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Assessing the Effects of Pit Latrines on Groundwater Quality in Hand Dug Wells in Mtendere East Compound Lusaka

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Abstract

The rapid population growth in Lusaka has brought adverse effects on water supply and sewerage treatment facilities in the district. Consequently, authorities in Lusaka have allowed use of pit latrines, septic tanks, boreholes and wells in the same area in some townships. Mtendere east located about 20.9km from town centre is one of such areas. Lusaka city is built on marble which is cut by a network of fissures that open hollows or filled with soil. This reduces the attenuation of pollutants that would occur through natural filtration. A study on groundwater that was conducted in 2010 in selected areas of Lusaka showed high levels of contamination with bacteria.

The general objective of this study was to assess the effects of pit latrines on underground water quality in wells in Mtendere East. Specific objectives were to determine the effect of distance between pit latrines and wells on ground water quality in Mtendere east, to assess the effect of siting water wells and pit latrines in relation to the direction of ground water flow on the ground water quality, to come up with a sampling frequency, to analyse Total and Faecal coliforms, PH, Turbidity, Conductivity, Nitrates and Total Phosphates levels in the water samples collected from the wells in comparison to WHO standards. The study site was purposively selected because all households in the compound used Pit latrines and wells for human waste disposal and drinking water supply respectively. The study population of the area is over 50 000 from which a sample size of 40 houses was raised (Rao soft sample size calculator, at 95% level of confidentiality and 5% level of error). Following oral consent of the respondents,

representative members of 10 houses in each of the 4 hand dug well locations were engaged which resulted into a total number of 40 respondents; this was reached by interviewing every 10th household in the area. In each of the households and the site that was visited, water sample from the local well, depth of the wells and that of a pit latrine was taken as well as the distance between the well and the corresponding pit latrines.

The majority of water samples collected from households in the first, second and third tests in Mtendere East were found to be contaminated by faecal coliforms, while in the second and third tests the control point was not contaminated by faecal and total coliforms. The study revealed that the direction of groundwater flow had an association with water quality (total coliform and faecal coliform) at 5% significance level with p-values equal to 0.001 and less than 0.001 respectively. Distance from Pit latrine to Wells was insignificant in the quality of water. In conclusion, siting wells and pit latrine systems in the same area was not suitable for Mtendere East compound and Lusaka at large because safety of groundwater cannot be guaranteed. Partners in water resource management such as ZEMA, Department of Water Affairs, Geological Department and Lusaka City Council should, therefore, work together each time projects that involve groundwater development and onsite wastewater treatment are to be implemented. LWSC to quickly finish the water and sanitation project currently under construction so as to provide piped water and sewage services to Mtendere East.

Keywords: Pit Latrines, Groundwater Quality, Hand Dug Wells

Introduction

Pit latrine has been identified as a major source of contamination of wells with faecal matter (Ayanlaja *et al.*, 2005; Pritchard *et al.*, 2007). Bacteria, viruses and other contaminants such as nitrates infiltrate the surrounding soil through leachate from pit

latrine to the underground water (Howard *et al.*, 2002). Presence of bacteria in water indicates the preference of pathogenic organisms causing water related diseases (Nassinyama *et al.*, 2000). The pathogenic organisms are the most important sources of serious illnesses and deaths especially among young children in poor countries such as Zambia. Some studies indicate that environmental and climatic factors may encourage the spread of cholera in African countries. An article based on the 632 reports had shown that 66% of cholera cases and 87.6% of fatality occurred in sub-Saharan Africa (Nkoko, 2011, Bompangue *et al.*, 2008). A recent study in Zambia showed some evidence that increase in atmospheric temperature is associated with the prevalence of non-bloody diarrhoea in children under-five years of age (Mudenda *et al.*, 2014).

Water related diseases such as cholera, bacillary dysentery, typhoid, hepatitis A, and diarrhoea are feco-oral in their transmission (Priis-Ustun, 2004). It was asserted that there is an indiscriminate digging of water wells and boreholes without proper survey in developing countries (including Zambia) scattered everywhere; some of which are close to unprotected pit latrines, septic tanks, soakaways and waste dump sites (second Earth watch conference, 2003).

The main aim of sanitation is to break the transmission route of pathogens that originate from faeces (Cairncross *et al.*, 2010b). This can be achieved through implementation of complex methods such as sewerage systems and simpler systems like Ventilated Improved Latrines and septic tanks. UNICEF and WHO in the joint Monitoring Programme classified the following as "Improved" sanitation that is likely to be hygienic: a connection to sewerage system, septic tanks, pour flush toilets, ventilated improved latrine and pit latrine with a concrete slab (WHO, 2012). It is therefore clear that having improved sanitation facilities is likely to be protective against acquiring diarrhoea (Pfadenhauer and Rehfuess, 2015). In 2008, an estimated 565 million people in sub Saharan Africa did not have access to improved sanitation and out of these 231 million were reported practicing open defecation (Hickling and Hutton, 2013).

Adequate water supply is essential for prevention of water related diseases especially diarrhoea (Howard and Bartram, 2003). The minimum quantity of water per person per day that is essential for personal hygiene and health is 150 to 200 litres for urban population and 40 litres per capita per day for rural areas (Park, 2007). In emergency conditions such as a refugee camp the guideline for provision of water is a minimum of 15 to 20 litres/person/ day. It has also been documented that level of access to water portrays different levels of health risk and that less water puts people at more health risk (Howard and Bartram, 2003). The quality of water for drinking is a powerful environmental determinant of health, and as such water safety is a foundation for prevention and control of water borne diseases (WHO, 2014). It is estimated that 10% of improved sources may be high risk, containing more than 100 E.Coli or total coliform per 100ml and that drinking water is found to be more often contaminated in rural areas (41%) than in urban areas (12%) (Bain *et al.*, 2012, Bain *et al.*, 2014). This is attributed to access to unsafe water sources that fail to meet the standard for water quality of zero faecal coliform in 100 millilitres of water (WHO, 1993).

