

Groundwater quality assessment for domestic purposes in Mpherembe, northwest of Mzimba district, Rural Malawi

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Abstract

Access to potable water is a public health problem in Malawi. Knowledge of water quality can significantly reduce waterborne diseases amongst users. The present study examines the groundwater quality for domestic use in Mpherembe, northwest of Mzimba district rural Malawi. Ten (10) water samples were collected from various sources and subsequently tested for physio-chemical and microbiological parameters using standard methods. The results obtained were compared against the Malawi Bureau of Standards (MS 733:2005) and World Health Organization (WHO) guidelines for drinking water quality. The microbiological examination of water samples revealed the presence of *E. coli* bacteria (range 62-136cfu/100m), and high levels of turbidity (range 5.58–46.8 NTU) in wells. However, Magnesium hardness and Electrical Conductivity (EC) were recorded high in boreholes compared to wells. The presence of faecal matter and high mineral concentration in domestic water is a health risk when consumed prior to treatment. To ensure public health safety, interventions that focus on household water treatment such as chlorination are recommended in this study area.

Introduction

Access to potable and safe domestic water is a critical public health issue as it minimizes the spread of waterborne diseases. However, about 2.1 billion people mainly in developing countries are currently facing scarcity of clean water. The United nations 2030 agenda for Sustainable Development Goal (SDG) number six advocate for deliberate programs that promote citizenry access to potable water. To achieve this goal, governments and developing partners should ensure proper management of domestic water services that include safeguarding water from faecal and noxious chemical contamination. At least 47% of the rural communities in Sub-Saharan Africa did not have access to safe water sources and 4–8% of people suffer from water-borne diseases annually (Bates, 2012). In Malawi, the National water policy recognizes that access to clean domestic water is a basic human right. However, only 65% of the total population has access to safe domestic water (Pritchard et al., 2008). Geographically, residents in formalized urban spaces have easy access to treated piped water compared to informal and rural settings. Currently, about 91% of rural communities in Malawi depend on groundwater sources through boreholes, wells, and open sources (National Statistical Office, 2017). Studies suggest that Malawi has limited data to ascertain the safety of ground water sources on the health of users. There are also minimal coordinated efforts among responsible stakeholders to examine the water quality from groundwater sources that form the backbone of rural water supply. The study provides baseline information regarding the geography of water quality in rural areas of Malawi. Literature suggests that the northern region of Malawi has limited access to systematic monitoring and evaluation of groundwater quality facilities as compared to the other two regions. The problem is prominent at district level due to lack of laboratories and human capacity to facilitate analysis of water quality from rural groundwater catchment areas (Holm et al., 2018). Our study aims at addressing this dearth in knowledge by examining water quality from selected domestic groundwater sources in rural areas of Mzimba district in northern Malawi. Malawi government regulates drinking water quality through series of drinking water standards such as (MS 733:2005) for borehole and shall well. However, some of parameter standards are lower compared to WHO guideline.

Nevertheless, the water sector faces numerous challenges regarding the analysis, and documentation of domestic water quality in Malawi (British Geological Survey, 2004). The absence of domestic water quality information is a problem of public health in rural areas of Malawi. Consumers tend to rely on local knowledge to determine safety of domestic water that poses a health risk. Nearly, 80% of Malawi's population live in rural areas and majority of the population do not have access to improved sources of water (USAID, 2010). Previous estimates showed that about 3.5 million people in Malawi access domestic water from open wells, streams, rivers, and lakes (Mhango, 2017). This is despite efforts made by the Malawi government to improve rural domestic water supply infrastructures. Both technical and economic factors constrain government's effort to provide potable water to the communities in rural areas (Government of Malawi, 2012). Limited access to potable water undermines household economic activities and this exacerbate household poverty (Adams et al., 2018).

