Groundwater at Mokonde, Kori Chiefdom, Moyamba District

Laying the foundation for Water Security planning at the Mokonde community

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Summary Note

This work sought to determine the perquisites that will define management options for water security in the Mokonde area. The two discussion points are the recharge need for reliable supply and the quality status for treatment options. Chapter one discusses the recharge needs while chapter two discusses the quality status of water from three observation wells in the study area.

The objective of chapter one is to determine the amount of rainfall needed to recharge the groundwater resources of the study area. Rainfall records were collected in order to cumulate rain amounts over time and estimate the potential to recharge aquifers, after evapo-transpiration and surface runoff. Data was also collected on flow patterns and spatial variations. These data sets were useful in estimating the amount of rainfall that would go into the aquifers, as recharge, over stipulated time periods. The Specific yield model was used to determine this potential.

Chapter two presents the quality status of the observation wells in the study area. The two parameters discussed are conductivity and coliform bacteria. The conductivity readings were taken on site. Microbiology data was analyzed from samples collected from the observation wells.

The results and discussions sections of both chapters presented the recharge and quality needs based on the parameters used. Other determinant factors that would have further clarified the points were recommended for further studies. They include but not limited to aquifer properties/soil properties, longer periods of data, other quality parameters, and anthropogenic factors.

Conclusively, a robust water security planning for Mokonde (particularly for groundwater resources) should include design for storing the requisite amount of rainwater, as recharge, over a given resident time. Of more importance is the relationship between recharge and discharge. Another factor that must be included in a robust water security planning for Mokonde is treatment needs to ensure potability. The results of this study asserted that bacteriological contamination should be the primary target of any treatment program. However, other quality parameters as well as the source of the contamination need be confirmed.

Chapter one

Groundwater Recharge at Mokonde, Kori Chiefdom, Moyamba District

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Abstract

When rain falls it undergoes a number of processes, depending on the landscape, soil type, and geologic formation of the area. Part of the rainwater is absorbed by the soil and becomes available for transpiration, while some runs off on the surface into lower elevation systems. Upon saturation of the soil, the excess infiltrate recharges the groundwater which slowly also enters into water bodies at lower elevation areas through base flow. The objective of this work was to determine the amount of rain needed to recharge the groundwater resources of the Mokonde area. Four monitoring wells were selected: Pa Mronya's well, Josephine's well, UMC School, all of which are located in the Mokonde community, and the well at Florence Carew student quarters on Njala University, Njala campus. An automatic water level logger and a dip meter were used to delineate the spatial and temporary variations in water level in the monitoring wells. A simple rain gauge was used to record rain events on a daily basis. The total rainfall cumulated to more than 1200 mm from July to December. The depth to water of the wells revealed that groundwater flows from Mokonde into the Tia River, through Njala campus. Using the Specific yield method, the maximum amount of rainfall needed to recharge the Mokonde area groundwater resources was found to be 270 mm with depth record ranging from September to December 2013. Thankfully, there is enough rainfall in this area to provide that threshold. However, this figure does not take into account peak dry season depths. Additionally, the rate of discharge need be factored into the estimated demand. Further studies, therefore, would focus on delineating the watershed of the area, the rate of discharge, geology and a complete record of rain intensity, particularly in the area of focus.

Key Words: Groundwater, Recharge, Discharge, Rainfall, Well, Dip Meter, Water-level Logger

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1.1 Introduction

When rain falls it undergoes a number processes, depending on the landscape, soil type, and geologic formation of the area. Some of the rainwater infiltrates and absorbs into the soil. This water is available for plants to take up through which they get their nutrient supply. The water, known as green water, is then transpired into the atmosphere (Gotkowitz, 2010).

The soil, upon absorbing the maximum amount of water, attains its saturation point and the rainwater becomes susceptible to two additional fates: surface runoff and groundwater recharge. The surface runoff floods into areas of lower elevation: wetlands, rivers, lakes and the oceans. The underground recharge also ends in these water bodies through a process known as base flow, though in a much slower pace. These two types of rainwater are normally referred to as blue water. They are the main sources of water for human use (Belottini et al., 2012).

Groundwater use is one of the main sources of domestic water supply for rural communities particularly in developing countries (http://www.unep.org/dewa). Its availability and retention time is therefore very crucial to water security of those communities that are solely dependent on it. Additionally, it is important to understand and plan for the factors affecting its recharge, amongst which lists climate, soil, geology, base flow, rainfall, elevation, transpiration and anthropogenic activities (New Jersey Stormwater Best Management Practices Manual, 2004) inclusive.

The Mokonde community is mainly dependent on wells as their main source of domestic water supply. According to preliminary survey results, the wells are shallow and hence easily accessible for water, particularly in the rainy season; additionally the consumers agree the water is palatable in terms of color, taste and odor. In essence therefore, any water security project that focuses on improving groundwater resources in this community will sound meaningful to the consumers. However, sustainable groundwater use plans must follow from understanding availability in space and time. This work seeks to develop groundwater trends in space and time, on the basis of which the recharge need will be established. The objective is to determine the influence of spatial and temporal changes on groundwater recharge need at the Mokonde community, in Kori chiefdom of Moyamba District, southern Sierra Leone. To achieve this the specific yield method have been employed; it requires water levels over a period of time

The need for this work becomes more obvious considering seasonality issues of groundwater availability in the area. In the dry season most of the dug wells become dried up. This poses the burden of covering long distances to fetch water, creating both economic and physical constraints on community members. Children miss morning classes at schools and evening studies at home, while women spend less time at home or at their business centers. In addition there is risk of confronting safety risks with minimal mitigation measures. Overcoming these challenges requires a better understanding of the amount of groundwater supplied in the rainy season compared to the amount required throughout the year. This will help water security planners in terms of priority setting, choosing alternatives, technology development, and resource mobilization. This research will therefore seek to answer the following questions:

- How much rainfall does the Mokonde community receive per year
- How much of the rain possibly goes to recharge the aquifer of a selected area?
- How do groundwater levels change with space and time in the Mokonde area?