The rapid population growth in Zambia and Lusaka in

particular has brought adverse effects on the delivery of public health services which include sewage treatment and water supply. In 1964, at the attainment of political independence, the population of Lusaka was about 195, 700 (Kawanga, 2003). In addition, according to central statistical office (2000), the population of Lusaka was estimated at 1,391,329 and this grew over 10 years to 2, 198,996 in accordance with the central statistical office (2011) and Currently Lusaka has a population of over 3 million and Mtendere East covers about 15 000 of that population in accordance with central statistical office (2021).

Resulting from this problem, authorities in Lusaka allow the use of pit latrines, soakaways and septic tanks for the disposal of human waste (excreta). Mtendere East has over 1000 households, located in Lusaka's Mtendere Main compound on the eastern side. Therefore it, becomes imperative to embark on a study (of this kind) to ascertain the impact of pit latrine leaks on shallow wells with the aim of studying and revealing the problems posed by the use of unhealthy pit latrines and its implication on the quality of underground water in a densely populated area like Mtendere East.

Problem of the Statement

In view of the pollution widely associated with pit latrines, and despite the fact that some studies have been carried out in Mtendere East with respect to pit latrines, as well as the known resultant risks to the health of the human and environment, the existence and use of pit latrines in Mtendere East has continued. However, it may probably not be known to residents how existing methods of constructing and maintaining pit latrines and wells, as well as how methods of management of pit latrine sludge and the distance between pit latrines and wells may be contributing to the pollution of the Water and natural environment. Neither has any ethical evaluation been made of these practices. The purpose of the study is to contribute towards filling these knowledge gaps in the available literature.

Objective of the Study

Main Objective

To assess the effects of pit latrines on ground water quality in wells.

Specific Objectives

To determine the effect of distance between pit latrines and wells on ground water quality in Mtendere east.

To assess the effect of siting water wells and pit latrines in relation to the direction of ground water flow on the ground water quality.

To come up with a sampling frequency.

To analyse Total and Faecal coliforms, PH, Turbidity, Conductivity, Nitrates and Total Phosphates levels in the water samples collected.

Study Hypothesis

The purpose of this study was to assess the effects of siting Pit latrines and Wells in the same area on groundwater quality in Mtendere East. This is the area where Pit Latrines system is the only means of disposing excreta and wells are the only source for drinking water. The null hypothesis and the alternative hypothesis were:

Ho: There are no effects on groundwater quality when Pit Latrines and Wells are in the same area in Mtendere East.

Hi: There are effects on groundwater quality when Pit latrines and Wells are in the same area in Mtendere East.

Research Justification

Water pollution and quality degradation is a growing problem, exacerbated by the growing anthropogenic activities in developing countries. It is becoming a threat to the existing natural water resources functions and uses. The research study add to the existing body of knowledge and fill in the gap in the existing knowledge of effects of pit latrines on groundwater in Mtendere East. It will help raise awareness of the factors to consider when constructing a pit latrine to avoid affecting ground water. This study will educate people on the importance of surveillance of quality of water to ensure safety water related diseases.

Significance of study

Although Florence Muleka Kabinga (2016), Tembo (2013), Banda (2014) had focused on the state of sanitation in Mtendere and Kanyama respectively in their studies, no study has been carried out with regards to an ethical assessment of the effects of pit latrines on ground water quality in wells, human and the environment in the compound. Hence, findings of this study will contribute to the literature in this respect. These findings will also help in alerting local government authorities as well as residents of Mtendere East to the implications of the threats posed by pit latrines to the health of human and the natural environment.

Materials and Methods

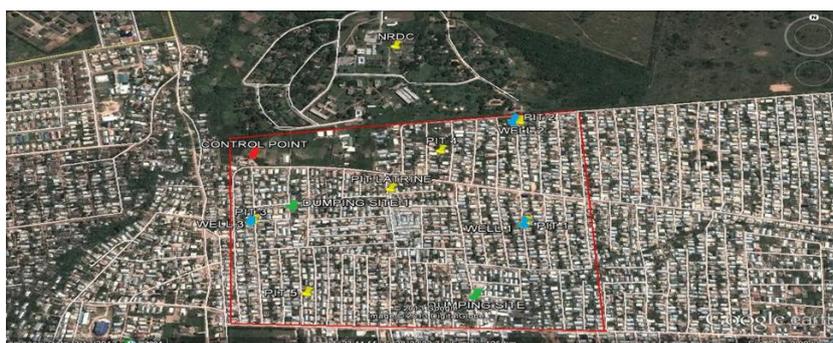
Study Area

Mtendere East is a compound located 20.9km east of Lusaka. It is south of NRDC, north of Kalikiliki, west of Avondale and east of Mtendere compound (main Mtendere compound), it started as an illegal settlement in 2000-2001. Towards the end of 2011, the government decided that, the compound should be established as a legal settlement. The population of this area is estimated to be around 50 000 (ZAMSTAT 2022). Due to the high levels of poverty in the area the cheapest and easiest means of excreta dispose in the area is through pit latrines and the main source of water is from hand dug wells which are contaminated by pathogens. As a result people suffer from different kind of diseases like, diarrhoea, dysentery and typhoid. The geology of this area is made up of the rocks called dolomite and schist's (The Ministry of Labour and Mines, report of the geological survey No.16).The effectiveness of the protective cover is very low, the degree of bypass of protective cover is very high and the vulnerability of groundwater is extremely high (The Groundwater Vulnerability PI-Map, Department of Water Affairs, 2012). A total of 4 sampling site were selected, and all these sites were hand dug wells. The average depth of the shallow wells in the settlement ranges from 2 m to 10 m, while the boreholes ranges about 40 m to 60 m deep. The diameter of each well is about 2.0 m. The wellheads are not adequately protect in most cases.



