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Assessment of Water Quality of Hand Dug Wells in a Riverine Community, Southern Nigeria

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Abstract— **The quality of hand dug wells used for domestic water supply in Burutu Community, Delta State, Nigeria were assessed. Samples were collected from twelve (12) wells and analyzed for physicochemical and microbiological parameters using standard methods. The results obtained revealed that the samples from the study area were acidic during the period of investigation. The parameters analysed were affected by both natural and anthropogenic sources. As regards physico-chemical parameters, the result revealed that some of the parameters analysed were within WHO guideline for drinking while others exceeded the threshold. The following ranges were recorded: pH (4.43 to 5.83), colour (5 to 15 Pt/Co), EC (150 to 460µS/cm), TDS (80 to 420mg/l), TSS (0.00 to 16.50mg/l), Total Hardness (14.40 to 113.19mg/l), chloride (7 to 117 mg/l), sulphate (6 to 200 mg/l), nitrate (2 to 12.20 mg/l), magnesium (11.08 to 14.87 mg/l), calcium (18.64 to 76.84 mg/l) and zinc (0.00 to 6.680 mg/l). In relation to microbiological contamination, the result revealed that all the sampled wells were contaminated with total and faecal coliform organisms as they exceeded WHO standard of 10MPN/100ml and 0MPN/100ml respectively. It revealed high concentrations of total and faecal coliform in all the wells: (TC 67 to 86 at Ambar, 110 to 360 at Chicoco, 111 to 114 at Low beach, 100 to 576 at Okorodudu and FC 18 to 29 at Ambar, 18 to 120 at Chicoco, 18 to 48 Low beach, 224 to 1218 at Okorodudu), suggesting high bacterial load. The water quality index (WQI) revealed variations in the sampled wells from very poor to fair category. In line with WHO standards and WQI results, the study established that the sampled wells in the community were contaminated and not safe for human consumption but usable for other domestic purposes. The study recommended that hand dug wells should be protected by sealing the walls, pouring of concrete apron, putting a lid over the top, and installing a hand pump as well as the use of pot chlorinator. The study also recommended proper sanitary practices, better alternative sources of water supply and intensive educational campaign to the indigenes of the area.**

Index Terms— **Burutu, Hand dug Wells, Potability, Riverine Communities and Water Quality Index .**

I. INTRODUCTION

Potable water is the fundamental need of man to sustain life. It serves as lubricant, regulates the body temperature and provides the basis for body fluids and metabolism [1]. Domestic water is used for drinking, cooking, bathing and potable water resources has often been used as a yardstick for socioeconomic and health status of many nations worldwide. However, the demand for potable water for drinking and other domestic use have been reported by different researchers to be of great challenge in modern day world. The continual improvement in the quality of water for purposes of drinking, personal hygiene and certain medical situations is among the top challenges of most riverine communities in Nigeria. Across most communities, waterborne diseases are the cause of death and suffering per annual. Reference [2], reported that nearly 10 million people cutting across the riverine communities in the Niger Delta region lack safe drinking water and at least 3 in every 8 deaths per year are attributed to waterborne diseases, with over 68 percent of the region covered by water. Not only is their poor access to readily accessible drinking water, but even when water is available in these small towns and villages, there are risks of contamination due to various factors. When wells are dugged, boreholes drilled and water sanitation facilities are developed, they are improperly maintained due to limited financial resources [2][3].Water quality testing is not performed as often as is necessary, and lack of education among the people utilizing the water source leads them to believe that as long as they are getting water from the source, it is safe.

Burutu is one of the twenty five Local Government Council Headquarters in Delta State, an oil producing State which supplies about 35 percent of Nigeria's crude oil and ranks second to Akwa-Ibom State [4]. One major challenge in the community is the ability to access potable water supply. Statistical survey has revealed an annual outbreak of epidemic resulting from waterborne disease. Across the community, there is no noticeable or functioning potable water scheme provided either by government, the multinationals nor NGOs and the situation has not improved over time [4]. Given such a grim situation, residents are left with no other choice than to seek sources of freshwater from rainfall, hand dug wells and the nearby water body. These self-sourced water are used for domestic work especially hand dug wells during the dry season as there are no alternative source of water supply [2]. Faecal matter/raw sewage, drops of petrol sold in unauthorized places and unwanted petrol from speedboat are released directly into the surrounding river body thereby making hand dug wells the only alternate source of freshwater for drinking. The population of Burutu increased drastically due to the presence of the Delta State School of Marine Technology and other multinationals located around the community. Increased release of effluent and other atmospheric pollutants are associated with population growth and industrialization, an unavoidable by-product discharged to the receiving environment thereby causing water, land and air pollution

