WATER AND WATER-BORNE DISEASES IN NORTH MASABA DISTRICT, KENYA

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Abstract

Approximately 1.1 billion people in the world lack access to safe drinking water. As a result 1.8 million people mostly in developing countries, and 90% of whom are children under 5, die every year from diarrheal diseases such as including cholera. This study was carried out with the objective of evaluating access to safe drinking water and the perceived incidence of water-borne diseases in North Masaba District, Kenya. Two samples were collected from each household, one sample of drinking water after treatment and another sample of water directly from the source. From each sample, the population of Total Thermotolerant Coliforms was determined. The results were recorded as the number of Colony Forming Units (CFU/100 ml). Only 49% of the households were found to consume drinking water that is considered by WHO to be of reasonably good quality while 16% of the households consumed water unsuited for human consumption. For the turbidity tests, 57% of the households achieved the WHO recommended standard of less than 5 NTU. It was noted that while many households have access to improved water sources, and while these sources provide drinking water that is less contaminated than unimproved sources, the quality of water from these sources does not meet WHO standards. This would explain the high percentage of people (34%) reporting incidence of water-borne diseases in the household. There is therefore need for sensitizing the 25% of the households that do not carry out point of use (POU) intervention to start doing so before consuming the water. There is also need for more research to establish why some of the POU interventions fail to provide safe water even though it is known that such methods are very effective in microbial decontamination.

Key words: Point of use (POU) intervention, biosand filtration, chlorination, boiling, water quality

1.0 Introduction

A large proportion of world population does not have access to safe and clean water. According to United Nations (2008), 1.1 billion people in the world's population lack access to safe drinking water. As a result of this, 1.8 million people die every year from diarrheal diseases (including cholera); 90% are children under 5, mostly in developing countries. Moreover, almost half of the environmental health-related disease burden can be attributed to unsafe water and sanitation (Eawag/Sandec, 2008). Of the 37 major diseases in developing countries, 21 are water and sanitation related; no single type of intervention has greater overall impact upon the national development and public health than the provision of safe drinking water and the proper disposal of human excreta (Water World, 2011).

Access to safe water refers to the percentage of the population with reasonable access to an adequate supply of safe water in their dwelling or within a convenient distance (less than 1 km) of their dwelling (UN, 2003). This is indicated by the number of people using 'improved water sources' and proper sanitary facilities (WHO, 2004). An improved drinking water source is defined as one that by nature of its construction or through active intervention is protected from outside contamination, and in particular from contamination with fecal matter (WHO/UNICEF, 2010). According to Gleick (2002), the most important and immediate risks to human health from using contaminated water are primarily from the ingestion of water polluted by human or animal faeces or urine containing pathogenic bacteria or viruses. Diseases caused by such contamination include cholera, typhoid, amoebic and bacillary dysentery and other diarrheal diseases. To achieve the Millennium Development Goal of halving the number of people without access to safe water by 2015 (United Nations, 2005) and therefore reduce the incidences of waterborne diseases, a variety of different interventions may be necessary (Levy *et al*., 2008).

With the growing recognition of the issue of household recontamination, many authors have recommended focusing interventions on improving water quality at the POU, rather than improving water quality at the source (Clasen and Bastable 2003; Mintz *et al*. 2001; Reiff et al. 1996; Hutton 2007). A wide range of interventions aimed at improving drinking water in the home are being implemented, including purification of drinking water using chlorine (Clasen and Cairncross, 2004; Quick *et al*., 1999; Reiff *et al.,* 1996), boiling (UNICEF 2008), sunlight (Hobbins, 2003; Vidal and Diaz, 2000; Qualls *et al.,* 1983), ceramic filtration (Clasen *et al*., 2006) and sand filtration (Colins *et al.* 1992; Duke *et al.,* 2006).

There has been an increase in drinking water coverage in Sub-Saharan from 56 per cent in 1990, to 65 per cent in 2008 (WHO/UNICEF, 2010) as well as the encouragement in the application of POU intervention (UNICEF, *2008*). However, the impact of such increase and encouragement on the quality of drinking water in many Kenyan homes has not been assessed. This study was therefore carried out with the objective of evaluating access to safe drinking water and the prevalence of water borne diseases in North Masaba District, Kenya.