This work will inform policy development/strengthening, water security planning and hence contribute to community development. The hydrologic data and its subsequent information will inform curriculum development from the domestic point of view.

1.2 Materials and Methods

1.2.1 Description of the Study Area

Figure 1 Map of Sierra Leone pinpointing the study area (www.maps.google.com)

The Mokonde community is located south of Njala University Njala Campus at Kori Chiefdom in Moyamba District, Southern Sierra Leone (Figure 1). It has a landscape characterized of an upland area with several swamps in between. Common economic practices include production of tropical crops like cassava, sweet potato, palm oil and the country's staple food, rice; petty trading, and small scale fishing. The community depends largely on the use of groundwater in the form of hand dug wells. Water scarcity in the dry season burdens the community on traveling one-half mile to fetch water from the Gbengitay stream, which is located south of the community.

Mokonde experiences dry season weather condition which last from end of November to April. The temperature is high at about an average of 30^{o}C. The rainy season lasts from May to October with relatively high humidity and heavy down pour of rain.

This community is growing rapidly with a population of indigenes and migrants from every part of Sierra Leone. The total population is about 2,879 (Statistics Sierra Leone, 2004).

1.2.2 Observation Wells and Rain gauge site

Two observation wells were selected to obtain the hydrological data: one at the UMC primary school, New Site section, and one at Madam Josephine's compound by Ngegba Street. The rain gauge site is situated by the office of the Dean of Environmental Sciences at Njala University.

Figure 2 Google earth image of Mokonde showing well locations and neighboring Njala (www.googleearth.com)

1.2.3 Data Collection

To estimate the recharge potential the specific yield method has been adopted because of the unconfined nature of the aquifer. It requires knowledge of changes in water levels over a given period of time. Advantages of this approach include its simplicity and insensitivity to the mechanism by which water moves through the unsaturated zone. Atmospheric pressure and temperature determination of the observation well at Madam Josephine's compound formed part of this process. The dip meter was used once every week to determine groundwater levels in both observation wells.

The hydrological monitoring focused on the influence of barometric atmospheric pressure on water level fluctuations in the monitoring well. The depth to water level is important because it is one of those factors that determine the recharge potential. The rain gauge was also strategically placed to determine the depth of rainfall in the environment.

With the help of the above data, a suitable method was used to estimate the recharge potential

1.2.4 Materials and Equipment

1.2.4.1 Win – Situ Aqua Software

This comprise of a rugged troll and rugged barro, both are easy-to-use software aquatic data logging instruments. The rugged troll was used to measure the temperature and depth to groundwater while the rugged barro was used to measure the atmospheric pressure on the water in the well. Both instruments have completely sealed bodies that contain an absolute (non-vented) pressure sensor, temperature sensor, real-time clock, microprocessor, lithium battery, and internal memory. The Rugged TROLL 100 is designed to hang by a back-shell hanger from a suspension wire.

1.2.4.2 Rain Gauge

The Rain gauge is made of plastic with a total capacity of (225) mm. It consists of an Outer Cylinder within which there is a smaller diameter measuring Cylinder marked in 0.5 mm units up to 25 mm. It is placed on a level ground, surrounded by Low Vegetation, located in an open ground with a distance greater than twice the height of the fence protecting it. It is mounted 1.2 m above ground level with the rim of the funnel above the height of the post.

1.2.4.3 Deployment of monitoring equipment

The win–situ software was installed into the laptop computer. The rugged troll was then connected to the docking station. The notch on the rugged troll body was aligned with the tab on the rim of the docking station to ensure the pins were in contact for communication. The docking station cable was connected to the computer. The rugged troll was then programmed in the computer, disconnected and then deployed in the well. The instrument was programmed to take automatic water level readings every 15 minutes. The data was downloaded after a number of days and the instrument redeployed to continue in-situ readings of water level fluctuations.

The amount of rainfall was measured at 9:00 AM each morning, to represent rain events in the previous day.. All the water collected in the Outer Container and the Central Graduated Cylinder was poured into a separate storage container taken care to avoid spillage of any water. The amount of water was then measured by the Central Graduated Cylinder held in one hand positioned inside the empty outer cylinder. A funnel was used to fill the graduated cylinder not exceeding the 10 ml mark. Care was taken to avoid overflow. The water was poured back into the Rain gauge Cylinder so that if an error was made the process could be repeated. The process was repeated, noting each measurement on the record sheet until all the water was measured.

1.2.4.4 Determination of Recharge Potential Using the Specific Yield Method

The Specific Yield method, S_y (Scanlon et al., 2002) was applied to the groundwater level data. The S_y method is based on the premise that rise in groundwater levels in unconfined aquifers are due to recharge water arriving at the water table. The recharge (R) is calculated as

$$R = S_y \Delta h$$

Where S_y is specific yield, Δh is change in water-table height (Scnalon et al., 2002). The method has been applied to groundwater level rise that occurred over several years in the High Plains aquifer. Difficulties in applying the method are related to ensuring that fluctuations in water levels are due to recharge following precipitation and are not the result of recovery after pumping, changes in atmospheric pressure, presence of entrapped air, or other phenomena. Determining a representative value for specific yield can also be problematic. The method is only applicable to unconfined aquifers and is best applied to shallow water tables that display sharp water-level changes (Cook et al., 2001). Typical S_y values range between 0.005 and 0.1.

1.3 Results and Discussions

1.3.1 Rainfall Records in the Mokonde area

Owor et al (2009) showed that groundwater recharge is related to the sum of heavy rainfall events exceeding a threshold of 10 mm day^{-1}. The rainfall records in figure 3 above shows enough rain to enhance recharge. As a matter of fact, some wells get as shallow as less than 2.0 m deep during the rainy season. The problem then is that the water levels drop as we move into the dry season, probably resulting from base flow and consumption: discharge becomes greater than recharge (Simpson et al., 2006).

