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Assessment of the Quality of Groundwater for its Suitability for Domestic Use in Chalala East, Lusaka

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Abstract

The use of onsite septic tank systems is the most common method carried out by people that live in Lusaka's forthcoming settlements, in Zambia. Furthermore, water for domestic use is primarily supplied from private boreholes because of the absence of piped water; and lack of municipal sewerage systems in the area is also an issue of concern to this problem.

The Research was experimental in nature and used simple random sampling design in water sample collection. Then water samples were taken to University of Zambia (UNZA) Environmental laboratory for testing. The sample size for the study was 10 water samples but due to limited finance resources only 6 samples were collected. This was based on the consideration of un engineered onsite sewerage systems and unplanned siting of boreholes and septic tanks from one plot to another. A number of households have no idea about groundwater contamination and 95 percent confidence level with 5 percent margin of error. A 50meter Tape measure was used to measure the distance from the borehole to the septic tank, coordinates from where water samples were taken were obtained by GPS locator. A sample size of 6 water samples was drawn from the total households that the researcher used for the purpose of the study which represented the total population. These were sampled randomly. In the study area, 50 percent of boreholes were found to be contaminated with fecal coliforms and total coliforms and 50 percent were found to be contaminated with E coli. Distances between borehole and septic tanks were limited by plot sizes and averaged about 50 percent less than the minimum required distance by WHO. Contamination of groundwater quality calls for rigorous management measures to be put in place by relevant Government authorities to safeguard human health and the environment.

Keywords: Groundwater, Onsite Wastewater Treatment System, Contamination, Total and Fecal Coliforms

1. Introduction

1.1 Background

In many places, particularly in areas with low population densities, it is common to store and treat wastewater onsite where it is produced. To do this, there are a number of technical options for on-site waste management which if designed, constructed, operated and maintained correctly will provide adequate services and health benefits when combined with good hygiene practices. On-site systems include ventilated improved pit latrines, pour-flush toilets and septic tanks WHO, (2015) [31]. A typical on-site wastewater treatment system consists of a septic tank with a soil absorption field that allows treated effluent (settled sewage) to infiltrate into the soil. These systems when functioning well are effective at removing pollutants before they enter into the environment. This process however, depends on certain circumstances such as geological and climatic conditions. The release of pollutants into the environment may result if a septic tank system if improperly sited and constructed according to Obropta and Berry, (2015) [24]. In addition, failure to adequately address issues of wastewater treatment and disposal can also lead to serious public health and environmental problems Goonetilleke, (2012) [16].

Septic tanks and soakaways are suitable means for On-site Wastewater Treatment System (OWTS) when lot size and subsurface conditions offer adequate natural means of reducing pathogenic organisms and organic matter Banda, (2013). Septic tank effluent can also be reduced through evapo-transpiration and also by geological barriers as it is seeping into the aquifer. Groundwater contamination has occurred in many settlements which are utilizing the OWTS because of the discharge of effluent which often percolates into the subsurface and contaminates the aquifer where the boreholes tap from (Ibid).

Groundwater is a vital source of water for human consumption, agriculture, and industry in Lusaka, Zambia. However, the quality of groundwater in Chalala, Lusaka, is a growing concern due to increasing urbanization, industrialization, and agricultural activities Mwansa *et al*., (2019) [23].

Subsurface sewage disposal systems are the largest sources of waste water to the ground and are the most frequently reported causes of groundwater contamination. The likelihood of groundwater contamination by these systems is greatest where septic systems are closely spaced as in subdivided tracts in suburban areas and in areas where the bedrock is covered by little or no soil USEPA, (2017) [27].

Chalala, a peri-urban area in Lusaka, has experienced rapid growth, leading to increased demand for groundwater. However, the area's geology, characterized by karstified dolomites and limestone, makes it prone to contamination as alluded by Kampata *et al*., (2017) [19]. Previous studies have reported high levels of nitrates, bacteria, and heavy metals in groundwater in Lusaka, posing health risks to consumers Mwansa *et al*., (2019) [23].

1.2 Statement of the problem

The city of Lusaka has and continues to experience rapid development of new housing settlements to cater for the ever-growing population. The key challenge is the non-existence of appropriate sewerage infrastructure which if available would be used to convey the household sewage to a suitable treatment facility. Chalala, a new housing area in Lusaka is no exception. Residents have to rely on on-site sewage collection and treatment facilities which results in sewage effluent percolating into the aquifer. The overall effects of this practice are not fully comprehended. Despite the importance of groundwater in Chalala, Lusaka, due to the practice of On-site Wastewater Treatment System there is need for scientific information on its quality. The lack of regular monitoring and assessment of groundwater quality poses a significant risk to human health and the environment.