2.0 Methodology

2.1 Study Site

North Masaba District is in the County of Nyamira in Nyanza Province of Western Kenya with a population of approximately 112, 430. The district was selected due to its predominantly rural setting, with rural communities considered to be the most affected by poor access to safe drinking water (United Nations, 2005). North Masaba District lies on a highland equatorial climate, and receives rain almost throughout the year averaging over 1900 mm. The district covers a total area of 110 square kilometers with the population density being 1, 022 per square kilometer. The average household in the district consists of 6 members, with a total of 18, 738 households (Ojowi *et al.,* 2001). This figure represents the research population.

2.2 Household Selection

To obtain the sample size, the formula $n= N/1+N (e)^2$ was used where n is the sample size, N is the population size and e is the level of precision (Israel, 2009). Taking a precision level of $\pm$ 7% and the computed population size of 18,000, a sample size of 201 was obtained. Each selected household was visited from between 8.00 am and 1.00 pm Monday through Friday between the months of June and August, 2009. No households were visited after 1.00 pm because the samples needed to be taken to the laboratory for testing the same day before six hours elapsed from when the first sample was collected. The member of the household responsible for providing drinking water in the home, usually the mother, was requested to help the interviewer with the study before resuming her chores.

2.3 Structured Interviews

The respondents were asked about their perception of their chosen method of water purification as well as occurrence of water-borne diseases such as typhoid, amoebiasis and cholera. From the interview, it was possible to identify the sources of water and the water purification methods used before collecting water samples.

2.4 Water Sample Collection and Testing

Two samples were collected from each household, one sample of drinking water after POU intervention and another sample of water directly from the source. A pre-sterilised plastic bag was used to collect about 500 ml of water from each sampling point and kept in an icebox. The samples were then transported to the laboratory and tested within six hours as per WHO recommendations (WHO, 2006). Samples were tested in the laboratory following the order in which they were collected in the field; that is, starting with the sample collected first and finishing with the sample collected last. From each sample, 100 ml was pumped through a 47-mm-diameter 0.45-pm cellulose filter and transferred to a growth medium plate containing Membrane Lauryl Sulphate Broth (MLSB) and incubated at 44.5^{o}C (+/- 0.5 ^{o}C). A negative control, that is 100 ml of sterile distilled water, was processed after every twentieth sample to ensure that the equipment had been adequately sanitized (Rufener *et al.,* 2008).

After 14-16 hours of incubating, the yellow colonies representing Total Thermo-tolerant Coliforms (TTC) were enumerated using a hand lens. The results were recorded as the number of Colony Forming Units (CFU/100 ml). Total Thermo-tolerant Coliforms are fecal coliforms that include all coliforms that can ferment lactose at 44.5^{o}C. The fecal coliform group comprises bacteria such as *Escherichia coli* and *Klebsiella pneumonae.* The presence of fecal coliforms indicates the presence of fecal material from warm-blooded animals (Bitton, 2005).

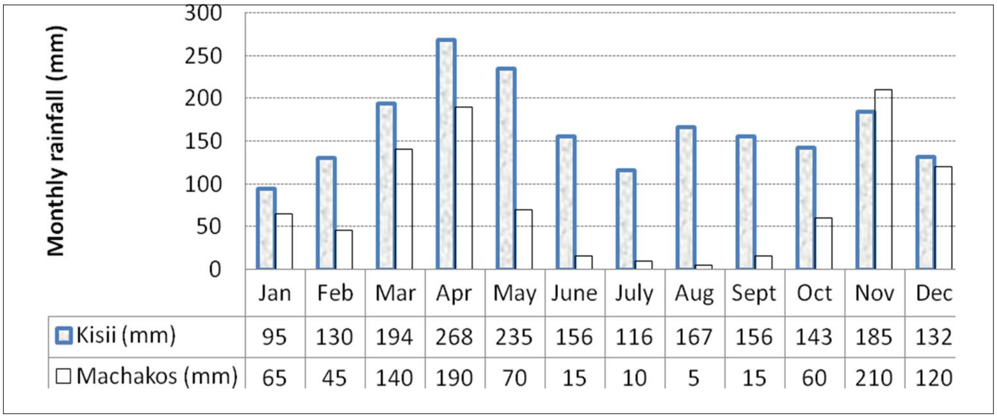
The turbidity of each water sample was determined using the Hach Turbidimeter. Turbidity is considered an important parameter of water quality because it impacts on the acceptability of water to the user. Turbidity is measured in Nephelometric Turbidity Unit (NTU), with values below 5 NTU considered safe for drinking (WHO, 2008). The Statistical Package for Social Science (SPSS) and Microsoft Excel were used to analyze the data obtained.

