Impact of On-Site Sanitation and Siting of Boreholes on Ground Water Quality in Choma Urban: A Case of New Kalundu and Humba Residential Areas.

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ABSTRACT

Groundwater is a climate–resilient source of freshwater for most sub–Sahara African countries and plays a vital role in sustaining improved access to safe water in pursuit of United Nations Sustainable Development Goal 6 – water and sanitation for all by 2030. However, the potential for on-site sanitation to cause major contamination to groundwater has been known for many years, prompting authorities to advise minimum safe distances between boreholes (water sources) and soakaway. This study evaluated the effects of on-site sanitation and borehole placement on the quality of groundwater in residential areas. The study employed an embedded mixed methodology with a descriptive cross-sectional approach. 138 household heads were involved in the study and 15 water samples were collected for microbiological analysis. Data from households was collected using structured questionnaires while upholding all ethical issues. The study found that 85% of households used on-site sanitation systems as their primary means of waste treatment and disposal, while the remaining 15% used other methods like pit latrines. Due to the utility company's unstable and unreliable supply of water, residents turned to alternative sources of drinking water, such as drilling boreholes and hand-dug wells within and around compounds, using soakaway systems for waste disposal close to the drinking water source. The chi-square tests revealed that the position of the soakaway, as well as the distance between the water sources and the soakaway, have an influence on water quality. The study concluded that establishment of water sources near any pollution source (soakaway) has a negative impact on the quality of groundwater resources. We recommended that local authorities should not permit construction at any plot less than 30 x 30 meters in its dimensions to have both borehole and on-site sanitation system but rather one of the two.

Key Terms: Borehole, On-site Sanitation, Water Quality, Residential, Soakaway, Knowledge

BACKGROUND

It is envisioned for every city to provide its residents with access to water to ensure public health, a productive economy, and environmental sustainability. However, two associated trends are complicating this task for cities now and into the foreseeable future. Firstly, the United Nations posits that urban population is growing and expected to reach 6.68 billion by 2050, with 5.56 billion of this urban population residing in the world's less developed regions (UN DESA, 2019). Second, climate change is threatening the sources and availability of urban water supplies (Abell et al., 2017, Intergovernmental Panel on Climate Change, 2014, McDonald et al., 2014). These two trends have increased the pressure on cities to plan and manage their entire water cycle—from source protection, to water access and use, to reuse and safe disposal.

Groundwater is a climate–resilient source of freshwater for most sub–Sahara African countries (Cuthbert et al. 2019), and plays a vital role in sustaining improved access to safe water in pursuit of United Nations Sustainable Development Goal 6 – water and sanitation for all by 2030. The strategic importance of groundwater in urban areas lies in: its lower vulnerability to contamination relative to surface waters reducing treatment costs, and its capacity for phased investment (Adelana and MacDonald 2008; Foster et al. 2018; Olago, 2019). The last 20 years have seen substantial growth in the use of groundwater in towns and cities across sub–Saharan Africa, both alone (e.g. Dodoma, Tanzania) and in conjunction with surface water (e.g. Cape Town, South Africa; Dar es Salaam, Tanzania) (Taylor et al. 2004; Laworth et al.2017 Gaye & Tindimugava 2019; Oliver & Xu 2019).

The proportion of urban dwellers in sub-Saharan Africa served by piped water supplies has declined over the last three decades (Tucker et al, 2014; Foster & Chilton 2017), whereas the proportion of on-site sources or self-supply has risen considerably (Healy et al. 2018). Zambia's population, for example, is quickly rising, notably in Choma, which was designated as the Provincial Capital of the Southern Province in 2011. This has led to public health services as treatment of sewage and supply of water being detrimentally affected. Choma's population has grown steadily during the last few decades. In 2000, the population was 180, 673, and it climbed to 204, 898 in 2010 (Zambia Statistics Agency, 2010). Zamstats (2022), showed that the population of Choma had grown to 266, 916, a phenomenon that could be attributed to the migration since it was declared a provincial capital of Southern Province.

Although it has emerged as a favored way of sanitation in places undergoing fast development due to the high expenses associated with off-site sanitation, on-site sanitation poses a danger to groundwater quality. Further. Parker and Carlier advanced that this technique has put a significant strain on groundwater, particularly its quality (Parker and Carlier, 2009). Septic tank effluent disposal is a possible source of bad odor, mosquito breeding, and health problems. One source of groundwater contamination is leachate from on-site sanitation systems (WHO, 2006). Chemical pollutants and harmful germs generated by these on-site sanitation systems are passed into nearby groundwater sources via soil, posing a danger. The issue is especially serious in densely populated areas when on-site sewage and groundwater are extremely near to each other. This is because drinking water is scarce in practically all peri-urban parts of the nation, water must be conserved (ZDHS, 2017). Roy (2020), adds that septic tanks are often employed in low-density residential areas, and establishments like schools and hospitals. The sewer generated is more for septic tanks to handle when using ordinary sewage is neither feasible nor inexpensive, septic tanks may be the best option. The wastewater may just consist of toilet waste (sewage) or may also contain sullage, commonly known as "greywater," which is waste water from the kitchen, laundry, and bathrooms. Despite being a dependable and odorless system, septic tanks still need frequent emptying, upkeep on the waste pipe lines, and a steady supply of water. This is particularly not efficient due to poor access and costs involved in emptying.

The risk to groundwater quality derives from fecal effluent, rich in organic nitrogen (urea: $CO\ (NH_2)$, chloride, and pathogenic microorganisms, that drains from on-site sanitation into the surrounding soil. Mineralization of this organic nitrogen (i.e. nitrification) then produces substantial concentrations of nitrate in the leachate (Harman et al. 1996; Buss et al. 2005). When soakaway are located within 30 meters of boreholes, the pollution effect levels are higher, resulting in soil saturation and, as a result, lower filtering. Mbunga (2016), septic tank systems in Ongata Rongai, Kenya are a source of nitrates, chlorides, salt, sulfates, and E. *coli*. The impact of septic tank distance on pollutant concentrations decreases as distance from the septic tank system increases.