Source: Google map, 2021

Fig: Map of the study area



Source: Google earth, 2023

Fig: Map of the study showing sampling points within Mutendere East

Reconnaissance survey

Reconnaissance survey was carried out in study areas by visiting Mtendere East, in the study area in order to familiarize myself to the area and evaluate their condition and their proximity to each other.

Materials of data collection**Field Methods**

Recurrent visits were made to the study area during which collection of primary data was done through group and individual interviews to the respondents.

Study design

This was a cross-sectional study, with respondents drawn from fixed point in time. The relevant information which was obtained was then classified as having or not having the attribute of interest. In this case water quality was the main subject of investigation, thus water samples were analysed in the laboratory to ascertain its microbiological quality and results were classified as either satisfactory or unsatisfactory.

The study has also collected information on both groundwater quality and potential risk factors that may determine the quality of groundwater. These risk factors include siting of wells and pit latrines in relation to source of drinking water supply (i.e. distance from pit latrine to water source (well) and direction of groundwater flow in the area).

Sampling procedure

The sample for households was randomly selected from Mtendere East using stratified systematic sampling. The process of procuring sample for this study applied a probability stratified method of sampling which was followed by systematic sampling of households from each stratum. Strata were defined by one major characteristic which was the size of plots on which households were located in Mtendere East site has a total number of more than 40 households comprising of specific plot size. The plots are classified under low cost plots (25 x 30) which consist of 40 households. (Rao soft sample size calculator, at 95% level of confidentiality and 5% level of error). The importance of plot sizes was on assumption that they might have effect on siting of water sources and pit latrine systems within the plot boundaries. It was therefore, important to employ stratified sampling method in order to capture these specific subgroups within the study population. This technique was useful because it ensured the presence of key elements in the sample. After stratification according to plot size, households in the stratum were listed and the first household was randomly picked from the list. To achieve this, the total number of households in each stratum was divided by the sample size using the formula:

Where

k = sampling interval,

n = sample size

N = population size

Thus, $k = 40/4$ and finally, $k = 10$.

This meant that the starting point was any number from 1 to 10 on the list. Households that corresponded to numbers from 1 to 10 on the list were subjected to a draw and the starting point was determined. After the first number was picked, every 10th household was selected. At the end of the procedure, 4 households were selected. In the event that the

respondent declined to be part of the study, the next household was picked. In the case where the owner of the picked household happened to be absent at the time of the study, the household was revisited. Similarly, if on the second visit the owner was absent, the respondent was replaced with the next household. In each of the households and the site that was visited, water sample from the local well, depth of the wells and that of a pit latrine was taken as well as the distance between the well and the corresponding pit latrines.

Sample collection and Transportation

A total of 24 samples were collected randomly from the 4 sites over a period of January to April, 2023. Two samples were collected for each well; one for physical-chemical analyses and the other for microbiological analyses. Distance, coordinates, depth of water well, infiltration layer will also be recorded. The water samples were marked Control Point (CP), w1, w2 and w3.

The samples were collected in sterilized 250ml capacity transparent blue screw capped clear bottles. The sample bottles were rinsed with the water to be sampled. Parameters such as temperature, and taste were measured right in the field. The samples were transported to the lab in a cold condition. Dissolved ice was used for this purpose.

Procedures for Sample Analysis**Determination of colour**

Colour was measured by comparison of water samples with a series of dilutions of potassium chloroplatinate and crystalline cobaltous chloride. It is possible for the colour to be altered by materials that decay from organic matter, the primary of which includes vegetation and inorganic matter such as rocks, soil and stones may also affect the colour of the water. Even though these changes to waters colour create aesthetic issues with the water, they don't change how the water tastes. You can effectively measure colour by comparing water samples to colour glass disk and standard colour solutions namely potassium chloroplatinate and crystalline cobaltous chloride as stated in the beginning of this write up.

When trying to identify the colour of water, it is important to understand the difference between the waters apparent colour and its true colour. Apparent colour is made up of suspended material and dissolved solid colour. The true colour of water is identified after all suspended material have been filtered out of the water. Bearing in mind that pure water has no colour units because it is essentially colorless (UNEP and WHO. 1996).

The Sample water was taken in a small beaker and then the probe of the PH meter was placed inside the water for a few minutes. The PH meter showed the reading, but the final reading recorded was the one when the reading became static.

Taste and Odour

Odour was measured in terms of the number of times a sample has to be halved with odour free water that yields the least definitely perceptible odour. It is possible for the taste of water to change and for odour to develop as a result of foreign matter being introduced to the water. This matter can include organic matter, dissolved gases, and inorganic compound. Most of this matter is derived from agricultural, natural and domestic sources. (UNEP and WHO. 1996).

Temperature

The temperature was taken in-situ with the use of capillary field thermometer. The thermometer was first suspended in the air to know the temperature of the environment (R). After this it was inserted in all the samples to read their temperature values in degrees Celsius (UNESCO/WHO/UNEP, 1996).

PH

PH was determined with the use of the PH meter. The electrode was inserted into the sample after inserting it in distilled water for (standardization); PH readings were then be recorded (UNESCO/WHO/UNEP, 1996). The meter said if the water was acidic or basic. Acidic water will invariably be comprised of more hydrogen ions on the other hand basic water contains more hydroxyl ions. It is possible for PH levels to range from 0-14. If you received a reading of 7, this means that water is neutral. Any reading below 7 are alkaline. Pure water has a neutral, however, rainfall is somehow more acidic and typically has a 5.6 PH. Water is considered to be safe to drink if it has a PH of 6.5-8.5. The many effects that changing PH levels can have on plants and animals include worsened quality of life, killing and damage of fish gills and eggs (research gate, 2021).