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problems which eventually result to a host of impacts on the lives of the residents. Therefore, the aim of the study was to ascertain the potability of hand dug wells used for drinking purposes in the community.

II. MATERIAL AND METHODS

A. Study area

The study was conducted in Burutu town, an ancient town and the headquarters of Burutu Local Government Area, Delta State, Nigeria. It lies between latitude 5° 21^1 – 5° 35^1 N and longitude 5° 31^1 – 5° 51^{1}E (see Figures 1 and 2) with an elevation of 13 m above sea level [3]. The island is located close to the bank of the Atlantic Ocean and falls within the Beach Ridges on-shore geomorphic sub-environment of the Niger Delta. The area is characterized by strong wave and tidal action especially in the dry season, which further compact the sediments. The hydrogeology of the area is highly influenced by the presence of ferruginous sandy formation due to high oxidation condition of the near surface aquifers, and predominant saline water intrusion [5]. The water table in the area varies with seasons and with rise and fall in tidal action. Generally, the water table is dynamic and ranges between 0.2-3m depending on the season. Common in the town are relicts of Port and harbour, which existed at the period of colonial rule in Nigeria [6].

The study area has a tropical climate condition comprising of two distinct seasons: rainy and dry seasons. The wet season spans from April to November whereas the dry months are from November to March. The mean annual rainfall is about 2573 mm. The relative humidity is about 70-95 %, sunshine 4.6 bars whereas the mean air temperature is about 325°C [7]. Two winds namely the Northeast and the Southwest which influence the climate of Nigeria [3] also govern the study area. The Northeast winds from the Sahara desert is responsible for the cool and dry harmattan period between December and February whereas the Southwest wind which blows from the Atlantic Ocean are moisture-laden and influence the rainfall [8]. The indigenes of the area are mainly the Ijaw ethnic group and major in fishing and hunting.