In Zambia, septic tanks and soakaway are mostly utilized in locations that do not have access to traditional sewer treatment ponds. Domestic effluent treatment technologies such as septic tanks and soil absorption systems (ST – SAS) are used in every urban development that poses a danger to groundwater pollution (Mumma et al., 2011). Choma has continued to experience establishment of new residential areas and population growth. The Southern Water and Sanitation Company (SWASC) 2022, posited that 88% of Choma's population uses on-site sanitation and 12% is connected to the sewer line. The key difficulty in the new settlement areas (Humba and New Kalundu – study areas) is the lack of sufficient sewerage infrastructure and residential property sizes for both a borehole and a soakaway.

This implies that home sewage is disposed of through septic tanks, creating a significant hazard to ground water from boreholes used for domestic purposes. As a result, the concern is that there is continual effluent dumped into the aquifer without any examination of the effects on the health of inhabitants who utilize groundwater for household purposes. This issue implies that individuals are not aware of the requirements that must be followed to ensure that septic tank effluent does not affect groundwater. If rules are not followed, Choma may face severe and deadly epidemics of avoidable diarrheal illnesses.

The Water Resource Management (Groundwater and Boreholes) Regulations, 2018 of the Zambian Laws require a minimum distance of 30 meters between the soakaway and the water abstraction point. However, the potential for on-site sanitation to cause major contamination to groundwater has been known for many years, prompting some to advise minimum safe distances between boreholes (water sources) and soakaway. However, septic tanks have problems with sludge discharge and frequent cleaning. In urban areas, where there are more households and public restrooms, 2.1 billion people use toilets connected to septic tanks that are not properly emptied or other systems that discharge raw sewage into open sewers or bodies of surface water (WHO, 2013).

However, evidence of inadequate enforcement of norms to advise residents that sewer from septic tanks is prevented from contaminating groundwater Word Bank (2015). Reason being lack of knowledge about the impact of septic tank systems on groundwater quality. WHO (2013) posits that poor drinking water causes 80% of all illnesses and deaths among children worldwide. It further said that every 8 seconds, a kid dies in the globe as a result of drinking polluted water, and Choma is no exception. As a result, if this practice is allowed to continue without remedial actions, the disease and fatalities that have been ranked will continue to pollute water (WHO, 2013).

Furthermore, no known investigations on the quality of subsurface water have been undertaken in Choma since it is assumed that borehole water is safe without considering the usage of a septic tank and soakaway in the same region. The study was intended to evaluate the impacts/effects of on-site sanitation and borehole placement in the same location on ground water quality in Choma urban districts, as Choma, the provincial capital of Southern Province, is quickly increasing at a rate faster than planned.

METHODS AND MATERIALS

Research Design

The study was an Embedded Mixed Methods (Quantitative and Qualitative) employing a Descriptive Cross-Sectional Design in nature, with respondents chosen from a fixed point in time. For the quantitative portion of the study, a survey in the form of a water sampling form with observational notes on it was utilized, and for the qualitative portion, a questionnaire was used. Water quality was the main focus of the inquiry; thus, water samples were obtained, examined in a laboratory to determine the microbiological quality, and the results were rated as satisfactory or not satisfactory. Data on groundwater and potential risk factors were gathered to ascertain the quality of the groundwater. The study's potential risk variables included the location of the soakaway in regards to the distance between boreholes and on-site sanitation and direction of groundwater.

Research Setting

The study was done in Choma Urban; New Kalundu and Humba areas. Purposively, the selection of the study site was based on the use of soakaway for human waste treatment and boreholes for water supply. The study population included 366 households with boreholes in New Kalundu and Humba areas. These are new settlement areas in Choma Urban established due to population growth from migration since it was declared a Provincial Capital for Southern Province in 2011.

Participants

The household sample from New Kalundu and Humba areas was selected using systematic random sampling method. The sample size was arrived at using a probability method of sampling which was followed by systematic sampling of households. The sample size was calculated using Dobson's Formula from 366 households with boreholes and an expected frequency of 10% (bacteriological contamination of groundwater). A sample size of 138 households was found at 95% confidence interval which was assumed to be equal to the number of boreholes as tabulated below;

$n= Z^2 \times P\ (1 – P)/d^2$

Where; n = the required minimum sample size

Z = the (Z – score) standard normal value at the level of confidence desired usually at 95% confidence level

P = the estimated prevalence of an indicator (proportion in a population)

d = absolute error/precision

$Z = 1.96$

$P = 20\%\ (0.20)$

$d = 0.05$

$\mathbf{n = Z^2 \times P\ (1 – P)/d^2}$

$n = 1.96^2 \times 0.10\ (1 – 0.10)/0.05^2$

$= 138.2976$

n = 138 respondents

The study locations include a sample size of 138 homes. However, due to limited resources, 15 samples of borehole water were collected from the predicted sample size, with every ninth household selected. This simply means that households matching to numbers 1 through 9 were drawn to identify the beginning point, and every ninth house was chosen.

The 15 samples were selected from the worst-case scenario of half of the homes in the research regions failing to meet the stated requirements for avoiding groundwater pollution at a 95% confidence level with a

5% (0.05) margin of error.

Every household with a septic tank and soakaway for wastewater treatment and a borehole for drinking water was considered for participation in this study. We also allowed for voluntary participation in the study through working only with those that consented after providing through information about the study and the need for them to support our study. We concentrated on heads of households in the homes we visited while only accommodating adult members of the household in the absence of heads of households. On the other hand, we excluded all households without on-site systems and boreholes. Visitors, children below the age of 18 years and those that did not consent to participating in the study were excluded.

The majority of the study participants were females (71.7%) while males were only (28.3%). Most of the respondents were aged between 18 – 25 years (64%) while (36%) were aged between 26 – 33 years. (43.3% of the respondents had secondary education, (29%) have tertiary education while (21.7%) had primary education.

Data Collection Procedure

Ethical approval was obtained from the University of Lusaka Research Ethics Committee and permission from relevant authorities. Choma Municipal Council gave permission, and household owners' permission was obtained and asked them to sign a consent form. Anonymity, confidentiality, and privacy was maintained during and after data collection since the identities of persons who participated in the research during sampling were not to be revealed. The objective, nature, and advantages of the research were conveyed to the participants who are the owners of the houses, ministry of health staff, local authority staff and water utility staff. The laboratory results of the water analysis were made available to participants so that appropriate action may be taken if their water was found to be contaminated with fecal coliforms and unsafe for drinking.