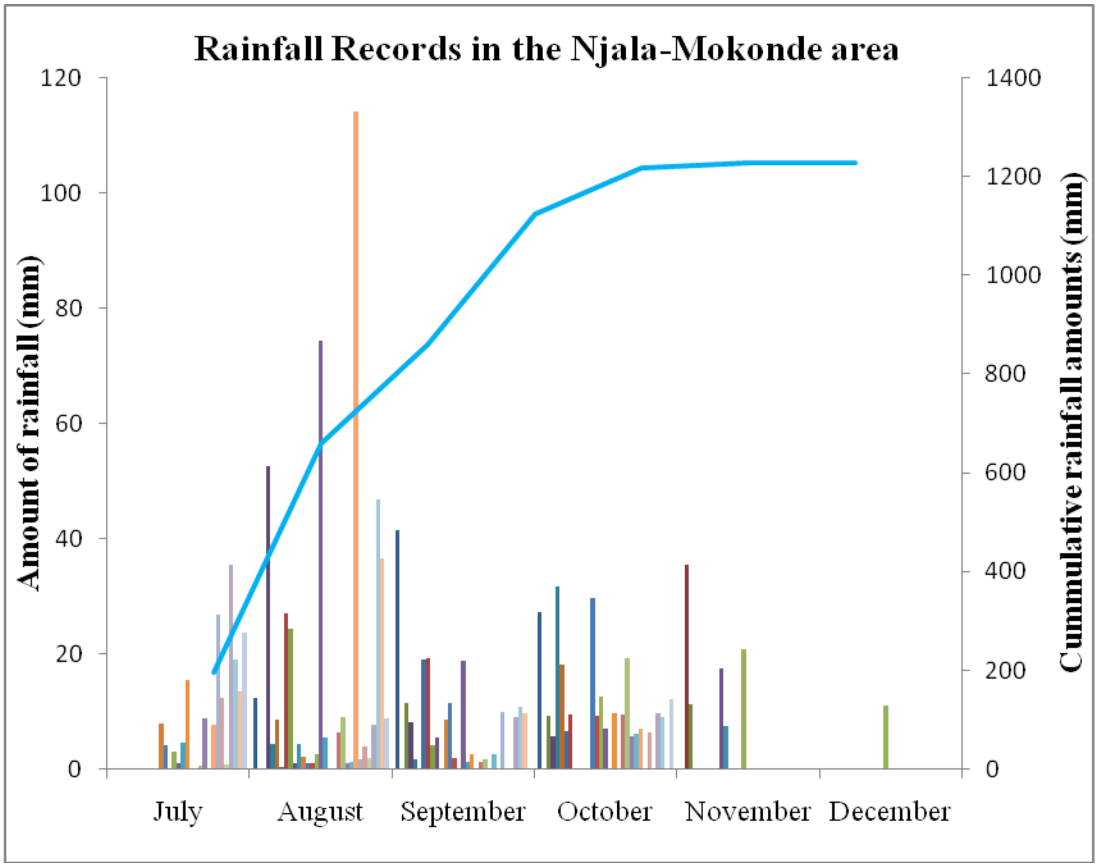

Figure 3 Amount of rainfall from July to December 2013 in the Mokonde area

Long term records of rainfall confirm the high potential of groundwater recharge in the study area. According to the map in figure 4, southern Sierra Leone receives an average annual rainfall of 3,000 mm. this makes rain harvesting in the form of recharge, or surface water plausible in this part of the country; for successful rain harvesting, the minimum average monthly rainfall recommended for at least half a year is 50 mm (Mihelcic et al., 2009).

Figure 4 Average annual rainfall across West Africa. Source: www.eb.com

1.3.2 Groundwater flow direction

Even though the sampling dates and times were different in the three wells (Figure 5), quality control check showed no change in any of the wells to make them comparable in terms of depth to groundwater. Hence groundwater seems to be flowing downstream of Pa Mornya's area, towards Josephine's area, to Njala Campus and finally into the sediments of the Tia river, which is located downstream, North of the wells. However, this could only be the case if all the wells share a common watershed. Delineation of the watershed was beyond the scope of this study. The water level drops with time, with the exception of few peaks (probably corresponding to rain events during that time), and the trend is consistent with dwindling rain events as the months enter into the early dry season.