Electrical conductivity

Conductivity was measured with a probe and meter. Voltage was applied between two electrodes in a probe immersed in the sample water. The drop in voltage caused by resistance of the water was used to calculate the conductivity per centimetre. The meter converted the probe measurement to micromhos per centimetre and displayed the results for the user. Note some conductivity meters can also be used to test for total dissolved solids and salinity. The total dissolved solids concentration in milligrams per litre can also be calculated by multiplying the conductivity results by a factor between 0.55 and 0.9, which is empirically determined (Standard methods #2510, APHA 1992).

Turbidity

According to the procedure described by Cheesbrough (2006), turbidity value was determined by inserting an upper tube into a lower one, holding the tube over the white surface and a black cross on the tube was identified. Sample was poured until when the cross was no longer be visible. Turbidity value (TU) was read from the graduation on the tube. Turbidity starts to become visible in water when sensors provides you with readings of over 5 NTU. As for muddy water, it can have turbidity readings of more than 100NTU. Turbidity is the measure of suspended solids in water. Turbidity represents the degree of cloudiness of the stream or river. Turbidity can be caused by mud, silt, plant pieces, wood ash, saw dust, algae or other microorganisms and precipitated chemicals that find their way into water bodies or thrive in water bodies. The presence of these suspended solids reduces the amount of light penetrating the water for the benefit of aquatic photosynthetic organisms (Lloyd *et al*, 1987; Anderson, 2003). Turbidity contributes significantly to the decline of aquatic organisms, its impact can be witnessed through pervasive alteration of local food chains (Henley *et al*, 2010).

Total Suspended Solids (TSS)

Data logging spectrophotometer was used. The program

number (630) for determining TSS was entered by pressing the button. The adjustable node, adjusted to 880nm and the control sample were put into the square box space and the read button was pressed to record the reading in mg/l.

Nitrate

A quality of sample was poured into a test tube and nitrate pillow powder was added, the test tube was covered with its lid and shaken vigorously until the content evened out. This was then be poured into a 25ml spectrophotometer test bottle, the sample was afterwards put into the square box space and the read button was turned on to observe the result in mg/L.

Biological Oxygen Demand

BOD was determined by measuring the amount of oxygen consumed after incubating the sample in the dark at 20 degrees Celsius, for five days. This gave rise to the commonly used term 'BOD5'. The oxygen consumption was determined from the difference between dissolved oxygen concentrations the sample before and after the incubation period. Because the concentration of the organic material in the samples were assumed to be very high, samples were diluted with distilled water prior to incubation so that the oxygen is not totally depleted (UNESCO/WHO/UNEP, 1996).

Total Coliforms

The most probable number (MPN) method was used in determining the coliform aerobic mesophilic bacteria in the samples. Serial dilution of 10^{-2} and 10^{-11} was prepared by injecting 1ml of the sample into 9ml sterile distilled water. One millilitre aliquots from each of the dilutions was inoculated into 5ml of MacConkey broth (1:5) with inverted Durham tubes and incubated at 35°C for total coliforms and 45°C fecal coliforms for 18-24 hours. Tubes showing colour change from purple to yellow and gas collected in the Durham tubes after 24 hours was identified as positive for both total and fecal coliforms. Counts per 100ml were calculated from the appropriate most probable number (MPN) tables with nine test tube readings.

E.Coli (Thermotolerant Coliforms)

From each of the positive tubes identified a drop was transferred into a 5ml test tube of tryptone water. All tubes showing a red ring colour development after a gentle agitation presumptive for thermotolerant coliforms (E.Coli). Counts per 100ml were calculated from the most probable number (MPN) tables with 9 test tube readings.

Total Dissolved Solids (TDS)

This was achieved by use of TDS meter. The electrode was inserted into each sample, the knob on the measuring machine was adjusted at intervals and readings were observed. The knob was continued to be adjusted until the pointer moved to detect a reading, the reading was then recorded and multiplied by number in the rotatable knob.

Statistical data analysis

The results were subjected to statistical analysis using excel 2010. Statistical analysis of the data was done using Analysis of Variance (ANOVA) at $\alpha=0.05$ level of significance. The results of this study were considered as significant when a P value was less than 0.05. PH, Faecal

Coliforms, Total Coliforms, Nitrates, Total dissolved solids, Conductivity, and Turbidity results were the only parameters to be subjected to ANOVA. The ANOVA was used to measure the variation in the concentration of the 7 parameters in the well water.

Results

Laboratory Results for physical, chemical and Biological tests

Laboratory Results For 30th February (1st Results)

DOCUMENT: ChWSSC/QA/001		PHYSICAL/ CHEMICAL LABORATORY ANALYSIS									
 <p>Chambeshi WATER SUPPLY AND SANITATION COMPANY</p>		DATE SAMPLED: 30/02/2023					DATE TESTED: 30/02/2023				
		Revision: 2					Page: 1 of 2				
		Date issued: September 2016					Effective date: September 2016				
Notes: maximum permissible limits SPECIFICATION: ZS 190:2010											
PARAMETER		RANGE		UNIT		PARAMETER		RANGE		UNIT	
1. Residual Chlorine		0.2-0.5		mg/L		7. T. Suspended Solids		0-25		mg/L	
2. pH		6.5-8.5		-		8. Nitrates		0-45		mg/L	
3. Color		<15		hazens		9. Iron		0.1		mg/L	
TEST RESULTS 1											
SAMPLE CODE	SAMPLE LOCATION	T.P (mg/L)	pH	TUR B (NTU)	TSS (mg/L)	TDS (mg/L)	Conductivity (mg/L)	COLOR (HAZEN S)	NO ₃ (mg/L)	Temperature (°C)	REMARKS/R/C L
1	Control Point	<0.01	7.61	0.89	<1.0	322	700	11 hazens	15	22.1	Unsatisfactory
2	Well 1	<0.01	7.34	10.17	<1.0	336	549	9 hazens	55.98	21.5	Unsatisfactory
3	Well 2	<0.01	7.80	3.51	<1.0	344	821	15 hazens	55.04	22.7	Unsatisfactory
4	Well 3	<0.01	7.92	1.44	<1.0	333	638	9 hazens	22.04	23.4	Unsatisfactory
Lab Analyst sign:  Designation: MTENDERE EAST Date: 02/03/2023 SHEQ sign:  Date: 02/03/2023											
COMMENT: All samples failed the laboratory tests.											