We used two approaches for data collection keeping in mind the two different datasets we needed for this study. The first approach involved collection of water samples from households. A total of 15 households with boreholes had their water sampled for laboratory testing. Aseptic procedures were complied with to ensure the biological results were representative of the source from which we sampled the water and not introduced by the sample collector or contamination of the tap or spout of the mono pump. We first washed our hands with running water and hand soap. In the absence of clean water for handwashing, we used alcohol-based hand rub popularly known as hand sanitizer. Once our hands were made safe for the sample collection, the tap and borehole spout were sterilized using a cotton wool dipped in methylated spirit held by forceps. The water tap was opened after being sterilized with a flame created by cotton wool soaked in methylated alcohol for 30 seconds.

300ml of water was collected into sterile bottles prepared by the Veterinary Medicine Laboratory at the School of Veterinary Medicine domiciled at The University of Zambia in Lusaka. To ensure that the water samples arrive at the Veterinary Medicine Lab in the same state as when they were collected, they were transported in a chilled box with frozen ice packs. In addition to water samples, knowledge on on-site sanitation was measured, environmental conditions surrounding soakaway, and groundwater flow direction was verified using a checklist. Water was tested from 15 borehole-equipped residences.

This was to guarantee the distance between the soakaway and boreholes as suggested by the World Health Organization (WHO) by physically measuring the distance using a 100-meter tape. Furthermore, a questionnaire was distributed to the 138 selected borehole homes in order to collect information on the soakaway and boreholes usage.

Data Processing and Analysis

Information was reviewed for completeness and internal consistency throughout data processing. A computer software Stata Version 14.2 was employed to enter and analyze data. When the microbiological water analysis findings and observations from the checklist were entered into the program, they were numerically coded. Descriptive statistics and the Pearson Chi Square Test were used to examine the relationship between bacteriological water quality and distance from soakaway to water source. P-values less than 0.05 were regarded statistically significant in order to answer the research questions.

Qualitative data collected through interviews, we triangulated the responses from key informants (including staff from the water utility company, local authority, ministry of health and household heads) to analyze and identify common themes emerging from their responses. Due to the small number of key informants, the themes that were held by more than two informants were considered for a frequency count and further presented as verbatims in this study.

The samples collected and results from the laboratory were compared with the standards in table 1 below.

Table 1: Bacteriological Quality of Drinking Water Standards

No.	Type of Water Source	Organism	Guideline Value
1	All water intended for drinking	E. coli or thermotolerant coliform bacteria	Must not be detectable in 100 ml of water sample
2	Untreated water	E. coli or thermotolerant coliform bacteria	Must not be detectable in 100 ml of water sample
3	Treated water entering the distribution system	E. coli or thermotolerant coliform bacteria	Must not be detectable in 100 ml of water sample
		Total coliform bacteria	Must not be detectable in 100 ml of water sample
4	Treated water in the distribution system	E. coli or thermotolerant coliform bacteria	Must not be detectable in 100 ml of water sample
		Total coliform bacteria	Must not be detectable in 100 ml of water samples. Where sufficient samples are examined in the case of large supplies, in the 12 months period of samples being taken must not be present in 95% of them.

Source: WHO (2011)

RESULTS

This chapter presents the data findings obtained from the (138) households that were included in the study. The chapter presents the findings according to the socio-demographic traits, microbial findings, and the specific variables.

Knowledge of Respondents on On-Site Sanitation and Ground Water Quality

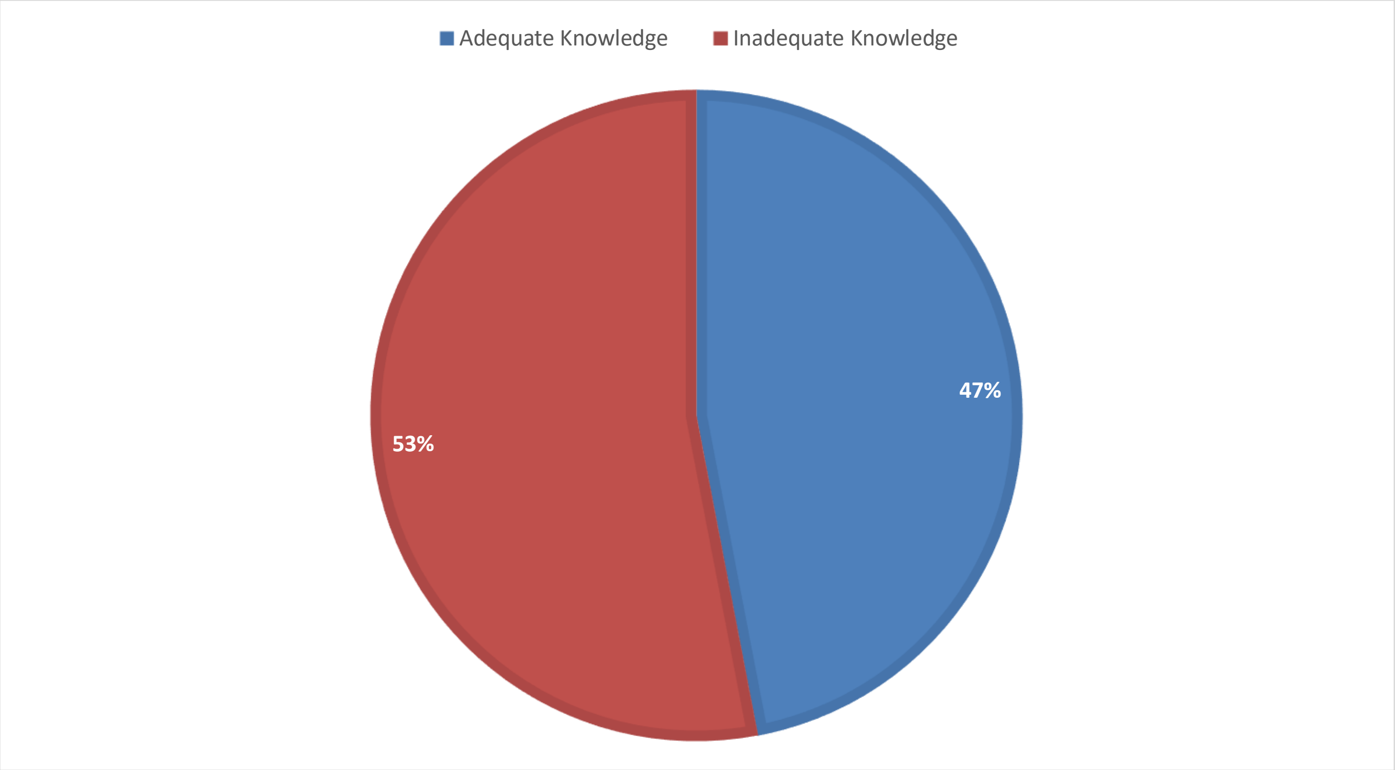

Figure 1: Respondents Knowledge levels

Fig. 1 shows the level of knowledge possessed by the respondents from Humba and New Kalundu concerning the influence of on-site sanitation on groundwater quality. The majority (53%) of the respondents were inadequately knowledgeable about the subject while 47% had adequate knowledge. This finding is further elaborated in table below