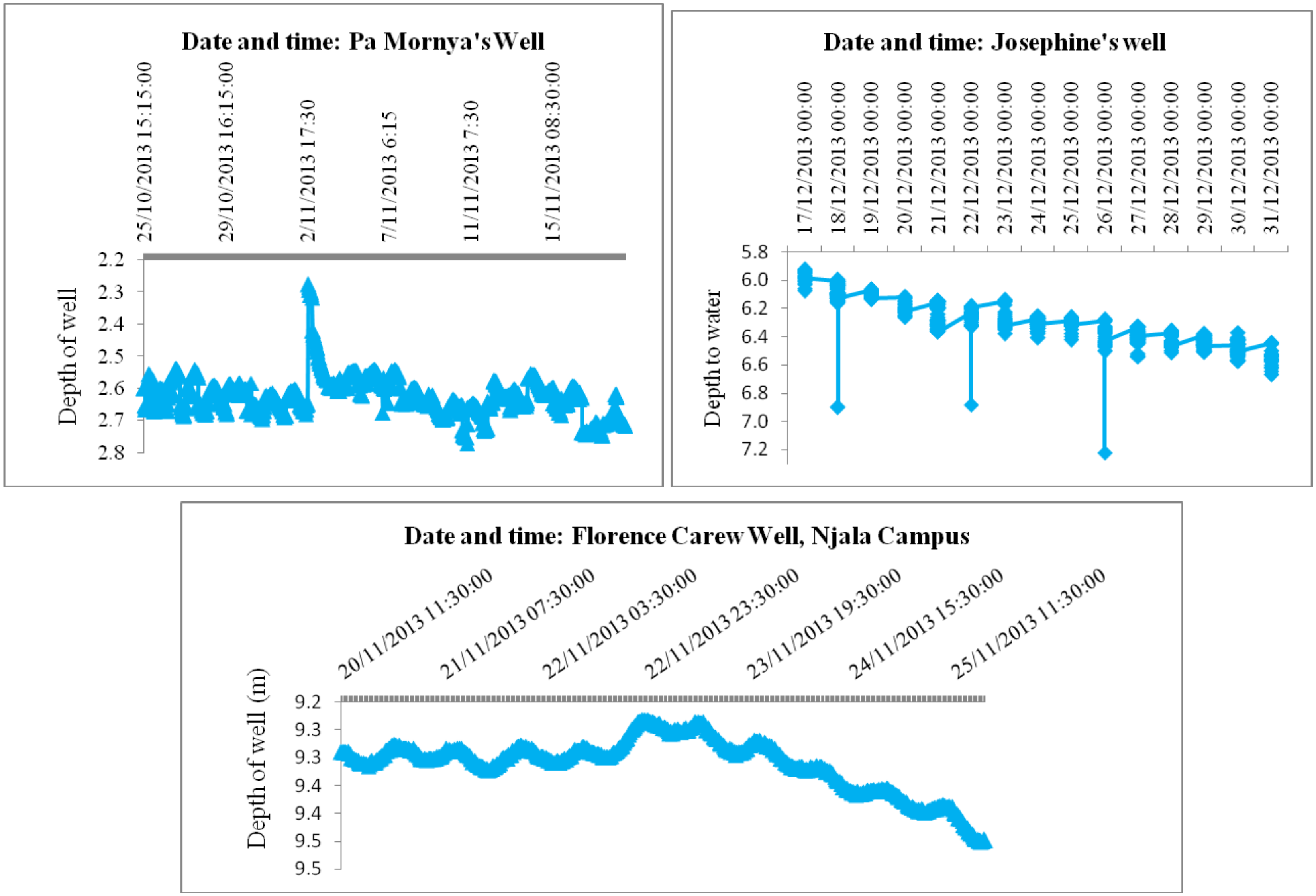

Figure 5 Depth to groundwater in wells at three different locations in the study area

1.3.3 Determination of recharge through the Specific Yield Method

The dip meter was used to take water level readings in pa Mornya’s well, Josephine’s well, the well at UMC School, and the Well at Florence Carew, Njala Campus, at weekly intervals. Readings were taken for 12 consecutive weeks, from September to December. The change in depth to water from the first to the last sampling week (Figure 6) was designated as change in height (Δh). A set of values for S_y ranging between the typical values of 0.005 and 0.1 (0.005, 0.007, 0.009, 0.01, 0.03. 0.05, 0.07, 0.09, 0.1) were used to determine recharge within this period (Figure 7).

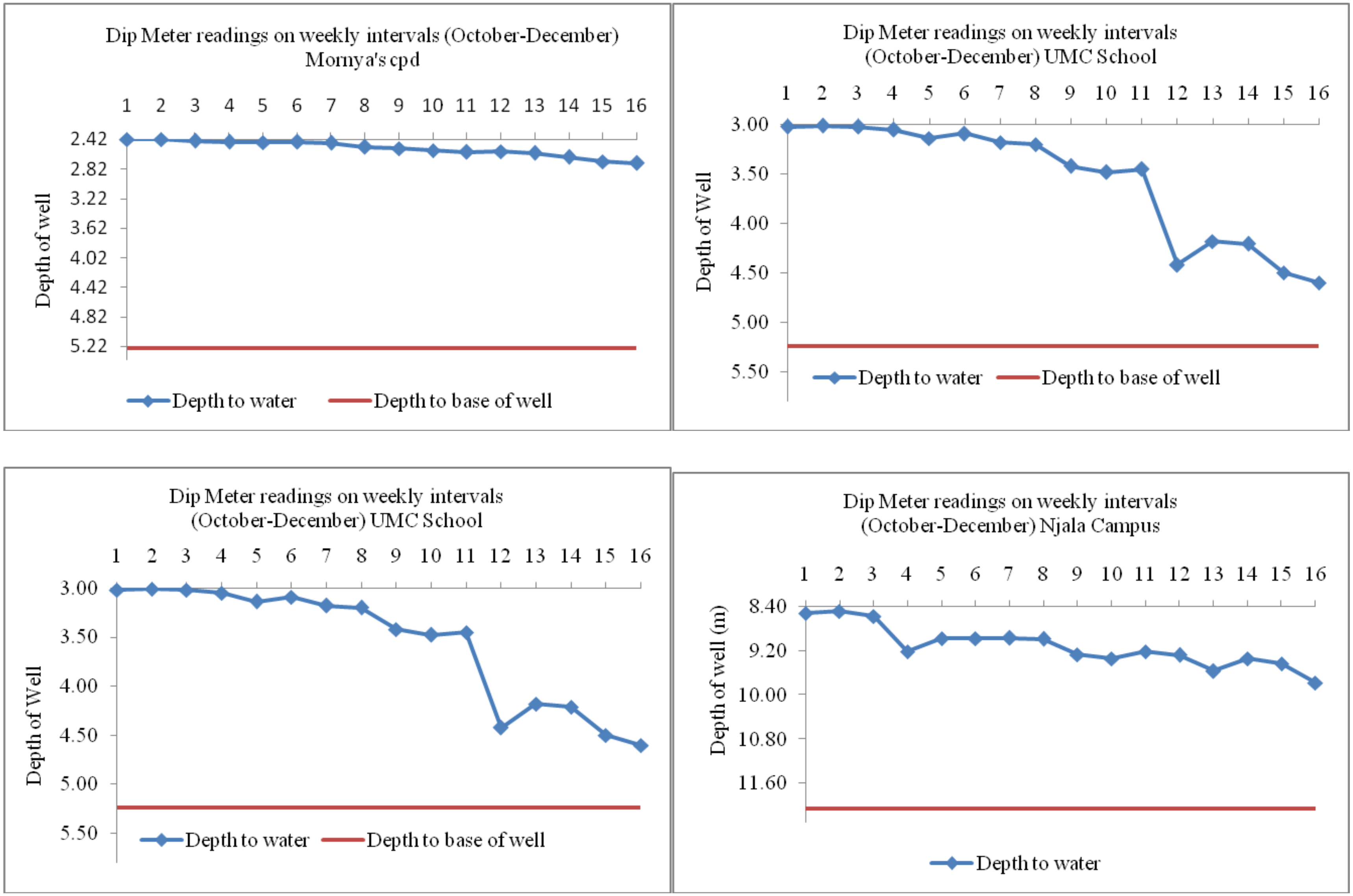

Figure 6 Depth to water and Depth to base in four wells in study area

Josephine's well recorded the highest recharge need for all the hypothetical S_y values, followed by UMC School, FC Njala, and Mornya's well, respectively. This translates to the extent of drop in water level within the stipulated time frame. Thankfully the amount of cumulative rainfall by this time is far above the maximum recharge need in the study area. The problem then is base flow adding to anthropogenic draw down for six months, in the absence of recharge from rain.

