Hand-dug Well Water Quality: The Case of Two Peri-Urban Communities in Ghana

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Abstract

Many rural and peri-urban areas in developing countries including Ghana face challenges with access to good quality drinking water. These areas often depend on surface water or ground water sources which are often compromised with excess levels of nitrate, chloride and microbial pathogens. This study sought to assess the effect of household latrine system on household water quality of two peri-urban communities in the Upper West Region of Ghana. Geographic Information Systems were used to map the latrine location and elevation of household wells relative to latrines. Latrines and wells were visually inspected. Water samples were also collected from the selected household wells and tested for pH, chlorine, turbidity, colour, conductivity, temperature, total dissolved solids, nitrites and nitrates. Selected community borehole water were used for controls. The study showed average latrine location relative to household well was 13.7 m. The difference in elevation between the wells and latrines is at an average of 0.7m. All the household latrines were improved latrines and household wells with 47% of them having lids to cover them. The water quality observed were all within the WHO drinking water quality for the physicochemical parameters assessed. The study however showed higher levels of nitrate in household wells than bore holes. The need to educate households in locating of Kraals relative to household water systems is needed. Further studies including environmental and geological assessments are required to establish the observations made regarding why areas of high latrine concentrations had lower nitrate levels. Also microbiological studies to establish the safety of water for drinking is required.

Keywords: Groundwater, water quality, hand-dug wells, peri-urban, water contamination, physico-chemical

Introduction

The importance of water to humans cannot be overemphasized hence the need for its availability in the right quantity and quality at any given time. It is therefore not surprising that good drinking water and sanitation are used as socio-economic development indicators by the United Nations (Griggs et al., 2013). Unfortunately, many developing countries including Ghana continue to face challenges with regards to access to good quality drinking water. In most instances, the source and quality of water utilized by individuals are dependent on their geographical location and socio-economic status (Adams, Boateng, & Amoyaw, 2016). Accordingly, varied sources of drinking water including harvested rainwater and hand-dug wells are utilized in Ghana to meet water needs (GSS, 2012). The hand-dug well remains a dominant source of drinking water especially amongst the rural and peri-urban poor households in Ghana (GSS, 2014a) . It is reported that about one-third (32.3%) of all households' main source of drinking water comes from the hand-dug wells in Ghana, with a little below one-third (28.9%) using pipe-borne water (GSS, 2014b). Moreover, about 13.9% and 55.3% of urban and rural inhabitants respectively, resort to hand-dug wells as their main source of water (GSS, 2014b). Notwithstanding the poor access to potable water, the limited sanitation facilities that are available are also overstretched (GSS, 2014b). Human waste management is poor and sewered excreta disposal systems are rare due to high costs and scarce water resources thereby compelling inhabitants to resort to on-site sanitation (Cofie et al., 2005, GSS, 2012

& GSS 2014a). This situation is worrisome considering the health implications this may have on a resource constrained country with limited health care facilities.

Wa, a city in the Upper West Region of Ghana has limited basic social amenities such as potable drinking water, roads, housing, sewered sanitation system and schools. Pit latrines both improved and unimproved are therefore the most common on-site sanitation facilities patronized in rural and peri-urban communities in the region (GSS, 2014a). Likewise, many rural and peri-urban households resort to hand-dug wells as their prime source of potable water for domestic use (GSS, 2014a). However, previous studies have associated the presence of pit latrines with ground water contamination. For instance, Zingoni et al. (2005) in a study of groundwater quality in an informal settlement of Zimbabwe associated detectable total and fecal coliforms in boreholes and existing domestic wells to the presence of household latrines. Similarly, nitrate occurrence in the shallow groundwater was associated with on-site sanitation practices in Mahitsy City, Analamanga Region, Madagascar in a study by Rasolofonirina et al. (2015).

According to the Ghana Community Water and Sanitation Agency, the distance between household water sources and latrines should not be less than 50m (Parker et al. 2009; Graham et al., 2013). However, this requirement is often ignored and hand-dug wells and latrines are mostly sited close (closer than 50 metres) to each other at the sole discretion of property owners. To the extent that all households in Ghana are being encourage to have water and sanitation facilities, we sought to assess how locating wells and latrines within household setting influenced water quality in Mangu and Kambali areas of Wa. This study assessed the effects of latrines on hand-dug well water quality in order to establish safety of well water used for domestic purposes in Mangu and Kambali; two peri-urban communities in the Upper West Region of Ghana.