DOCUMENT: ChWSSC/QA/002		BACTERIOLOGICAL ANALYSIS									
 <p>Chambeshi WATER SUPPLY AND SANITATION COMPANY</p>		Revision: 2					Page: 2 of 2				
		Date issued: September, 2016					Effective date: September, 2016				
		Membrane filtration method: BACTERIOLOGICAL Notes: Allowable permissible limits SPECIFICATION: ZS 190:2010 ● Volume filtered=100ml, ● Satisfactory (S) means total coliforms ≤3 coliforms and faecal coliforms = 0 ● Unsatisfactory (U) means total coliforms >3 and faecal coliforms >0									
SAMPLE CODE	Sample source	Res Cl ₂ mg/L	Total coliforms per cfu /100ml	Faecal coliforms per cfu/10 Oml	Remarks						
1	Control Point	Nil	58	29	Unsatisfactory						
2	Well 1	Nil	TNTC	35	Unsatisfactory						
3	Well 2	Nil	124	68	Unsatisfactory						
4	Well 3	Nil	TNTC	TNTC	Unsatisfactory						
Lab Analyst sign:  Designation: MTENDERE EAST Date: 02/03/2023 SHEQ sign:  Date: 02/03/2023											

Laboratory Results for 30th March (2nd Results)

DOCUMENT: ChWSSC/QA/001		PHYSICAL/ CHEMICAL LABORATORY ANALYSIS									
 <p>Chambeshi WATER SUPPLY AND SANITATION COMPANY</p>		DATE SAMPLED: 30/03/2023					DATE TESTED: 30/03/2023				
		Revision: 2					Page: 1 of 2				
		Date issued: September 2016					Effective date: September 2016				
Notes: maximum permissible limits											
SPECIFICATION: ZS 190:2010											
PARAMETER		RANGE		UNIT		PARAMETER		RANGE		UNIT	
1. Residual Chlorine		0.2-0.5		mg/L		7. T. Suspended Solids		0-25		mg/L	
2. pH		6.5-8.5		-		8. Nitrates		0-45		mg/L	
3. Color		<15		hazens		9. Iron		0.1		mg/L	
TEST RESULTS 2											
SAMPL E CODE	SAMPLE LOCATION	T.P (mg/L)	pH	TUR B (NTU)	TSS (mg/L)	TDS (mg/L)	Conductivity (mg/L)	COLOR (HAZEN S)	NO ₃ (mg/L)	Temperature (°C)	REMARKS/R/C L
1	Control Point	0.48	8.0	1.10	0.32	250	701	8 hazens	12.17	19.5	satisfactory
2	Well 1	0.84	7.26	6.14	0.69	90	728	5 hazens	33.77	23.7	Unsatisfactory
3	Well 2	0.82	7.44	3.47	0.49	163	530	15 hazens	53.53	23.5	Unsatisfactory
4	Well 3	0.92	7.70	2.29	0.53	255	528	3 hazens	56.44	21.9	Unsatisfactory
Lab Analyst sign:  Designation: <u>MTENDERE EAST</u> Date: 03/04/2023 SHEQ sign:  Date: <u>03/04/2023</u>											
COMMENT: All samples failed the laboratory tests except for the Control Point											

DOCUMENT: ChWSSC/QA/002		BACTERIOLOGICAL ANALYSIS									
 <p>Chambeshi WATER SUPPLY AND SANITATION COMPANY</p>		Revision: 2					Page: 2 of 2				
		Date issued: September, 2016					Effective date: September, 2016				
		Membrane filtration method: BACTERIOLOGICAL Notes: Allowable permissible limits SPECIFICATION: ZS 190:2010 ● Volume filtered=100ml, ● Satisfactory (S) means total coliforms ≤3 coliforms and faecal coliforms = 0 ● Unsatisfactory (U) means total coliforms >3 and faecal coliforms >0									
SAMPL E Code	Sample source	Res Cl ₂ mg/L	Total coliforms per cfu /100ml	Faecal coliforms per cfu/100ml	Remarks						
1	Control Point	Nil	Nil	Nil	satisfactory						
2	Well 1	Nil	TNTC	TNTC	Unsatisfactory						
3	Well 2	Nil	TNTC	TNTC	Unsatisfactory						
4	Well 3	Nil	TNTC	TNTC	Unsatisfactory						
Lab Analyst sign:  Designation: <u>MTENDERE EAST</u> Date: 03/04/2023 SHEQ sign:  Date: <u>03/04/2023</u>											

Laboratory Results for 30th April (3rd Results)

DOCUMENT: ChWSSC/QA/001		PHYSICAL/ CHEMICAL LABORATORY ANALYSIS									
		DATE SAMPLED: 30/04/2023					DATE TESTED: 30/04/2023				
		Revision: 2					Page: 1 of 2				
		Date issued: September 2016					Effective date: September 2016				
Notes: maximum permissible limits											
SPECIFICATION: ZS 190: 2010											
PARAMETER		RANGE		UNIT		PARAMETER		RANGE		UNIT	
1. Residual Chlorine		0.2-0.5		mg/L		7. T. Suspended Solids		0-25		mg/L	
2. pH		6.5-8.5		-		8. Nitrates		0-45		mg/L	
3. Color		<15		hazens		9. Iron		0.1		mg/L	
TEST RESULTS 3											
SAMPLE CODE	SAMPLE LOCATION	T.P (mg/L)	pH	TURB (NTU)	TSS (mg/L)	TDS (mg/L)	Conductivity (mg/L)	COLOR (HAZEN S)	NO ₃ (mg/L)	Temperature (°C)	REMARKS R/C L
1	Control Point	<0.01	7.46	0.48	0.32	153	693	10 hazens	22.77	24.6	satisfactory
2	Well 1	<0.01	7.61	12.60	0.69	51	490	7 hazens	62.71	24.7	Unsatisfactory
3	Well 2	<0.01	7.50	3.60	0.49	52	1048	12 hazens	53.58	24.9	Unsatisfactory
4	Well 3	<0.01	7.47	2.29	1.36	100	490	11 hazens	51.57	24.9	Unsatisfactory
Lab Analyst sign:  Designation: <u>MTENDERE EAST</u> Date: 02/05/2023 SHEQ sign:  Date: <u>02/05/2023</u>											
COMMENT: All samples failed the laboratory tests except for the Control Point											