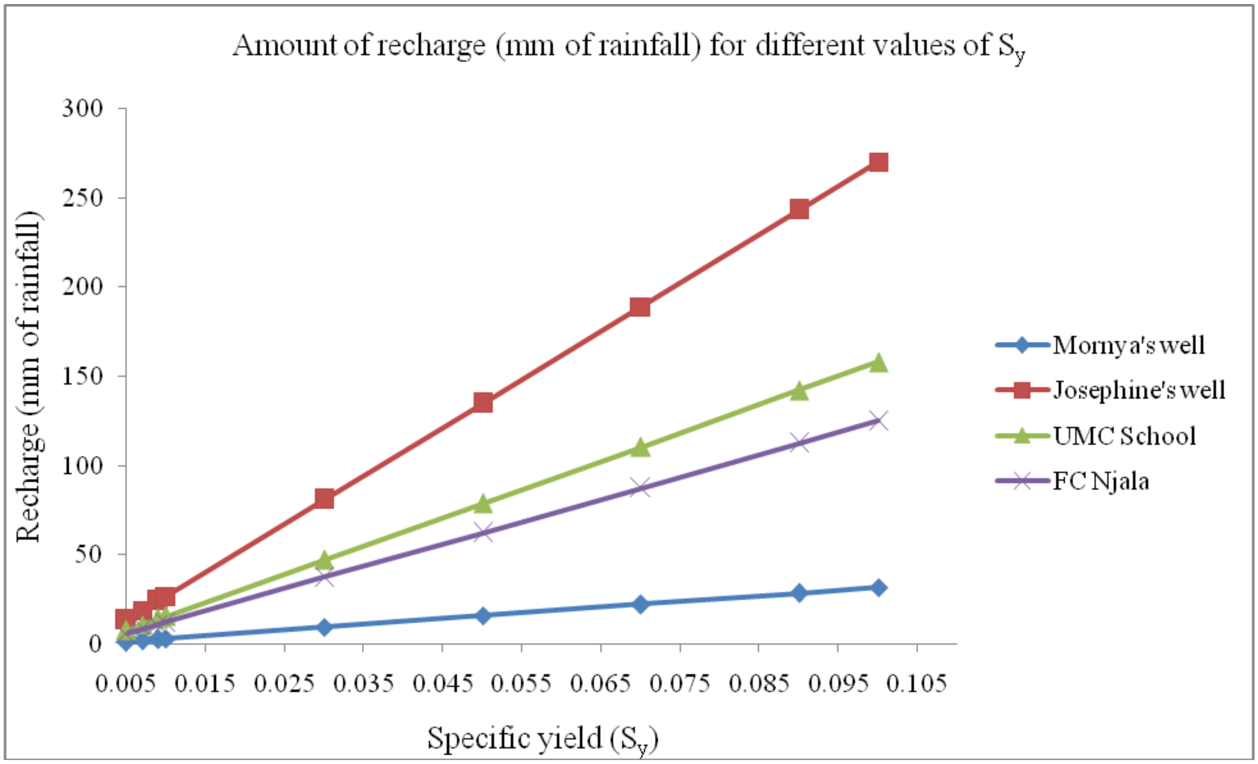

Figure 7 Varying recharge values based on different hypothetical S_y values

1.4 Conclusion

The objective of this work was to determine the influence of spatial and temporal changes on groundwater recharge need at the Mokonde community. The direction of base flow was determined using the depth to water at various wells in the study area. It follows that groundwater flows northwards from the Mokonde area through Njala campus, into the Tia river. The maximum rainfall needed to recharge the groundwater of the Njala area based, on a four-month forecast (October to December), was found to be 270 mm using the 0.1 specific yield criterion. With total cumulative rainfall above 1200 mm by December, this threshold seems very feasible to meet. Additionally long term rainfall records satisfy this criterion. Worthy of noting, however, is the continued dwindling in water level with time. The actual recharge need would accurately be determined in the peak dry season, when all discharge factors would have peaked. It is therefore recommended that groundwater monitoring is continued until the cycle is complete. More accurate results will be achieved with long term data.

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www resources:
http://www.unep.org/dewa
www.eb.com
www.googleearth.com
www.maps.google.com

Chapter two

The Quality of Groundwater at Mokonde, Kori Chiefdom, Moyamba District

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Abstract

Some of the factors that affect the quality of groundwater can be natural: rock weathering, precipitation, evaporation, crystallization and soil conditions; and/or anthropogenic: Land use for agricultural practices, waste disposal, construction, and industrial activities). The objective of this work was to determine two quality parameters (conductivity and bacteriology) in striving to inform best practice for water security planning in the Mokonde community. With data on conductivity, first step in managing dissolved ions in the groundwater would be enhanced while bacterial counts will pinpoint disinfection needs to enhance potability. Conductivity readings were taken at site using the portable multi-purpose aquatic meter while the Oxfam Delagua kit was used to determine faecal and non-faecal Coliform counts in samples from three observation wells: Mornya's compound, Josephine's compound and the well at the U.M.C. School Mokonde. The results indicated acceptable conductivity readings as recommended by the World Health Organization (WHO). Microbial counts, however, violated the recommended standards in all three observation wells. Only the Mornya well had zero count for faecal Coliform, though non-faecal Coliform bacteria were too numerous to count (TNTC). This implies that disinfection was a priority if groundwater should be potable in Mokonde. Whether the microbial population was encouraged by aquifer conditions or supply of atmospheric oxygen together with organic carbon was beyond the scope of this study.