1.3 objectives

1.3.1 general objective

To comprehensively assess the quality of groundwater in Chalala east, Lusaka, for its suitability for domestic use.

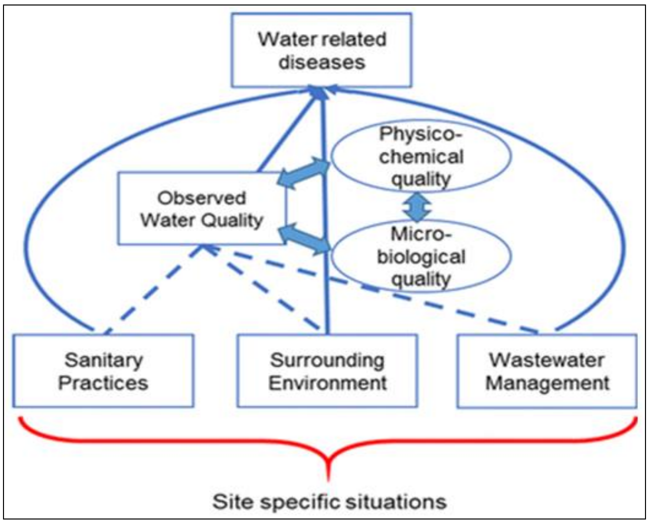
1.3.2 specific objectives

1. To measure if the distance between the borehole and the onsite waste water treatment system are within the recommended measurements.
2. To evaluate the bacteriological quality of groundwater in Chalala, Lusaka, including total coliforms, fecal coliforms, and E. coli.

1.4 Theoretical/Conceptual Framework

The conceptual framework for assessing the quality of groundwater in Chalala, Lusaka, is based on the Driver-Pressure-State-Impact-Response (DPSIR) model European Environment Agency, (2015). This framework is adapted to incorporate the specific context of groundwater quality in Chalala, Lusaka.

Urbanization, population growth, Industrialization and economic development are the major drivers in this framework according to Kampata *et al*., (2017) [19], Increased demand for groundwater, Contamination from onsite wastewater management system, Inadequate waste management and sanitation is pressurizing the ground water resources as alluded by Chewe *et al*., (2015) [8], The state ofGroundwater quality parameters include (physical, chemical, and biological) and theImpacts caused are Human health risk and Environmental degradation according to Kampata *et al*., (2017) [19]. Furthermore, the response should be Groundwater monitoring and assessment, Implementation of mitigation measures (for example wastewater treatment, pollution control), Development of policies and regulations for groundwater management.



Source: University of Maryland, (2015)

Fig 1.1: Conceptual framework

1.5 significance of the study

This study will focus on quality of groundwater in Chalala in relation to onsite wastewater treatment. The major factor that can contribute to the contamination of groundwater is siting boreholes and septic tanks in the same plot area, capacity of septic tanks in Lusaka's Chalala area.

This study has an environmental management system perspective which will bridge the gap with scientifically proven information on the quality of groundwater in Chalala Lusaka Zambia.

The findings of the study will help in sensitizing the stakeholders concerned with aspects of mitigating septic tank wastes from contaminating groundwater. The suggested recommendations will greatly benefit the residents and the country at large by minimizing groundwater contamination.

2. Literature Review

2.0 overview

This Chapter presents the Literature Review in connection with sanitation challenges arising from groundwater contamination caused by effluents from septic tanks. It also reviews literature on septic tanks and parameters affecting groundwater quality. It also reviews the legal and regulatory framework and existing policies in the water and sanitation sector. Septic tanks sometimes referred to as conventional septic tanks are onsite systems used in many parts of the world for domestic wastewater treatment Busan *et al*., (2015) [7]. Their use is not only limited to single households, but also to moderately small institutions or housing compounds of up to 500 people Eko, (2013). High use of septic tanks in Sub-Saharan Africa stems from its simplicity to manage and comparatively low construction costs Sibooli, (2013).