Poor access to quality water directly affects public health and overall human development through transmission of waterborne diseases. In Malawi, a study conducted in Nkhata Bay district found that the majority of the population in Limphasa area were vulnerable to water borne related diseases due to consumption of contaminated water (Kanyerere et al., 2012). The physio-chemical properties commonly found in groundwater in Malawi include chlorides and sodium and these parameters denote the presence of salinity in water (British Geological Survey, 2004). Agricultural practices such as use of chemical fertilizers, poor sanitation, and health services as well as industrial waste have a significant impact on groundwater quality. A study conducted in Brazil, Ecuador and Malawi revealed that poor water governance has led to poor access to safe water supply (Kaysera et al., 2015). The challenges have greatly affected the provision of safe water services especially in rural areas of Malawi. Studies have shown that most of the residents continue to consume unsafe water from poor sources without prior treatment (Mkwate et al., 2016). This has resulted in outbreak of water related diseases which account to nearly 50% of the illnesses in Malawi (Kalua and Chipeta, 2005). Household water treatment (HWT) is commended to be effective intervention towards reducing outbreak of water related diseases (Mkwate et al, 2016; UNICEF, 2008; GoM, 2012). Unfortunately, only 32% of the Malawians use this intervention (GoM, 2012). Previous studies have been done to evaluate the groundwater quality in Mpherembe area with focus on irrigation purposes (Wanda, 2014; Wanda et al., 2011). Given that the majority of the population in the area rely on groundwater for drinking through boreholes and wells, information about its quality is crucial for human health and safety. Our study was conducted to address this gap by assessing the quality of groundwater sources used for domestic purposes in the Traditional Authority Mpherembe, northwest of Mzimba district, rural Malawi.

Materials And Methods

Description of the Study Area

This study was conducted in Traditional Authority (TA) Mpherembe, Mzimba District situated in Northern Malawi (Fig. 1). The district covers an area of 10,430 Km² with an estimated total population of 940, 184 as of 2018 national census (Socio-economic Profile, 2017). Current statistics show that 60.9% of the population in the district are poor and 31.7% are ultra-poor households (Socio-economic Profile, 2017). The district has ten (10) TAs which include Mberwa, Mtwalo, Kampingo, Jaravikuba, Chindi, Mabilabo, Mpherembe, Mzikubola, Khosolo, and Mzukuruku (Fig. 1). Mpherembe is situated to the northwest of Mzimba district and comprises over 162 villages with an estimated population of about 67, 292 (Socio-economic Profile, 2017). Masawani and Zimema are

some of the villages situated to the north and south of Mpherembe trading center respectively (Fig. 2). Masawani settlement category has 8 Group Village Headmen (GVH) while Zimema comprises 10 GVH. People in the area are predominantly engaged in subsistence agriculture and only a few practices commercial farming. The topography of Masawani area is slightly hilly while Zimema is generally flat and both settlements consist of several unknown non-perennial rivers/streams. Residents in both settlements heavily rely on groundwater as their source of water for drinking and other domestic use.

The area's geology is made up of crystalline metamorphic and igneous rocks of Pre-Cambrian to Lower Paleozoic age called the Basement Complex (Malawi Government, (GOM), 1986). The water table in the area is low such that water is reached at a depth of 45 to 72 meters. Boreholes, shallow wells, and rivers are the common sources of drinking water and for other domestic purposes for the residents.

Collection of water samples

A total of ten water sources namely boreholes and wells were sampled for physio-chemical and microbiological examination of drinking water quality. Samples for physio-chemical analysis were collected using 1 litre plastic bottles with screw caps and were all cleaned and rinsed before sampling. The bottles were secured and labeled with dates, location, time, and name of the site. The boreholes were flamed and run for 2 minutes before collecting the samples. A sterile cup was rinsed twice before collecting the water samples for microbiological analysis. Samples from wells were taken using a sterilized sampling cup and tied to a rope. Subsequently, all samples were taken to the laboratory owned by Northern Region Water Board of Malawi within the same day.

