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Original Article

Implication of Urban Domestic Water Distribution on Human Health in Machakos Central Ward, Machakos County

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ABSTRACT

The world's water resources are running out, and this situation is made worse by how quickly people are populating new areas, particularly in developing nations. This has highlighted the critical requirement for prepared action to manage water resources for sustainable development efficiently. Increasing water demands due to climate change, global pressures from urbanization, the already-existing unsustainable variables, and challenges of water supply systems in urban centres pose a challenge in managing water resource effectively. The purpose of the study was to investigate the implication of urban domestic water supply on human health in Machakos Central Ward, Machakos County. Using a Survey Research Design (SRD) both primary and secondary data was collected by use of questionnaires, face-to-face interviews, photography, use of GIS, authors' observation, and the review of relevant literature in order to (1) document household water supply, (2) determine water quality for the identified categories of households and domestic water supply systems, and (3) Determine how the distribution and coverage of domestic water in a household or home affects the prevalence of water-borne illnesses. The target population was 8,331 households, from which a sample size of 381 respondents was selected. These included households, water vendors and key informants from the Machakos Water and Sewerage Company. Questionnaires (for households and vendors), interview schedules (for water officers and chiefs) and observation schedules were used as instruments for data collection. Data was analysed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) software. The results revealed that the major factors attributed to lower accessibility are shortage of water, high cost of piped water connection, poor coordination, and participation of stakeholders, repairing of old and broken pipes. As a result, nearly half of the dwellers prefer to use alternative sources, exposing them to the risks of water-born diseases.

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INTRODUCTION

Although access to clean water is a fundamental human right many people worldwide lack this essential resource (WHO/UNICEF, 2006). The issue of potable water scarcity has gained critical importance and has attracted significant attention. At least 40% of the world`s population representing slightly over two billion people now lack access to clean water and sanitation, this is reflected in 80 nations' health and economy (Miya *et al*., 2020). Water stress is prevalent in many developing nations due to reasons such as inadequate distribution efficiency across urban networks and inequities in service supply between the wealthy and the poor (Khatri & Vairavamoorthy, 2007). High population growth rates in developing countries, insufficient rates of capital investment, difficulties in developing local water resources appropriately, and the futility of institutes delegated to manage water supplies in urban and rural areas are among the reasons for the slow progress toward universal access to and adequate water supply (Hunter *et al*., 2010). and consistent economic expansion has resulted in increasing demand, while climate change is putting a strain on raw water resources. The lack of clean water is a serious problem in the 7.7 billion-person globe of today. By 2050, when there will be a 22–34% rise in global population, to between 9.4 and 10.2 billion people, the burden on the water system will increase (Burek P. *et al*., 2016). Unrelated to local resources, uneven population increase in different locations will exacerbate the strain.

Safe water and conveniently available water is critical for optimum health (Armah, 2014). Despite this, around a billion people in underdeveloped nations have been without a safe and sustainable water supply for several decades (Hunter *et al*., 2010). A better water supply creates potential for increased production both directly and indirectly. Appropriate water may support productive activities including agricultural farming, livestock rearing, and various other associated micro-businesses with better quality and dependable supply (Abanyie *et al*., 2023). However, water quality is experiencing serious issues as water demand rises. Water contamination will occur if waste from human activities and operations is discharged into aquatic environments without sufficient treatment (Chowdhary *et al*., 2020).

Efforts to develop the water sector have been built on water being a catalyst to accelerate social and economic development. World Health Organisation defines the term reasonable access to a water source as the "availability of at least 20 litres per person per day (L/capita-day) from a source within one kilometre of the user's dwelling" (WHO, 2000).

Factors affecting access to safe water can either boost or impair safe water supply programs (Kamble, 2022). Eberhard (2019) noted that failure to handle the urban water service supply problem risks social stability and economic growth. It is expected that understanding the elements influencing urban residential water distribution on human health in Machakos Central Ward shall assist various stakeholders in designing and implementing solutions to the region's existing difficulties of safe water supply.

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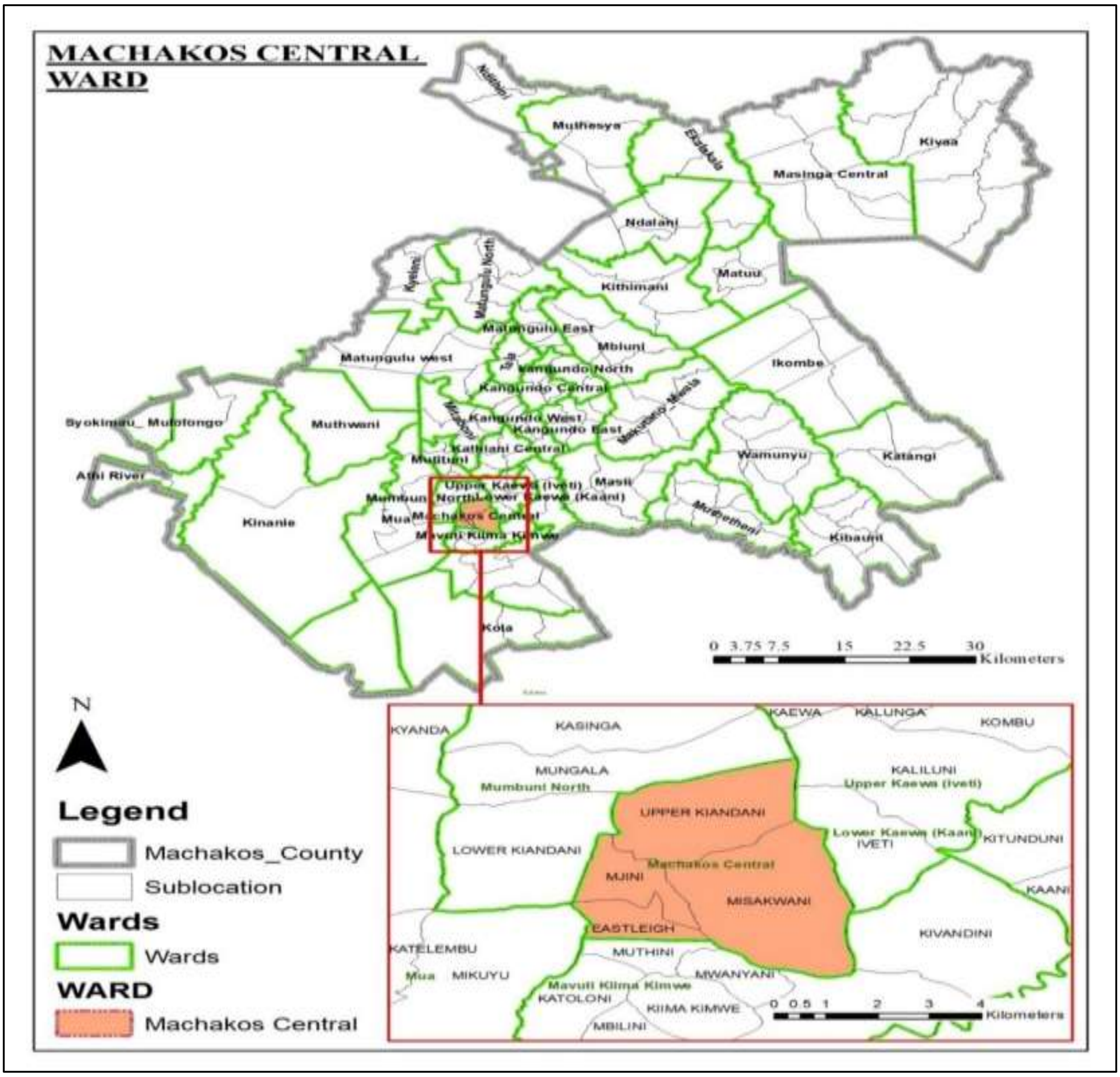
MATERIALS AND METHODS