2.1 Septic tanks and aqua privies

A septic tank is a sewage treatment system comprised of the tank and soakaway. The wastewater generated by the household is disposed off in the septic tank where it is retained for one to three days. During retention, the treatment process commences where the solid substance settles at the bottom to form sludge, then the liquid effluent passes on to the secondary disposal system known as soakaway where further treatment takes place. A septic tank is comprised of an inlet and outlet and is usually constructed with two compartments so as to improve the efficiency of sewage treatment. The size is also important as it provides an optimal retention time for the treatment of sewage. The sewage is broken down into heavy solids also known as sludge which settles at the bottom of the tank where it accumulates and increases in thickness. The light solid materials float to the surface to form scum Wickell, (2018) [33].

The digestion process which takes place in the septic tank produces some gases which rise to the surface to join the scum and with time, the scum layer thickens and the surface hardens and can shut down the septic tank, hence the need for pumping out periodically Moving.com, (2018) [22].

Septic tanks are commonly used for the treatment of wastewater from households and may also be appropriate to situations where the volume of wastewater produced is too large for disposal in pit latrines or where conventional sewerage is not economical. The Septic tank systems are reliable and Oduor-free systems. However, they require a reliable water supply, maintenance of waste pipe systems and regular emptying. The major disadvantage is that groundwater pollution from septic tank drainage fields is more likely to occur than from pit latrines because the volume of liquid infiltrated is much greater Health and Social Services, (2017).

Wastes generated from the household flows to the septic tank where it is partially treated. After one to three days of retention, partially-treated effluent flows to a soakaway, where the wastewater is allowed to soak into the soil where the liquid is disposed off and naturally treated at the same time (Ibid).

The aqua privy is similar to the septic tank, the difference being that the tank is located just below or adjacent to the toilet. The water needed for flushing is less as compared to septic tank systems. The cost of construction is low as it utilizes less space and sub-surface drainage for soaking away the effluent is reduced. Furthermore, the quantities of waste pipes used are minimized as they connect directly into the pit. Blockages are less likely and solid anal cleansing material may be used. An aqua-privy is therefore an ideal solution where pit latrines are considered unacceptable. The tank of the aqua privy must be watertight to maintain a constant liquid level. The Advantages of aqua privy are that the latrines are easy to clean, and it is more efficient to empty one big tank than individual pour flush latrines. They are cheaper and require less maintenance than septic tank systems. The disadvantages are that they are difficult to construct, and need a reliable water supply. The tank must have an external access cover and vehicular access, as it will need to be emptied. The site for the tank should not be waterlogged or prone to floodingGrisaru S, (2015).

2.2 Construction, operation and maintenance of septic tanks

Septic tanks are generally constructed from concrete, polyethene (plastic) or fiber glass materials. Traditionally septic tanks are made of reinforced concrete material relative to other materials. The reason being that concrete materials are readily available and lower in cost than alternative materials Datta, B *et al*., (2016) [10]. The material of construction should be resistant or slow to corrosion by hydrogen sulphide gas and other possible corrosive contents, therefore concrete tanks should be regularly inspected to prevent leaks of raw sewage that cause soil contamination and pollution by pathogens EPA, (2017). Contamination of groundwater by failing OWTS may increase concentration of pathogens that may impact on humans Gunady *et al*., (2015) [18]. The size of the tank is technically determined by the number of occupants in the house. For large systems with number of bedrooms more than six or systems other than residential, the tank is to be sized using the following formulae:

$$V \text{ (liters)} = 0.75 * Q \text{ (liters)} + 5100;$$

Where: V is minimum liquid capacity;
:Q is estimated sewage flow per day.

Thus, the volume of septic tank is dependent on the size and type of building to which it will be connected Health and Social Services, (2017).

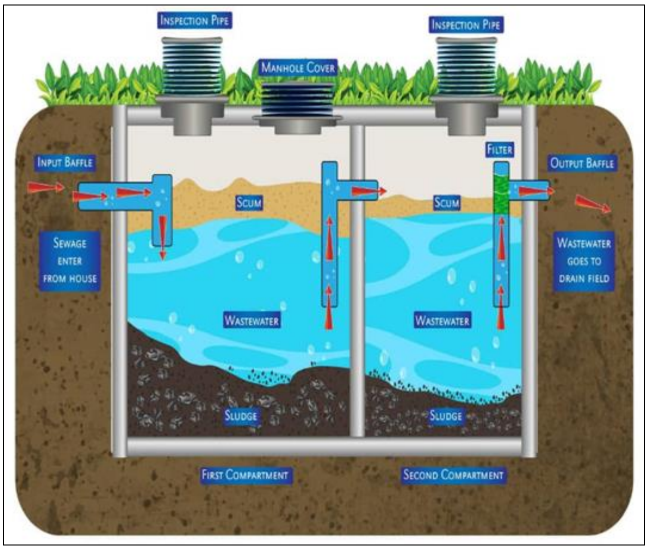
A typical septic tank system may include the following: Sanitary plumbing fixtures, a septic tank, a pumping sump and a soakaway. The operations of a septic tank system requires that household wastes flow to the septic tank using gravity where initial treatment takes place. Then, aerobic bacteria partly break down the sewage within the tank. Heavier solid matter settles at the bottom and forms sludge, whilst light matter floats to the surface and forms scum. Thus, three distinct zones exist within a septic tank, namely: - sludge, clear zone and scum according to Moving.com, (2018) [22].