Table 2: Knowledge of Respondents

#	**Variable/Statement or Question**	**SA**	**A**	**N**	**D**	**SD**	**Mean**
	Range	**5**	**4**	**3**	**2**	**1**	**–**
1	Distance between soakaway and water point should be less than 30 meters	20 (14.5%)	65 (47.1%)	47 (34.1%)	6 (4.3%)	–	2.2826
2	Soakaway should be sited on an upper slope	23 (16.7%)	48 (34.8%)	65 (47.1%)	2 (1.4%)	–	2.3333
3	Minimum plot size for both a borehole and a soakaway is 30x30m plot	–	27 (19.5%)	43 (31.2%)	68 (49.3%)	–	2.1304
4	Diarrheal diseases can be caused by groundwater contamination from Soakaway	39 (28.3%)	99 (71.7%)	–	–	–	1.7174

5	Poor siting of soakaway and water sources causes diseases	26 (18.8%)	68 (49.3%)	44 (31.9%)	–	–	2.1304

Table 2 above highlights responses obtained on the awareness of respondents/households on on-site sanitation and ground water quality. The study reported that the majority of the respondents (47.1%) agreed that the distance between soakaway and water point should be less than 30 meters with (34.1%) of the respondents being neutral with a mean range of 2.2826. Regarding the question on siting of the soakaway in relation to the gradient; (soakaway should be sited on an upper slope), the findings show that the majority (47.1%) were neutral suggesting either that their either were not abreast with the standards or had personal reasons for not sharing what they knew while (34.8%) of the respondents agreed. The table also shows that the majority (49.3%) of respondents disagreed to the minimum plot size (30x30m) for setting up both a soakaway and a borehole while 19.5% agreed and 31.2% of the respondents were neutral. 71.7% and 28.3% of the respondents agreed and strongly agreed representing a 100% of the participants agreeing that diarrheal diseases could be caused by groundwater contamination from soakaway. 49.3% of the respondents also agreed that poor siting of soakaway and water point causes diseases. This was in addition to the 18.8% of the participants who strongly agreed to this statement. Whereas 31.9% of the respondents were neutral about it, no participants disagreed.

Our interaction with health workers revealed that Information Education and Communication (IEC) on water quality was an ongoing activity. In an interview with a health facility in-charge, it was found that information was passed on to patients and clients at the clinic every morning.

We know most households in our catchment use boreholes and are not connected to the sewer line by the utility company. This is why we always encourage our population to install online chlorinators to their boreholes. We give health education every morning before we start attending to patients. There is actually a book which I always check to ensure health education has been done. Not only that, we continue talking to our patients especially those presenting with diarrheal symptoms. women attending antenatal are also given health talk on water quality (KI – In-charge).

We always follow up diarrhea cases in our catchment and the issue we have observed is that the community trust so much water from boreholes thinking that its pure water, in the actual sense, we always find it contaminated and no chlorine residue when we test with our rapid tasting kits such as the Lovibond comparator and Hydrogen Sulfide bottles (KI – Clinic EHT).

They say that borehole water is also a danger but what can we do since we don't have water from the utility company? sometimes we add chlorine to the water especially in the rainy season (KI Household Head).

Effect Distance has Between Boreholes and On-site Sanitation System (Soakaway)

Plot Sizes in the Study Sites

The findings reported in the table shows that the majority of the respondents (37%) stated that they own 30 by 40 plots, (35.5%) stated their plots are less than 30 by 40 plots and (27.5%) stated they have land more than 30 by 40 plots.

Table 3: Size of the Plot

	Frequency	Percent	Valid Percent
30 x 40	51	37.0	37.0

> 30 x 40	38	27.5	27.5
< 30 x 40	49	35.5	35.5
Total	**138**	**100.0**	**100.0**

Distance has between Boreholes and On-site Sanitation System

Figure 2 below reports that out of the 15 points where water samples were collected, majority of the households (60%) found the distances between the two variables were sited less than 30 meters, a minority of the households (20%) stated that they were more than 30 meters and another (20%) reported that they are sited within 30 meters.