Study Area

The study was carried out in Machakos Central Ward which lies on latitude 1°29′59″ South, longitudes 39°14′60″ East with an altitude of 1138 m above sea level. The ward covers an area of 22.70 Km² and has four locations namely Misakwani, Mjini, Eastleigh and Upper-Kiandani. The study area's climatic conditions are semi-arid, with monthly temperatures ranging from 12.2 ºC between the coldest months of July and August to 25.1 ºC between the hottest months of October and March and a total annual rainfall ranging between 400 mm and 800 mm.

Figure 1: Machakos Central Ward Map



(**Source**: ArcGIS, 2017)

Experimental Design

A survey study design was employed to help collect data on human health in Machakos Central Ward. Both primary and secondary data collection methods were utilised. Data was collected through administration of household questionnaires, key informant questionnaires, water sampling and analysis both in the field and in the laboratory, secondary data collection from relevant institutions, observation and photographing of participants and items relevant to the study.

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Water quality physical-chemical parameters of interest during laboratory analysis were turbidity, pH, Total Alkalinity, Magnesium, Calcium, Salinity, Total Hardness, Chloride, Total Dissolved Solids and Conductivity. The results were compared to the World Health Organization (WHO) and the Kenya Bureau of Standards (KEBS) drinking water guidelines.

Data Collection

Water samples were collected from 15 selected boreholes and water kiosk and each sample coded uniquely and systematically such as B1 for borehole one. The primary data was derived from 15 community-based water source location questionnaires that were administered randomly and key informants from officials from the Machakos Water and Sewage Company and the Department of Water and Irrigation. Field and laboratory analysis of various water parameters was conducted from all water sample points that were mapped out using the GPS technology. Both qualitative data and quantitative information was gathered through structured questionnaires, interview schedules and direct observations. The main sources of secondary data were relevant documentation from Machakos Level IV General Hospital on instances and frequency of various waterborne diseases, the World Health Organization and the Kenya Bureau Standards.

Water samples were obtained from operating community water sources of interest. A 250 mL glass stopper container is used for collecting water samples. The bottles are washed and rinsed thoroughly (EMCA, 2007). After that, the bottles are covered in aluminium foil and sterilized overnight at 170°C in the oven. The sterilized bottles are delivered to the sampling site in a sterile ice cooler box on the day of the sampling. The bottle tops are removed with care by hands wearing sanitized gloves during the sample process. The tap is then filled with water and left to run to waste for two or three minutes before being turned off. The outside of the bottle is wiped with a dry cloth, and the tap is framed for two minutes with a blow light. To avoid splashing, the bottle is filled with water that is running gradually (NPHLS, 2008). The stopper, paper cap, and label are then reinstalled, and the insulated box is sent to the laboratory packed with ice. The results are then recorded and compared to check if the water meets WHO or national drinking water quality criteria in terms of physical, chemical, and microbiological characteristics, allowing it to be safely ingested and cooked.

A sample population of 32,530 people with an average of 4 people in a household was targeted during this study. The number of households was found by dividing the total population size by the average household size as shown below.

$$\frac{32{,}530}{4} = 8{,}133$$

The sample size for households was drawn from the available population using Role (2013) formular as shown in equation (ii) below.

$$n = \frac{N}{1 + (Ne^2)}$$

Where: n = sample size; N = population size = 8133; E = margin of error (e<0.05

Therefore, the sample size = $\frac{8133}{1+(8133\times0.05^2} = 381$

The study's target population was 360 households, 14 Community water points, 5 health facilities and 2 water institutions.

Data Analysis

The data was reviewed for accuracy and completeness using Microsoft Excel as part of the data cleaning process, arranged and coded before analysis using the Statistical Package for Social Sciences (SPSS) software. The results were presented in graphs and tables then compared with the WHO and KEBS guildelines before drawing conclusions.

RESULTS

Demographic Information

A household survey of 8,331 people residing in 360 houses was undertaken as part of the research. The ratio of males to females differed, showing that the sample had a gender balance (*Table 1*).

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Table 1: Socio-economic Characteristics of Machakos Central Households (N=360).

Socio-economic Characteristic	Categories	Eastleigh	Mjini	Misakwani	Upper Kiandani
Gender	Male	46%	40%	51%	57%
	Female	54%	60%	49%	43%
Education (water drawer)	Not Educated	1%	11%	12%	6%
	Primary Sch. Edu	3%	7%	5%	6%
	Seco Sch. Edu	36%	33%	69%	72%
	Post Sec. Sch. Edu	53%	49%	14%	16%
Occupation	Employed	79%	39%	73%	34%
	Self- Employed	17%	56%	18%	57%
	Unemployed	4%	5%	9%	9%

As per the results of the study tabulated in *Table 1,* a mean of 49 percent of the respondents were men, with 51 percent of the respondents being female. On the level of education as per the table shown above of the household respondents an average of 8 percent of the household respondents were uneducated, with 5 percent average of the household respondent having attained Primary School education level.

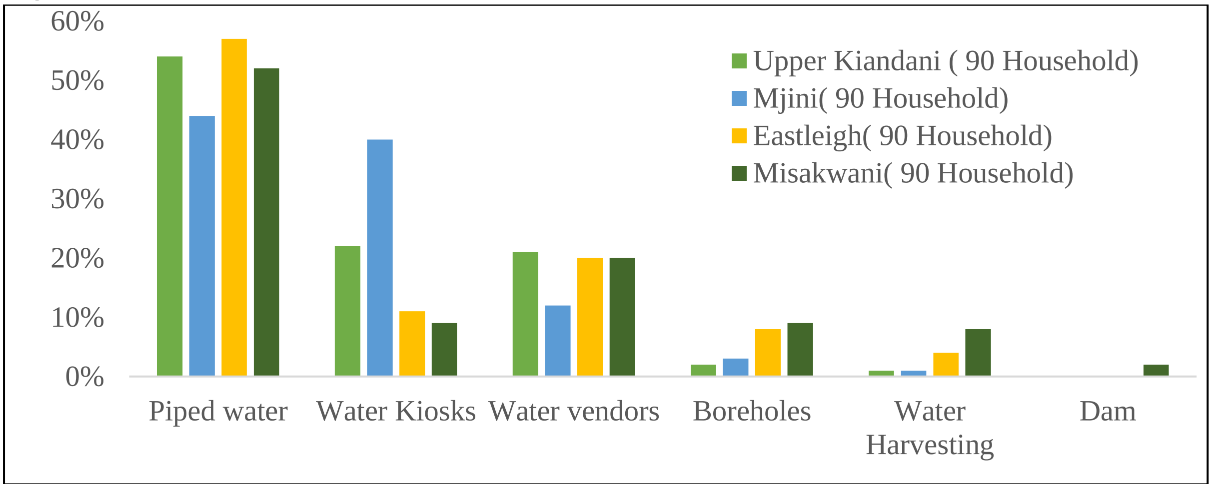
In line with the study results, an average of 56 percent of the respondents were employed, with an average of the respondent being self-employed whereas an average of 7 percent were unemployed.