The effective settling of solids is directly dependent upon the detention time within the tank. Minimum detention time should be at least 24 hours to ensure 60 to 70 percent of the suspended solids are removed and Biochemical Oxygen Demand (BOD) is reduced by 30percent. Therefore, the septic tank should be of sufficient capacity to provide for a 24-hour retention of the daily inflow into the tank.

2.3 The design criteria for a septic tank suitable for a typical residential household are

A minimum daily inflow or hydraulic load of 150 litres per person per day, minimum detention of the daily inflow for 24 hours, sludge/scum accumulation rate of 80 litres per person per year, daily inflow based on not less than six persons, disludging frequency of at least once in three years, or more often where high solid loads are experienced according to EPA, (2017).

Excessive build-up of sludge and scum reduces the capacity of the clear zone, resulting in discharge of untreated sewer to the subsurface. Properly constructed or installed septic tanks and absorption field coupled with proper care and maintenance can mitigate groundwater contamination and provide many years of service [ibid].



Source: University of Maryland, (2015)

Fig 2: Showing Schematic diagram of a septic tank, showing the three layers of a Septic Tank

Sitting of Septic Tank

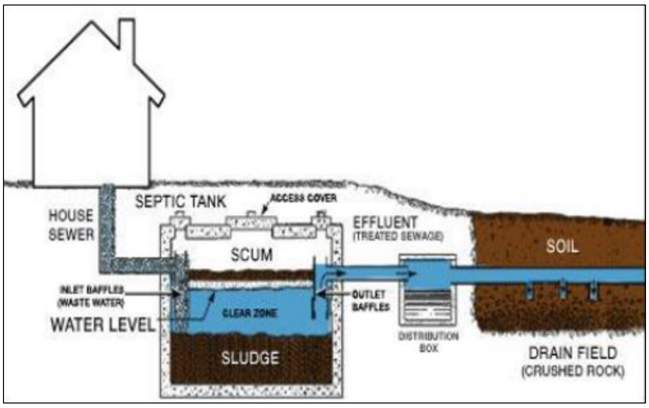
The national building code, gives the guidelines and regulations on sitting of septic tanks and soakaway, such that they should be impervious to liquid. NBR, (2014). Soil evaluation and soil percolation tests should be considered as factors for sitting the septic system. The site evaluation is the first step towards installing a septic system and involves gathering detailed information about the lot and the surrounding area. This information includes the topography, separation distances, owner's preferences, physical properties of the soil, existing water sources and the depth to any limiting layer. The most important factor in determining whether an onsite system will work on a particular site is the soil properties and the soil's ability to treat and dispose the wastewater according to Goulding, (2016).

2.4 Mechanism of Groundwater Contamination

Point sources of pollution are described as those that are readily identifiable and typically discharge water through systems of pipes, but non-point sources originate from a wider area Mali *et al*., (2015) [20]. Septic tank systems are a non-point source. Comparison with streams or rivers, the flow of groundwater is very slow and has very little turbulence or mixing. As a result, when a contaminant enters into the groundwater, it is not disturbed. It forms a flux of high concentration of the contaminant within the fluid (a plume) that flows along the same path as the groundwater. Among the factors that determine the size, form, and rate of movement of the contaminant plume are the amount and type of contaminant and the speed of groundwater movement (Ibid). The contaminant plume is often found down-gradient from a point source of pollution, not easily noticed and can stay in the water even for years until the water is abstracted from the borehole. Size and speed of plume depends on the amount and type of contaminant, its solubility and density, and the velocity of the surrounding water.

Groundwater and contaminants can move rapidly through fractures in rocks. Also, groundwater can become contaminated from natural sources or numerous types of human activities: Residential, municipal, commercial, industrial, and agricultural activities can all affect groundwater quality. Furthermore, the size of a community that produces unacceptable groundwater pollution is determined by many factors which are: The number and size of infiltration systems, The depth to the water table, Soil and rock conditions within and above the aquifer, the aquifer depth and groundwater flow rate and direction by Datta *et al*., (2016) [10].