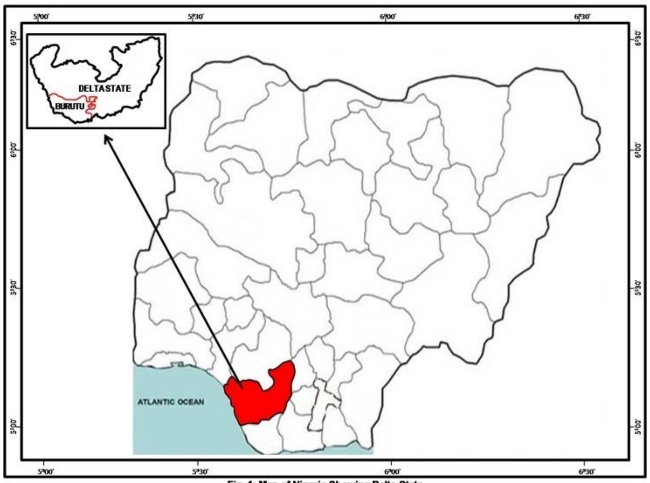

Fig. 1: Map of Nigeria Showing Delta State

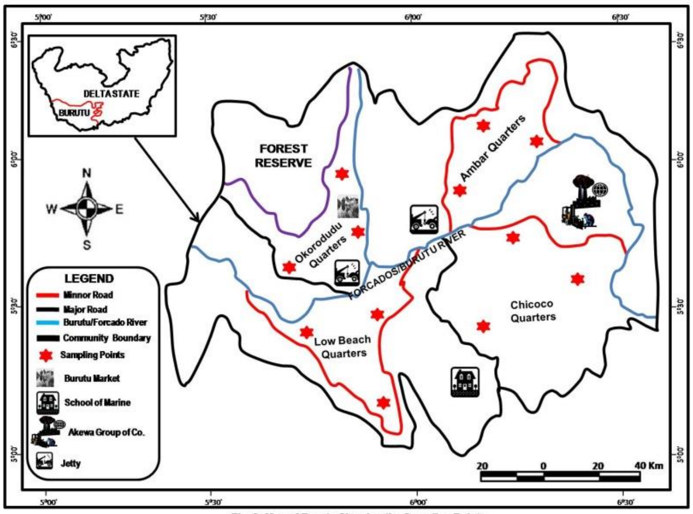

Fig. 2: Map of Burutu Showing the Sampling Points

B. Description of sampling location and sampled wells

Water samples from some selected hand dug wells were collected from twelve locations categorised into four major quarters: Ambar, Chicoco, Low Beach, Okorodudu that made up the Island. Samples were randomly collected from each well and analysed. Sample containers were clearly labelled to enhance record keeping. Samples of well water from Ambar, Chicoco, Low Beach and Okorodudu quarters were coded AWW1, AWW2, AWW3, CWW1, CWW2, CWW3, LWW1, LWW2, LWW3, OWW1, OWW2, and OWW3 respectively. All the samples were labelled with the locations, quarter, date and time of sampling on the containers. And all the sampled wells were either built by concrete or protected with metal drums and were directly exposed to sunlight.

C. Sample collection

For accuracy, proper sampling procedures were adopted to eliminate or minimise potential contamination of the samples. Sample containers were soaked in nitric acid (NHO_3) overnight and washed with distilled water, rinsed with deionised water and dried in a drying cabinet. Sampling was done on the 16th day of June, 2016 at about 8:00am to 11:00 am. All the samples were collected in clean containers, properly labelled and taken to the laboratory in an ice cooled container. Analyses were done immediately after sampling.

D. Physicochemical analysis

Samples were analyzed for major physical and chemical parameters like pH, TDS, TSS, total hardness, chlorides, sulphate, nitrates, magnesium, calcium, manganese, copper, zinc, iron and lead. pH were taken in the laboratory using an already standardized pH meter with glass electrode Model pHS-25 from Rex Instrument Factory Shanghai. EC was measured using the battery operated conductivity bridge Model MC-1 Mark V Electronic Switchgear at room temperature. TDS and TSS were determined according to the procedure and protocols outlined in [9]. Colour was determined using a Nessleriser. Nitrate was determined by the use of colorimetric methods. Chloride was determined using MOHR’s method. Sulphate was determined by turbidimetric method, while total hardness, calcium and magnesium were determined according to the methods described in [9]. Heavy metals were determined after digestion of solution of the samples and placed inside an

AAS (UNICAM Model 929) according to the method described by [9].

E. Total coliform bacteria

Total and faecal coliform were enumerated by multiple tube fermentation tests as described by [9]. Coliform count was obtained using the three tube assay of the Most Probable Number (MPN) technique. Presumptive coliform test was carried out using MacConkey broth (Oxoid). The first set of the five tubes had sterile 10 ml double strength broth and the second and third sets had 10 ml single strength broth. All the tubes contained Durham tube before sterilization. The three sets of tubes received 10 ml, 1 ml and 0.1 ml of water samples using sterile pipettes. They were carefully labelled and incubated at 37º C for 24-48 hours for estimation of total coliforms. Acid production was determined by colour change in the broth from reddish purple to yellow and gas production was checked for by entrapment of gas in the Durham tube. The MPN was then determined from the MPN table for the three set of tubes.

F. Total bacterial count (Microbial load)

Surface plate method was used. Samples were placed on Nutrient Agar and incubated at 22º C for 72 hours to isolate the bacteria. Another set was incubated at 37º C for 24 hours to isolate parasitic bacteria. Plates containing between 30 and 300 colonies were used in assessing bacterial density. Results were expressed as number per ml of sample.

G. Statistical analysis

Data obtained through laboratory experiments were subjected to statistical tests by calculating Mean ± SD. The results obtained were compared with WHO guideline for potable drinking water quality.