Materials and Methods

Study area

The study was conducted in two peri-urban communities, Kambali and Mangu located in Wa Municipal Assembly (Figure 1) in the months of October and November, 2013 which was the dry season and April and May 2013 which was the wet season. Wa is the capital town of the Upper West Region (UWR) of Ghana. According to the 2010 population and housing census, the Wa Municipal has a total population of 107, 214 (GSS, 2013).

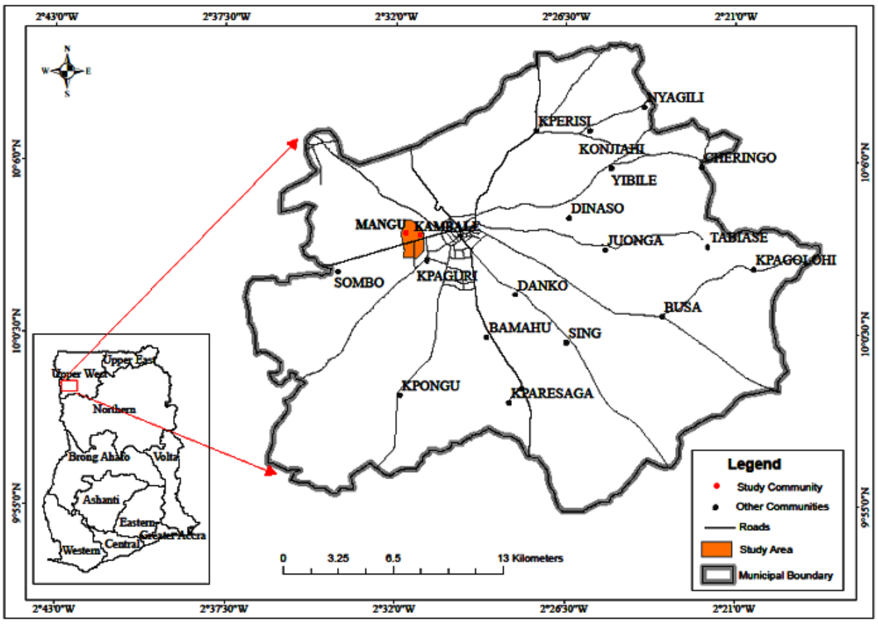

Figure 1 Map of study area

The landscape is generally a gently undulating plain (about 200-350 m above mean sea level) and is characterized geologically by the Birimian Supergroup comprising of the metavolcanics and metasediments (Smith, Henry, & Frost-Killian, 2016).

The region consists of mainly shale, volcaniclastic and volcano-sedimentary rocks, basalt, granite, paragneiss and orthogneiss, rhyolite and granitoids (Amponsah et al., 2016). The region is also characterized by the tropical equatorial or continental climate. May to October marks the wet or raining season whiles November to March is associated with the dry harmattan winds (GSS, 2013). Sparsely and poorly distributed annual rainfall of between 840 mm and 1400 mm are recorded for the raining months (Ministry of Food and Agriculture, 2011). The region has an average minimum temperature of about 22.6°C and maximum of about 40°C (GHS, 2008).

Study design

The study used convenience sampling which is a non-probability sampling technique, to select thirty households with hand-dug wells and latrines. Additionally, five boreholes which were at least 50 m away from the latrines (GCWSA standards) were selected as controls. Boreholes were selected as controls instead of hand-dug wells because it was practically impossible to get a distance of 50 m and above between hand-dug wells and pit latrines. Using a handheld Global Position System (GARMIN 45 GPS), the location and elevations of the hand-dug wells and latrines were measured (Figure 2). The physical conditions of the hand-dug wells and latrines were also recorded.

Sample collection

To avoid extraneous contamination of samples, thoroughly washed and sterilized plastic