Key words: Groundwater, Water quality, Conductivity, Faecal Coliform, Non-faecal Coliform, Disinfection

2.1 Introduction

Some of the factors that affect the quality of groundwater can be natural: rock weathering, precipitation, evaporation, crystallization and soil conditions; and/or anthropogenic: Land use for agricultural practices, waste disposal, construction, and industrial activities). About 1% of the rainwater infiltrates through the soil to the saturated zone as underground water. This water could be threatened either directly or indirectly by pollution. As the water passes through some chemical exchange occur within the soil and the water (Williams, 2006).

Animal waste can reduce the quality of groundwater by polluting it with nitrogen, phosphorus, and pathogenic organisms. In addition, groundwater could be contaminated, resulting from poor sanitary condition of the area. Poor toilet facilities lead to improper disposal of waste and fecal materials. Thus pathogens associated with these materials find their way through the soil by the infiltrated water. Also improper location of toilets will lead to leachates from the toilets into the groundwater (Simpson et al., 2006).

A sustainable water supply system cannot neglect water quality for public health concerns (USEPA, 2002). The amount of rain needed to recharger groundwater in the study area should not be source for groundwater contamination neither should it join contaminated groundwater. Treatment designs will be developed if such situation exists. Hence water supply systems with treatment requirements will have quality monitoring to inform the level of intervention.

This research will develop water quality data using two quality parameters: conductivity and bacteriological state of water samples from selected wells in the study area. This will set the foundation for sustainable rural water supply as far as water quality is concerned. Essentially, the findings will be useful in curriculum development, policy formulation/strengthening, and public health.

2.1.1 Conductivity

According to the USEPA:

“Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25^o C.

Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Groundwater inflows can have the same effects depending on the bedrock they flow through. Discharges to streams can change the conductivity depending on their make-up. Sewage disposal would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity”.

2.1.2 Microorganisms in groundwater

Krauss and Griebler (2011) asserted the factors that determine the abundance, survival, and distribution of pathogens in groundwater. According to this report, fine pore sizes of aquifers discourage large amounts of microorganisms in the groundwater, compared to large pore sized aquifers (Figure 1).

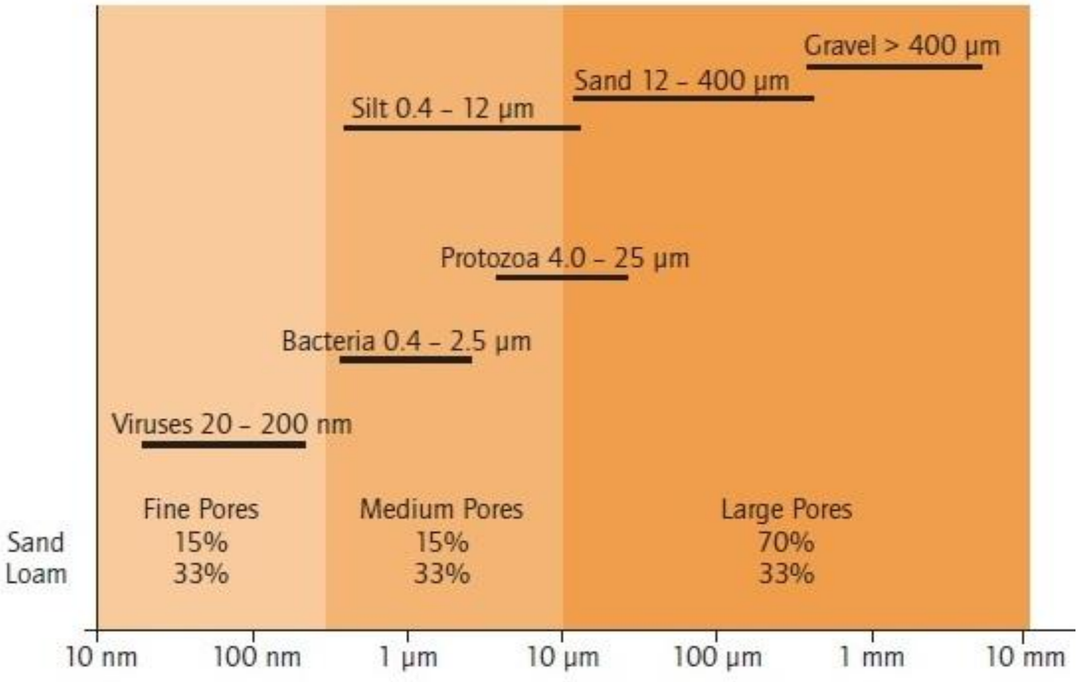

Figure 8 Effect of pore size on the abundance of pathogens in groundwater

Their survival depends on a number of factors including temperature, moisture content, sunlight, pH, micro-flora, organic carbon content, and cations (Table 1).

Table 1 Factors affecting survival of pathogens in groundwater

Factor	**Influence**
Temperature	Long survival at low temperatures, rapid die-off at high temperatures. For some faecally-derived bacteria high temperatures might give rise to growth.
Moisture Content	Desiccation is detrimental to most microorganisms (spores excepted). An increased rate of reduction will occur in drying soils. This is of most relevance in the unsaturated zone.
pH	Bacteria die-off more rapidly in acid soils (pH 3-5) than in alkaline soils. The pH influences the adsorption of microorganisms and viruses to the soil matrix and indirectly influences survival.
Microflora	Soil bacteria and fungi may produce exo-enzyems that damage the structure of faecal microorganisms, while amoebae and other protozoa may feed on them. Bacterial survival is shorter in natural soils than in sterilized soils, but for viruses no clear trend is observed.
Organic Carbon Content	The presence of organic carbon increases survival and may give rise to the growth of bacteria.
Cations	Certain cations have a thermal stabilizing effect on viruses and increase virus survival. Cations also enhance virus adsorption to soil and this indirectly increases survival, as viruses appear to survive better in the adsorbed state

Their transport potential depends on both the properties of the aquifer and the characteristics of the aquifer (Table 2). The distance of dispersal from source depends on the soil type (Figure 2).

