. *International journal of scientific and research publications*, *2*(10), 1-6.

Sarmiento & Gruber (2006). Chemical composition of Seawater: Salinity and the major constituents OCN 623–Chemical Oceanography pg 9, 16, source https//www.soest.hawai.edu/oceanography/couses/OCN623/Spring%202015/Salinity2015web.pdf Accessed 14/7/2016

Sefelnasr, A., & Sherif, M. (2014). Impacts of seawater rise on seawater intrusion in the Nile Delta aquifer, Egypt. *Groundwater*, *52*(2), 264-276.

Sherif M.M and Singh V.P. (1996) Chapter 10. Salt water intrusion – an overview https://www.sciencedirect.com/topics/engineering/salt-water-intrusion

Singh, M., Kaur, S., & Sooch, S. S. (2003). Groundwater pollution-An overview. *J. IPHE*, *2*, 29-31.

U.S. Geological Survey/General Interest Publication 1999 "Ground Water http://pub.susgs.gov/gip/gw/gw_a.html

U.S. Geological Survey/General Interest Publication 1999 "Quality of Ground Water" page last modified in 2013 http://pubs.usgs.gov/gip/gw/quality.html

Valcarel, M. (2000).Principles of Analytical Chemistry. Springer-Verlag Berlin Heidelberg, New York.

VanDerslice, J., & Briscoe, J. (1995). Environmental interventions in developing countries: interactions and their implications. *American journal of epidemiology*, *141*(2), 135-144.

Water Resource Management Authority Strategic plan 2012 – 2017 pg 7, 12 , 14source-http://wrma.or.ke/index.php/publications/wrma-strategic-plan.html

WHO (2014) Water Safety in Distribution Systems pg 15 source https://www.who.int

WHO (2013) Multiple tube method for thermotolerant (fecal) coliforms Annex 5 pg 189 source http://www.who.int./water_sanitation_ health/dwq/2edvol3i,pdf

World Water Assessment Programme -Paris, France, (2006) Kenya National Water Development Report. Prepared for the 2nd UN World Water Development Report 'Water: A shared responsibility', pg. 3, 20, 144, source – http://www.ircwash.org/sites/default/files/WWAP-2006-Kenya.pdf

APPENDICES

Appendix 1 Report on ant-plagiarism check

Effect of Salt Harvesting on Ground Water Quality in Gongoni, Kilifi County

ORIGINALITY REPORT

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Appendix 2 Reports on chemical analysis of water

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/47/2015/50
Lab Sample No: 47/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Storage Tank (Kensalt firm)

RESULTS

Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^{0}C(Micro ohms/cm^3) 820

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	NIL	-
Free Saline Ammonia Nitrogen (N)	0.06	0.5
Phosphate PO^{-3}_4	NIL	2.2
Fluorides	0.73	1.5
Oxygen Absorbed, Four hours 27^{o}C(O)	0.8	1
Alkalinity as $CaCO_3$ ---Phenolphthalein (Carbonate)	0.2	-
Methyl Orange (Bicarbonate)	285	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	285	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	NIL	
Chloride (Cl^-)	130	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	56	200
Potassium (K)	09	100
Calcium (Ca)	130	150
Magnesium (Mg)	54	100
Total Dissolved solids, Residue dries at 180^{o}C	700	1000
pH	8.2	6.5 – 8.5

REMARKS:

Alkaline and hard water as per the parameters tested. Treatment is recommended before domestic use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52
REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/48/2015/51
Lab Sample No: 48/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Storage Tank (Krystalline salt firm)

RESULTS

Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C(Micro ohms/cm^3) 1780

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	0.5	-
Free Saline Ammonia Nitrogen (N)	0.16	0.5
Phosphate PO^{-3}_4	0.02	2.2
Fluorides	0.73	1.5
Oxygen Absorbed, Four hours 27°C(O)	0.8	1
Alkalinity as $CaCO_3$ –Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	45	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	45	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	30	
Chloride (Cl^-)	500	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	230	200
Potassium (K)	04	100
Calcium (Ca)	35	150
Magnesium (Mg)	10	100
Total Dissolved solids, Residue dries at 180°C	1000	1000
Ph	7.5	6.5 – 8.5

REMARKS:

Slightly alkaline, saline and soft water as per the parameters tested. Treatment is recommended before domestic use.