Analysis of water samples

The physio-chemical parameters analyzed included turbidity (NTU), Calcium hardness, Total hardness, Magnesium hardness, Electrical conductivity (EC), pH, and Chlorides (Cl). The values for turbidity were determined using a turbidity meter (HANNA HI93703-11). That is a 10ml water sample was placed on the NTU meter to measure the levels of turbidity. Average of triplet turbidity results were taken as reading for each sample. A calibrated multimeter (pH-TDS) was used to determine Electrical conductivity (EC) and pH. Reagents were prepared to standard solutions to test the presence of chlorides. The solution prepared included potassium chromate indicator, standard silver nitrate of (0.0141M) Parameters were analyzed according to ALPHA water quality testing procedure. All tests for chemical analysis were duplicated to get true results. The results obtained were compared with the Malawi Bureau of Standards (MBS) and World Health Organization (WHO) guidelines on drinking water specifically for boreholes and shallow wells. All quantitative data were analyzed descriptively and presented using frequency tables and graphs.

Bacterial analysis involved the use of a standard colony plate count method. 100ml quantity of water sample was passed through a sterile filter to trap bacteria. The filter was placed on the pad soaked in lauryl broth media, which is food for bacteria of interest. Incubated at 44⁰c, the results were expressed as colony-forming unit per 100ml of water. The appropriate volume to process was that allowed the most accurate count of the bacteria colonies. Some high turbid samples, a smaller volume was measured and then adjusted the results to give count per 100ml of the original sample. The standard formulae used is expressed below;

$$\text{Colonies /100 mL of sample} = \frac{N*100}{DF} \quad (\text{Eqn 1})$$

In this equation, *N* represents the number of colonies counts while *DF* is a dilution factor (Mkwate et al, 2017). Fecal coliforms are of sanitary significance when present in drinking water supplies.

Results

Physio-chemical parameters

Physio-chemical and microbiological quality of water sources used by various households are presented in Table 1. The results show that physio-chemical properties of water sources in the study areas were good when compared to the national and WHO guidelines. The areas' water sample mean turbidity result was 6.75 NTU, and a range of 0.89–46.8 with 90% and 80% of water samples below MBS and WHO the regulatory limit, respectively. The relatively good water turbidity results could be due to reduced surface-groundwater interaction and good groundwater filtration mechanism. pH tests showed that 100% were within the limit for MBS and WHO with a range of 6.64–8.04. Water sample for total hardness mean result was 396.4mg/L, and range of 30-793mg/L with highest result recorded at Thera village BH. Similarly, results for electric conductivity (EC) showed all samples conformed with national standard and 80 % samples complied to WHO standard with mean results of 748.49 µs/cm, and range of 98- 2189 µs/cm. EC is an indicative parameter for the presence of mineral elements in water. High EC results in water samples may denote that the water contains a lot of dissolved minerals which can impact on water taste from boreholes in the study area, which is a common characteristic of groundwater. Results for chlorides show that 90% of the samples tested were below < 750mg/L MBS limit while 70% of samples conformed to WHO standards. The sample mean result was 393.6 mg/L with standard deviation of 485.87, and range of 60-1477 mg/L. Although chlorides may not be of health concern at a certain concentration in drinking water, its presence at elevated concentration may affect acceptability of drinking water especially on organoleptic depending on associated cations such as Sodium, Magnesium and Potassium. High concentration of chlorides when coupled with low alkalinity can induce iron and plumbing metal corrosions affecting the functionality of boreholes. The presence of chlorides in water may be a result of direct sewage or human/animal excreta discharge into the ground as most people use latrines in these areas.