H. Water quality index (WQI)

Water Quality Index (WQI) was calculated using the Weighted Arithmetic Index method as described by [10]. In this model, different water quality components were multiplied by a weighting factor and then aggregated using simple arithmetic mean. To assess the quality of water in this study, firstly, the quality rating scale or sub index (q_n) for each parameter was calculated using the following equation;

$$q_n = 100[(V_n - V_{io})/(S_n - V_{io})] \quad (1)$$

Where

q_n = quality rating for the nth water quality parameter.

V_n = actual value of the water quality parameter obtained from laboratory analysis

S_n = recommended WHO standard of the water quality parameter

V_{io} = ideal value of that water quality parameter can be obtained from the standard table

All the ideal values (V_{io}) were taken as zero for drinking water except for pH = 7.0 and dissolved oxygen = 14.6 mg/L. Then, after calculating the quality rating scale (q_n), the relative (unit) weight (W_n) was calculated by a value inversely proportional to the recommended standard for the corresponding parameter using the following expression;

$$W_n = k/S_n \quad (2)$$

Where

W_n = relative (unit) weight for nth parameters

S_n = standard permissible value for nth parameters

k = constant for proportionality and is calculated by using the equation as follows:

$$k = \left[1/\left(\sum 1/S_n = 1,2, \dots n\right)\right]$$

Where Sn is the standard value for nth parameters

This means, the relative (unit) weight (W_n) to the various water quality parameters are inversely proportional to the recommended standards for the corresponding parameters. Finally, the overall WQI was calculated by aggregating the quality rating with the unit weight linearly by using the following equation:

$$WQI = \sum q_n W_n / \sum W_n \quad (3)$$

The index equation generates a number between 10 and 100, with 10 being the poorest and 100 indicating the excellent water quality. Within the range designations, the quality of the water was classify into six categories of water quality as very poor, poor, fair, good, very good and excellent.

III. RESULT AND DISCUSSION

A. Variation of physicochemical quality of the different hand hug wells

Table 1 presents a summary of the physicochemical and microbiological analyses of the different water samples collected randomly from hand hug wells in the study area. Also presented in Table 2 are the mean, standard deviation, minimum and maximum values (statistical analysis) of the samples.

pH

The pH of the sampled well water in the study ranged from 4.43 to 5.83; the lowest being observed in well 9 and the highest in well 1. The pH values in the various quarters varied between wells; with Ambar quarter having a range of 4.80 to 5.83, Chicoco: 5.16 to 5.69, Low Beach quarter: 4.43 to 4.52, Okorodudu quarter: 5.68 to 5.8. All the sampled wells had a pH lower than the neutrality. The relative low pH of the samples may be due to high concentration of dissolved organic loads [11]. Ambar, Chicoco, Low Beach, and Okorodudu are situated along and close to Akewa group of company, NPA, Burutu Local Government industrial plant house and Delta State School of Marine Technology industrial workshop, hence the lower mean pH values can be attributed to industrial emission. One major attribute resulting to low pH is that the community is situated in an island that is surrounded by the ocean; hence salt water from the creek may have altered the acid-base equilibrium of the surrounding water table [4]. This finding is similar with the report of [12]. The pH for the twelve sampled wells from three different quarters in Burutu were observed to be far below [13] guideline for drinking water.

Table 1: Variation of Physicochemical and Bacteriological Quality of Hand dug Wells water from Burutu Community, Delta State