Date:*22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA   TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/49/2015/52
Lab Sample No: 49/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Mapimo-Gongoni)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^{0}C(Micro ohms/cm^3) 9300

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	0.5	-
Free Saline Ammonia Nitrogen (N)	2.5	0.5
Phosphate PO^{-3}_4	0.02	2.2
Fluorides	0.68	1.5
Oxygen Absorbed, Four hours 27^{o}C(O)	0.8	1
Alkalinity as $CaCO_3$ ---Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	450	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	55	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	NIL	
Chloride (Cl^-)	2500	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	1100	200
Potassium (K)	12	100
Calcium (Ca)	35	150
Magnesium (Mg)	20	100
Total Dissolved solids, Residue dries at 180^{o}C	6500	1000
Ph	7.3	6.5 – 8.5

REMARKS:

Highly saline and moderately soft water as per the parameters tested. Treatment is recommended before domestic use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/50/2015/53
Lab Sample No: 502015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Timboni)

RESULTS

Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C(Micro ohms/cm^3) 1150

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	2.0	-
Free Saline Ammonia Nitrogen (N)	0.2	0.5
Phosphate PO^{-3}_4	0.24	2.2
Fluorides	0.56	1.5
Oxygen Absorbed, Four hours 27°C(O)	0.8	1
Alkalinity as $CaCO_3$ ---Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	350	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	220	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	NIL	
Chloride (Cl^-)	175	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	65	200
Potassium (K)	05	100
Calcium (Ca)	200	150
Magnesium (Mg)	20	100
Total Dissolved solids, Residue dries at 180°C	800	1000
Ph	7.7	6.5 – 8.5

REMARKS:

Hard and alkaline water as per the parameters tested. Treatment is recommended before domestic use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'SDEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/51/2015/54
Lab Sample No: 51/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Timboni)-hand pump
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C(Micro ohms/cm^3) 720

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	2.5	-
Free Saline Ammonia Nitrogen (N)	0.17	0.5
Phosphate PO^{-3}_4	0.21	2.2
Fluorides	0.73	1.5
Oxygen Absorbed, Four hours 27°C(O)	0.8	1
Alkalinity as $CaCO_3$ ---Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	300	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	300	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	NIL	
Chloride (Cl^-)	100	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	28	200
Potassium (K)	04	100
Calcium (Ca)	175	150
Magnesium (Mg)	125	100
Total Dissolved solids, Residue dries at 180°C	520	1000
pH	7.6	6.5 – 8.5

REMARKS:

Well mineralized but slightly alkaline water as per the parameters tested.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

<u>REPORT ON CHEMICAL ANALYSIS OF WATER</u>

Report Reference: WQ.1/ VOL IV/52/2015/55
Lab Sample No: 52/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Timboni)
<u>RESULTS</u>
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^{0}C(Micro ohms/cm^3) 1390

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	1.5	-
Free Saline Ammonia Nitrogen (N)	0.17	0.5
Phosphate PO^{-3}_4	0.92	2.2
Fluorides	1.3	1.5
Oxygen Absorbed, Four hours 27^{o}C(O)	0.8	1
Alkalinity as $CaCO_3$ —Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	350	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	350	300
Non-Carbonate Hardness as Calcium Ca rbonate ($CaCO_3$)	50	
Chloride (Cl^-)	80	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	76	200
Potassium (K)	14	100
Calcium (Ca)	140	150
Magnesium (Mg)	210	100
Total Dissolved solids, Residue dries at 180^{o}C	900	1000
pH	7.6	6.5 – 8.5

<u>REMARKS:</u>

Very hard but slightly alkaline water as per the parameters tested. Treatment is recommended before domestic use.

Date: *22/07/2015* Mwabwagizo Juma ***<u>GOVERNMENT ANALYST</u>***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/53/2015/56
Lab Sample No: 53/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Ngomeni A)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^{0}C(Micro ohms/cm^3) 700

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	2.5	-
Free Saline Ammonia Nitrogen (N)	0.15	0.5
Phosphate $PO^{-3}{}_4$	0.42	2.2
Fluorides	0.24	1.5
Oxygen Absorbed, Four hours 27^{o}C(O)	0.8	1
Alkalinity as $CaCO_3$ —Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	230	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	175	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	NIL	
Chloride (Cl^-)	45	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	24	200
Potassium (K)	13	100
Calcium (Ca)	135	150
Magnesium (Mg)	40	100
Total Dissolved solids, Residue dries at 180^{o}C	500	1000
pH	7.6	6.5 – 8.5