3.0 Results

3.1 Access to Drinking Water

This study established that North Masaba District, within the greater Kisii area, receives about 1977 mm of rainfall annually, compared to less than 1000 mm in Machakos District, which is an arid area (Figure 1). In July and August when the country is relatively dry, the area receives monthly rainfall of 116 and 167 mm, respectively (http://www.climatedata.eu/climate.php), compared to an average monthly rainfall in July and August of less than 10 mm per month at Machakos (Moore, 1979). Therefore, North Masaba District is a reasonably humid area where access to water should not be a problem. The study established that over 43% of the population had access to permanent sources of water. The water sources in the study area included protected springs (75%), piped water, protected dug wells and boreholes (Figure 2).

The majority of residents (70%) had access to less than 5 L of drinking water per day per household (Figure 3). Some 25% of the households obtained their drinking-water from unimproved sources such as unprotected dug wells, surface water and unprotected springs.



	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Kisii (mm)	95	130	194	268	235	156	116	167	156	143	185	132
Machakos (mm)	65	45	140	190	70	15	10	5	15	60	210	120

Figure 1: The average monthly rainfall of the Kisii study site (http://www.climatedata.eu/climate.php) compared to Machakos (Moore, 1979)

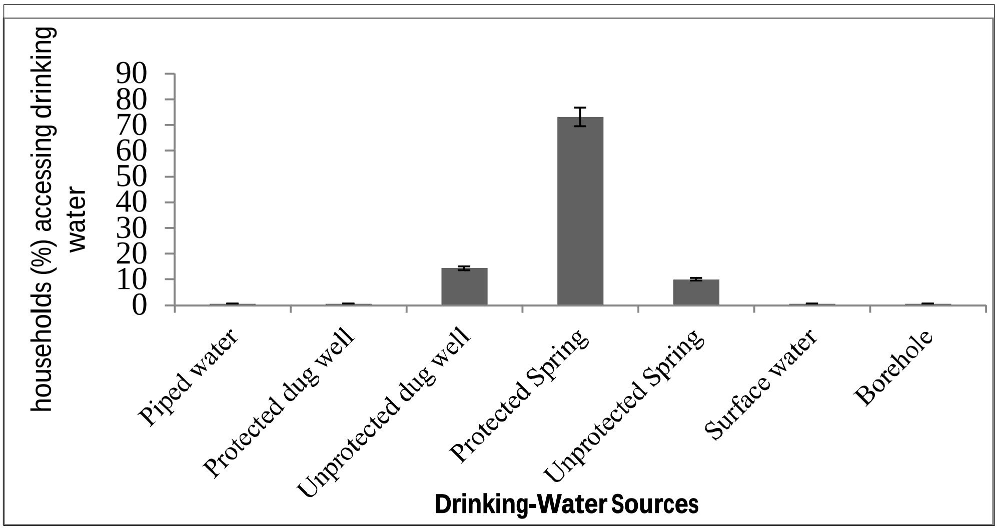


Figure 2: Drinking water sources for residents of North Masaba District

Less than 5% of the households had access to more than 20 L of water in a day. Some 70% of the households accessed less than 5 L per household per day (Figure 3). Over 90% of the population accessed water within a distance of less than a kilometer (Figure 4). It was noted that during the rainy season, 92% of the population harvested rainwater for domestic use (Figure 5). However, the quantity of rain water harvested was minimal, with 68% of households only able to collect a maximum of between 50 and 200 liters due to lack of larger collection tanks. When the rate of domestic water utilization is 20 L per day, harvested rainwater would last for 10 days. Further studies are required to establish the optimum rainwater tank size for North Masaba District.