Table 2 Factors affecting abundance and distribution of pathogens in groundwater

Characteristics of the pathogen	**Aquifer properties**
Size	Groundwater flow velocity
Shape	Dispersion
Organism type	Pore size (intergranular or fracture)
Cell mobility motility	Kinematic/effective porosity
Density	Organic carbon content (solid)
Growth phase	Temperature
Surface charge	Chemical properties of groundwater (ionic charge, pH, etc)
Inactivation rate (die-off)	Mineral composition of aquifer/soil material
(Ir)reversible adsorption	Predatory microflora (bacteria, protozoa, fungi, algae, etc)
Physical filtration	Moisture content Pressure

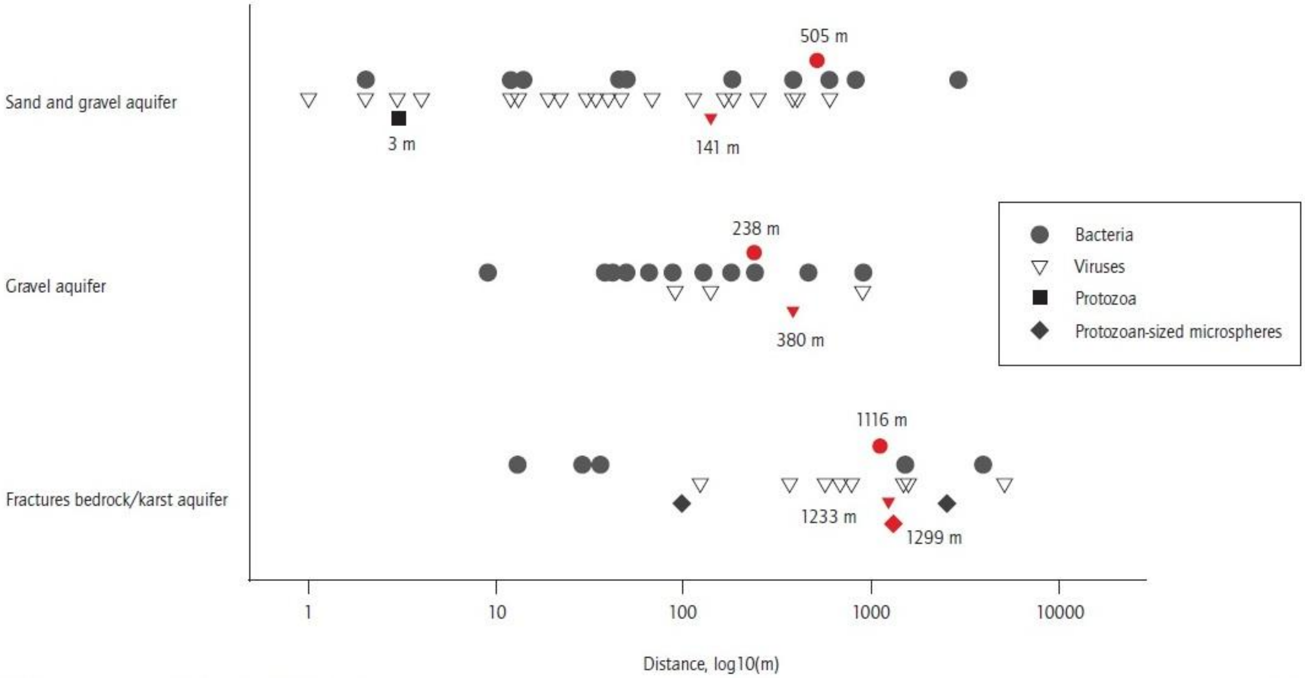

Figure 9 Distance of pathogens from source, depending on soil types

It was also established that bacteria is a major causative agent for diseases resulting from groundwater consumption. Figure 3 is a result of studies conducted in the US

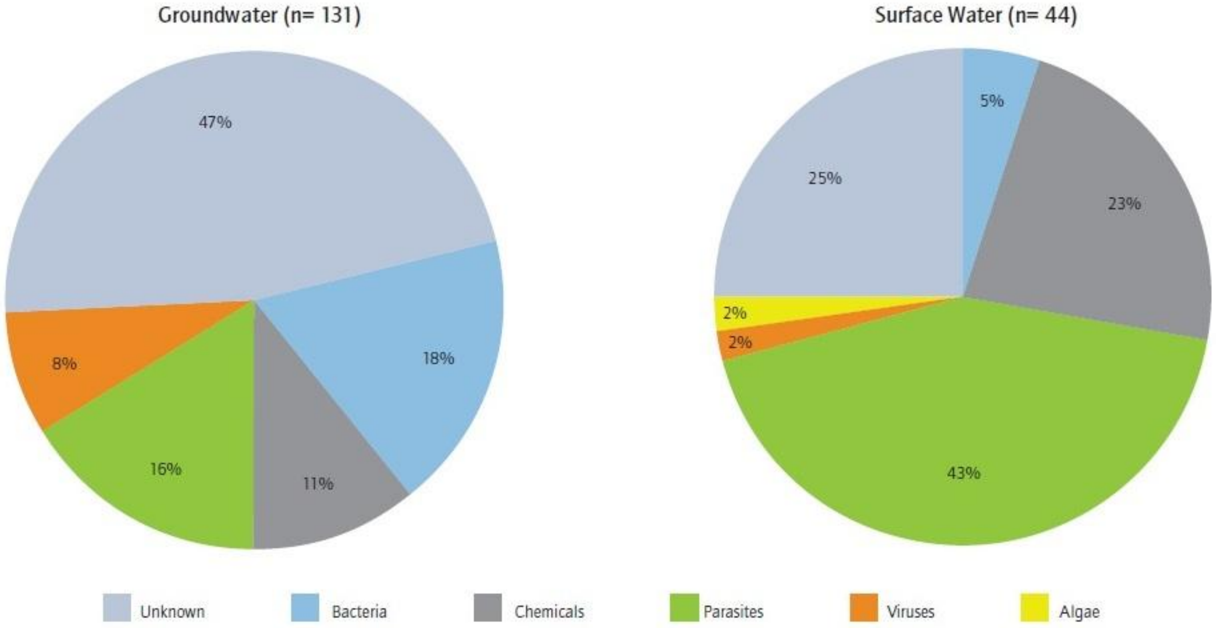

Figure 10 Causative agents of diseases resulting from consuming groundwater

2.2 Materials and Methods

2.2.1 Conductivity

The samples were collected and analyzed immediately at the site. The water sample was first put into the base of the container whilst the meter was being removed. The meter was turned on and then set to a 0.00 reading and later inserted back into the base containing the water sample. Consequently, it started to run taking reading in sequence, starting with the pH mode, conductivity and temperature. However, only the conductivity readings were considered in this study. The meter was removed from the sample, rinsed with clean water and wiped ready for another sample.