Table 1
Water quality results in boreholes and wells in Mpherembe, Mzimba District

| Sample site | Type of source ¹ | Depth (m) | Turbidity (NTU) | pH | Chloride (mg/L) | Total hardness (mg/L) | Calcium hardness (mg/L) | Magnesium hardness (mg/L) | Electrical conductivity $\mu\text{s}/\text{cm}$ | <i>E. coli</i> (CFU/100 mL) |
|---------------------------------------------------------------------------------------|-----------------------------|-----------|-----------------|---------|-----------------|-----------------------|-------------------------|---------------------------|-------------------------------------------------|-----------------------------|
| WHO limit (2008) | - | - | < 5 | 6.5–8.5 | < 250 | < 800 | - | - | < 1000 | 0 |
| MBS ² limit | - | - | < 25 | 6.5–9.5 | < 750 | < 800 | - | - | < 3500 | 0 |
| Masawani | BH | 45–75 | 0.89 | 7.34 | 640 | 703 | 82 | 621.2 | 1517 | 0 |
| Zimema | BH | 45–75 | 1.09 | 7.83 | 137 | 566 | 62.2 | 503.8 | 870 | 0 |
| Zimema | OSW | 3–7 | 46.8 | 7.00 | 60 | 30 | 20.6 | 9.2 | 98 | 136 |
| Masawani | BH | 45–75 | 2.8 | 8.04 | 52 | 360 | 42.1 | 318.3 | 401 | 0 |
| Zimema | CSW | 3–7 | 3.35 | 7.98 | 250 | 351 | 162.2 | 189.2 | 921 | NS |
| Masawani | OSW | 3–7 | 5.58 | 7.40 | 75 | 140 | 40.2 | 99.4 | 253 | NS |
| Masawani | BH | 45–75 | 1.96 | 7.40 | 975 | 434 | 71.6 | 362.7 | 2179 | 0 |
| Masawani | OSW | 3–7 | 1.61 | 6.64 | 100 | 40 | 27.2 | 13.2 | 249 | 62 |
| Zimema | BH | 45–75 | 0.92 | 7.96 | 170 | 547 | 47.4 | 499.7 | 99.9 | 0 |
| Masawani | BH | 45–75 | 0.75 | 7.77 | 1477 | 793 | 95.8 | 696.9 | 897 | 0 |
| ¹ BH is borehole, OSW is open shallow well, CSW is closed shallow well + A | | | | | | | | | | |
| ² MBS is Malawi Bureau of Standards of 2005 | | | | | | | | | | |
| ` | | | | | | | | | | |

Microbiological results- Fecal coliform

Bacteriological water sample tested positive to Faecal coliform at Kamuhanya Thera (62 cfu) in Masawani and Kaherere well (136 cfu) in Zimema (Table 1). The presence of *E. coli* is of healthy concern when found in drinking water. This causes water related diseases such as diarrhea, nausea, stomach cramps, low grade fever, and vomiting (Gaffield, Richards, & Jackson, 2003). Water samples collected from boreholes tested recorded zero coliform thus denoting no contamination with sewages. However, several reasons could explain zero coliform in other sites sampled: thus, seasonality factor, topographical factor, and distance to the nearest latrines. Samples collected in the dry season means that groundwater table was below depths of most latrines hence reducing chances of contamination. Also, water sources located far from pit latrines have minimal chances of Fecal contamination than those close to pit latrines. Topographical factors play a significant role when a latrine is at altitude above water source such that groundwater can pass through latrine or form part of either a well or borehole recharge.