Parameters	Ambar Burutu			Chicoco			Low Beach			Okorodudu		
	Well 1	**Well 2**	**Well 3**	**Well 4**	**Well 5**	**Well 6**	**Well 7**	**Well 8**	**Well 9**	**Well 10**	**Well 11**	**Well 12**
Colour	5	5	5	5	10	10	5	10	5	10	15	5
pH	5.83	5.10	4.80	5.16	5.66	5.69	4.52	4.45	4.43	5.68	5.8	5.73
EC (µS)	200	150	460	500	490	670	230	400	250	670	270	170
TDS (mg/l)	130	100.00	300.00	330	320	420	140	260	160	420	180	80
TSS (mg/l)	1.05	1.05	1.05	1.05	12.60	12.85	1.25	14.50	0.00	16.50	15.05	1.05
TH (mg/l)	46.97	14.40	113.19	86.24	45.43	61.60	23.87	61.60	56.21	83.16	96.25	16.17
Chloride (mg/l)	29	7.0	48	76	87	87	44	52	34	171	73	10
Sulphate (mg/l)	20	6	40	150	25	30	40	200	40	200	20	21
Nitrate (mg/l)	2.02	0.50	2.53	5.05	6.10	6.50	2.10	2.80	2.06	12.20	4.85	0.85
Magnesium (mg/l)	8.45	4.94	46.05	16.65	14.85	12.95	5.25	11.25	12.85	20.85	18.16	6.25
Calcium (mg/l)	36.47	8.64	85.95	68.85	28.95	46.70	17.66	48.64	39.06	59.86	76.84	8.96
Manganese (mg/l)	0.082	0.000	0.210	0.205	0.213	0.478	0.000	0.000	0.000	0.050	0.135	0.010
Cu (mg/l)	0.137	0.080	0.285	0.048	0.041	0.053	0.015	0.025	0.069	0.000	0.013	0.000
Zn (mg/l)	0.342	3.190	3.285	5.120	0.000	6.680	1.025	1.127	5.589	0.000	0.024	0.000
Fe (mg/l)	0.420	0.837	0.865	0.900	0.874	0.921	0.163	0.245	0.311	0.343	1.799	0.068
Pb (mg/l)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TC Count (cfu/100ml)	67	86.00	70	110	360	294	112	111	114	102	576	100
TF Coliform (cfu/100ml)	22	18.00	29.00	18	120	60	48	20	18	46	282	20
TB Count (cfu/100ml)	208	264	169	312	996	888	181	266	238	224	1218	273

Table 2: Mean values of Physico-chemical and Bacteriological Quality of Hand dug Well water from Burutu Community, Delta State

Parameters	N	Minimum	Maximum	Mean	Std. deviation	WHO
Colour(pt/Co)	12	5.0	15	7.5	3.371	15
pH	12	4.43	5.83	5.24	0.563	6.5-8.5
EC (µS)	12	150	670	371.66	186.24	1000
TDS (mg/l)	12	80	420	236.66	120.78	500
TSS (mg/l)	12	0.0	16.50	6.50	6.96	400
TH (mg/l)	12	14.40	113.19	59.83	31.70	NA
Chloride (mg/l)	12	7.0	171.0	59.83	44.32	250
Sulphate (mg/l)	12	6	200	66	72.51	250
Nitrate (mg/l)	12	0.5	12.2	3.96	3.25	10
Magnesium (mg/l)	12	4.94	46.05	14.87	11.08	0.20
Calcium (mg/l)	12	8.64	85.95	43.88	25.61	75
Manganese (mg/l)	12	0.0	0.478	0.12	0.144	NA
Cu (mg/l)	12	0.0	0.285	0.06	0.07	NA
Zn (mg/l)	12	0.0	6.68	2.19	2.47	5.0
Fe (mg/l)	12	0.068	1.799	0.65	0.48	0.3
Pb (mg/l)	12	0.0	0.0	0.00	0.00	0.01
TC Count (cfu/100ml)	12	67	576	175.16	155.73	0
TF Coliform (cfu/100ml)	12	18	282	58.42	76.33	0
TB Count (cfu/100ml)	12	169	1218	436.41	106.68	0

Note: NA – Not Available

Colour

According to [13], there should be no colour, odour or taste in drinking water. Out of all the well water sources sampled, samples from Ambar, Chicoco, Low Beach, and Okorodudu quarters showed light and dark brown colour with a range of 5 to 15 (Pt/Co) across the wells. The source of the samples were open well where the water table was 8 ft deep. The possible contamination sources were found to be decayed plants since the community was land filled (dredging). Thus the colour of the sample may be attributed to decaying organic matters. Also, another major factor contributing to colour change in the wells may possibly be due to suspended minerals and dead organic matter [14]. The finding confirms the study of [4] who worked on the physico-chemical and microbiological characteristics, comparative analysis and potability of fresh water sources for domestic water supply in four Riverine Communities, Delta State, Nigeria.