Water Distribution and Supply Systems for Households

Main Sources of Water

According to the results in *Figure 2,* the main source of water used in the area of the study is Piped water, which is mainly pumped from Maruba Dam by the Machakos Water and Sewage Company. Although other sources of water such as water from water vendors, sunken borehole, and water kiosk, a great percentage depend on piped water for their domestic use

Figure 2: Sources of Household/Domestic water in the Ward



Alternative Sources of Water

From the results, alternative sources in the event of water shortages or disruptions of normal supply differed differently as displayed in *Table 3*. In Upper-Kiandani; 33% buy water from available water kiosks, 28% of households buy from water vendors, 20% of respondent households rely on piped water, 10% draw water from available boreholes and the remaining 9% practice rainwater harvested during the rainy season. In Mjini; 41% of households buy water from public water kiosks, 39% are supplied by water vendors,

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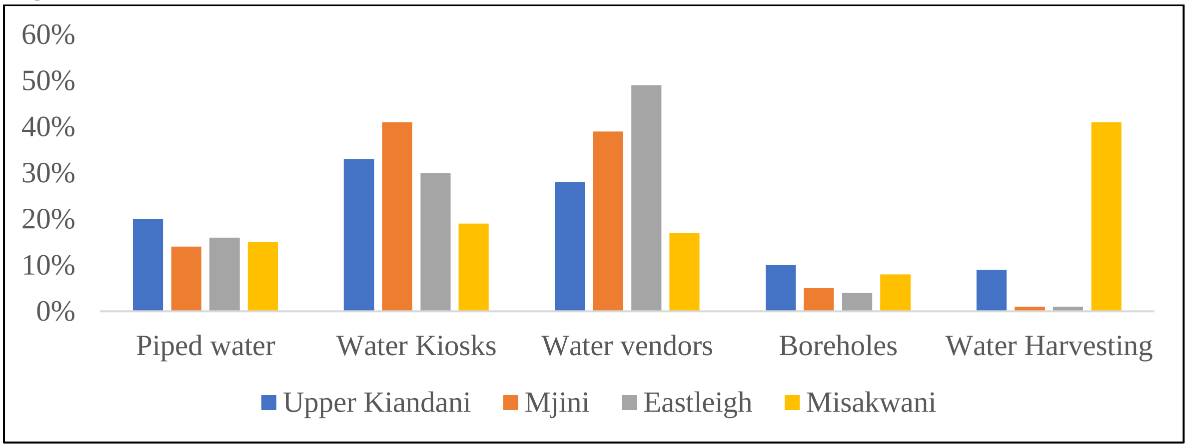
14% utilize piped water, 5% draw water from boreholes and the remaining 1% adopts rainwater harvesting during the rainy season. In Eastleigh; 49% are supplied by water vendors, 30% buy water at public water kiosks, 16% utilize piped water, 4% draw water from boreholes and the remaining 1% harvest rain water. Lastly in Misakwani; 41% adopt rainwater harvested during the rainy season, 19% buy water at public water kiosks, 17% are supplied by water vendors, 15% utilize piped water and the remaining 8% draw their water from boreholes.

Figure 3: Alternative Sources of Household/Domestic water in the location



Geographical Location of Community Water Sources

The 14 sampled community water source points were mapped with GPS technology as shown in *Figure 4*.

Figure 4: The GPS mapping of Community Water Sources

Quality of Water

The study also looked at critical chemical factors like pH, TDS, Colour, Turbidity, Conductivity,

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Total Hardness, Total Alkalinity, Fluoride, and Iron to see if water quality meets WHO requirements for home use. According to the World Health Organization and KEBS drinking guidelines, the chemical content criteria for groundwater are shown in Table 2 below.

Table 2:
WHO and KEBS Drinking Water Quality standards (KS 459-1:2007)

Parameters	WHO STDS	KEBS(KS 459-1:2007
pH	6.5-8.5	6.5-8.5
Colour	Max 15	Max 15
Turbidity	Max 5	Max 5
Conductivity (25^{0}C)	Max 2500	-
Iron	Max 0.3	Max 0.3
Manganese	Max 0.1	Max 0.5
Calcium	Max 100	Max 150
Magnesium	Max 100	Max 100
Sodium	Max 200	Max 200
Total Hardness	Max 500	Max 300
Total Alkalinity	Max 500	-
Chloride	Max 250	Max 250
Fluoride	Max 1.5	Max 1.5
Nitrate	Max 10	-
Sulphate	Max 450	Max 400
Total Dissolved Solids	Max 1500	Max 1000

(Source: KEBS, 2007)

Analysis of Water Quality Physical-Chemical Parameters

The results of the physical-chemical parameters analysis of the 15 water sources of relevance were compared to the WHO and KEBS (KS 459-1:2007) drinking water guidelines as shown in *Table 3*

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Table 3: Water Quality Parameters for Boreholes (BH) and Water Kiosks (WK) in relation to the WHO and KEBS (KS 459-1:2007) Drinking Water Quality Standards

