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Assessment of the Quality of Water from Hand-Dug Wells in Shama Ahanta West Metropolitan Assembly: Western Region of Ghana

John Jackson Nsiah, Ebenezer Boakye
Department of Civil Engineering, Takoradi Polytechnic, Box 256,Takoradi- Ghana

ABSTRACT

This study investigated the physico-chemical and bacteriological properties including coliform bacteria from hand-dug wells in communities within Shama Ahanta West Metropolitan Assembly (SAWMA) in the Western Region, Ghana. The purpose was to assess its quality. Six hand-dug wells were sampled from communities within SAWMA to test for physico-chemical and bacteriological parameters. The results of the study indicated ranges for the various parameters as follows: pH, 6.26 – 7.48; turbidity, 2.85 – 13.9 NTU; conductivity, 896 – 3400 µS/cm; colour, 1 -5 Hz; TDS, 493 – 1870 mg/L; TSS, 4 – 6 mg/L; alkalinity, 36 – 372 mg/L; total hardness, 198 – 762 mg/L and total iron, 0.06 – 0.41 mg/L. Cations and anions showed variations in samples as follows: Na^+, 38 – 750 mg/L; K^+, 2.5 – 11 mg/L; Ca^{2+}, 40.1 – 105 mg/L; Mg^{2+}, 22.3 – 121 mg/L; Mn^{2+}, 0.01 – 0.37 mg/L; NH_4^+, < 0 mg/L; HCO_3^-, 43.9 – 454 mg/L; NO_3^-, 0.09 – 0.62 mg/L; NO_2^-, 0.01 -0.09 mg/L; SO_4^{2-}, 26 – 206 mg/L; PO_4^{3-}, 0.12 – 0.91 mg/L; F^-0.17 – 0.41 mg/L andCl^-99.3 – 1032 mg/L. Total coliform ranged between 34 – 2046 CFU per 100mL and fecal coliform between 19 – 930 CFU per 100mL. The Geographical locations of the wells were picked with Garmin eTrex hand-held GPS receiver and their coordinates used to develop a geo - spatial map using Arc GIS version 10.3.Charts of the test results compared with WHO guidelines for domestic water use was presented using MS excel 2010 edition. This revealed that total and faecal coliform were abnormally high above the permissible limit for wells in the study area. Conductivity, turbidity, chloride, TDS and total hardness also showed significant levels of concentrations above WHO limits. This indicate that open dump sites and pit latrines close to wells are the major cause of the abnormally high counts of total and faecal coliform. The significant levels of conductivity, turbidity, chloride, TDS and total hardness above WHO limits can be attributed to uncovered and unkempt wells which receive erosive runoff from upland. These quality indicators render hand-dug wells in the study area unsuitable for direct human consumption according to WHO guidelines for drinking water use. Thus, hand-dug wells within the study area requires immediate treatment before they can be used for drinking purpose.

Keywords: *Assessment, Hand-dug well, water quality, physico-chemical, bacteriological*

1. INTRODUCTION

Portable drinking water is a basic necessity of life and its availability in terms of quantity and quality is of prime importance to the socio-economic development of a nation [8]&[9]. It is however unfortunate that in many developing countries around the world, including Ghana, access to quality drinking water and sanitation is increasingly a major [8], [12]&[13]. Even in the urban centers water is rationed to many customers with only a few customers able to get water 24-hour supply.[7] concluded that in the Sekondi-Takoradi metropolis, inhabitants connected to the Ghana Water Company Ltd systems for water supply receives water for four days per week and that in absence, about 39% resort to hand-dug wells. [8] and [13] also emphasized on the increasing use of hand-dug wells in many peri-urban and rural communities in Ghana, and Shama Ahanta West Metropolitan Assembly (SAWMA) in the Western Region is no exception. This is because hand-dug well has become the most reliable freshwater source ([3], [12] & [23] as supply from Ghana Water Company is intermittent and does not cover the entire assembly. It is important therefore to assess their quality as it impacts on the health of consumers [3] & [23]. [12] cited that contaminants such as bacteria, viruses, heavy metals, nitrates and salts have polluted water supplies as a result of inadequate treatment and disposal of waste from humans and livestock, industrial discharges and many other anthropogenic activities. Others have shown that bacteria contaminates shallow groundwater depending on location and lateral distance from potential pollution sources[18] & [16]. As such wells in unhygienic areas could be contaminated bacteriologically, especially, if they are close to pit latrines and refuse dump sites. Owing to indiscriminate disposal of untreated water from sewage and sanitary discharge sites, rivers and hand-dug wells become contaminated physico-chemically [13]. The problem is worse in areas where there are no proper sanitary and waste disposal facilities. Moreover, mineral enrichment from underlying rocks can change the chemistry of the groundwater, making it unsuitable for human consumption [1].Thus, the chemistry of the geological formation in any area has a great influence on the quality of water, which determines the concentration of introduced cations and anions in the water[17]. It is therefore important that, impurities in water be treated to meet certain standards before use for domestic purposes. The overall aim of this study was to assess the quality of water from hand-dug wells in SAWMA with the specific objective of investigating the physico-chemical and bacteriological characteristics of the wells.