Discussion

Physio-chemical water quality in sampled wells indicated that most parameters were within acceptable standards for drinking as set by the National and WHO guidelines. However, Turbidity (NTU) was not satisfactory in all wells compared to boreholes as it was found above the WHO and National standards (Table 1). Further, most physio-chemical parameters such as EC and Magnesium hardness were significantly high in boreholes when compared to WHO (2008) guidelines on drinking water quality. High EC values in drinking water is an indicator of high salinity (Chakraborty et al, 2019). The presence of salinity in drinking water has significant health effects on people such as diarrhea, abdominal pain, and cardiovascular diseases (Chakraborty et al., 2019). Thus, there is high probability that people in the area are prone to water related illnesses due to high concentration of salinity in their drinking water from the boreholes. However, microbial results indicated that wells were highly contaminated with fecal matter especially water samples collected from Masawani area. Our results are consistent with a study by Msilimba et al.(2013) who found high concentration of fecal coliforms in shallow wells ranged from 129–920 in 96.3% of the samples posing health threat for the residents in Mzuzu City, Malawi. Likewise, Kanyerere et al. (2012) found that wells are vulnerable to contamination compared to boreholes putting the majority of the rural residents at high risk to water-borne diseases in Nkhata Bay district. Based on the study findings, water from wells, mostly from Masawani was found to be highly contaminated with faecal matter due to the presence of *E.coli* bacteria in sampled water. Consumption of water from unsafe sources is therefore a public health threat for the majority of households in the study area. Previous studies revealed that about 50% of all illnesses in Malawi are linked to water related diseases (Kalua and Chipeta, 2005). A recent report by WHO estimated that nearly 842, 000 people die every year from water-borne diseases such as diarrhea due to consumption of unsafe water, poor sanitation, and hygiene practices (WHO,2020). Despite water from the borehole was free from microbial contamination, most chemical and physical parameters exceeded the WHO limit making water not suitable for human consumption.

Conclusion

This study assessed the quality of groundwater sources for domestic purposes in Mpherembe area, northwest of Mzimba district, rural Malawi. The study revealed that drinking water quality from selected sources is extremely poor. Thus, water from wells is highly contaminated with fecal matter while most physio-chemical parameters analyzed in boreholes were found above the WHO and MBS guidelines. The presence of fecal matter in drinking water signifies that water is not safe for human consumption without any treatment. Users should refer to country water quality guidelines or World Health Organization guidelines for drinking water quality to decide when action should be taken to improve contaminated water supplies. To ensure public health safety, the study recommends for interventions that focus on household water treatment such as chlorination, provision of more safe water facilities as well as putting emphasis on water education in this study area.

Declarations

Acknowledgements

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Declaration of interests

We declare no competing interests

Ethics approval and consent to participate

Ethics approval to conduct this study was obtained from the IRB at Miami University, Oxford USA (protocol number: 03222e), and the University of Livingstonia research ethics committee in Malawi by the second author (protocol number: UNILIA-REC/1/CUP 2/01).

Consent for publication

We informed the participants that they would disseminate the study through various media such as policy briefs, and scholarly journals to inform water quality supply and provision in Malawi. With a full understanding of the research and its intended purpose, all participants gave full consent for us to publish the findings.

Availability of data

For data accessibility, contact the corresponding author (s).

Funding

The study was funded by the graduate school of Miami University, Oxford, USA.

Authors' contributions

MD designed the study, collected, and analyzed some of the data and wrote the sections of the first draft manuscript. Dr. Levy, Dr. Chilanga, and Mr. M'tenga revised the first manuscript. All authors read and approved the final manuscript.