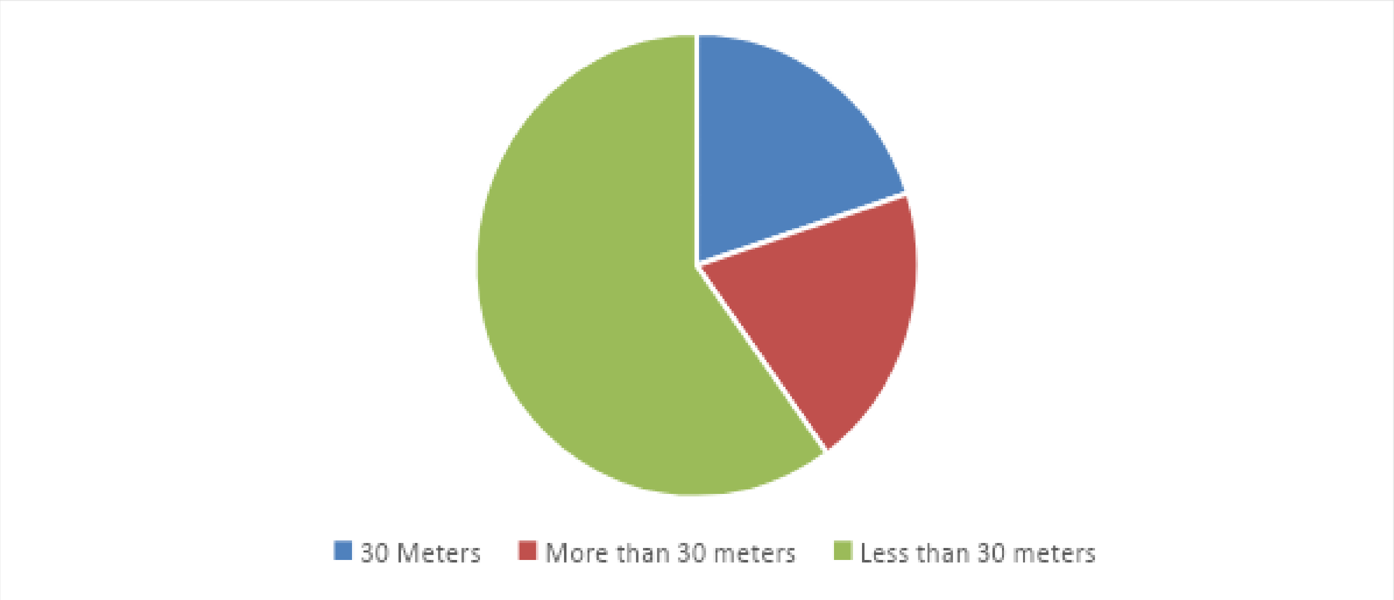

Figure 2: Distance Between Water Source and Sanitation facility

The local authority confirmed the existence of both water source and on-site sanitation facilities in the area. However, it was indicated that it was an illegal practice which they don't encourage.

Yes, we are aware of households that have both water sources and soakaway within the same plot. We do not encourage that and we do not approve any plans that have this combination. I think the other issue is that for boreholes, the licenses are not generated from the council. There is need for us to harmonize this with Water Resource Management Authority (WARMA) but I know the law does not allow water sources to be near a soakaway (KI – Council).

Mostly the council does not monitor the construction following all the stages of the project such that once the building is done, they stop visiting the site to control what happens at the site (KI – EHT, Clinic)

For us, in most cases these developers only put up boreholes which are not in the initial plans submitted and when we find such I think we have been very lenient to act (KI – Council Health Inspector)

Groundwater Water Quality from Boreholes and On-site Sanitation Facility

Table 4: Water Quality Microbial Results

#	Sample ID	Total Coliforms	Fecal Coliforms	Enterobacteriaceae Identified
1	1a	1.0×10^1	1.0×10^0	Proteus

2	1b	0.8 x 10^1	0.7 x 10^0	
3	1c	0.9 x 10^1	0.9 x 10^1	
4	2a	< 1 x 10^0	< 1 x 10^0	Nil
5	2b	< 1 x 10^0	< 1 x 10^0	
6	2c	< 1 x 10^0	< 1 x 10^0	
7	3a	9 x 10^1	< 1 x 10^0	Proteus, Klebsiella
8	3b	8.9 x 10^1	1.0 x 10^1	
9	3c	9.1 x 10^1	1.0 x 10^0	
10	4a	1.6 x 10^3	1.0 x 10^3	Escherichia Coli, Klebsiella
11	4b	2.1 x 10^3	9.2 x 10^2	
12	4c	1.5 x 10^3	1.1 x 10^2	
13	5a	5.3 x 10^2	3.2 x 10^2	Escherichia Coli, Klebsiella
14	5b	4.4 x 10^2	1.3 x 10^2	
15	5c	4.9 x 10^2	3.2 x 10^2	

Source (Water sampling lab results, 2022)

The above table highlights the microbial lab results obtained prior to the sampling of 15 water samples for microbial analysis to ascertain the quality of water. The lab results obtained reported that out of the 15 water samples collected from households at an interval of 10'', only 3 (20%) samples (Sample 2a – 2c) revealed not to have the presence of an enterobacteriaceae while the 12 (80%) other collected samples (1a – 1c, 3a – 3c, 4a – 4c and 5a – 5c) were found to have bacterial life in them as outlined above.

The figure below depicts the quality of water obtained from the 15-bacteriology sampling result tested for microbial contamination. The figure shows that the large proportion of samples (80%) collected were substandard while only (20%) of the samples collected were adequate.

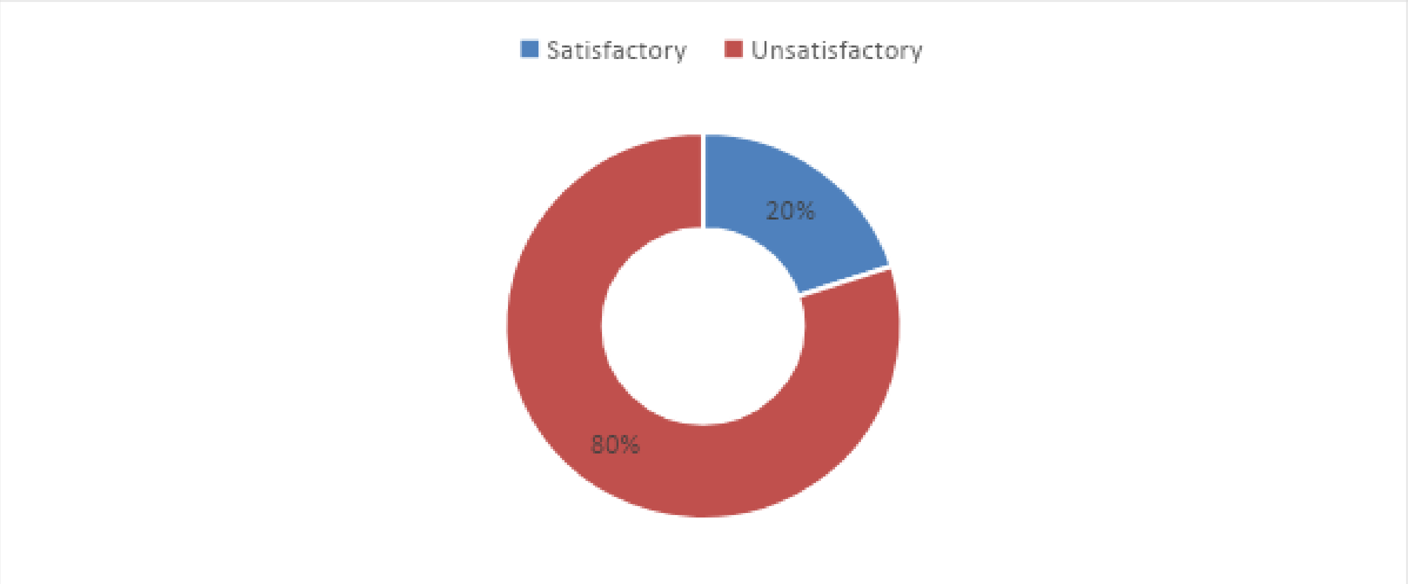

Figure 3: Quality of Water

The results obtained from the laboratory confirm the assertion by the Environmental health Technologist (EHT) when interviewed above. He suggested that the water was contaminated which is consistent with these results shown here. we further asked what could be associated with the contamination. A surveyor from the local authority suggested that the sitting of the two, (borehole and soakaway) is compromised.