Parameters	Unit	BH1 Kwa Matuu BH	BH5 Macha Girls BH	BH6 KwaIssa BH	BH10 Ithae BH	BH11 Macha Park BH	WK2 Kyulu	WK3 ABC	WK4 Kwa Mutua	WK 7 Chief Camp	WK8 Kitolo	WK9 James	WK12 Ithinga	WK 13 Muema	WK 14 Kyuuni	WK 15	WHO	KEBS (KS 459-1:2007)
pH	pH Scale	7.82	6.05	6.77	7.47	7.28	7.78	6.45	7.45	7.45	8.28	7.68	7.45	7.28	7.78	7.36	6.5-8.5	6.5-8.5
Colour	MgPt/I	40	<5	60	60	<5	<5	5	<5	<5	<5	<5	<5	<5	<5	20	Max 15	Max 15
Turbidity	N.T.U.	16.85	1.32	8.27	8.27	4.2	5.09	76.5	4.47	4.47	4.2	5.09	4.47	4.2	5.09	31.9	Max 5	Max 5
Iron	mg/L	0.8	<0.01	0.37	0.37	0.1	<0.01	0.19	0.19	0.19	0.1	<0.01	0.19	0.1	<0.01	0.73	Max 0.3	Max 0.3
Manganese	mg/L	0.8	0.3	0.3	0.3	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	Max 0.1	Max 0.5
Calcium	mg/L	22.4	33.6	80.4	30.4	37.6	137.6	61.6	31.6	31.6	37.6	137.6	31.6	37.6	137.6	103.2	Max 100	Max 150
Magnesium	mg/L	85.5	17.5	14.6	14.6	61.7	0.6	12.6	12.57	12.57	61.7	0.6	12.57	61.7	0.6	19.99	Max 100	Max 100
Sodium	mg/L	257	90	50	46	87	84	52	52	52	87	84	52	87	84	203	Max 200	Max 200
Total Hardness	$mgCaCO_3/1$	408	156	216	136	348	346	120	128	128	348	346	128	348	346	340	Max 500	Max 300
Total Alkalinity	$mgCaCO_3/1$	350	44	416	316	192	110	132	132	132	192	110	132	192	110	326	Max 500	-
Chloride	mg/L	370	175	51	51	122	62	67	67	67	122	62	67	122	62	265	Max 250	Max 250
Fluoride	mg/L	2.12	0.04	1.34	1.34	0.19	0.17	0.426	0.426	0.426	0.19	0.17	0.426	0.19	0.17	0.88	Max 1.5	Max 1.5
Conductivity (25^0C)	µS/cm	1966	728.1	1924.3	1824.3	1103	1080	500.1	500.1	700.1	1103	1080	500.1	1103	1080	1605	Max 2500	-

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Water pH

In accord to *Table 3* above the pH fluctuation was ranging between 6.0 and 8.3 in various water samples according to various water sources. The pH values for all 5 boreholes and the 10 water Kiosks were found to fall within the required limits of between 6.5 and 8.5 with a mean value of 7.35. B1 had the highest value of 7.82, B5 had the lowest value of 6.05, and the water kiosk the highest pH level of 7.78 and the lowest having 6.45 which was within the KEBS and the WHO standards.

Colour

The water colour of 11 samples as shown in *Table 3* above ranged below the detection limit of a maximum of 15MgPt/I of the WHO and KEBS Standards, with the highest value of less than 5 MgPt/l. . On the other hand, 4 samples exceeded the set limit and these are ranging between 20-60 MgPt/l.

Turbidity

The turbidity of 8 of some of the water samples according to *Table 3,* was way above the permitted maximum limit for drinking water as per the WHO standard ranging between 5.09-16.65 N.T.U with a mean difference of 12.29; 7 samples were within the recommended limit with them ranging between 1.32 N.T.U to 4.47meaning that all the samples fell below the standard value of 5 N.T.U as shown above.

Iron

As shown in *Table 3* above the Iron levels in 13 samples were within set standards by both the WHO and the KEBS with value between <0.01 to 0.3 mg/L. Only 2 water samples had exceeded the set limits of WHO and KEBS standard. mg/L slightly exceeded the standards.

Manganese

The Manganese levels of 12 water samples as shown in *Table 3* were within the set standards of 0.1 and 0.5 of the acceptable limits of WHO and KEBS standard limit respectively with an exception of three sample that were slightly over above.

Calcium

The Calcium content as shown in *Table 3* above in the water samples analysed for all boreholes was below the set standards of both the WHO and KEBS of a maximum of 100 mg/L and 150 mg/L respectively with the sample value ranging between 22.4 to 137.6mg/L. and with a mean value of 63.46.

Magnesium

According to the results of the study the Magnesium content in the water samples were within the KEBS and WHO standard of a maximum of 100 mg/L and a mean value of 25.96mg/L and the value ranging within 0.6 to 85.5mg/L

Sodium

As shown in *Table 3* above the Sodium concentration in 13 water samples was within the acceptable KEBS and WHO standards with a maximum of 200mg/L with range limit of between 46 to 87mg/L and only two water samples exceeded the set limit and they all had a mean value of 91.13mg/L.

Total Hardness

The total hardness of the water samples ranged between 135 mg$CaCO_3$/L to 408 mg$CaCO_3$/L which exceeds the KEBS set standards of 300 mg CaCO3/L; but they met the WHO standards of a maximum of 500 mg$CaCO_3$/L with a mean value of 256.13 mg$CaCO_3$/L.

Total Alkalinity

The Total Alkalinity from the study results samples shown in *Table 3* above ranged from 44 mg $CaCO_3$/1 to 326 mg $CaCO_3$/1. The total alkalinity in all sampling sites was under the WHO's recommended guideline for residential water, which is 500 mg CaCO3/l.

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Chloride

The water samples tested had chloride ion concentrations ranged from 51 mg/L to 371 mg/L as indicated in *Table 3*. From the results, chloride io concentration in BH1 370 mg/L and WK15 265mg/L were way above the set standards of a maximum of 250mg/L in both the set standards under comparison.

Fluoride

Although all of the samples included Fluorides, their concentrations were below the permitted maximum limit of 1.5 mg/L with the exception of 1 water sample as displayed in *Table 3* above which surpassed the limit of the WHO and KEBS Standards.

Conductivity

According to the research results shown in *Table 3* the conductivity of the water samples ranged from 500 to 2000 S/cm which is within the set standard the WHO standard of 2500 S/cm with a mean value of 1119.80.

Biological Results of Water Quality

Results indicated in *Table 4* displays results of specific water quality biological factors during the study.

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Table 4: Biological Results of Water Quality

Sample Source	Exact site sample taken from	MPN of Coliforms organism per 100ml	*E. Coli* per 100 ml	Legionella spp per 100 ml	Micro-organisms	Remarks by Head of Laboratory
Sample No. 1467-Machakos Town	Tap (Piped Water)	Nil	Nil	-	-	Water is bacteriologically suitable for domestic purposes
Sample No. 1466-Maruba Dam	Direct from Dam	$8.16*10^3$	$8.6*10^2$	-	-	Highly contaminated water that should be treated before domestic use
Sample No. 1750 Misakwani Borehole	Direct from borehole	$5.2*10^3$	$5.3*10^2$	-	-	Highly contaminated water that should be treated before domestic use
Sample No. 1070-Misakwani Water Kiosk	Direct from tap	Nil	Nil	-	-	Water is bacteriologically suitable for domestic purposes
Sample No. 0472 Eastleigh Machakos Water Supply consumer point	Tap (Piped Water)	Nil	Nil	-	-	Water is bacteriologically suitable for domestic purposes
Sample No. 3060 Upper Kiandani School borehole	Direct from borehole	$9.5*10^3$	$8.3*10^2$	-	-	Highly contaminated water that should be treated before domestic use
Sample No. 1756 Mjini Mosque Community Water Kiosk	Tap	Nil	Nil	-	-	Water is bacteriologically suitable for domestic purposes
Sample No. 1093 Mjini Water Kiosk	Direct from tap (treated)	Nil	Nil	-	-	Water is suitable for domestic use