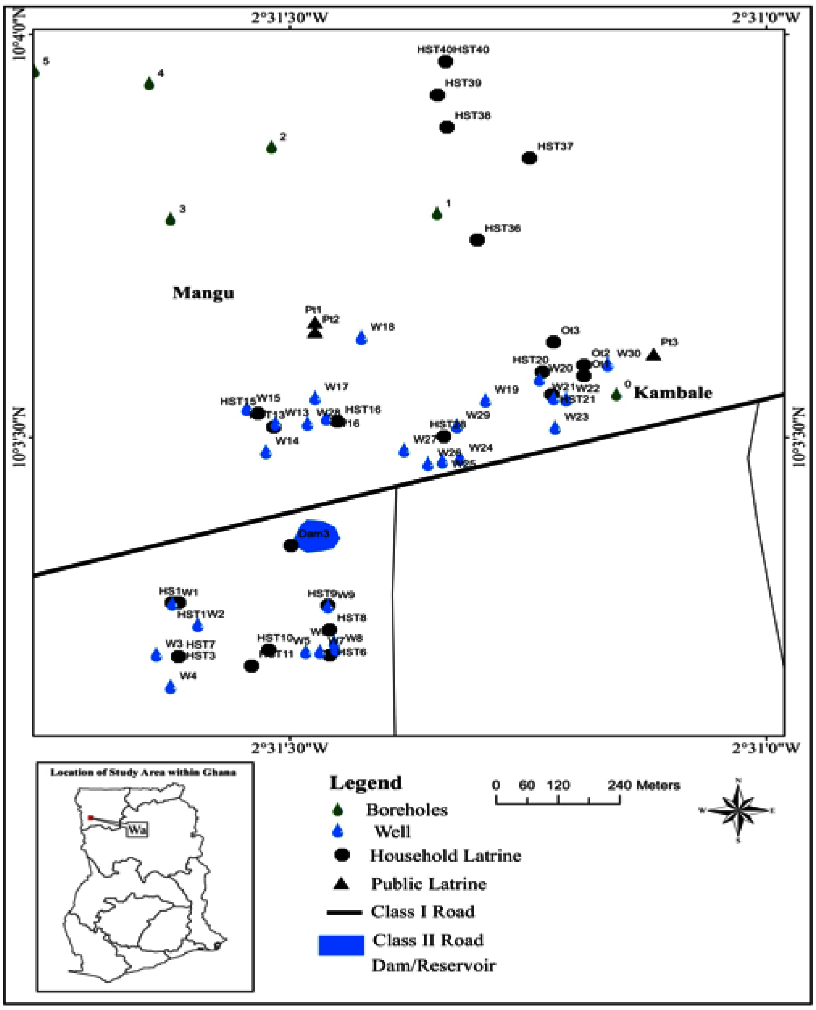

Figure 2 Locations of water sources and latrines mapped for the study

buckets were used to collect water from 30 randomly selected household hand-dug wells into 500 ml sterilized bottles. Triplicates of 500 ml water samples were collected from selected hand-dug wells into sterile containers and transported under cold storage of 4°C to the laboratory for analysis.

Laboratory Analysis

Physicochemical analysis

Parameters assessed were pH, chlorine (mg/l), turbidity (NTU), colour (Hz), conductivity (µs/cm), temperature (°C), TDS (mg/l), nitrites (mg/l), and nitrates (mg/l). The analysis of these parameters are briefly presented below

*p*H

The *p*H of the samples was determined using the pH meter (Jenway pH meter, model no.370). Measurement was carried out by immersing the cell in the samples. The readings were then allowed to stabilize, and results recorded. The cell was rinsed in deionized water, shaken to remove internal droplets, and the outside wiped prior to immersion in the next sample to avoid possible contamination by samples from the previous well.

Temperature

Temperature of the samples was taken using the thermometer (Jenway pH meter, model no.370). This was done by placing the cell below the water surface of the sample to a depth of about four inches for about a minute. The readings were then allowed to stabilize and recorded.

Conductivity

The general purpose hand held conductivity meter (MODEL 470) was used to measure the conductivity of the samples. Measurement was carried out by immersing the probe into the sample. The readings were then allowed to stabilize, and results recorded.

Colour

The colour of the samples was tested using Lovibond cmparator (2000+). One Nessler cylinder was filled just on the 50 ml. mark with the samples and the antimeniscus plunger fitted. The cylinder was then placed in the right-hand compartment of the Nesleriser. Another Nessler cylinder was filled in the same way with deionized water and place in the left-hand compartment. The disc was then inserted into the lid and Nesleriser fitted to the Daylight 2000 unit. The disc was then rotated until the closest colour match was obtained. Displayed values were then recorded.

Turbidity

Turbidity was measured using HACH 2100Q and 2100Qis. The turbidity meter was powered on after which the 20 NTU (Nephelometric Turbidity Unit) cell was filled with the sample. The cell was then cleaned with a cloth. The sample cell holder was then inserted and covered with the lid and the readings recorded.