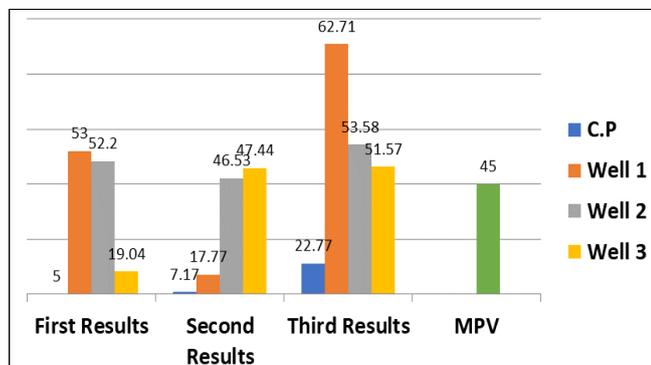
DOCUMENT: ChWSSC/QA/002		BACTERIOLOGICAL ANALYSIS									
		Revision: 2					Page: 2 of 2				
		Date issued: September, 2016					Effective date: September, 2016				
		Membrane filtration method: BACTERIOLOGICAL Notes: Allowable permissible limits SPECIFICATION: ZS 190:2010 <ul style="list-style-type: none"> ● Volume filtered=100ml, ● Satisfactory (S) means total coliforms ≤3 coliforms and faecal coliforms = 0 ● Unsatisfactory (U) means total coliforms >3 and faecal coliforms >0 									
SAMPLE Code	Sample source	Res Cl ₂ mg/L	Total coliforms per cfu /100ml	Faecal coliforms per cfu/100ml	Remarks						
1	Control Point	Nil	Nil	Nil	satisfactory						
2	Well 1	Nil	120	96	Unsatisfactory						
3	Well 2	Nil	165	130	Unsatisfactory						
4	Well 3	Nil	99	87	Unsatisfactory						
Lab Analyst sign:  Designation: <u>MTENDERE EAST</u> Date: 02/05/2023 SHEQ sign:  Date: <u>02/05/2023</u>											

Chemical parameters

This section details the physical parameters that affect the quality of water in the environment. The analysis of the Chemical parameters from the samples obtained from four (4) well sampling points.

Nitrates (NO₃-Nmg/l)

The figure showing variations of Nitrates in comparison to the maximum permissible value of the World Health Organisation standard.

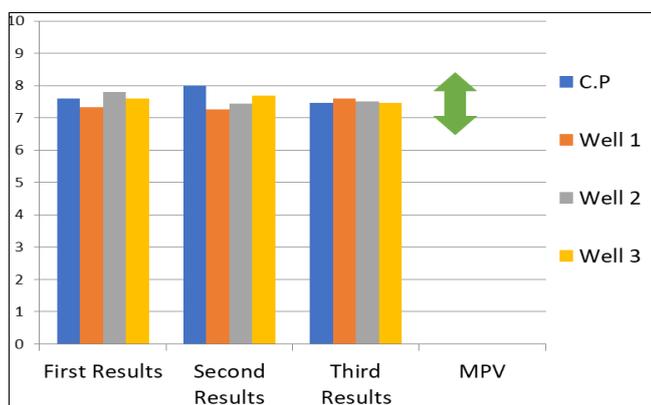


Source (Microsoft office graphical analysis method, 2010)
Nitrates of the first results indicate that the C.P and well 3 were within the MPV, then well 1 and 2 exceeded the range. Second results displays that the C.P and well1 were within the MPV and well 2 and 3 exceeded it and the third results shows that all the 3 wells exceeded the MPV and only the C.P was within it. MPV is 45 (NO₃-N mg/l).

After conducting the ANOVA test, the results showed that there is enough proof that Ho is true since F critical is greater than the F calculated (4.26>0.869) at a significant level of $\alpha=0,05$. This concludes that there are no effects on groundwater quality when Pit Latrines and Wells are in the same area in Mtendere East. Increase in nitrates can be caused by runoff or leakage from precipitated chemicals, fertilized soils and landfills.

PH

The figure below is showing variations in PH



Source (Microsoft office graphical analysis method, 2010)

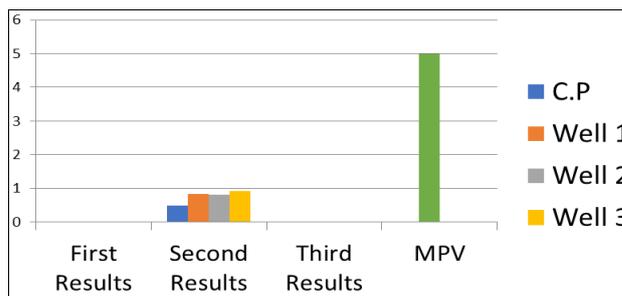
All the samples were within allowable range they ranked from 7.26 to 8.0. Excessively high and low PH's can be detrimental for the use of water. A high pH makes the taste

bitter and decreases the effectiveness of the chlorine disinfection, thereby causing the need for additional chlorine. The amount of oxygen in water increases as pH rises. Low-pH water will corrode or dissolve metals and other substances (Kowalski, 2014).