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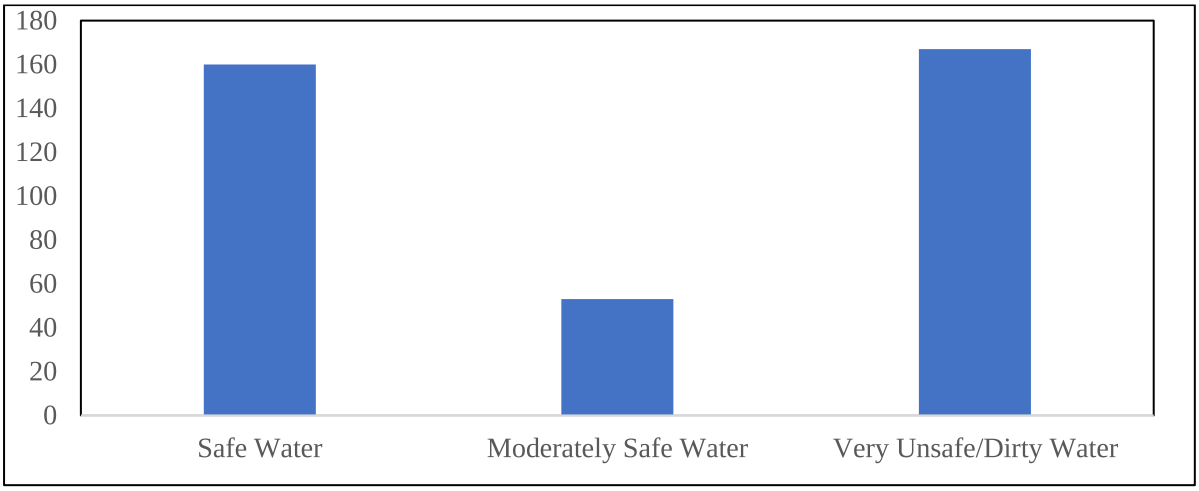
Relationship of Domestic Water Distribution and Coverage with Incidences of Water Borne Diseases

Results to establish the relationship of domestic water distribution and coverage with incidences of waterborne diseaseswas carried out to establish a link between domestic water and waterborne diseases. 44% of the respondents classified the water they use as very unsafe whereas 42% classified it as safe for use as shown in *Figure 5* below.

Figure 5: Perception of domestic/household water for use

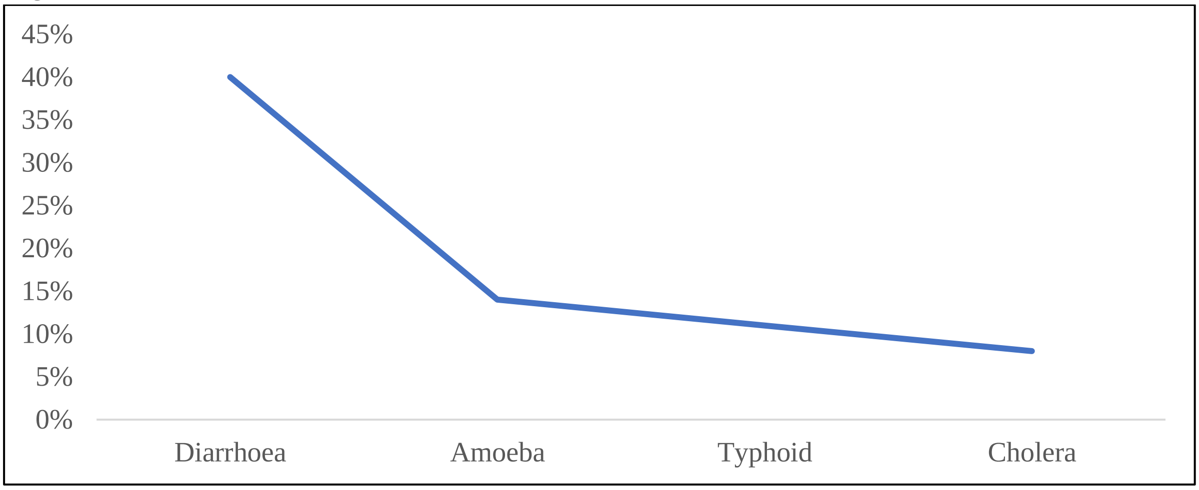


Where: Safe is water that was good for consumption that did not need any treatment before use; Moderate safe is water that was safe enough; and Very unsafe is water that was not safe at all.

Common water-borne Diseases

Results indicated that the most prevalent waterborne disease six months prior to the study was Diarrhoea at 45%, followed by Amoeba at 38%, Typhoid at 15% and the less prevalent was Cholera at 2% as shown in *Figure 7*.

Figure 6: Common waterborne disease



Family Members Affected by Diarrhoea

The results as displayed in *Figure 7* show a trend in the number of diarrhoea incidences, and the pattern varied over the six months prior to the study, with high cases in the fifth month and a drop in cases in the sixth month. This could be perhaps that households were using methods of improving the quality of water they were drinking.

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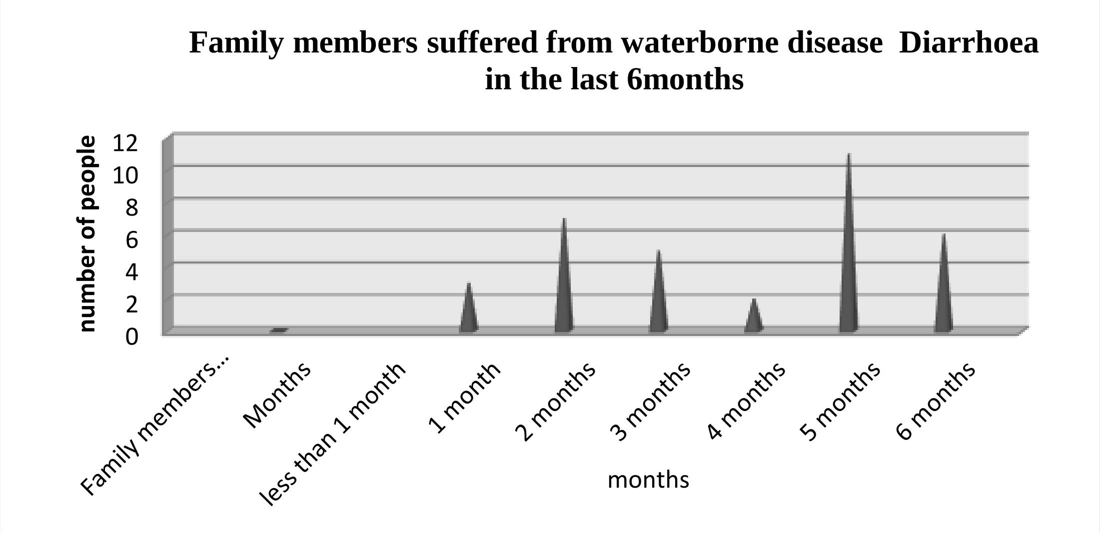
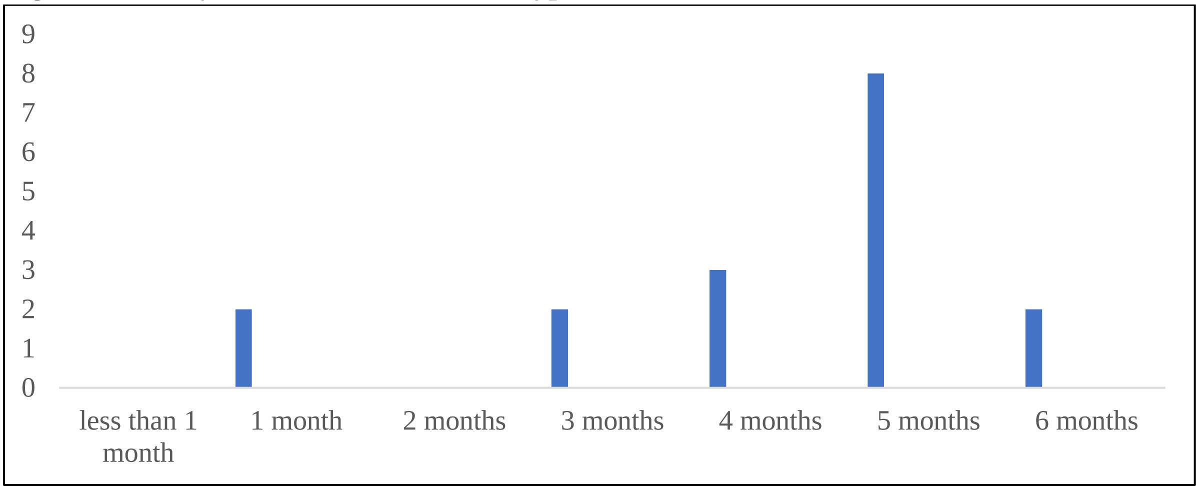
Figure 7: Family members suffered from diarrhoea