Nitrite and Nitrate

Nitrates were used as an indicator of contamination from nitrogenous waste products including that from human and animal excreta (WHO, 2011) for this study. Nitrite and Nitrate tests were done employing Hach Aquachek . A strip was dipped into the sample for a second and removed. The strip was held level, with the pad side up for about 30 seconds. The Nitrite test pad (bottom pad) was then compared to the colour chart and the recordings taken. Afterwards, the Nitrate test pad was also dipped into the sample and the pad side held up for 60 seconds after which the test pad (top pad) was also compared to the colour chart. The results were then also estimated and recorded.

Chlorine

Residual Chlorine in the samples was determined using HANNA Instrument . A pipette was used to fill each glass vial with 5 ml of sample. One of the vials was then inserted into the left hand opening of the checker disc. Deionized water was then added to the other vial up to the 10 ml. mark. The cap was then placed back and shaken to mix after which 1 packet of HI 93701-0 reagent was added. This was also shaken vigorously to mix to form the reacted sample. The reacted sample was then inserted into the right hand of the checker disc. The checker disc was then held to light to illuminate the samples from the back of the window. The checker disc was kept at 30-40 cm (12-16") from the eyes to match the colour. The disc was then rotated whiles looking at the colour test windows and stopped when the colour match was found. Readings and recordings were then noted.

Well and latrine mapping

A Geographic Information System database was created using the GPS coordinates for wells with Nitrates, pH, Turbidity, Conductivity and Total Dissolved Solids values. The data was then classified based on the range of parameters. Latrine concentration maps were also generated in ArcMap using the Inverse Distance Weighted (IDW) interpolation method. The IDW relies on a linear combination of weights at known points to estimate unknown locations. Overlay analysis were then carried out on the datasets for interpretation and map generation.
Physical observation of the wells and latrines in 15 households was carried out to inspect the location, latrine type, type of structure and condition.

Data Analysis

Data was entered into SPSS version 16 and analyzed using descriptive statistics. The student's t-test was used in assessing water quality variations between the seasons. Analysis was conducted at 95% confidence interval. To also enhance the interpretation of the results, the levels of nitrate detected in hand dug wells were plotted in an ArcMap to show latrine relationship with nitrate levels in hand dug well water for both seasons.

Results and Discussion

From the visual inspection of hand-dug wells and latrines in fifteen households. Out of these, 11(73%) hand-dug wells were centrally located within the households that were compound houses with the remaining 4 (27%) hand-dug wells located outside the houses. Five (33%) out of the fifteen hand-dug wells lacked headwalls, which exposed them to surface run off from rains and other sources. Headwalls varied in height ranging from about half to one meter above the ground. The inner walls of all 15 hand-dug wells were however

Figure 3 A hand-dug well with a kraal and animals besides the headwalls of the well

lined with either concrete or stones. Thirteen (87%) of the hand-dug wells had covers made from wood and metal out of which 9 (69%) had locks. Surroundings of the hand-dug wells were generally clean since most of them are situated within the houses. All households use ropes tied to gallons or buckets to draw the water. Hand-dug wells were not fenced which enabled domestic animals and fowls near the water source. and in some instances, animals were seen beside or on the headwalls (Figure 3).

All latrines visually inspected could be considered as improved pit latrines, with superstructures and mostly located away from the dwelling structures. All the latrines had cover slabs with footrests. Seven (47%) out of the 15 pit latrines assessed had lids to prevent flies and odour from emanating from the pits. Five (5) of the lids were made of wooden boards that were large enough to cover the whole openings of the pits. All latrines had a single opening for both urine and faeces dumping. Majority of the households, 12 (80%) out of the 15 had one pit latrine whiles 3(20%) had two pit latrines. All the pit latrines had vents and none of them had hand-washing facility. On average, five (5) people used a latrine. The distances between household latrines and the hand-dug wells ranged from 5 m (household 9) to 30 m (household 6) as shown in Table 1. The average distance recorded between household latrines and hand-dug wells were 13.7 m. The difference in elevation of hand-dug wells and household latrines was an average of 0.7m. This is below the approved standard distance of 50m by the CWSA.