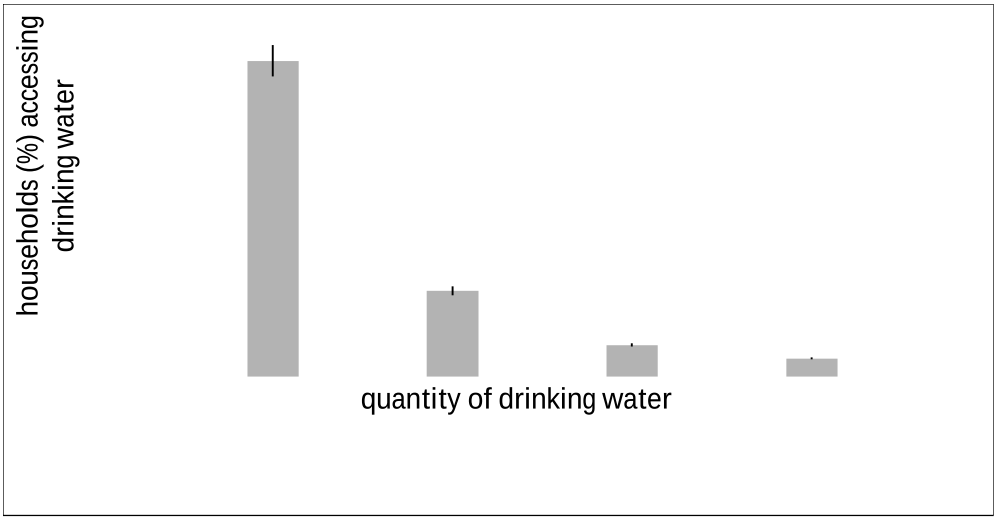


Figure 3: Quantity of drinking water available in households per day

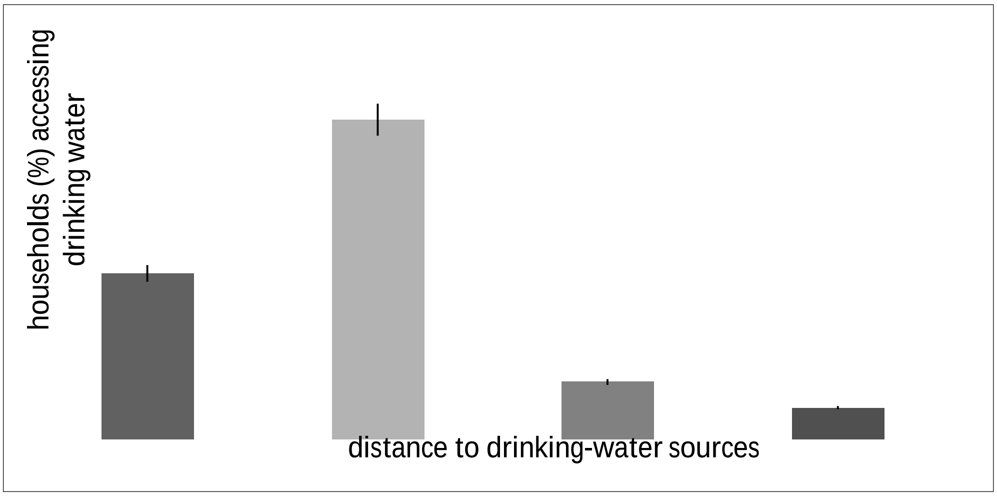


Figure 4: Distance to domestic-water sources in North Masaba District

According to Gadgil (1998), less than 40% of Africa's population has access to safe drinking water. Therefore, North Masaba District seems to be better off than the average situation in Africa. However, it is still important to note that a quarter of the population has no access to protected water sources.