After conducting the ANOVA test, the results showed that there is enough proof that Ho is true since the F critical is greater than the F calculated (4.26>0.431) at a significant level of $\alpha=0.05$. This concludes that there are no effects on groundwater quality when Pit Latrines and Wells are in the same area in Mtendere East.

Total Phosphates

The figure below showing variations in Total Phosphates



Total Phosphates of the first, second and third results displays that all the three wells and the C.P were within the MPV ranging from 0.01 to 0.92 mg/l, the MPV being 5.0 mg/l. Excessive phosphorous existing in water bodies will cause mass reproduction of algae and death of other organisms. Moreover, the decay and decomposition of algae would deplete the dissolved oxygen in water and lead to eutrophication (X yang, 2008).

After the ANOVA test, the results showed that there is enough proof that Ho is true since F critical is greater than the F calculated (4.26>0.889) at a significant level of $\alpha=0.05$. This concludes that there are no effects on groundwater quality when Pit Latrines and Wells are in the same area in Mtendere East.

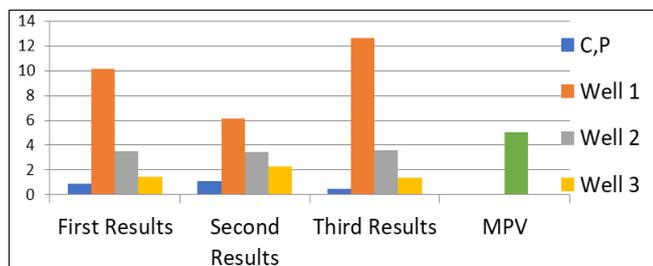
Pollution can modify the PH of water, which can damage animals, plants, humans and other living things that depend and live in water. A PH below 3 or above 10 will kill most fish, and very few animals can endure water with PH below 3 or above 11 (Kowalski, 2014).

Physical parameter

This section details the physical parameters that affect the quality of water in the environment. The analysis of the Chemical parameters from the samples obtained from four (4) well sampling points showing the results for Turbidity and Conductivity.

Turbidity (NFU)

The figure below showing variations of Turbidity in comparison to the maximum permissible value of the World Health Organisation standard.

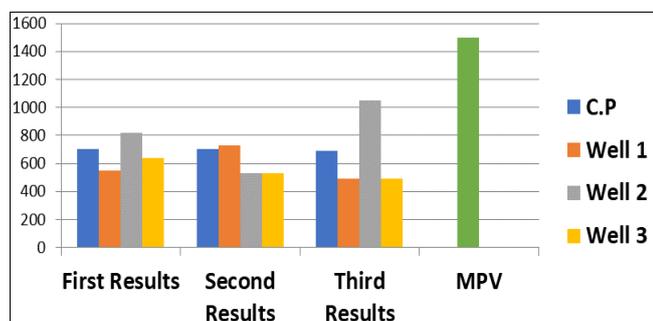


Source (Microsoft office graphical analysis method, 2010)
 The Control Point, well two and three had values of all the samples lying within the permissible limits of the World Health Organisation standards except Well One which had values exceeding the maximum permissible value in all the three samples collected. The fact that not all the samples were collected in the post rain season could be the reason the well one samples recorded high turbidity levels since runoff from rainwater is not excluded. Weather changes affect turbidity, particularly heavy rainfall. The increase in the flow of water during rainy season affects turbidity through the impact of erosion due to rainfall (Gorranson *et al.*, 2013).

After the ANOVA test, the results showed that there is enough proof that Ho is true since F critical is greater than the F calculated (4.26>0.090) at a significant level of $\alpha=0.05$. This concludes that there are no effects on groundwater quality when Pit Latrines and Wells are in the same area in Mtendere East. This simply shows that turbidity can be caused by rainfall runoff, mud and silt, plant pieces, algae and many other debris. The levels of turbidity are usually high during rainy season and low during dry season (Lloyd *et al.*, 1987; Anderson, 2003).

Conductivity (us/cm)

Figure Showing variation in Conductivity



Source (Microsoft office graphical method analysis, 2010)

Conductivity values were lying within the maximum permissible values. Conductivity in the waters of Mtendere East were very low thereby making it suitable for used such as drinking, livestock, and agriculture.

After the ANOVA test, the results showed that there is enough proof that Ho is true since F critical is greater than the F calculated (4.26>0.179) at a significant level of $\alpha=0.05$. This concludes that there are no effects on groundwater quality when Pit Latrines and Wells are in the same area in Mtendere East.

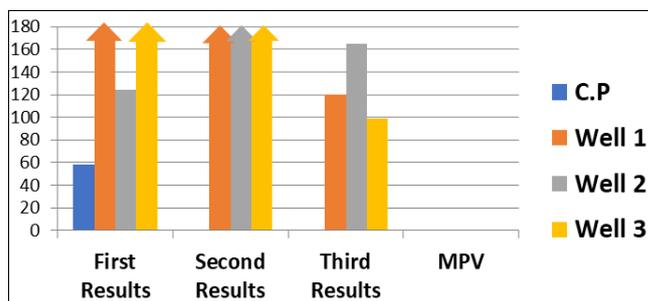
Bacteriological parameter

This section details the bacteriological parameters that affect the quality of water in the environment. The analysis of the bacteriological parameters from the samples obtained from

four (4) well sampling points showing the results for Total Coliforms and Faecal Coliforms.