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2. METHOD

2.1 Brief Description of Study Area

SAWMA also known as Ahanta West District (AWD)is one of 25 districts in the Western Region, Ghana with Agona-Nkwanta as its administrative capital. It is found within the South-Western Equatorial Climatic Zone of Ghana and lies approximately between latitude0º 05º and longitudes 0º 01ºW and 0º 12ºW 4º.45"N and longitude 1º.58"W. The District covers an area of 591km^{2}representing about 2.5 %of the total land area of Western Region and 0.6 %of Ghana respectively, with a population of 115,500projected from the 2012 population census. It is bounded to the east by SAEMA, west by Nzema East District, north by Mpohor Wassa East and Tarkwa Nsuem Districts and south, by the Gulf of Guinea. It consist of about 199 settlements and the major economic activities are farming and fishing. The topography is flat and undulating with few isolated hills at Butre and Banso ranging between 20 -140 m. The study area has lots of water bodies with river Butre, Miemia and Akwidaa being the major rivers. An average maximum temperature of 34ºC is recorded between March and April while, an average minimum of20ºC is experienced in August. Relative humidity is very high averaging between 75 - 85 % in the rainy season and 70 - 80 % in the dry season. It experiences a double maxima rainfall of over 1700 mm/yr with the peaks ranging from April to July and August to October respectively. The geology of the area consists of a small strip of Paleozoic and Cretaceous to Tertiary sediments. They are mainly Devonian sediments of the Sekondi Series and the soil types include loose sand, loam and clay. The main sources of drinking water are boreholes, hand-dug wells, streams and ponds. There are as many as about 600 unprotected wells scattered within the districts and animal hovering and grazing is common.

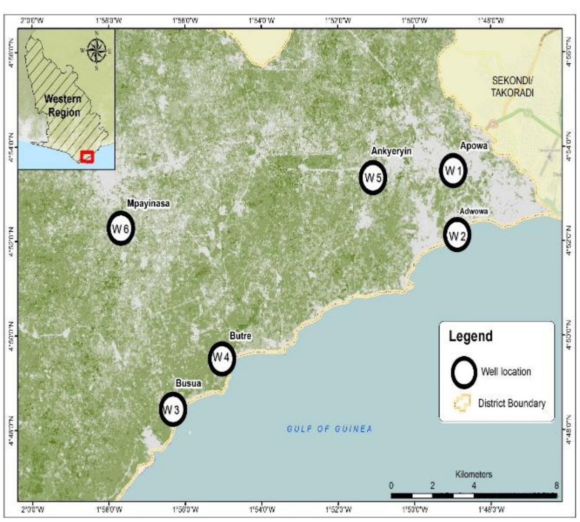

Figure 1: Map of SAWMA showing the location of the wells in relation to the Gulf of Guinea

2.2 Materials and Methods

Six water samples were collected from hand-dug wells within the study area to assess their physico-chemical and bacteriological properties. They were collected into 750mL pre-washed (distilled water) polyethylene bottles and each labelled according to their geo-spatial location as thus – Apowa (W1); Adwowa (W2); Busua (W3); Butre (W4); Ankyernyin (W5) and Mpayinasa (W6) as shown in figure 1. They were placed in improvised ice box to protect it from contamination and transported immediately to the Centre for Scientific and Industrial Research (CSIR) Accra, where samples were stored at 4ºC prior to analysis. The Geographical locations of the wells were picked with Garmin eTrex hand-held GPS receiver and their coordinates used to develop a geo - spatial map using Arc GIS version 10.3 [6]& [14]. A detailed analysis of the results compared with World Health Organisation (WHO) guidelines for domestic water use was presented using MS excel 2010 edition in the form of charts for susceptible parameters. All the analysis were based on standard methods as appropriate to each water quality parameter, as prescribed in [4].