We are never consulted when developers are sitting these two important facilities in their plots. We normally do some calculation to determine the gradient which informs the flow of groundwater before we advise on sitting. but people just place the soakaway after the house is done and the remaining space they later drill a borehole which is wrong (KI – Council Surveyor).

We further wanted to get the views of the household owners and planning and sitting of the water source and sanitation facility.

Well, I don't know that I am supposed to get permission on where to put my borehole. I actually didn't plan to have a borehole, I thought the area will be supplied with water but up to now there is nothing so i had to and then once I had water I did flushable toilets (KI – Household Owner).

Location and Gradient of Soakaway

The figure below highlights the location and gradient of the soakaway from a water source in the 15 households where water samples were collected for lab analysis. The study findings report that the majority of the households (66.7%) have their soakaway located on an upper ground to the water source with a relatively lower proportion (33.3%) having their households soakaway sited at a lower slope from the water source.

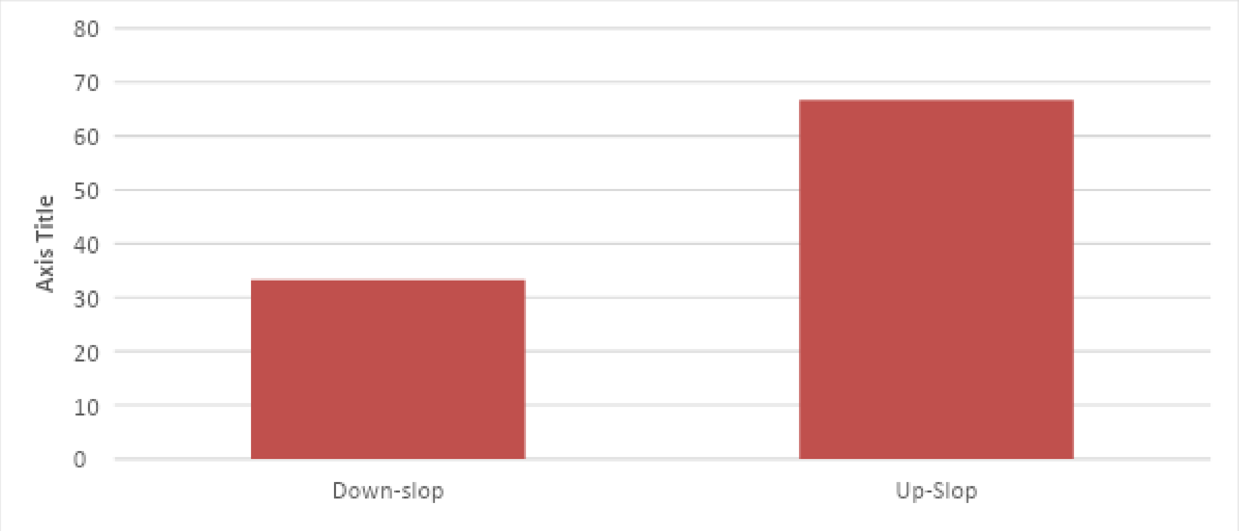

Figure 4: Location of Waterpoint in Relation to Sanitation Facility

DISCUSSION AND IMPLICATIONS

Respondents Knowledge on On-site Sanitation and Groundwater Quality

The study tested respondents' knowledge of on-site sanitation and ground water quality. Findings revealed that the majority (53%) of the respondents were inadequately knowledgeable about the subject while 47% had adequate knowledge. In general, the indication from the results is that household owners lack knowledge on on-site sanitation and groundwater quality. Sanitation knowledge is important for the long-term and effective adoption of appropriate hygiene practices in communities. Lack of sanitation education results in unsanitary behaviors and attitudes that contaminate water and spread diseases as established in reviewed literature (Titus, 2020, Adagiri et al. 2021). Water and sanitation knowledge are factors that influence the incidence of waterborne diseases in communities. Low levels of domestic water purification to avoid disease, a high reliance on surface waters for drinking, inaccurate perceptions of open defecation practices, and poor water collection, treatment, and storage methods are all the results of inadequate sanitation education (Titus, 2020).

According to the survey findings, respondents'/households' understanding of on-site sanitation and groundwater quality on the distance between soakaway and water closet should be less than 30 meters was good, with a mean of (2.2826). On whether soakaway should be placed on a higher slope, the data revealed that the majority of respondents were unsure, with a smaller number agreeing. This conclusion might be attributable to the relevant authorities' failure to provide enough information during the building of these facilities. The majority of respondents agreed that diarrheal illnesses can be caused by soakaway groundwater pollution, and that inadequate soakaway and water source sitting also causes diseases, with (31.9%) remaining neutral (M-2.1304). These findings underline the need of ensuring that relevant authorities offer proper information on the building of structures such as soakaway and the establishment of water sources in order to restrict / prevent the spread of illnesses.

Distance of Soakaway from Water Sources

The results showed that households did not comply with the minimum distance between boreholes and soakaway of 30 meters. The analysis found a $p< 0.036$ for the distance between soakaway and borehole water source. In our study, the majority of the soakaway were located fewer than 30 meters from the water supply, which is contrary to WHO recommendations. Gideon et al. (2004) stated that on-site wastewater treatment systems are point sources of pollution, and hence have the greatest influence on groundwater sources in their area. This might be attributable to the community receiving small-sized home plots without sufficient planning. The study results are similar to those of (Ibiang, 2016), who discovered that (distances) had a highly significant effect in explaining the association between soakaway distance to drinking water source and groundwater bacteriological quality.