Total Coliforms (#100/ml)

Figure Showing variation in Total Coliforms



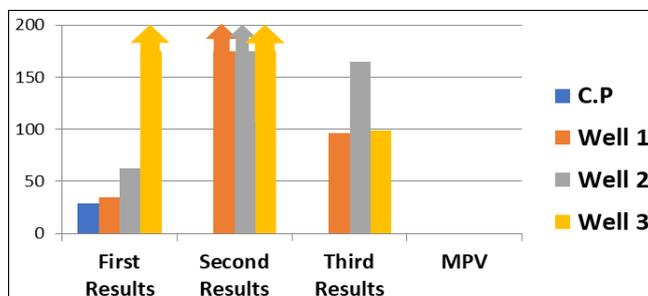
Source (Microsoft office graphical method analysis, 2010)

Total coliforms (T.C):T.C of all the wells including the C.P from the first results tested positive, except the control point from second and third results which tested negative to T.C ranging from 0 to TNTC. A positive total coliform sample should be considered an indication of pollution in your well (New York Centre for health, 2017).

After the ANOVA test, the results showed that there is enough proof that H1 is true since F critical is less than the F calculated (4.26<5.00) at a significant level of $\alpha=0.05$. This concludes that there are effects on groundwater quality when Pit Latrines and Wells are in the same area in Mtendere East.

Faecal coliforms (#100/ml)

Figure showing variation in Total Coliforms



Source (Microsoft office graphical method analysis, 2010)

F.C of all the wells including the C.P from the first results tested positive, except the Control Point from second and third results which tested negative to F.C ranging from 0 to TNTC. Because the origin of faecal coliforms are more general than total coliform group of bacteria, faecal coliforms are considered a more accurate indication of animal or human waste than t After the ANOVA test, the results showed that there is enough proof that H1 is true since F critical is less than the F calculated (4.26<5.530) at a significant level of $\alpha=0.05$. This concludes that there are effects on groundwater quality when Pit Latrines and Wells are in the same area in Mtendere East.otal coliforms. (New York Centre for health, 2017).

Discussion

The general picture of groundwater bacteriological analysis in this study showed that majority of water samples collected from households in Mtendere East were contaminated. These results indicate that households use

water that was not safe for drinking purposes. According to WHO (2003), drinking water from untreated sources like shallow wells is said to be safe when total coliform count is 1 to 10/100 ml and Faecal coliform is not present in 100 ml. This, therefore, indicates that about 90% of households in Mtendere East used water that did not meet water safety standard.

To get an insight of groundwater safety in Mtendere East, relationships between water quality and factors which included distance between water source and Pit latrines, direction of groundwater flow, plot size, water use at household, operation and maintenance of Pit latrines, age of Pit latrines and environment around pit latrines were explored. This was done using ANOVA test (F distribution at $\alpha=0.05$); results of the analysis were presented in tables 7 to 13.

Turbidity results showed that well 1, 2 and 3 from the three sets of sampling results ranged from 6.14 to 10.17 NTU, this exceeded the maximum permissible value of 5.0 NTU, and this could be attributed to the season when the research was done. Weather changes affect turbidity, particularly heavy rainfall. The increase in the flow of water during rainy season affects turbidity through the impact of erosion due to rainfall (Gorranson *et al.*, 2013). Turbidity was found to be relatively low in the rest of the water samples. This should be attributed to the fact that the population is lower that uses the shallow well compared to the rest.

Conductivity is other parameter which recorded values lying within the permissible values. This showed that the effect is too small to be noticed because the results puts the water in the area good in terms of conductivity. Since the electrical current is carried by ions in solution, the conductivity increases as the concentration of ions increases. Therefore, it is one of the main parameters used to determine the suitability of water for drinking, irrigation and fire fighting (Kowalski, 2014).

PH values were all within the maximum permissible values they ranged from 7.26-8.0 which falls in the allowed standards by WHO. The permissible range of values is from 6.5-8.5, the effectiveness of disinfectants such as chlorine used to distract pathogens in drinking water depends on PH. The lower values in PH increase the corrosiveness water thereby putting at risk the pipes that carry water (Kowalski, 2014).

Conclusion

The results of this study revealed the following;(i) only the control point in the second and third results met the WHO drinking water standards (ii) that the majority of Mtendere East residents use pit latrines for human waste disposal as a better alternative to open air urinating and defecation; (iii) that water and sanitation structure in this area is not good; (iv) that inappropriate methods of constructing pit latrines are mostly used; (v) that most pit latrines are constructed close to water sources instead of the recommended spacing of 30m; that there is high presence of total and faecal coliforms in ground water especially in the first sample that was collected during the peak of rain season (vi) that three parameters such as conductivity, PH and Total phosphates were within the range of the MPV; (vii) although the residents of Mtendere East are aware of the threats posed to human health and groundwater quality and the natural environment by pit latrines they still believe that they have no option but to continue using them. These findings led to

the conclusion that although pit latrines affect negatively on the quality of ground water, human health and the natural environment in Mtendere East, total absence of pit latrines would result in greater harm to human health and natural environment. However there is need for residents to take steps to improve on the structures and maintenance of these pit latrines to reduce on the threats to human health and contamination of the natural environment especially ground water.

The ethical evaluation of these findings brought out two positions. On one hand utilitarianism would justify the presence and use of pit latrines in Mtendere East because majority of residents benefit from using them despite some negative consequences associated with some of them and also because of failure to implement more appropriate alternatives regarding human waste disposal. On the other hand, the land ethic would not justify the existence and use of pit latrines because they run the risk of polluting the environment and harming human health thereby disrupting the stability, integrity and beauty of the biotic community. The precautionary principle would support the land ethic in that there is adequate evidence of potential effects to ground water quality, human health and the natural environment at large. The principle of lesser evil helps to resolve the tension by choosing to act on the basis of a choice that although recognized not to be good that is to retain pit latrine is rather better than open air defecation and urinating for the present. Generally the study provided additional information to previous studies with regard to the effects the use of pit latrines on ground water quality, human health and the natural environment at large in Mtendere East compound. Further the research of the findings helped to fill a gap in biological and chemical tests to the existing body of knowledge relating to pit latrines.

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