3. RESULTS AND DISCUSSION

The result of the physico-chemical analysis compared with WHO standard for drinking water is presented (Table 1).pH values range from 6.26 to 7.48 with a mean of 6.71 compared to WHO limit (6.5 – 8.5). Hand-dug wells in the study area is slightly acidic to alkaline and thus, influence the weathering process of the basement rock complex of the study area [17].

Table 1: Physico-chemical parameters and trace metal in hand-dug wells in SAWMA compared with WHO standards

Wells	Units	W1	W2	W3	W4	W5	W6	WHO
pH	pH units	6.26	7.48	6.27	6.74	7.24	6.29	6.5 – 8.5
Turbidity	NTU	4.61	5	2.85	5.21	7.06	13.9	5
Conductivity	µS/cm	2330	3400	916	1716	1651	896	900
Colour	Hz	1	5	1	1	1	5	15
Odour		-	-	-	-	-	-	Inoffensive
TDS	mg/L	1282	1870	504	944	908	493	
TSS	mg/L	5	4	5	4	5	6	1000
Alkilinity	mg/L	36	372	65.8	175	197	137	
Total Hardness	mg/L	762	499	198	287	465	229	
Total Iron	mg/L	0.292	0.127	0.061	0.406	0.107	0.173	0.3

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Thus, no significant adverse health effect due to toxicity of dissolved metal ions, protonated species and aesthetics is expected. [1], [12] & [20] pointed out that pH values lower than 6.5 are considered too acidic for human consumption and can cause health related problems such as acidosis whiles those greater than 8.5 are considered too alkaline for human consumption as it hastens scale formation in water heater, pipes and reduces the germicidal potential of chlorine. Concentrations recorded for conductivity as illustrated in figure 3 ranged from 896 µS/cm to 3400 µS/cm with a mean of 1818 µS/cm.

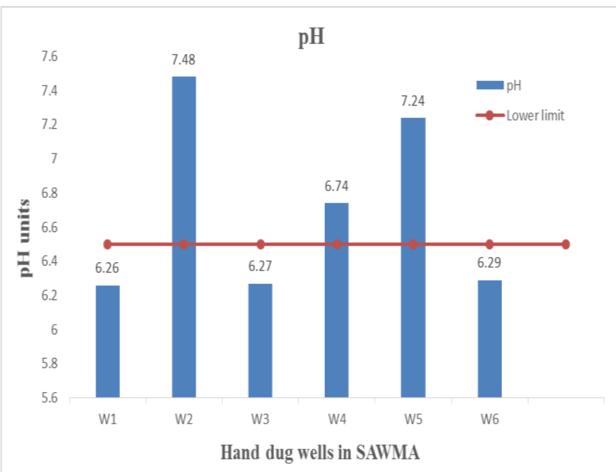

Figure 2: pH values of wells in SAWMA

The acidic nature of wells W1, W3 and W6 can be attributed to poor sanitation and domestic effluent discharge that runs off into hand-dug wells. They are also likely to be associated with the erosion of loamy and clayey soils from cultivated fields that increase the concentration of ions [1].

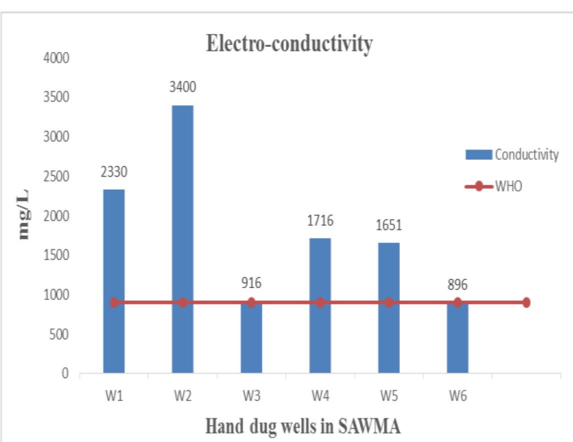

Figure 3: Electro-conductivity values of wells in SAWMA

Turbidity levels range from 2.85 – 13.9 NTU with a mean value of 6.44 NTU which was above WHO limit of 5.0 NTU. This might come from the extensive ploughing of farm lands to release suspended particles into wells to increase the turbidity[1] &[22]. Also, unlined or unstable sidewalls of the wells allow soil particles to fall into the water [8].