If the Septic Tank-Soil Absorption System (ST-SAS) in developed settlements are not located properly, poorly built or unmaintained, they can allow contamination of groundwater by synthetic detergents, anions, cations, bacteria and viruses. In isolation, an individual ST-SAS has got no impact as far as contamination to groundwater is concerned Mbugua, (2016) [21]. When considered collectively, the number of such systems and their wide spread use in every area that does not have a public sewage treatment system makes them serious contamination sources US EPA, (2015) [25].



Source: University of Maryland, (2015)

Fig 2.1: Septic system showing mechanism of groundwater contamination by a septic plume below the soak pit

2.5 Total coliforms, faecal coliforms and E. coli bacteria in groundwater

Total coliforms and Feacal coliforms are main indicators that the groundwater is contaminated. Coliform bacteria are described and grouped, based on their common characteristics, as either Total or Feacal Coliform. The Total group includes Fecal Coliform bacteria such as Escherichia coli (E. coli), as well as other types of Coliform bacteria that are naturally found in the soil. Fecal Coliform bacteria exist in the intestines of warm-blooded animals and humans, and are found in bodily waste, animal droppings, and naturally in soil. The British Columbia Groundwater Association, (2007).

Table 2.1: Shows the Scale of measure of bacteriological water quality

Parameter	Indicator	Scale of measure	
Bacteriological water quality	No. of feacal coliforms (E. coli) in 100ml of water	Nil	Satisfactory
		Any presence	Unsatisfactory
	Total coliforms in 100ml of water	0 to 10 cells	Satisfactory
		More than 10 cells	Unsatisfactory

Source: UNHCR (2016)

3. Research Methodology

3.0 overview

This Chapter presents the approach and methodology which was used in this study. Initially, Literature was reviewed in detail with respect to groundwater contamination from septic tanks. Information and data available from scientific research reports and organizational reports available in Zambia were also reviewed, then field observations will be done in Chalala.

Study area

Lusaka stands at 1,280m above sea level and is overlain by flat topped hills marking prominent quartzite horizons. Dolomite and limestone form flat lying area, where as schist and quartzites underlie more broken, hilly country and the order quartzites in particular form extensive ridges several metres high. Schist-dolomite boundaries are usually indicated by steep downward slopes from schist to dolomite. The general topography is important especially in the mitigation of groundwater contamination involving septic tank systems. Flat terrains make it difficult to drain and the area becomes vulnerable to flooding Source: ADB, (2015) [1].

Topographic map

Chalala is a suburb in Lusaka Province, Zambia. Chalala is situated nearby to the suburb New Woodlands Extension, as well as near Chandamali.

Source: Google earth map

3.1 Research design

The Research was descriptive in nature. Then field observations which included laboratory testing of water samples for contamination, the idea was to collect facts about various parameters on groundwater contamination from septic tank effluents. Document review was carried out based on scientific research reports, publications and reports from organizations in Zambia.

3.2 Sample size

To determine an appropriate sample size for assessing the quality of ground water in Chalala. The researcher only managed to collect a maximum number of six samples randomly for laboratory analysis.

3.3 Sampling design

The research design that was used in water sampling is Simple random sampling which is a probability sampling method where every member of the population has an equal chance of being selected for the sample, and the selection is done in a way that is independent of any other characteristic of the population as alluded by Sarantakos, (2020).

In simple random sampling: Each member of the population has an equal probability of being selected. The selection is done randomly, without any bias or systematic pattern. The sample is representative of the population, with no inherent patterns or correlations.

3.3.1 Tools

1. Geographic Information System (GIS) software such as ArcGIS to create maps.
2. Global Positioning System (GPS) devices to locate sampling sites and record coordinates.
3. Measuring tape.
4. Water sampling bottles (Sterilized).

3.4 Study parameters

Measurement of physical, chemical,and biological parameters. parameterspH, turbidity, electrical conductivity, temperature, TDS, chemical and bacteriological parameters for E. coli and total coliforms concentrations were determined in the laboratory..' Chloride, nitrate, and faecal coli forms are the indicator parametersused to assess impact of onsite sanitation systems by most of researchers Ormrod, (2018). Also, Sarantakos, (2020) alludes that: To assess the influences of sanitation facilities on the quality of ground water of Chalala, the study focused mainly on analysis of chemical and biological parameters (Chloride, Nitrates Faecal and Total coliforms).