Family Members Affected by Typhoid in The Last Six Months

It was clear that typhoid was not so intense compared to as shown Figure 9 below, the first month there was no incidence reported of typhoid, though in the second to fourth month the respondents reported an increase in cases affected as shown below.

Figure 8: Family members suffered from typhoid



Health Centres Data on Common Waterborne Disease

The results as displayed in *Figure 10* established that diarrhoea was the leading waterborne reported and treated in the area of study, and although typhoid and amoeba were reported the impacts were minimal.

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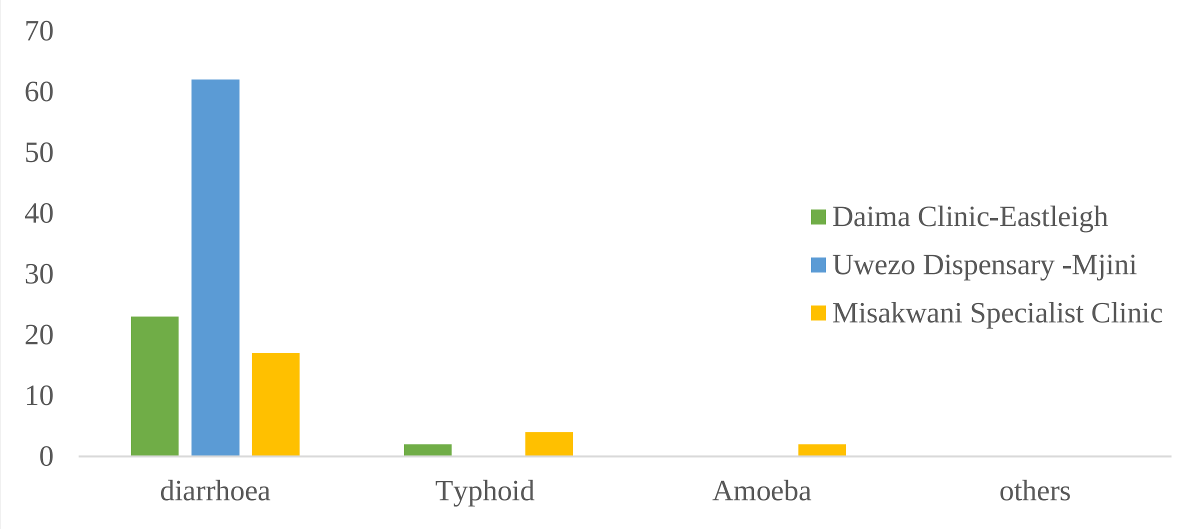
Figure 9: Waterborne disease reported/treated in the locations Health centres



DISCUSSION

Household Water Supply and Distribution Systems

Water from the Maruba dam, piped water pumped by Machakos Water and Sewage Company, water from water vendors, water harvesting, and water kiosks were among the many water sources. Access to safe water sources, such as piped residential water connections, public standpipes, boreholes, protected drilled wells, protected springs, and rainwater collection should supply clean drinking water, according to a report on the water problem (European Commission, 2007). Majority of residents use piped water as their major source of household water, while others rely on other options such as borehole water, water from vendors and water kiosks, water harvesting, and dams.

Main Sources of Household and Domestic Water

Although water from Maruba Dam is occasionally used, it is not widely utilised. For a few days every week, piped water is pumped by Machakos Water and Sewage Company (Machakos County (2015). Water kiosks are located near homes and charge for water drawn. Depending on where the water kiosk is located, different amounts are charged. Several houses have drilled boreholes, and although some pump water to their taps, others use a bucket to get water directly from the borehole. Water vendors provide door-to-door services via bicycle or tuk-tuk, charging according to the distance from their water sources; depending on the season, the amount charged is higher during the dry season. In certain families, water harvesting is prevalent Water harvesting is prevalent in certain families, and water is stored in large capacity tanks.

The majority of houses in the study region utilize piped water, which is more safe and clean because it is treated before being pumped by the Machakos Water and Sewage Company at the Maruba Treatment Plant near Maruba Dam. Water vendors and kiosks are the primary water sources for certain families. This is wiudespread in locations where water pipes have been vandalized or there is a lack of water pressure. Contamination is more likely to happen here as the water is transported from the source to the dwelling. A few families use boreholes, while others collect water. Assumptions include the cost of drilling a borehole and the paucity of water in some regions; water harvesting necessitates huge tanks; and rainfall is not always consistent.

Alternative Sources of Water

Primary water supply in the four areas is not always reliable due to population growth, which increases commercial and social activity. Piped water is not the primary alternative source and some households prefer other options such as water kiosks and water sellers. MAWASCO, the main water service provider, only pumps water on

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a few days of the week, forcing the household to seek alternative sources.

Water sellers and water kiosks are the most popular option because they are plentiful across the ward and are more accessible due to their proximity to residential areas. Furthermore, they provide door-to-door services, making this a more convenient option for homeowners.

Water harvesting is another alternate source, in which most people collect water from roof gutters and store in plastic tanks or subterranean tanks for use during water shortages. Despite the fact that rainwater is presumed to be safe to drink, it is only available during the rain seasons, which are not always guaranteed to occur. Few households prefer boreholes as an alternative supply of water since most boreholes are privately owned and expensive to install.