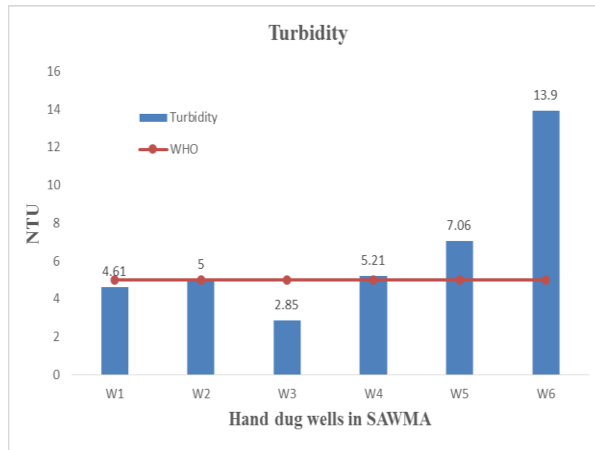

Figure 4: Turbidity values of wells in SAWMA

Turbidity correlated well with the abnormally high counts of total and fecal coliform bacteria. This is because turbid water stimulate bacteria growth and thus increase the cost of treatment ([8], [13], [19] &[20].The levels of TDS range between 493 – 1870 mg/L with a mean value of 1000 mg/L, incidentally the WHO standard limit is also 1000 mg/L. According to [17], high levels of TDS can lead to gastro-intestinal irritation and stains to fabric. Drinking water containing TDS levels above 500mg/Lusually has a disagreeably strong taste [3] and generally indicate hard water, which can cause scale buildup in pipes, valves and filters.

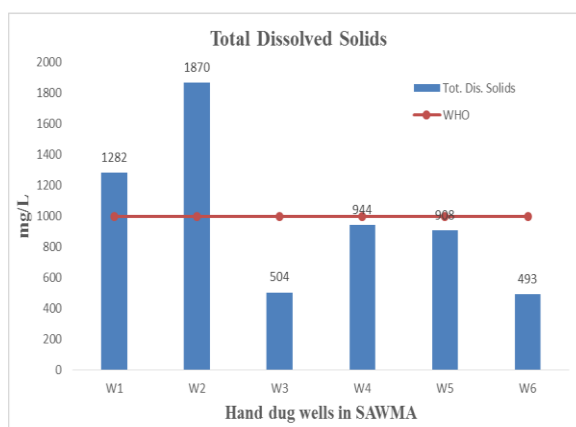

Figure 5: Total Dissolved Solids values of wells in SAWMA

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TDS concentration had a good correlation with turbidity [8] as well as conductivity [14]. The alkalinity levels range from 36 to 372 mg/L with a mean of 164 mg/L however, there is no standard specification for alkalinity by WHO. Although alkalinity in itself is not harmful to human, water samples with less than 100 mg/L are desirable for domestic use[24]&[21].Total alkalinity is the quantitative capacity of an aqueous media to react with H^+ ions [9] and elevated concentrations impacts unpleasant taste to water. The levels of total hardness range from 198 to762 mg/L with a mean of 407 mg/L while the WHO accepted value for total hardness is 100mg/L and maximum permissible limit is 500mg/L. This shows that (figure 6)all wells within the study area recorded concentrations below WHO limit for drinking water use, except well W1. This is seen in the relative increase in concentration of calcium and magnesium ions recorded in well W1 (Table 2).Normally, hardness in water does not pose any health problem although high levels may cause gastro-intestinal irritation as well as kidney problems.

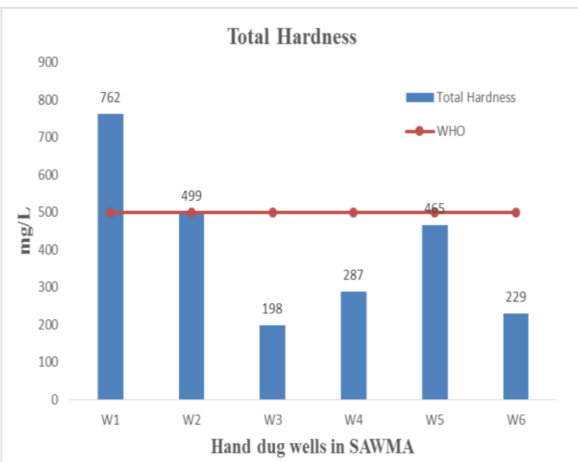

Figure6: Total hardness values of wells in SAWMA

Total iron concentration recorded for wells in the study area fell below the desirable limit of WHO except well W4(Table 1).According to health consideration, iron concentrations are essential to human health, because iron helps transport oxygen in the blood [22]. Iron in groundwater may originate from geological formations, especially under reducing conditions. They are also found in strong reducing environments and are caused by decaying organic matter resulting in a foul odour [22].High levels of iron may impact taste and cause stains. The results of the major cations and anions compared with WHO standard for drinking water use is also presented (Table 2).