3.5 Data collection methods

The quality of groundwater is the main subject of investigation. Groundwater samples were collected and analyzed in the laboratory to ascertain its bacteriological quality, physical and chemical parameters. The table below presents information of the collected water samples including sample number, GPS coordinates, distance from the borehole to the septic tank and the soakaway.

A non-probability (purposive sampling) procedure was chosen since the assessmentof groundwater would be done for the available boreholes. Purposeful sampling is a technique widely used in qualitative research for the identification and selection of information-rich cases for the most effective use of limited resources Bryman (2015). Purposeful sampling is widely used in qualitative research for the identification and selection of information-rich cases related to the phenomenon of interest Sampling was done in the morning,mid-day and in the afternoon forconvenience purposes; the procedure was not affected bypeak or nonpeak hours since pumps are not switched off, they run continuously. The process of water sampling was aided by Quality Assurance Officer (lab Tech)from UNZA laboratoryy.Water samplings from 6 boreholes were done according to the processes in Bryman (2015).

Sampling from the Taps

The procedure involved grab sampling in sterilised350 mills glass bottles, packed in cooler box then transported to the laboratory for testing.six (6) samples were collected from each borehole, in the morning, afternoon and evening the samples were taken to UNZA laboratories the same day. Care was taken in ensuring that the samples were representative of the source and handled carefully so that no contamination occurred before testing. The Tap on raising main above the borehole covers were fully opened, to allow stagnant water to run out for a period of time, then the flow was adjusted to a fine stream and the sample was collected.

Table 3.1: Showing coordinates and distances

Sample No.	GPS coordinates		Distance from borehole to septic tank in meters	Distance from borehole to soakaway in meters
	Lat (X)	Long(Y)		
1	-15.47395	28.34844	15 m	20m
2	-15.47964	28.35372	28 m	34 m
3	-15.48349	28.35047	15 m	19 m
4	-15.48741	28.20474	9m	7.6m
5	-15.48961	28.34973	26m	31m
6	-15.49969	28.34973	12 m	9 m

3.6 Data analysis

Statistical data analysis

The results were subjected to statistical analysis using excel. Statistical analysis of the data was done using Analysis of Variance (ANOVA) and Regression Analysis. TSS, TDS, and faecal and total coli forms results were the only parameters subjected to ANOVA as they are the indicator parametersused to assess impact of onsite sanitation systems by most of researchers according to Lawrence, (2011).

The ANOVA was used to measure the variation in the concentration of nitrate and microbial contaminants inboreholes and tap water. The regression analysis was used to compare the relationship between the distance between the water source and sanitation facilities.

Analysis of Variance(ANOVA)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares (MS)	F
Within	$SS_w = \sum_{j=1}^{k}\sum_{j=1}^{l}(X - \bar{X}_j)^2$	$df_w = k - 1$	$MS_w = \frac{SS_w}{df_w}$	$F = \frac{MS_b}{MS_w}$
Between	$SS_b = \sum_{j=1}^{k}(\bar{X}_j - \bar{X})^2$	$df_b = n - k$	$MS_b = \frac{SS_b}{df_b}$	
Total	$SS_t = \sum_{j=1}^{n}(\bar{X}_j - \bar{X})^2$	$df_t = n - 1$		

The ANOVA also measures the total variation among observations. It measures two sources of variation in the data and compares their relative sizes: First the total sum of squares was calculated.

$$SS_{total} = \sum_{j=1}^{n}(\bar{X}_j - \bar{X})^2$$

Variation Between Groups: For each data value this looks at the difference between its group mean and the overall mean using the following formula.

$$SS_{between} = \sum_{j=1}^{k}(\bar{X}_j - \bar{X})^2$$

Variation between groups

Where

x = mean for entire data set

i x = mean for group i

i = the group

Variation within groups: For each data value we look at the difference between that value and the mean of its group and it is found by the following equation

$$SS_{within} = \sum_{j=1}^{k}\sum_{j=1}^{l}(X - \bar{X}_j)^2$$

Where

xij= value for individual *j* in group *i*

i x = mean for group *i*

Regression Statistics					
Multiple R	0.03184128				
R Square	0.00843482				
Adjusted R Square	- 0.23945647				
Standard Error	4.4926373				
Observations	6				
ANOVA					
	Df	*SS*	*MS*	*F*	*Significance F*
Regression	2	9.255392	9.255392	0.034026	0.862625406
Residual	4	1088.028	272.0071		
Total	6	1097.284			