Water Quality

Water quality defined the state of residential water in the study area as meeting the predetermined universal criterion for genuine and vital water usage at any level, whether locally, regionally, or internationally

The aesthetic qualities of water from various water sources, such as taste, odour, and colour in their drinking water, influenced the household's choice of water source; it also included their water being treated at treatment plants to make it safe before it was pumped to their homes, or using different methods of treating the water to increase the quality of the water prior use. To assess the water's quality, the researcher was interested in both physical and chemical characteristics This is in accordance with World Health Organization research that classified drinking water, commonly known as freshwater resources, it is water of sufficient physical, chemical, and bacteriological purity, allowing it to be safely consumed and cooked (WHO, 2004). If there are no substantial health concerns during the scheme's lifetime and when it is used, WHO considers drinking water to be safe and of good quality.

Chemical contents of drinking water pose health issues distinct from those highlighted by microbiological contamination, because chemical constituents can cause severe health effects with prolonged contact (WHO, 2006). This involved testing some water samples from the water collection points and collecting opinions of the residents of Machakos Central Ward.

Household's Perception and Indicators of Water Quality

The study aimed to determine how the population perceived water quality based on taste, colour, and odour. Most household perceived the water they use for their domestic use as being of good quality. Consumer impression is one of the most important elements in drinking water quality, sometimes even surpassing actual water quality, especially when it comes to the quality of drinking water for user communities (Doria, 2010). Their opinion of water quality was based on factors such as the colour of the water, the taste, and the odour or smell of the water. Residents' decisions regarding which water source to use are influenced by their perceptions of the quality of water available.

Water Quality Physical – Chemical and Biological Parameters

Water pH

The pH of any water resource is an important parameter that can affect the dynamics of other water quality indicators, especially when it shifts from acidic to basic circumstances. The most pathogenic bacteria in mesophilic environments are involved in the biodegradation of organic materials dissolved in water; for development and reproduction, according to Boone and Xun (1987), a pH value greater than 7.0 is required. These fell between the pH scale that was acceptable range for drinking water as per KEBS and WHO standards which is usually between 6.5 -8.5 for portable drinking water. Low pH levels can promote corrosive qualities, resulting in pollution of drinking water, as well as undesirable impacts on its flavour and appearance, according to a World Health Organization study, whereas

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higher pH values can lead to calcium carbonate build-up (WHO, 2004)

Colour

Throughout the research period, the water colour of most water sources was below the detection limit of less than 15MgPt/L except for Water Kiosk (WK)15 and BH1, BH6, and BH10. The proportion of dissolved and colloidal humic compounds in the water bodies studied explains the differences in water colour. The high-water colour in the sources is very significant in that, it increases the cost of water treatment.

Turbidity

According to the results, seven water samples from the selected fifteen had high turbidity with their values being above 5NTU. Water with a high turbidity level is typically thought to have a significant risk of harmful microorganism contamination, as high turbidity levels might make disinfecting the water difficult. Water purification processes such as flocculation and filtration are made easier with low turbidity, resulting in lower treatment costs which was the case in some of the samples

Conductivity

Electrical Conductivity values were within the permissible range for drinking water in all of the water sources tested (2500 S/cm), according to the WHO water consumption regulations. According to a study, water's ability to carry electrical current is determined by its electrical conductivity (Karikari & Ampofo, 2013). EC can provide information on ion concentrations or total dissolved salts (TDS) in the water being studied because electric current is transmitted by the movement of ions in solution. In relating this study with the researcher's study, although the water was unsuitable for domestic use before treatment, the electrical conductivity of the measured water was good because it did not exceed the permitted level.

Iron

According to the results of the study shown in *Table 3*, most of the samples dissolved iron was found to be within the acceptable limits set by WHO. Although few samples had increased dissolved iron, this can be attributed by iron concentration may increasing despite water being of good water chemical composition when pumping water into the network as a result of picking off sediments due to changes in water flow direction or rate in water distribution network and iron penetration into water by its dissolution (A. M. Wolde *et al.* 2020).

Manganese

From the results shown in *Table 3*, it was certain that the water sample BH1 had the greatest threshold of manganese content as per the KEBS standard of 0.5 mg/L and WHO standards of 0.3 mg/L. Manganese is the primary cause of unfavourable test results, and uses a lot of detergent when washed. Manganese can generate an unpleasant taste as well as staining clothing when levels above 0.1 mg/L, according to a World Health Organization study (WHO, 2004). Moreover, to the samples within the KEBS standard, there were, some samples that were beyond the WHO standard of 0.3 mg/L. Although the manganese percentage was not high enough to make the water unsafe for drinking, the presence of manganese could cause deposits to build up in the pipe system (WHO, 2004).

Calcium

The levels of calcium according to 11 samples of the study shown in *Table 3* above revealed that the results of the research fell below acceptable standards of WHO of 100 mg/L in samples This was not the case in 4 water samples which exceeded the WHO standards but did not exceed the acceptable standards of KEBS of 150 mg/L. The water quality considering calcium hardness is good for drinking in this study, although the total hardness of water is increased by calcium in water, amplified amounts of calcium in the water

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precipitate on heating making detrimental patches in vessels, conduits, and kitchenware.

Magnesium

The water samples were all within acceptable WHO and KEBS requirements of a maximum of 100 mg/L, according to the results of magnesium concentration in the water samples presented in *Table 4*, with the greatest being BH1 with 85.5 mg/L and the lowest being WK2 with 0.6 mg/L. The magnesium concentration of all the water samples was within WHO and KEBS permitted limits, indicating that the water quality was suitable for home use.

Sodium

Two out of fifteen water samples from the study in *Table 4* exceeded the acceptable limit of sodium concentration as per the WHO and the KEBS standard of 200 mg/L. The other thirteen water samples were within the acceptable limit the water quality in terms of sodium was suitable for domestic use.

Total Hardness

All of the water samples were below the WHO's recognized hardness limit of 500 mgCaCo3/l, although several were above the KEBS standard limit of 300 mgCaCo3/L, according to the study's findings (*Table 3*). The hardness of drinking water is defined as gentle, moderate soft, 50 to 100 mg/L, somewhat hard, 100 to 150 mg/L, moderate hard, 150 to 200 mg/L, hard, 200 to 300 mg/L, and extremely hard, over 300 mg/L, according to a study by the WHO (2004).

As per this study and also the rating, some of the water samples fell in the category of slightly hard water, because the water samples fell above 100 to 150 mg/L.

Total Alkalinity

Most test sites had total alkalinity levels that were under the WHO's recommended range for drinking water (*Table 4*). At the study sites, total alkalinity ranged from 44.0 to 416 mg/L, which is typical of freshwater lakes. These water sources had a consistent pH because total alkalinity is a measure of a water's capacity to resist changes in pH when acid is added to it. Because the ions CO3, HCO3, and OH are the principal drivers of alkalinity in water, there is evidence that these ions were present in lower concentrations in these water sources.

Chloride

Water sample BH1 and WK15 recorded the highest level of chloride (Table 4) which exceeded the limit set by WHO and KEBS standard, with both of them having 370 mg/L and 265 mg/L respectively. The lowest level of chloride was at 51 mg/L which was within the limit. As a result, even though Owolabi *et al.* (2011) argue that too much chloride in water causes bad taste and may indicate contamination from urine and sewerage, too much iron residue can cause taste and odour problems in water, the study's assumption about water quality in terms of chloride is that it is suitable for domestic use.