Plot sizes in the study area were found to be a limiting factor on distance between boreholes and soakaway. From Table 4.3.1, thus the results showed that distance between boreholes and soakaway were all less than the required minimum of 30 meters. From this, it was clear that plot size had a corresponding effect on distance between borehole and soakaway and vice versa. Therefore, plot sizes in areas where boreholes and on-site systems are to be considered, relevant stakeholders (e.g. Las etc.) must provide a minimum lot size which could accommodate a minimum distance between boreholes and soakaway of 30m. Furthermore, the Las must provide guidance to developers to ensure that the minimum requirements are met. Or else there should be no soakaway development or standardized communal on-site system to be developed under the guidance of the Local Authorities.

This circumstance might indicate that standards to assist house owners in ensuring that waste water from on-site systems is prevented from contaminating groundwater are not being enforced effectively. This might also be attributable to a lack of knowledge about the impact of on-site systems on ground water quality. As a result, if this practice continues, a disastrous outbreak of avoidable diarrheal illnesses caused by pollution of borehole water, at times thought to be fit for consumption, is envisaged.

Location of Soakaway and Water Source in Relation to Groundwater Flow

The lab findings revealed that 80% of the 15 water samples collected were contaminated with fecal coliforms and total coliforms as shown on Table 4.4.1. The lab results indicate the presence of enterobacteriaceae in 12 water samples tested, indicating that drinking water quality is inadequate. According to the US EPA (2015), it is expected that the groundwater quality will deteriorate because the boreholes are located in close proximity to soakaway which are prone to groundwater pollution.

Daka (2019) in Meanwood – Kwamena, Lusaka found that 61.5 % of the 13 samples collected for bacteriological examination were satisfactory (not contaminated) whereas 38.5 % were unsatisfactory (contaminated). The contaminated boreholes were those located down slope at lower elevation and might be the cause of the 38.5% contamination while those that were not contaminated were those on the slope at higher elevation. According to Waller (2016), the sewage can discharge through leach lines located at higher elevation and could raise the groundwater level and flood leach fields at lower elevation.

Similar results were observed from logistic regression analysis for the fecal coliform by Banda et al. (2014). In this case, the direction of groundwater flow came out as having a relationship with fecal coliform count at 5 percent significance level with p-value less than 0.001 and the odds ratio of 0.042. This indicates that up-slope location of boreholes with respect to soakaway was 0.042 times less likely to lead to presence of fecal coliform in 100ml of groundwater.

In addition, results of this study agree with those of Luke (2013), who reported that (67.27%) sampled water taken from St. Bonaventure residences were satisfactory whereas only 32.72% were not. At the 5% level of significance, only the groundwater flow direction was demonstrated to be associated with water quality (total coliform and fecal coliform), with p-values of 0.001 and less than 0.001, respectively. Similar results were found by Ibiang (2016) in another study, which showed that placing a borehole adjacent to a source of pollution (such as a soak away) has a significantly negative impact on the groundwater quality in Nigeria.

This could further be attributed to the area’s population development, which has caused a build-up of structures without enough spacing, and the fact that the majority of households utilize boreholes as one of their main sources of domestic water supply and soakaway systems for on-site waste disposal.

CONCLUSION

In conclusion, the study’s findings showed that a bigger percentage of the households use soakaway and soak away systems as a significant method of on-site wastewater treatment and disposal because of the close proximity of the building structures and small plot sizes within the studied area. Residents have turned to alternative sources of drinking water, such as drilling boreholes and hand-dug wells within and around compounds, using soakaway systems for waste disposal, and operating soakaway systems close to the drinking water source, due to the state utility company’s unstable and unreliable supply of water to the growing population. The chi-square tests performed in this study demonstrate that all p-values are less than the significance level of 0.05, showing that the position / sitting of the soak ways, as well as the distance between the water sources and the soak away, have an influence on water quality. The establishment of water sources near any pollution source (soak away) has a negative impact on the quality of ground water resources. The respondents’ degree of knowledge based on onsite sanitation revealed that they are well-versed in water sanitation and hygiene. We recommend that government should connect the residence to water and sewer grid as well as restrict having both borehole and soakaway on plots less than 30 x 30 meter in dimension. Residents should install online chlorinators on existing boreholes in the area as a short-term measure. More experimental studies are needed on the subject in Zambia.

REFERENCES

1. African Development Bank. (2015). Environmental and Social Management Framework Summary. P-ZM-E00-010 Lusaka: African Development Bank Group
2. Adelana, S. & MacDonald, A. M. 2015 Applied Groundwater Studies in Africa. CRC Press, Leiden, Netherlands, pp. 127–148. (IAH selected papers on hydrogeology, 13).
3. ADB. Water Supply and sanitation in Africa: Findings, Lessons and Good Practices to Improve Delivery. Abidjan, Côte d’Ivoire: African Development Bank Group.