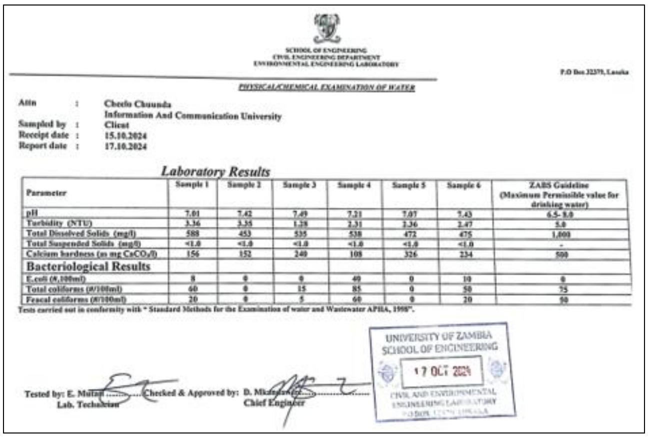
4. Presentation of Research Findings and Discussion of Results

4.0 Overview

This chapter presents the results in accordance with the objectives of this study based on the approach and methodology from chapter 3. It presents data collected from the study area. The initial data presented was a topographic map which highlighted the sampling sites and GIS data. Then data obtained through questionnaires from the respondents was presented. Finally, the process flow chart was developed from which the frame work for mitigating the effects of septic tank effluents from households on groundwater quality was developed.

4.1 bacteriological analysis

The general picture of groundwater bacteriological analysis in this study showed that half (50% percent) of groundwater samples collected from boreholes at households in Chalala were satisfactory, and the other half (50%) percent were unsatisfactory. These results indicate that some households used groundwater that was not safe for drinking purposes. According to WHO (2018) [32], drinking water from untreated sources like boreholes is said to be safe when total coliform count is 1 to 10 per 100 ml, faecal coliform count is 0 in 100 ml and E. coli is not detected. This therefore, indicates that about 50 percent of the sampled households in Chalala use groundwater for drinking and domestic purposes that is not safe.



SCHOOL OF ENGINEERING
CIVIL ENGINEERING DEPARTMENT
ENVIRONMENTAL ENGINEERING LABORATORY

P.O Box 32379, Lusaka

PHYSICAL/CHEMICAL EXAMINATION OF WATER

Attn : Cheelo Chuunda
Information And Communication University
Sampled by : Client
Receipt date : 15.10.2024
Report date : 17.10.2024

Laboratory Results

Parameter	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	ZABS Guideline (Maximum Permissible value for drinking water)
pH	7.01	7.42	7.49	7.21	7.07	7.43	6.5-8.0
Turbidity (NTU)	3.36	3.35	1.28	2.31	2.36	2.47	5.0
Total Dissolved Solids (mg/l)	588	453	535	538	472	475	1,000
Total Suspended Solids (mg/l)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	-
Calcium hardness (as mg $CaCO_3$/l)	156	152	240	108	326	234	500
Bacteriological Results							
E.coli (#/100ml)	8	0	0	40	0	10	0
Total coliforms (#/100ml)	60	0	15	85	0	50	75
Feacal coliforms (#/100ml)	20	0	5	60	0	20	50

Tests carried out in conformity with "Standard Methods for the Examination of water and Wastewater APHA, 1998".

Tested by: E. Mutati .... Lab. Technician
Checked & Approved by: D. Mkandawire .... Chief Engineer

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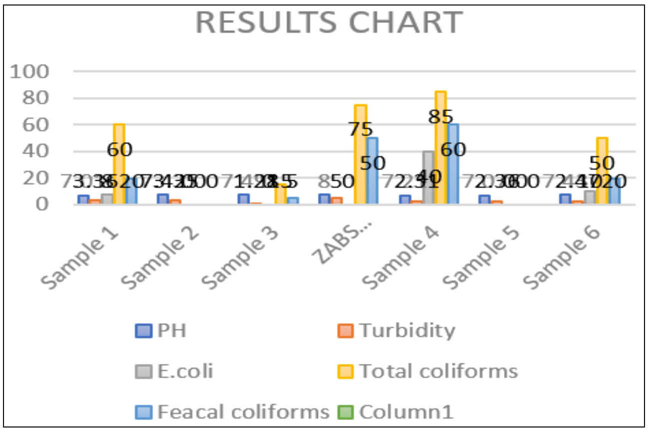
Fig 4.3: Showing laboratory results