Hand-dug well water quality resides on a complex interplay of factors relating to sanitation practices and the environmental conditions of the area amongst which include hydrology, soils and distance between pollution and water source (Graham & Polizzotto, 2013). Within the context of peri-urban areas, human activities such as general household sanitation practices and the lateral distance between pollution and water source may be critical factors to water quality. Having a safe distance between hand-dug wells and pit latrines is critical for household water safety (Lutterodt et al., 2018, Abanyie et al 2016). Establishing a valid lateral distance however, is difficult as various factors such as hydrogeology, cultural practices regarding environmental sanitation must be factored in determining approved standards in peri-urban communities in developing countries, which are characterised by illegal settlements or

TABLE 1

Household wells and latrine distance of separation and elevations

House	*Distance (m)	Well Elevation (m)	Toilet Elevation (m)
1	14	299.6	301.5
3	13	301.1	299
6	30	302.1	298.7
7	14	296.6	310
8	19	306.3	298.7
9	5	302.1	302.1
10	16	292	285
11	17	288.7	290.8
13	10	296.9	298.7
15	10	302.1	304.2
16	11	292.9	300.8
20	16	298.7	296.9
21	8	296.3	298.7
28	9	291.7	292
Mean value	13.7	297.7	298.4

**Distance was measured as lateral distance between household hand-dug well and latrine*

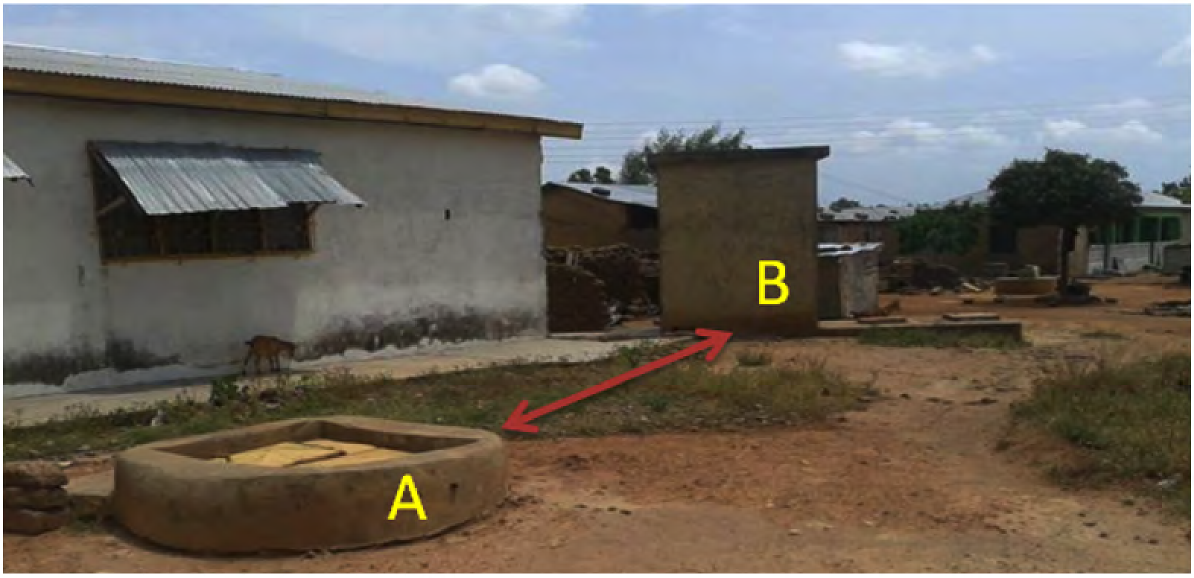

Figure 4 A protected hand-dug well (A) and latrine (B) constructed close to each other

slums with unpleasant sanitation conditions and environmental problems as evident in the study findings (Torres, 2008). For this study for instance, none of the household studied had latrine and well distance 50 m apart. They were all less than 50m which is the approved distance by Community Water and Sanitation Agency (Ministry of Water Resources Works and Housing, 2010).

The physico-chemical water quality parameters assessed are presented in Table 2. The means of all the parameters assessed for both household hand-dug wells water and control bore holes were found to be below WHO standard for drinking water.