REMARKS:

Well mineralized and alkaline water as per the parameters tested.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/54/2015/57
Lab Sample No: 54/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well(Ngomeni B)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C(Micro ohms/cm^3) 610

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	NIL	-
Free Saline Ammonia Nitrogen (N)	0.41	0.5
Phosphate PO^{-3}_4	0.22	2.2
Fluorides	0.1	1.5
Oxygen Absorbed, Four hours 27^oC(O)	0.8	1
Alkalinity as $CaCO_3$ ---Phenolphthalein (Carbonate)	5.0	-
Methyl Orange (Bicarbonate)	115	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	115	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	NIL	
Chloride (Cl^-)	45	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	24	200
Potassium (K)	06	100
Calcium (Ca)	94	150
Magnesium (Mg)	21	100
Total Dissolved solids, Residue dries at 180^oC	420	1000
pH	7.6	6.5 – 8.5

REMARKS:

Well mineralized and moderately hard water as per the parameters tested.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/55/2015/58
Lab Sample No: 55/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Mjanaheri A)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C (Micro ohms/cm^3) 1380

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	1.5	-
Free Saline Ammonia Nitrogen (N)	0.2	0.5
Phosphate PO^{-3}_4	0.68	2.2
Fluorides	0.84	1.5
Oxygen Absorbed, Four hours 27°C(O)	0.8	1
Alkalinity as $CaCO_3$ — Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	425	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	335	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	90	
Chloride (Cl^-)	2500	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	75	200
Potassium (K)	23	100
Calcium (Ca)	195	150
Magnesium (Mg)	140	100
Total Dissolved solids, Residue dries at 180°C	1000	1000
pH	7.7	6.5 – 8.5

REMARKS:

Excessively saline and very hard water as per the parameters tested. Treatment is recommended before domestic use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/56/2015/59
Lab Sample No: 56/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Mjanaheri B)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C(Micro ohms/cm^3) 516

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	2.1	-
Free Saline Ammonia Nitrogen (N)	0.24	0.5
Phosphate PO^{-3}_4	0.4	2.2
Fluorides	0.85	1.5
Oxygen Absorbed, Four hours 27°C(O)	0.8	1
Alkalinity as $CaCO_3$ ---Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	610	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	610	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	90	
Chloride (Cl^-)	90	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	360	200
Potassium (K)	31	100
Calcium (Ca)	575	150
Magnesium (Mg)	125	100
Total Dissolved solids, Residue dries at 180°C	3600	1000
pH	7.2	6.5 – 8.5

REMARKS:

Neutral pH and very hard water as per the parameters tested. Treatment is recommended before domestic use.

Date: ***22/07/2015*** Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/57/2015/60
Lab Sample No: 57/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Gongoni A)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C(Micro ohms/cm^3) 2600

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	1.5	-
Free Saline Ammonia Nitrogen (N)	0.15	0.5
Phosphate PO^{-3}_4	0.59	2.2
Fluorides	0.52	1.5
Oxygen Absorbed, Four hours 27°C(O)	0.8	1
Alkalinity as $CaCO_3$ – Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	305	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	150	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	NIL	
Chloride (Cl^-)	55	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	330	200
Potassium (K)	18	100
Calcium (Ca)	60	150
Magnesium (Mg)	90	100
Total Dissolved solids, Residue dries at 180°C	2400	1000
pH	7.5	6.5 – 8.5

REMARKS:

Slightly alkaline and moderately hard water as per the parameters tested. It is fit for domestic use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/58/2015/61 **Lab Sample No:** 58/2015 **Date Received: 10**/07/2015
Sender: Ali Gakweli
Source: Tap (Mambrui Sec)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C (Micro ohms/cm^3) 1200

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	1.5	-
Free Saline Ammonia Nitrogen (N)	0.23	0.5
Phosphate PO^{-3}_4	0.32	2.2
Fluorides	0.08	1.5
Oxygen Absorbed, Four hours 27°C(O)	0.8	1
Alkalinity as $CaCO_3$ – Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	295	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	295	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	10	
Chloride (Cl^-)	70	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	67	200
Potassium (K)	56	100
Calcium (Ca)	385	150
Magnesium (Mg)	95	100
Total Dissolved solids, Residue dries at 180°C	700	1000
pH	8.3	6.5 – 8.5