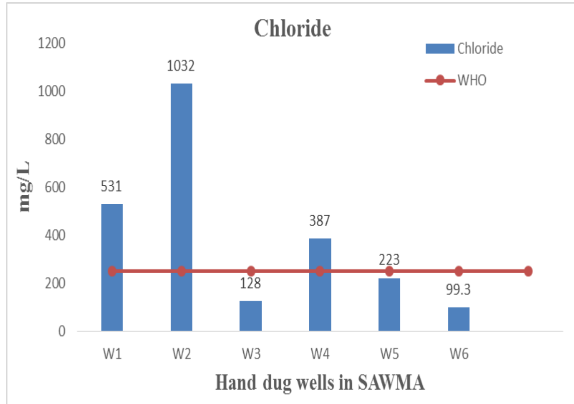

Figure 6: Chloride values of wells in SAWMA

Wells W1, W2 and W4 had chloride concentration above WHO limit while wells W3, W5 and W6 fell slightly below WHO limit. The elevated levels of chloride were expected since the study area is very close to the Gulf of Guinea (figure 1.0). This had a good correlation with sodium (Table 2).Thus, water from these wells reflect a possible sodium chloride type of water with marine origin [5].

Table 2: Levels of cations and anions in water samples from hand-dug wells in SAWMA compared with WHO standards.

Wells	Units	W1	W2	W3	W4	W5	W6	WHO
Sodium	mg/L	101	750	75	220	95	38	200
Potassium	mg/L	2.8	11	2.5	4	5.1	2.6	30
Calcium	mg/L	105	93	42.7	41.7	95	40.1	200
Magnesium	mg/L	121	64.8	22.3	44.4	55.3	31.3	150
Ammonia	mg/L	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	0.00 – 1.5
Manganese	mg/L	0.101	0.014	0.014	0.281	0.081	0.368	0.4
Chloride	mg/L	531	1032	128	387	223	99.3	250
Sulphate	mg/L	154	206	100	26	186	52.9	250
Bicarbonate	mg/L	43.9	454	80.3	214	241	167	-
Nitrate	mg/L	0.622	0.09	0.148	0.112	0.189	0.107	10
Nitrite	mg/L	0.093	0.015	0.093	0.011	0.044	0.016	1
Phosphate	mg/L	0.907	0.671	0.123	0.123	0.154	0.59	-
Fluoride	mg/L	<0.005	0.171	0.419	0.186	0.369	0.233	1.5

Chlorides are common constituents of all natural waters [9] & [20] and levels in excess (>250 mg/L) imparts a salty taste to water and have laxative effect on consumers [24]. The concentration of sulphates varies from 26 mg/L to 206 mg/L while the maximum permissible value is 500 mg/L and the highest desirable limit for WHO standard is 250 mg/L. With regards to sulphates, the recorded levels were below WHO limit so, no adverse health and aesthetic effects is expected. Sulphates occur in natural unaffected water up to 50 mg/L and may also originate from the small amount of gypsum and gypsiferous clay found within localities in the South-Western part of Ghana [11]. Thebi-carbonate concentration range