Portable Multipurpose Aquatic Meter: This is an instrument that is used to measure pH, conductivity, turbidity, total dissolved solids and temperature of the water sample. The parameters are automatically measured in sequence. The meter is always set at 0.00 reading.

2.2.2 Coliform Bacteria

The Oxfam Delagua Kit was used for bacteriological examination. The kit has a petridish, absorbent pads, membrane filters, pressure rubber and grease. In order to prevent any form of contamination, the equipment and all other accessories were sterilized. The samples were analyzed by the use of the membrane filtration method. Each sample was collected and shaken well for a minute to make sure that there was an even distribution of micro-organisms present. 10 ml of the water sample was measured using a standard sterilized measuring cylinder. This was later transferred into the filter funnel. With the application of a Vacuum pump, the water sample was allowed to flow through a membrane filter of pore size 0.45 microns. The membrane filter was incubated for 24 hours at 45^0C in suitable colonies of characteristic shape and color. Red Colonies were formed for the Faecal Coliforms and presumed to be the bacteria content of the water sample. The same procedure was repeated for all the water samples that were collected. The Faecel Coliforms were counted per 100 ml of water sample as follows: [Number of colony forming unit/Volume of water sample filtered (10ml.)] x 100. Non-Faecal Coliform examination was carried out using the same procedure in the determination of Faecal Contamination but blue colonies were however counted.

2.3 Results and Discussions

2.3.1 Mean Recorded Values of Faecal and Non-Faecal Coliform Bacteria (Table 3)

Table 3 Mean Coliform counts in well samples

Sample ID	Faecal Coliform Cfu/100ml (Red)	Non-Faecalcoliform Cfu/100mL (Blue)
Monya's Compound	0	Too Numerous to Count (TNTC)
Josephine's Compound	88	TNTC
U.M.C. Primary School	142	TNTC

Faecal Coliform Count: Result from Table 3 show that only the sample collected from Monya's Compound was free from faecal Coliform Contamination. The other two samples were seriously contaminated with pathogens. The highest value analyzed (142 Cfu/100 ml) was that from the U.M.C, followed by that from Josephine's Compound (88 Cfu/100ml). This may be attributed primarily to leachates from latrines built on top of hill slopes or close to the water sources. The highest faecal coliform value from U.M.C. School could also be attributed the abandonment of the well which makes it unprotected.

The faecal coliform counts extremely exceed the accepted limit stated by the World Health Organization (WHO), zero. This result shows that the two wells are highly contaminated; this is a cause for concern given the dispersal potential of the pathogens, as discussed in section 2.1.2, above. Whether the high number corresponds to encouraging properties of the aquifer needs further studies. It is also important to note that these are open wells and oxygen supply may encourage aerobic metabolism (Mansaray, 2010). However, the absence of Coliform bacteria in Mornya's well is counterproductive to this speculation, making aquifer properties (section 2.1.2) the most likely determinant factor.

Non-Faecal Colifrom Counts: It is showing in table I that the mean value of Non-Faecal Coliform from samples collected from the three observation wells were too numerous to count. Non-Faecal Coliform bacteria are usually associated with soil particles, animals, plants, and some can adhere to the skin of humans (Williams, 2006). These points of contact could be sources of transmission of these bacteria to the wells, in addition to those discussed in section 2.1.2. Additionally improper waste disposal could also contribute to this problem (Nazina et al., 2000). The WHO recommended value is less than 10; therefore, the results for the three wells indicated presence of high Non-faecal coliform contamination. This can also serve as threat for any underground recharge potential within this community.

2.3.2 Mean Values of Electrical Conductivity in Samples (Table 4)

Sample ID	Time of Day	Reading (µS/cm)	Average (µS/cm)
Mornya's Compound	Morning	66.72	66.72
	Evening	66.72	
Josephine's Compound	Morning	84.78	84.44
	Evening	84.10	
U.M.C School	Morning	220.00	220.05
	Evening	220.00	

The well at the U.M.C. School showed an extremely high conductivity value than the other two observation wells. This result shows that there are much dissolved solids in the well at U.M.C School than those in the other two wells. This high value is probably due to the nature of the soil at the water source. This well is also an abandoned well located within the school premise. So it is possible that some waste material must have been dumped into the well resulting in an increase in the total dissolve solids in the water.

The accepted value by the WHO standards for electrical conductivity is recommended at values under 450 µs/cm. the three observation wells therefore have mean conductivity values that satisfy this criterion. Hence it could be inferred that microbial contamination is the major quality issue of the observation wells.

2.4 Conclusion

The objective of this work was to determine the quality of three observation wells in the Mokonde community in order to inform best practice in water security planning for the benefit of the consumers. All the wells recorded average conductivity values (66.72, 88.44, and 220.05 µS/cm in Mornya's well, Josephine's well and the well at U.M.C. School, respectively) that were below (and hence acceptable) the recommended WHO threshold value (<450 µS/cm).

The microbiology of the wells however did not satisfy the WHO recommendation; with the exception of Mornya's well for faecal Coliform bacteria (zero count) all the wells had high populations of faecal and non-faecal Coliform bacteria in them. The bacteriological contamination is a clear indication that there is a possible threat of pathogenic pollution which if not paid attention to may likely negatively affect groundwater supply potential in the area. At this stage it is not clear whether the microbial populations are due to the aquifer properties, or the supply of atmospheric oxygen coupled with high organic matter content in the water, or both. This will therefore be the recommendation for further studies. The data obtained will inform best practice in sustainable quality management.

References

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