REMARKS:

Alkaline and hard water as per the parameters tested.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/59/2015/62
Lab Sample No: 59/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Tap (Mambrui Dispensary)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^{0}C(Micro ohms/cm^3) 1700

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT(PPM)
Free Carbon Dioxide	NIL	-
Free Saline Ammonia Nitrogen (N)	0.35	0.5
Phosphate PO^{-3}_4	0.02	2.2
Fluorides	0.05	1.5
Oxygen Absorbed, Four hours 27^{o}C(O)	0.8	1
Alkalinity as $CaCO_3$ ---Phenolphthalein (Carbonate)	1.5	-
Methyl Orange (Bicarbonate)	75	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	75	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	25	
Chloride (Cl^-)	900	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	120	200
Potassium (K)	5	100
Calcium (Ca)	20	150
Magnesium (Mg)	80	100
Total Dissolved solids, Residue dries at 180^{o}C	1400	1000
pH	8.7	6.5 – 8.5

REMARKS:

Very saline and alkaline water. The water has to be treated before use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/60/2015/63
Lab Sample No: 59/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Tap (Krytalline)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^{0}C (Micro ohms/cm^3) 1500

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	NIL	-
Free Saline Ammonia Nitrogen (N)	0.15	0.5
Phosphate PO^{-3}_4	0.02	2.2
Fluorides	0.65	1.5
Oxygen Absorbed, Four hours 27^{o}C(O)	0.8	1
Alkalinity as $CaCO_3$ — Phenolphthalein (Carbonate)	1.5	-
Methyl Orange (Bicarbonate)	65	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	65	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	125	
Chloride (Cl^-)	600	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	220	200
Potassium (K)	16	100
Calcium (Ca)	25	150
Magnesium (Mg)	60	100
Total Dissolved solids, Residue dries at 180^{o}C	1100	1000
pH	7.6	6.5 – 8.5

REMARKS:

Very saline and alkaline water. The water has to be treated before use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/62/2015/65
Lab Sample No: 62/2015 **Date Received:** 10/07/2015
Sender: Ali Gakweli
Source: Well (Fundisha Village)

RESULTS

Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C(Micro ohms/cm^3) 2600

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	1.2	-
Free Saline Ammonia Nitrogen (N)	0.15	0.5
Phosphate PO^{-3}_4	0.59	2.2
Fluorides	0.52	1.5
Oxygen Absorbed, Four hours 27°C(O)	0.8	1
Alkalinity as $CaCO_3$ – Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	310	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	160	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	NIL	
Chloride (Cl^-)	60	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	330	200
Potassium (K)	18	100
Calcium (Ca)	60	150
Magnesium (Mg)	90	100
Total Dissolved solids, Residue dries at 180°C	2500	1000
pH	7.2	6.5 – 8.5

REMARKS:

Slightly alkaline and moderately hard water as per the parameters tested. It is fit for domestic use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

GOVERNMENT CHEMIST'S DEPARTMENT
P. O. BOX 81119-80100MOMBASA TEL. 4473951/52

REPORT ON CHEMICAL ANALYSIS OF WATER

Report Reference: WQ.1/ VOL IV/61/2015/64
Lab Sample No: 61/2015 **Date Received:** 10/07/2015

Sender: Ali Gakweli
Source: Well water (Fundisha Village - pump)
RESULTS
Colour: 10 **Hazen Unit** **Turbidity:** Clear
Deposit Nil **Odour:** Unobjectionable
Taste: -
Electrical Conductivity at 25^0C(Micro ohms/cm^3) 1800

TYPE OF CHEMICAL ANALYSIS	PARTS PER MILLION (mg/L)	MAXMUM LIMIT (PPM)
Free Carbon Dioxide	0.3	-
Free Saline Ammonia Nitrogen (N)	0.16	0.5
Phosphate PO^{-3}_4	0.02	2.2
Fluorides	0.74	1.5
Oxygen Absorbed, Four hours 27^oC(O)	0.8	1
Alkalinity as $CaCO_3$ Phenolphthalein (Carbonate)	NIL	-
Methyl Orange (Bicarbonate)	45	300
Carbonate hardness as calcium carbonate ($CaCO_3$)	45	300
Non-Carbonate Hardness as Calcium Carbonate ($CaCO_3$)	35	
Chloride (Cl^-)	550	250
Silica (SiO_2)	-	-
Heavy Metals (Fe,Pb,Cu)	Not Detected	1
Sodium (Na)	240	200
Potassium (K)	04	100
Calcium (Ca)	35	150
Magnesium (Mg)	10	100
Total Dissolved solids, Residue dries at 180^oC	1100	1000
pH	7.5	6.5 – 8.5

REMARKS:

Slightly alkalne, saline and soft water as per the parameters tested. Treatment is recommended before domestic use.