The figure below summarizes laboratory results compared to Zambia Beaure of standards

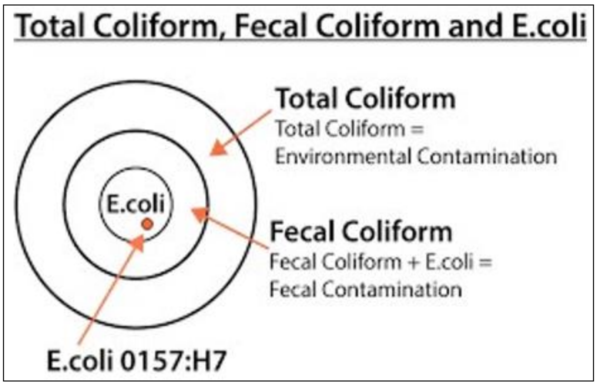


According to Gunady, *et al*., (2015) [18] 80 percent of sicknesses and deaths among children in the world are caused by unsafe drinking water. WHO (2017), also states that on average, every 8 seconds in the world, a child dies as a result of contaminated water intake. Zambia and Lusaka in particular is not exceptional; if this practice is allowed to go on without taking corrective measures, morbidity and mortality due to waterborne infections that have been highlighted at global level as a result of drinking contaminated water may even get worse locally.

About E. Coli

According to Grisaru *et al* (2017) [17]. Escherichia coli (E. coli) bacteria normally live in the intestines of healthy people and animals. Most types of E. coli are harmless or cause relatively brief diarrhea. But a few strains, such as E. coli O157:H7, can cause severe stomach cramps, bloody diarrhea and vomiting.

The figure below summarize type of contamination of ground water



Source: University of Maryland, (2015)

Problems associated with poor sanitation in Zambia

WSP, (2012) [35] reported that Zambia loses 1.3 percent of Gross Domestic Product (GDP) due to poor sanitation, which results in illnesses and premature deaths. In addition, the economic burden of inadequate sanitation falls mostly on the poor who usually have inadequate sanitation facilities WSP, (2012) [35].

Furthermore, Lusaka is suffering from a sanitation crisis that claims lives through annual outbreaks of cholera, typhoid and dysentery. About 70 percent of Lusaka's urban residents live in peri-urban areas, which are comparatively high density, unplanned and comprised mainly of low-income residents. Additionally, an estimated 90 percent peri-urban areas rely on pit latrines and the remaining 10 percent use septic tanks, sewer systems or defecate in the open area ADB, (2015) [1]. [But in Chalala specific 99 percent of residents use septic tanks from what the researcher observed when collecting water samples]. In addition, 57 percent of Lusaka's water supply comes from groundwater sources which are prone to contamination through fissures in the underlying rock (Ibid). [For chalala 95 percent of the population depend on ground water for all the uses of water except 5 percent that buy water for drinking].

Moreover, susceptible areas coincide with low-income neighborhoods, making OWTS an attractive sanitation option in these areas. Despite widespread consensus regarding the need to construct sewers, the city has been reluctant to shoulder investment costs which are relatively high as compared to the OWTS (Ibid).

5. Conclusion

This study established that 50 percent of boreholes sampled in Chalala had water that was safe for drinking purposes and 50 percent of boreholes were contaminated with bacteria that were pathogenic in nature. This implies that 50 percent of households were at risk of contracting waterborne diseases such as Cholera, Dysentery, Typhoid and other diarrheal diseases. This study further revealed that there was a relationship between distance from borehole to soakaway and the quality of groundwater in chalala. There could be attributed to other factors that might have influenced the quality of groundwater such as geological formation (presence of fissures and rocks) that need further investigation.

Despite the existence of policies and guidelines for constructions and designs of septic tank systems in relation to boreholes and septic tank distances, compliance was non-existence and also enforcement by the relevant authorities was lacking.

For enhanced assessment of the quality of ground water and mitigation of groundwater contamination; it is imperative that all stakeholders in the water sector start coordinating and convening meetings to raise awareness (educate residents) on the importance of ground water quality maintenance and monitoring, and diseases (public concern) related to ground water contamination in order to achieve the objectives of mitigation of groundwater contamination.

Since 50 percent of the samples collected and examined are contaminated with E. coli, the researcher rejected the Null (H_0) hypothesis and conclude that; There is a relationship between the quality of ground water and occurrence of waterborne diseases in chalala.

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