3.2 Water Quality in North Masaba District

Drinking water quality was assessed in terms of turbidity and coliform count. Rainwater had the best quality with turbidity of 3.168 NTU and a coliform count of 45 CFU/100 ml. Protected springs and protected wells had average turbidity of 5.96 NTU and 6.85 NTU, respectively (Table 1), which exceeded the recommended WHO guideline and Kenya Bureau of Standards (KEBS) standard of 5 NTU. Protected springs and wells had coliform count of 189 and 149 CFU/100 ml, respectively compared to the recommended standard of 0 CFU/100 ml. The quality of unprotected sources was much less than the KEBS recommended quality (Table 1). Al-Kharabsheh (1999), found that coliform bacteria concentration in spring water in Jordan exceeded 100 CFU/100 ml. Pollution of spring water in Jordan was associated with increasing human population and the intrusion of human waste into ground water sources. Poor domestic water quality in North Masaba District could be as result of the same factors. The European Union Council directive on drinking water quality states that drinking water must be free from any microorganisms and parasites and from any substances which, in numbers or concentrations, constitute a potential danger to human health (Szewzyk *et al*., 1999).

Domestic water quality in North Masaba is comparable to the quality in other parts of the world. Admassu *et al*., (2004) and Rufener *et al.* (2008) found that water from 'improved' sources did not meet the WHO standards. It has been noted that whereas North Masaba district receives an ample supply of rain water annually (Ojowi *et al.,* 2001), and whereas the quality of this rain water was much better than the quality of other sources, less than 5% of the households had rainwater tanks larger than 1000 L (Figure 3). Therefore, the rainwater harvested in the study area cannot satisfy household demand. It is concluded that drinking water sources in the study area are polluted and that the water must be treated before consumption.

Although harvested rainwater is expected to have the best quality, this does not apply when the water is harvested from dirty surfaces. In a study done in China, Zhua, *et al.* (2004) found that rainwater harvested from sloping land and roads surfaces had turbidity ranging from 6 to 18 NTU and fecal coliform count varying between 5,000 and 100,000 CFU/100 ml.

Table 1: quality of drinking water sources

Water Source	**Turbidity (NTU) against WHO standard of 5 NTU**	**Coliform (CFU/100 ml) against WHO standard of 0 CFU/100 ml**
Protected Spring	6.0	189.1
Unprotected Spring	15.9	297.6
Protected Well	6.9	148.9
Unprotected Well	23.4	559.2
Rainwater	3.2	45.1

Only 19% of the population in North Masaba District consumed domestic water that WHO could classify as safe (0 CFU/100 ml) and 16% of the households consumed dangerously polluted water (Table 2). Some 43% of the population accessed water with turbidity greater than 5 NTU (Table 3), the WHO standard for drinking water quality.

Table 2: Microbial contamination of domestic water in North Masaba District

Coliform bacteria concentration (CFU/100 ml)	WHO Classification of Risk*	Percentage of Households in North Masaba District
0	Safe	19%
1-10	Reasonable quality	30%
11-100	Polluted	35%
>100	Dangerous	16%

*Source: WHO (2006)

Table 3: Turbidity of domestic water in North Masaba District

Turbidity	Households (%)	WHO drinking-water standard (< 5NTU)
< 5 NTU	57	Meets standard
5.01- 10 NTU	32	Does not meet standard
>10.01 NTU	11	Does not meet standard

3.3 Water Treatment Methods

The goal of water treatment is either to physically remove or to inactivate waterborne pathogens. This is done primarily through filtration and disinfection through boiling, chlorination, ozonation, or ultra-violet (UV) radiation. Chlorinated lime was first used in the United States for water disinfection in 1908, liquid chlorine in 1912, and high-test hypochlorite in 1928 (Kabler, 1962). In Kenya, ozonation and UV radiation are rarely used. Ideally, filtration should precede disinfection to physically remove particles and pathogens (Davies and Mazumder, 2003). In North Masaba District, the most preferred interventions at the household level included boiling (65%), chlorination (5%), Biosand filtration (3%) and cloth filtration (2%). Some 25% of the population did not carry out any POU water treatment (Figure 4). All water treatment methods showed a general reduction in turbidity and coliform bacteria with Biosand Filtration reducing turbidity and bacteria by about 90% each. Chlorination reduced coliform bacteria, by over 90% (Figure 5).