Date: *22/07/2015* Mwabwagizo Juma ***GOVERNMENT ANALYST***

Key chemical parameters of Gongoni ground water sources expressed in Mg/l

Sampled Well	Distance	Salinity as Nacl	TDS	Total Alkalinity	PH	Total hardness
Krystalline salt firm	<500m	730	1000	45	**7.5**	**75**
Kensalt firm	<500m	186	700	285.2	8.2	285
Krytalline	<500m	820	1100	66.5	7.6	190
Mapimo Gongoni	500 meters	3600	6500	450	7.3	55
Gomgoni A	1KM	385	2400	305	7.5	150
Gomgoni B	1KM	156	900	350	7.6	400
Mjanaheri A	3KM	2875	1000	425	7.7	425
Mjanaheri B	3KM	450	3600	61	7.2	151
Gongoni Fundisha A	3KM	390	2500	310	7.2	160
Gongoni Fundisha A pump	3KM	790	1100	45	7.5	80
Timboni A	5KM	240	800	350	7.7	220
Timboni)-hand pump	5KM	128	520	300	7.6	300
Ngomeni A	8KM	69	500	230	7.6	175
Ngomeni B	8KM	69	420	120	7.6	115
Mambrui Dispensary	15KM	1020	1400	76.5	8.7	100
Mambrui Sec	15KM	137	700	295	8.2	305

Appendix 3 Sample collection form

Date				State of water source		Analysis	
Sample No.	Name of water source	Operational for (Years)	Distance from sea shore	Covered/not covered	Treated/ Not treated	MBA	FCA

Appendix 4 Microbiological results from groundwater sources from Gongoni - Kilifi County.

S/ No	Lab.No	Sample at	Facility	Area (exact locality)	Chlorinated/ Not Chlorinated	Total Coliform Count(MPN/ mL)	Faeca(*E. Coli*) Count(MPN/ mL)	Remarks
1	228/2015	Ken-salt	Storage tank	Kadzuhoni	Chlorinated	93	15	Contaminated
2	229/2015	Krystalline salt firm	Tap	Madukani	Chlorinated	>2400	34	Contaminated
3	230/2015	Krystalline salt firm	Well water (open)	Within the firm	Chlorinated	>2400	460	Heavily contaminated
4	231/2015	Gongoni	Well water (open)	Mapimo village	Notchlorinated	93	7	Contaminated
5	232/2015	Timboni (A)	Well water (open)	Timboni	Chlorinated	>2400	1100	Heavily contaminated
6	233/2015	Timboni (B)	Well water(open)	Timboni	Not chlorinated	>2400	42	Contaminated
7	234/2015	Ngomeni (A)	Well water (open)	Ngomeni	Not chlorinated	210	9	Contaminated
8	235/2015	Ngomeni (A)	Well water (open)	Ngomeni	Not chlorinated	>2400	>2400	Heavily contaminated
9	236/2015	Mjanaheri (A)	Well (covered)	Gongoni	Chlorinated	>2400	1100	Heavily contaminated
10	237/2015	Mjanaheri (B)	Well (covered)	Gongoni	Not chlorinated	>2400	>2400	Heavily contaminated
11		Gongoni(A)	Well water (open)	Gongoni	Chlorinated	>2400	>2400	Heavily contaminated
12		Gongoni(B)	Water water (open)	Gongoni	Not chlorinated	>2400	>2400	Heavily contaminated
13	238/2015	Mambrui	Well(covered)	Mambrui Sec	Chlorinated	>2400	29	Contaminated
14	239/2015	Mambrui	Well water (open well)	Mambrui Dispensary	Chlorinated	>2400	29	Contaminated
15	240/2015	Gongoni	Well water(open)	Fundisha village (A)	Not chlorinated	>2400	>2400	Heavily contaminated
16	241/2015	Gongoni	Well (covered)	Fundisha village(B)	Chlorinated	>2400	1100	Heavily contaminated