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Figures

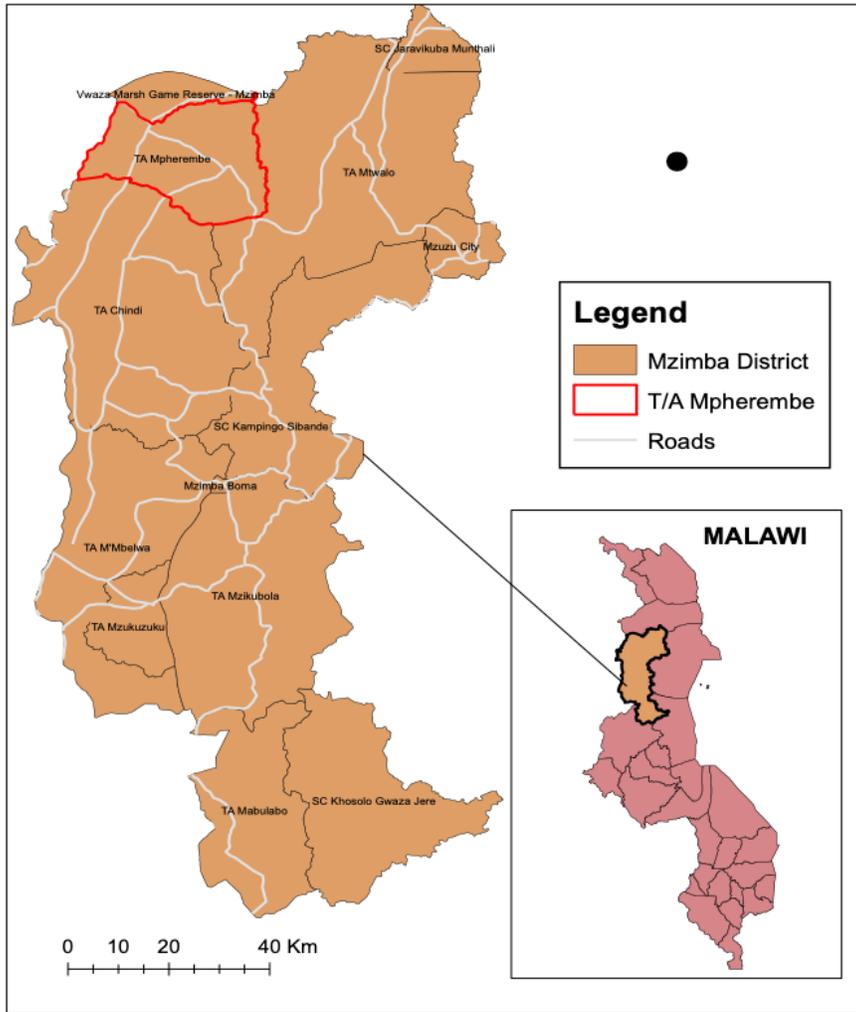


Figure 1

Location of Mpherembe area within Mzimba district, Malawi. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.

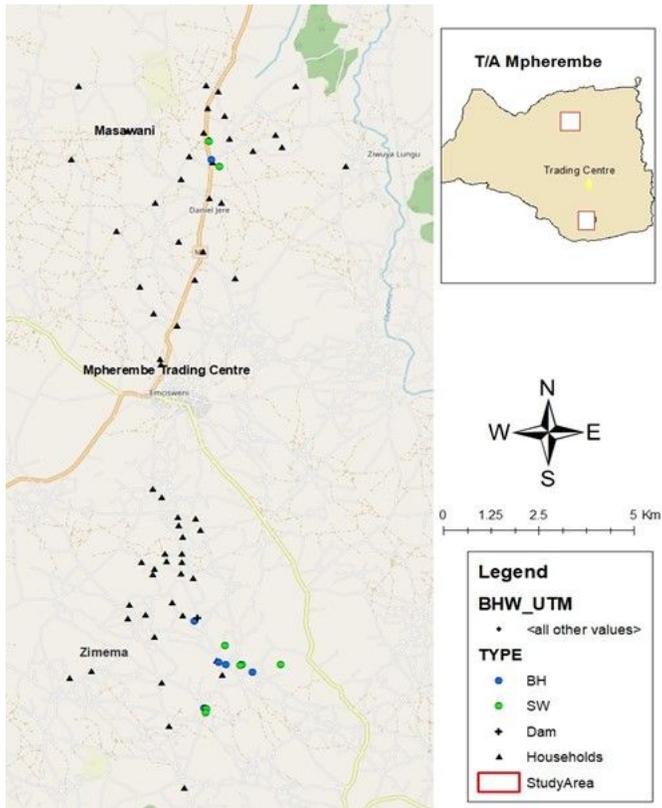


Figure 2

Location of Zimema and Masawani within Mpherembe, Mzimba district, Malawi. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



Figure 3

Incubating microbes

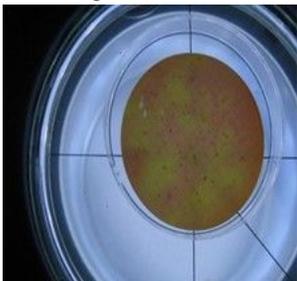


Figure 4

Colony forming (blue color)



Figure 5
counting colonies