About 65% of North Masaba District population used boiling (also referred to as pasteurization) as means of water disinfection. Boiling using biomass fuel pollutes the air and is expensive. Yet, over 50% of the world's population boils drinking as a way of disinfection. Maintaining water at a temperature of 70^{o}C for at least 6 minutes is enough to disinfect it. Boiling sufficient water for a family is likely to consume up to 12 kg of firewood daily (Gadgil, 1998). In this study, the boiled water maintained about 40% of the coliform bacteria (Figure 5). The high content of coliform bacteria in boiled water might be because boiling alone does not remove the solids in water and that there is lack of residual protection after treatment. Furthermore, poor storage of boiled water could lead to a deterioration of water quality because of recontamination in the home due to poor hygiene and water-handling practices (Levy *et al.,* 2008; Oswald *et al*., 2007). In interventions like chlorination where there is a residual disinfectant, recontamination can be countered (Rufener *et al*., 2008).

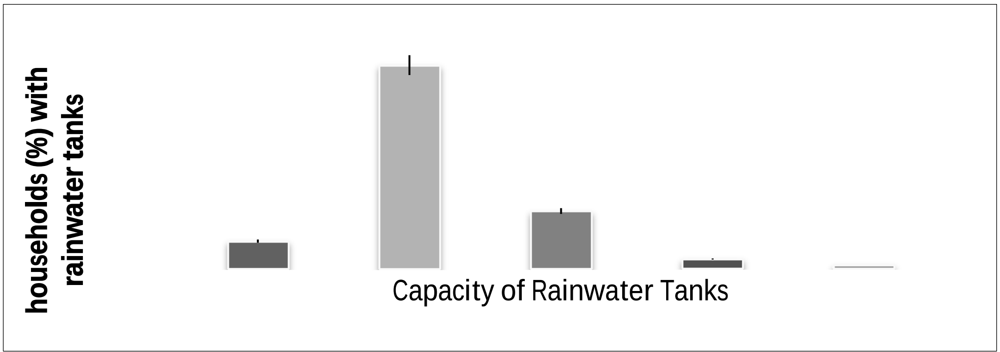


Figure 5: Capacity of rainwater harvesting containers in Masaba North District

Chlorination and biosand filtration resulted in the best reduction of coliform bacteria compared to boiling and using cloth filters. Filtering with cloth resulted in less than 40% reduction in turbidity and less than 10% reduction of coliform bacteria (Figure 5). Boiling and cloth filtration need to be combined with other interventions to be effective. For instance boiling water that has gone through a cloth filter might result in water of a higher quality than when each of these methods is used alone.

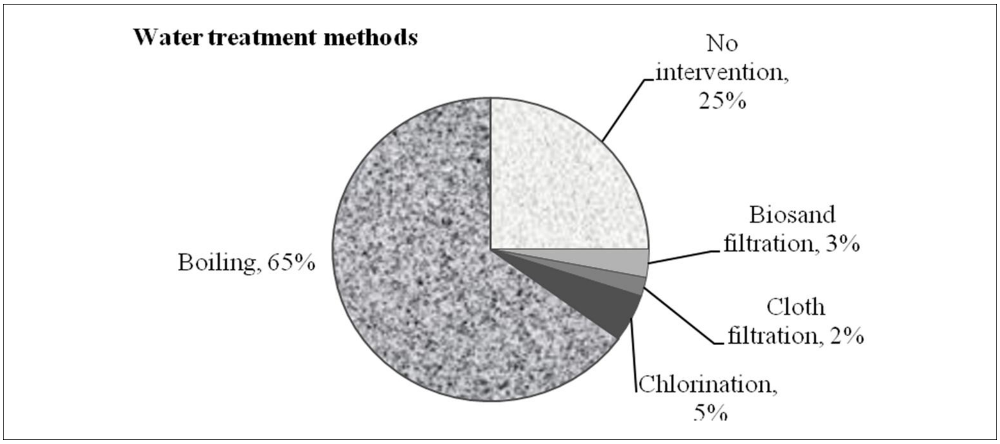


Figure 6: Point of use (POU) interventions in North Masaba District

Biosand filters qualify as slow sand filters, which are more effective than rapid filters at removing particulates and microbial contaminants. The rate of water movement through slow sand filters is 0.1 to 0.2 meters per hour (Gadgil, 1998).

The rate of movement through a cloth filter is likely to be higher. Slow sand filtration is low cost and low maintenance, but may not be adequate for processing large quantities of water. Furthermore, the incoming water should not have a very high concentration of suspended solids, high coliform counts, or large quantities of algae; otherwise, the filter can clog rapidly.