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between 43.9 – 454mg/L with a mean of 200 mg/L while the WHO standard for water quality is not stated. In the study area, well W2 recorded the highest concentration (454 mg/L) and this had a good correlation with calcium and magnesium concentrations (Table 2). Possible sources of bicarbonate ion in water are carbon dioxide of the atmosphere, carbon dioxide in the soil and dissolution of carbonate limestone and other carbonate rocks[6]. Its stability in water however depends on the pH of the water. Nitrate and nitrite levels recorded for wells within the study area also fell below WHO limit for domestic water use. This shows minimal contribution of fertilizer from agriculture practices and absence of direct sewage disposal in the vicinity of the well [24]. NO_3^- and NO_2^- may give rise to potential health risks such as Methemoglobinemia or 'blue-baby-syndrome' particularly in pregnant women and bottle-fed infants respectively[10] . Nitrate at elevated concentrations is also known to result in cyanosis in infants [10] &[12]. Recorded phosphate levels also fell below limit of WHO specification standard. This confirms that farming activities should not encourage the use of N-P-K fertilizer which has the potential of being leached or washed into groundwater [1] & [20]. And as such, no adverse health effect is expected. Phosphorus occurs widely in natural plants, micro-organisms and animal wastes. It is widely used as an agricultural fertilizer and as a major constituent of detergents, particularly for domestic use. It has no health effect on water according to [22]. Similarly, recorded levels of fluoride also fell below WHO limit and no adverse health effects or tooth damages are expected[21]. Fluoride has a significant mitigating effect against dental caries. However, continuous consumption of higher concentrations in the order of 4 mg/L or more can cause dental fluorosis [5], [20] & [22]and in extreme cases even skeletal fluorosis. Research has shown that although fluoride is essential for human beings as trace element, high levels become potent neurotoxin and can cause a wide array of severe health problems [22]. It can be seen in table 2 that manganese concentrations fell below limit specified by WHO standard for domestic water use and so no adverse health effect could be expected. It can clearly be seen in all charts that Well W2 recorded the highest concentration of pH, conductivity, TDS and chloride. This finding agrees with [14], that TDS which is an index of conductivity, has a direct relationship to salinity and high TDS limits the suitability of water for portable use. As such, W2 is the most questionable well in terms of quality.

It was revealed in table 3 that total coliform and faecal coliform bacteria for wells in the study area were abnormally high compared with stipulated standards. Total coliform count ranged between 34 – 2046 cfu/100mL while fecal coliform count ranged between 19 – 930 cfu/100mLcompared to WHO limit of 0.00 cfu/100mL.

Table 3: Result of bacteriological parameters of samples of hand-dug wells in SAWMA and their comparison with WHO standards

Wells	Units	Total Coliform	Fecal Coliform
W1	cfu/100mL	34	19
W2	cfu/100mL	930	279
W3	cfu/100mL	2046	465
W4	cfu/100mL	1488	930
W5	cfu/100mL	1860	22
W6	cfu/100mL	1395	465
WHO	cfu/100mL	0	0

This renders hand-dug wells within the study area unacceptable for drinking purposes. It could be due to the lateral distance of the wells to pit latrines and refuse dump sites[1], [16], [13] & [20]. Animals reared by free-range system might be responsible for the introduction of faecal matter into uncovered or unprotected wells [8]&[15]. Also, domestic animal pens sited close to household wells and animal hovering or resting close to wells can contribute to the high bacteria counts. Moreover, uncovered wells and the unkempt nature of buckets and gallons used in drawing water from the wells might also contribute to the contamination. Fecal coliforms have been shown to represent 93–99% of coliform bacteria in feces from humans, poultry, cats, dogs and rodents [20] &[21]).The high levels of fecal coliform in these wells indicate significant and increasing risk of contamination of water-borne diseases [3].

4. CONCLUSION

The geo-spatial locations of the hand-dug wells in the study area have been determined and the major water types based on the geological units are established. From the physico-chemical and bacteriological analysis carried out on the water samples, the following conclusions were made concerning the quality of hand-dug wells in the study area.

i. The total bacterial count in terms of total coliform (34 - 2046) cfu/100mL and faecal coliform (19 – 930) cfu/100mL were far above the WHO standard. These contaminants might have come from pit latrines and refuse dumpsites located close to the hand-dug wells. Animals hovering and resting around uncovered wells contributes to the high bacterial counts. Moreover, uncovered wells and the unkempt nature of buckets and gallons used in drawing water from the wells might also contribute to the contamination

ii. The high conductivity levels recorded for wells within the study area might be attributed to surface runoff from cultivated fields and poor sanitation practice.
iii. The significant levels of turbidity recorded can be related to erosion of loamy and clayey soils from cultivated agricultural fields leading to runoff of suspended sediments.
iv. The high levels of chloride were expected since the study area is close to the gulf of Guinea

5. RECOMMENDATIONS

Having assessed the quality of hand-dug wells in the study area, the following recommendation are proposed to enhance the quality of water from these wells.

1. Hand-dug wells in the study area must be disinfected using calcium hypochlorite before consumption.
2. There is the need to promote constructive and well-engineered measures to prevent erosion of the riparian land use
3. The environs of the wells should be kept clean and well developed.
4. wells should be provided with covers and protected from hovering animals.
5. Communities within the study area should be provided with sanitary facilities to control open defecation while individual homes are provided with modern toilet facilities.

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