Fluoride

According to *Table 4*, most of the water samples from both boreholes and water kiosk fell within the acceptable guideline limits of WHO and KEBS standards for portable water except for BH1 which recorded a 2.12 mg/L content. In minimal level fluoride can decrease the dangers of dental fissures but an introduction of advanced amounts of fluoride can lead to teeth fluorosis of the teeth. In its slightest level, it leads to teeth discolouration and extended consumption can lead to bone alteration and thus skeleton fluorosis.

Low fluoride concentrations protect against dental caries, especially in youngsters, while high fluoride levels in water can harm tooth enamel and cause mild dental fluorosis at fluoride levels of 0.9 to 1.2 mg/Litre, depending on intake. Even though the majority of the physico-chemical parameters for water quality were within the WHO and KEBS acceptable guideline limits for potable water, there is still cause for concern, especially with regard to some elements that are not removed during normal treatment, and possible sources of

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these elements should be identified and preventive measures taken to prevent their discharge.

Biological Parameters results

MPN of coliforms

There should be no disease-causing microorganisms or toxic microbial species in the water. According to the WHO standards set limit for water to be bacteriologically suitable for domestic use in terms of the MPN of coliforms organisms per 100ml had to be less than 1.1. The WHO (2004) necessitates that no faecal coliform ought to be identified in 100 millilitres of any portable water source. Some of the sources selected for this study were within the WHO standards and they included Machakos Town Tap water (Sample 1467), Misakwani water kiosk (Sample 1070), Eastleigh Tap Consumer point water supply (Sample 0472), Mjini Mosque community water kiosk (Sample 1756) and Mjini Tap water (Sample 1093). This meant that the water is bacteriologically suitable for domestic purposes.

The assessment of drinking water sources for coliform microorganism is crucial in establishing the quality of portable water as escalated amounts of coliform counts imply a polluted supply, insufficient treatment, or short comings after treatment (Hendricks, (2018). Some of the sources selected for this study exceeded the set limits and included Maruba dam (Sample 1466), Misakwani Borehole (Sample 1750) and Upper Kiandani borehole (Sample 3060). According to the head of laboratory, this meant the water sample sources were highly contaminated and should be treated before domestic use.

E. coli

The occurrence of faecal coliform or *E. coli* has been broadly applied as an index of water-related diseases causing microorganism (Ibe & Okplenye, 2005). In the water sources analysed, total coliform (TC) levels ranged from 0.0 to 8.6 102 colony forming units (CFU) per 100 mL. In Maruba Dam, the largest total coliform load was recorded (Sample 1466), Misakwani Borehole (Sample 1750) and Upper Kiandani borehole (Sample 3060). The World Health Organization (WHO) acclaims that in in 100ml of drinking water faecal coliform should be absent. This was centrally to the researcher's results, which showed the presence of faecal coliform in some samples. According to these results and remarks from the head of laboratory, these water sources were highly contaminated and should be treated before domestic use.

Relationship of Domestic Water Distribution and Coverage with Incidences of Water Borne Diseases

Natural water sources, such as boreholes, are at risk of contamination from a variety of sources, according to the study's findings, including pollutants in groundwater due to seepage of organic and inorganic chemicals, heavy metals, and pathogenic microbes from human and animal waste, domestic waste, extensive agricultural, industrial, and urbanization activities.

The health of residents in a certain settlement may be affected by the water quality. The goal of the study was to see how improved sanitation and safe water availability affected the prevalence and occurrence of water-related diseases among Machakos Central Ward people.

Common Water Borne Diseases in The Area

According to the results, diarrhea, typhoid, cholera, and amoeba were the most common water-borne infections in the research region. This could be owing to a lack of drinking water; some respondents indicated they were compelled to take risks by buying and consuming water from unknown sources, which was sometimes unsafe to drink, leading to the water-borne illnesses described.

Family Members Affected by Diarrhoea in The Last Six Months

Diarrhoea was the most common water ailment affecting residents in the research region, according to the results. Due to a lack of adequate water, people in developing nations are at risk of developing diarrhoea and other severe, life-

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threatening illnesses (Sobey *et al*. 2008). Diarrhoea has long been recognized as a major cause of morbidity and mortality, particularly in developing countries (WHO, 2008). This was also supported by World Health Organization research (WHO, 2005), which indicated that unsafe water supplies, poor sanitation, and poor hygiene habits cause 88 percent of all diarrhoea cases.

Treatment Measures Used in The Households and Domestic Water

Residents utilize a range of treatment procedures to lower and improve the quality of the water they consume, especially drinking water. The majority of locals choose to boil their drinking water to improve its quality and make it safe to consume. This was overcome by a study that found that in rural Kenya, boiling is the most popular method of water purification (UNICEF, 2008). Bio-sand was the second measure of water treatment, according to research findings, and the majority of them indicated that it has proven to be an effective, easy, economical, and reliable procedure. Bio-sand filtration has the advantages of being able to be made locally with readily available resources, being simple to maintain, requiring no energy input, and being relatively economical (Duke *et al.*, 2006). According to the data, chlorination was also used as a treatment procedure in the research region. However, some homes complained about the taste and odour of chlorinated water, claiming that it was unpleasant and that there was a tendency to add more chlorine than was suggested.

Common Water Borne Diseases According to Machakos Level 5 Hospital 2016/2017

It was noted that diarrhoea and dysentery were among top ten diseases treated in Machakos Level 5 hospital, with diarrhoea being the third in the list with 52,809 cases recorded as shown

It was vital to find out if the respondent had ever taken part in any educational or awareness activities related to water, sanitation, or hygiene, which ran concurrently with water delivery. 42% of respondents had taken part in educational and awareness initiatives on sanitation and hygiene in conjunction with water delivery, whereas 58% had not.

CONCLUSION

In Machakos Central Ward, piped water pumped from Maruba Dam, water kiosks, rainwater collection systems, and boreholes were the most popular water sources. Though most inhabitants believe the water they drink is pure, the water is treated using boiling, chlorination, and bio-sand. Many years ago, the Machakos Central ward's water supply problem became well-known. Several interviewees stated that they had to hike all the way to Maruba Dam in order to receive water. Residents in Upper Kiandani suffer more because of the proximity of the dam compared to the other sub-locations. Some people are forced to buy water from what appear to be expensive water kiosks or vendors.

As a result, homes in the study region augment their water supply with water from water vendors, boreholes, and other sources in the event of a water shortage. As a result, the water supply from a given water source in the study area was not consistent and trustworthy for all water users. Some households noted challenges to getting pipe water connections, such as high connection costs, the age of the existing line, water shortages, and pipeline breakdowns on a regular basis.

Recommendations

The study recommended that In order to improve the current water sources, community members should brainstorm new ideas and resolve to support them collectively. Some ideas include increasing the number of boreholes and wells drilled as well as implementing any beneficial water-saving techniques.provides the following recommendations based on the study's findings:

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