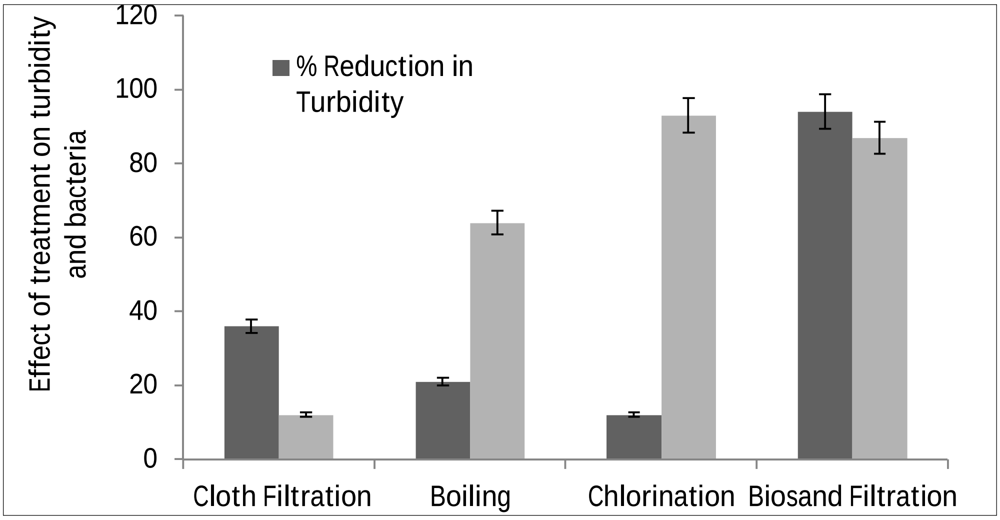


Figure 7: Effectiveness of water purification Methods

Household Perception on Water-Related Diseases

This study established that 35% of the population in North Masaba District suffered from diarrheal illnesses. The organisms responsible for diarrhea include *Escherichia coli*, *Salmonella*, *Giardia lamblia*, *Entamoeba histolytica*, *Cryptosporidia*, and *Isopora*, which every year cause the death of 5 million people globally (Rubinoff and Field, 1991). Fewtrell *et al.* (2005) found that treating drinking water just before use resulted in 50% reduction in the occurrence of diarrheal diseases. Therefore, simple, low-cost interventions at the household and community level are likely to enable treatment of water just before use, improve the microbial quality of household water and reduce the risk of diarrheal diseases.

According to Kabler (1962), *E. coli* can enter drinking water when unfiltered surface water gains access to a water source. Over 80% of the diarrhea related deaths involve children who are less than a year old. Prevention of waterborne illnesses requires identification and breaking of pathogen cycles. Studies in developing countries have demonstrated that improved sanitation resulted in greater health benefits than provision of clean drinking water alone (Davies and Mazumda, 2003).

4.0 Conclusion

The National Environmental Management Authority (NEMA) has number of policy instruments to control human activities that affect water quality. Despite Kenya having good environmental protection policies, there is very little being done to protect water resources. Over a half of the residents of North Masaba District use water that does not meet the minimum domestic water standards for turbidity and microbial quality.

The main goal of this study was to evaluate access to safe domestic water in North Masaba District. To obtain the proportion of the population with access to safe drinking water, parameters defined by the Millennium Development Goals (MDGs) such as use of 'improved' water sources (WHO, 2004) and proximity to water sources (UN, 2003) were used. Our conclusions were as follows:

(i) Whereas a large proportion of the residents of North Masaba District could be classified as having access to safe drinking water within acceptable distance, some 25% of the population consumed water from unprotected sources.

(ii) None of the water sources evaluated had water of the quality recommended by the WHO for human consumption. Therefore, some form of treatment also referred to as point of use (POU) intervention, is required for all drinking water in the District.

(iii) There is need to sensitize 25% of the population, which does not carry out POU interventions to start doing so before consuming the water. Furthermore, there is need for more research to improve the effectiveness of boiling and various other POU interventions which are used in rural areas.

(iv) Although there are good policies to protect the environment and guarantee public health, these policies are often not followed and citizens like those in North Masaba District are left exposed to water-related sicknesses.

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