4. Alexander, G. (2015). Greywater Disposal Practices in Northern Botswana-The Silent spring? International Journal Environ Res Public Health, 12(11). doi:103390/ijerph121114529
5. Arnold Roy (2020) Sewer vs septic tank system: which is better for the environment? Earth .com.
6. Buss, S. R., Rivett, M. O. & Bemment, C. D. 2005 Attenuation of Nitrate in the Subsurface Environment. Technical Report, 99
7. pages. Environment Agency Rio House Waterside Drive Aztec West Almondsbury, Bristol, BS32 4UD.
8. Appling D. et al. 2013; Preliminary study on the effects of wastewater storage in septic tank on E. coli concentration in summer water, (5, (3))
9. Banda, et al. (2014). Effects of Siting Boreholes and Septic Tanks on Groundwater Quality in St. Bonaventure Township of Lusaka District Zambia (Masters of Public Health (Environmental Health)), University of Zambia, Lusaka. Retrieved from www.unza.zm
10. BGR, (2012) Groundwater Resources of the Mwembeshi and Chongwe Catchments including the Lusaka region
11. Busan, A., Shahalam, A., Mydiarezyk, A., Ahmed M., (2015). Treatment of Septic Tank Effluent for Reuse as Irrigation Water. International Journal of Environmental Engineering, 2(1). https://www.researchgate.net/publication/276267829 Treatment of Septic Tank Effluent for Reuse as Irrigation water. Access date: August 2018.
12. Cuthbert, M. O., Taylor, R. G., Favreau, G., Todd, M. C., Shamsudduha, M., Villholth, K. G., MacDonald, A. M., Scanlon, B. R., Kotchoni, D. O. V., Vouillamoz, J.-M., Lawson, F. M. A., Adjomayi, P. A., Kashaigili, J., Seddon, D., Sorensen, J. P. R., Ebrahim, G. Y., Owor, M., Nyenje, P. M., Nazoumou, Y., Goni, I., Ousmane, B. I., Sibanda, T., Ascott, M. J., Macdonald, D. M. J., Agyekum, W., Koussoubé, Y., Wanke, H., Kim, H., Wada, Y., Lo, M.-H., Oki, T. & Kukuric, N. (2019). Observed controls on resilience of groundwater to climate variability in sub-Saharan Africa. Nature 572 (7768),230–234.
13. California Water Board. (2012). Groundwater Fact Sheet. Retrieved from www.waterboards.ca.gov. Access date September 2018
14. Chang, X. (2014). Ecological Modelling and Engineering of Lakes and Wetlands Environmental Pollution. 1st Ed, Vol. 26, ISBN 9780444632555. https://www.elsevier.com/books/ecological-modelling-and-engineering-of-lakes-and-wetlands/jorgensen/978-0-444-63249-4. Access date: September 2018.
15. Cheremisinoff, N. (1997). Groundwater contamination in Groundwater Remediation and Treatment Technologies.
16. Connecticut Department of Public Health. (2018). On-site Sewage Disposal Regulations and Technical Standards for Subsurface Sewage Disposal Systems. State of Connecticut: Department of Public Health Retrieved from https://portal.ct.gov/-/media/Departments-and-Agencies/DPH/dph/environmental health/environmental engineering/2018-Uploads/Technical-Standards-2018-Master-011918.pdf?la=en
17. Datta, B., Zuo, R., Amirabdollahian, M., Prakash, O. (2016). Groundwater Contamination Plume Delineation using local Singularity Mapping Technique. International Journal of GEOMATE, 11(25). doi:10.21660/2016.25.5157
18. Defo, C., Yerima, B., Mabou, P., Mishra, A. (2016). Current conditions of groundwater resources development and related problems in the Republic of Cameroon, West Africa.
19. Department of Environment Labour & Justice. (2013). On-site Sewage Disposal Systems in Price Edward Island. Prince Edward Island, Canada: Department of Environment, Labour & Justice, Retrieved from http://www.gov.pe.ca/photos/original/elj_sewage_rpt.pdf. Access date: August 2018.
20. Dutches County. (2016). Residential and Commercial Onsite wastewater Treatment System and Sewer Mains for Less than 1, 000 Gallons per Day. Retrieved from www.co.dutchess.ny.us/countygov/departments/DBCH/Reports/HDdesigns.pdf. Access date: August 2018.
21. Eko, M. (2013). Four Wastewater Treatment Methods Evaluated from a Sustainability Perspective in

the Limbe Urban Municipality Cameroon (Central Africa). (Masters), Mittuniversietet Mid Sweden University, Sweden. Retrieved from http://www.diva-portal.se/smash/get/diva2:603393/FULLTEXT01.pdf

22. EPA, (2011). Water treatment manual Disinfection. ENVIRONMENTAL PROTECTION AGENCY An Ghníomhaireacht um Chaomhnú Comhshaoil PO Box 3000, Johnstown Castle, Co. Wexford, Ireland. ISBN 978 – 184095 – 421 – 0
23. EPA. (2012). Summaries of Water Pollution Reporting Categories. (EPA841-R-12-104). EPA Retrieved from https://epa.gov/sites/production/files/2015-08/documents/34parentattainsdescriptions.pdf. Access date: September 2018
24. EPA. (2017). How to Care for Your Septic System. USA: USEPA Retrieved from https://www.epa.gov/septic/how-care-your-septic-system. Access date: September 2018.
25. FAO, (2016) City Region Food System Situational Analysis, Lusaka, Zambia. FAO- food for the Cities programme.
26. Farmer, B. (2016). pH and Chlorine-A Hands-On Look at Drinking Water Fundamentals. . Retrieved from https://www.mae.gov.nl.ca/waterres/training/adww/2016/07_Brenna_Farmer.pdf. Access date: September 2018
27. Fosse Septiques (2008), Aguide to septic tank. Available at www.fosseseptique.com
28. Foster, S., Bousquet, A. & Furey, S. (2018) Urban groundwater use in Tropical Africa – a key factor in enhancing water security? Water Policy 20 (5), 982–994.
29. Foxon K. and Still D. (2012) Water research Commission (WRC), University of Kwazulu-Natal, Partners in Development (P.D), South Africa
30. Francis Dabwiso Daka, 2019; Mitigating the effects of septic Tank effluent from households on groundwater quality: A case study of Meanwood Kwamwena, Lusaka
31. Fulazzaky, M. (2014). Challenges of Integrated Water Resources Management in Indonesia. Water. 6. 2000-2020. 10.3390/w6072000. Universiti Teknologi Malaysia. https://www.researchgate.net/publication/277673781 Challenges of Integrated Water Resources Management in Indonesia. Access date: September 2018.
32. Gauff, I. (2016). Water supply study report. SAB MILLER, ZAMBIAN BREWERIES PLC. Consulting services for the water supply for Zambian breweries.
33. Goulding, K. (2016). Soil Acidification and the Importance of Limiting Agriculture Soils with Particular Reference to the United Kingdom. NCBI, 32(3), 390-399. doi:10.1111. https://onlinelibrary.wiley.com/doi/abs/10.1111/sum.12270: Access date: August 2018.
34. Info Isoteem Fubara – Manuel and Rapheal Butter Jumbo 2017; The effect of septic tank location on borehole water quality in Nugeria
35. Bremer J. E. and Harter T. (2012) “Domestic wells have high probability of punping septic tank leachate” Hydrology and Earth system sciences
36. Ugbebor J.N and Ntesat, U. B. 2019; Effects of septic tank proximity of boreholes on groundwater contamination at Igwuruta, Riverstate, Nigeria
37. Pradhan S., Micheal T., Hoover G., Clark H., M. Gumpertz, C. Cobb and J. Strock (2011) Impacts of biological additives; Part 2 Septic Tank effluent quality and overall additives efficiency
38. Water and Sanitation Program and Unicef, 2015; Water supply and sanitation in Ghana: Turning finance into services for 2015 and beyond. World Bank.
39. Williamson E. (2010) “Cold climate performance analysis of on-site domestic wastewater treatment systems”, Water environment Research, 82 (6)