It was also observed that apart from conductivity and temperature, all the other parameters such as total dissolved solids, turbidity, pH, colour, and nitrates showed slightly higher levels in hand-dug wells compared to bore hole water. A similar study by Efe et al., (2005) in Western Niger Delta Region in which hand-dug wells were found to have higher levels of total dissolved solids, turbidity, pH, colour and nitrates compared to borehole and rain water is consistent with our findings. These may be due to the mode of construction of the well, activities that go around where the well

TABLE 2

Physico-chemical characteristics of sampled hand-dug wells and boreholes

Parameter	Hand-dug wells			Boreholes			WHO Guideline values (2011)
	Range	Mean	SD	Range	Mean	SD	
pH	6.56-7.67	7.21	±0.33	6.59-7.25	6.96	±0.27	6.50-8.50
Turbidity (NTU)	0.18-85.30	9.25	±16.36	0.31-4.20	2.60	±1.43	15.00
Colour (Hz)	5.00-85.00	10.33	±14.23	-	5.00	±0.00	5.00
Conductivity (µs/cm)	85.00-921.00	368.40	±191.81	202.00-530.00	376.80	±88.70	-
Temperature (°C)	24.90-32.10	28.72	±1.96	28.40-31.60	30.33	±1.38	-
TDS (mg/l)	47.10-553.00	225.98	±119.22	124.00-318.00	218.00	±52.13	1000.00
*Nitrates (mg/l)	0.00-10.00	2.08	±2.84	0.00-3.00	0.90	±1.10	50.00

SD=Standard Deviation

is sited and general environmental sanitation practices that may account for recorded differences between the boreholes and hand-dug wells (Akinbile & Yusoff, 2011, Dan-Hassan et al., 2012). Where hand-dug wells are left uncovered unlike the boreholes, they may be exposed to contamination, particularly from external sources such as dust and excreta from domestic animals. In addition, hand-dug wells per their mode of construction and geology of the area are often shallow, hence easily contaminable compared to boreholes, which are drilled much deeper. Water colour on the other hand can be attributed to materials in solution, primarily organic compounds, and inorganic coloured compounds found in waste (Adejuwon and Adeyini, 2011).

Significant seasonal variations were observed in hand-dug wells for turbidity, total dissolved solids, conductivity, and temperature as shown in Table 3. Conductivity and total dissolved solids and temperature were higher in the dry season than the wet season while turbidity was lower in the dry season compared to the wet season. These observed variations may be linked to the rainfall, which generally increase pollutant load through runoffs and leachates from the surrounding environments. Variations in water temperatures in the study area may be following the ambient temperature pattern (Agbaire et al., 2009; Parmar, 2012), which are usually high during the dry season in the northern parts of Ghana. This is because the dry harmattan winds come with low humidity and higher temperatures especially during the day. Furthermore, higher total dissolved solids recorded in the dry season could be due to excessive evapotranspiration that may have left higher concentration of ions in the wells (Ramachandramoorthy et al., 2009) and or dilution effect from the rains during the raining season (Pritchard et al. 2007; Sivasankar et al., 2009).

Figure 5 shows latrine concentration and nitrate levels for both seasons. (Figure 5). It was found that, in areas of moderate to high latrine concentration, nitrate levels were generally low, while areas with lower latrine concentration showed variations of high and low nitrate levels. Contrary to expectations, many studies had previously established a positive relationship between latrine densities and nitrate levels in groundwater (Ndoziya et al 2019, Vinger et al 2012). However it was also observed by Graham & Polizzotto (2013) from their study that, in areas with high latrine concentration but where groundwater is devoid of oxygen, nitrate concentrations are minimal due to denitrification. This may be a reason for the observation made in this study.

It must be noted that this study was limited in determining the faecal contamination in well water, an important indicator for water safety due to capacity limitations in the study area. In addition, the study was conducted in only two peri-urban communities in Wa which

TABLE 3

Seasonal variations of hand-dug wells and boreholes ($p<0.05$)

Parameter	Hand-dug wells				Boreholes			
	Mean (wet)	Mean (dry)	t-test statistic	Sig.	Mean (wet)	Mean (dry)	t-test statistic	Sig.
pH	7.170	7.240	-0.767	0.446	7.194	6.722	6.277	0.003
Turbidity (NTU)	14.500	4.010	2.603	0.012*	3.306	1.942	4.349	0.012
Colour (Hz)	11.830	8.830	0.814	0.419	5.000	5.000		-
Conductivity (µs/cm)	253.630	483.170	-5.763	0.000*	418.800	334.800	4.540	0.011
Temperature (°C)	27.160	30.280	-10.189	0.000*	29.280	31.380	-4.005	0.016
TDS (mg/l)	153.000	298.560	-5.923	0.000*	237.000	199.160	2.388	0.075
Nitrates (mg/l)	1.480	2.670	-1.638	0.107	1.200	0.600	2.449	0.070

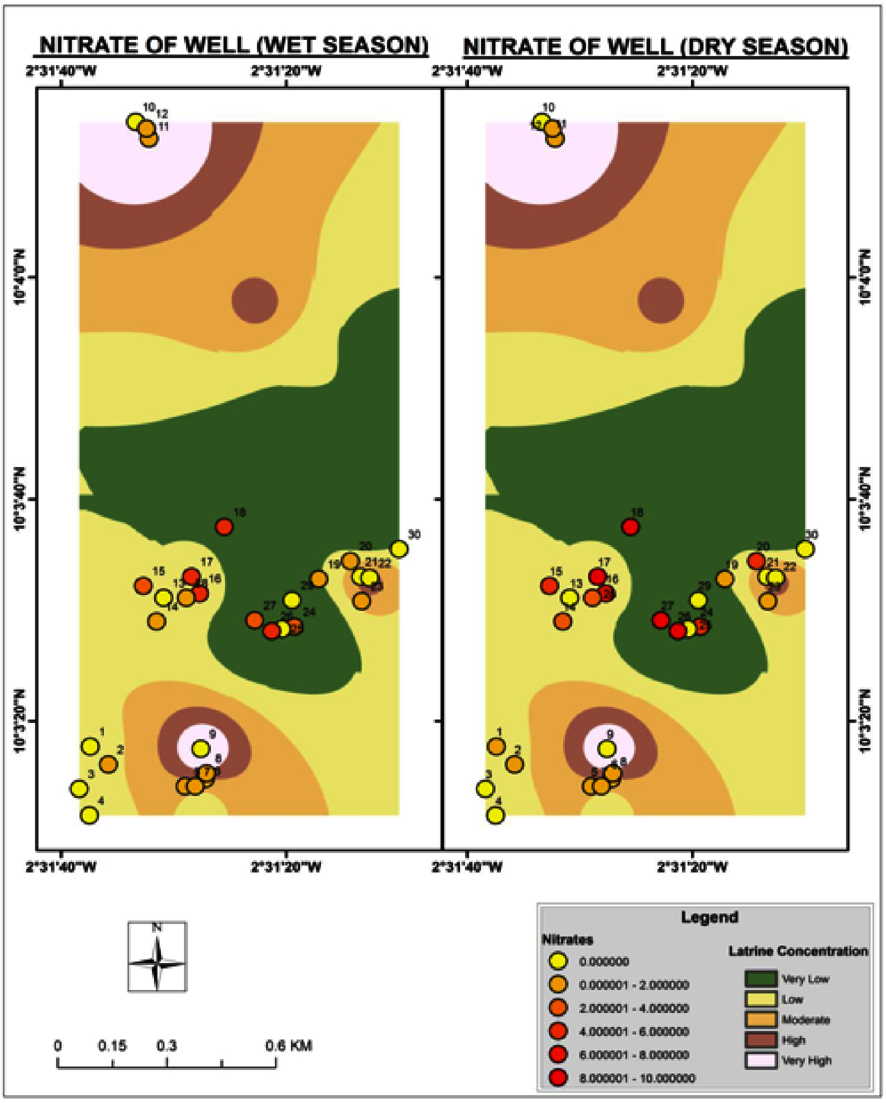

Figure 5 A map showing nitrate levels in hand-dug wells during the wet and dry seasons

may not be generalizable to another context. Notwithstanding these limitations, these findings are still relevant in highlighting the state of household hand-dug well water quality in the area at the time. Within the context of the study area household activities such as rearing of animals and poultry was common and this may have significant implications on well water quality, (Jun et al., 2005).

Conclusion

All physico-chemical parameters assessed for this study were below WHO limits and permissible for drinking. However, the fact that nitrates were generally higher in hand dug wells than the bore holes may be an indication of some level of nitrogenous waste contamination which may arise from household practices such as having kraals and latrines near household hand dug wells. The main source of contamination is however unclear in this study and calls for further studies into microbiological assessment of household hand-dug wells in the study area. Also microbiological studies to establish the safety of water for drinking is required.

The need to also educate households in location of Kraals relative to household water systems is needed. Further studies including environmental and geological assessments are required to establish the observations made regarding high latrine concentrations had lower nitrate levels. The Environmental Health Officers at the Districts should enforce the minimum approved standard distance of 50 meters between latrine and household well.

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