Electrical conductivity

Electrical conductivity is a measure of water capability to transmit electric current and [13] standards confirmed the mean value of EC to not exceed 1000 µS/cm. In this study, EC value in samples from Ambar quarter ranged from 150 to 460 µS/cm across the wells, 490 – 670 µS/cm in samples from Chicoco quarter, 230 to 400 µS/cm for Low Beach quarter, and 170 – 670 µS/cm in well samples from Okorodudu. However, the high mean conductivity of samples from Chicoco quarter can be adduced to high amount of dissolved ions resulting in the built up of industrial activities in that area [4]. That of Low beach and Okorodudu quarters may be attributed to run-offs that carried human waste materials, pesticides and other particles from cultivated fields in and around the sampled wells. These findings clearly indicate that hand hug well water in the study areas were considerably ionized. It may also be possible that the high values of EC recorded from the sampled wells were result of low water table and the geological strata of the area. This finding confirmed the assertion of [15] that soil contents of shallow water table are rich in variety of salts, which flow through the water table in dissolved states from the higher strata to the lower strata. However, the electrical conductivity values were within the standards for drinking water quality [13].

Total dissolved solid

TDS in this study is considered to be a good indicator for water salinity, and it gives general information about the sum of ions in the water. TDS values of the sampled wells across the quarters varied in the range of 80 to 420 mg/l, the lowest being observed in well 12, while the highest were in wells 6 and 10. This range is similar to the one obtained by [16]. The relatively high mean TDS of water samples from Chicoco quarter can be attributed to organic sources such as leaves, silt, plankton and waste as most of the wells were opened and surrounded by green plants. The most remarkable observation of this study was the alarming high level of total dissolved solids (TDS) in wells 6 and 10. Samples from wells from Okorodudu quarter were collected from domestic tube wells and metal drums having age of 5-10 years and water table of 8 ft. The surrounding sewage line and gutter were located at about 15-22 ft away. Viewing other chemical profile of these samples, it was suggested that the areas of these samples were rich in various water soluble minerals causing high TDS values. On overall basis, it is evident that the underground strata contain high concentration of easily soluble salts, which may be the main cause of high TDS value across the quarter's well water samples [17]. However, the level of TDS recorded in the samples was an indicator of potential concern and this warrants further investigation.

Total suspended solid

The total suspended solid values of the different samples varied in the range of 0.00 to 16.50 mg/l, the lowest being observed in well 9 while the highest was in well 10. TSS values of water from Ambar, Chicoco, Low beach, and Okorodudu varied in the range of 1.05 mg/l, 1.05– 12.85, 0.00 – 14.50, and 1.05 to 16.50 mg/l respectively. The relatively high TSS mean for samples from Okorodudu quarter corroborated the relationship of high concentration of nutrients and metals in the water. The mean values of TSS recorded for samples from Okorodudu quarter were much higher than that of Ambar and Low beach samples. High TSS values were recorded across the sampled wells except well 9. The higher values of TSS in the wells confirm the resultant taste of the water, high water hardness and could also result in laxative effect. These findings were similar with the report of [18]. The relative high concentrations of TSS recorded from the wells are not acceptable due to the resulting taste. Water with very low concentrations of solids is also unacceptable to consumers because of its insipid taste, often resulting to corrosion of water supply systems [19].

Total hardness

Total hardness in water is characterized with high mineral contents that are usually not harmful to humans and often measured as calcium carbonate ($CaCO_3$). Total hardness values of the samples were found in the range of 14.40 to 113.19 mg/l. Samples from Ambar, Chicoco, Low beach, and Okorodudu quarters varied in the range of 14.40 to 113.19, 45.43 to 86.24, 23.87 to 61.60, and 16.17 to 96.25 mg/l respectively. The relatively high mean of total hardness recorded for samples from Ambar quarter may be due to run-off that carried dissolved calcium and magnesium ions into the wells as some of them are not properly protected with concrete. The total hardness values recorded across the sampled wells may be adduced to dissolution of ions by rainwater percolation in the soil. The ions may have originated from run-offs that infiltrated into the soil through leaching [20]. The values of total hardness recorded from the samples also indicated that Burutu land is rich in calcareous and carbonaceous minerals. During the course of the study, the consumers of water having hardness value beyond permissible level complained about scale formation and salty taste. Generally scales formation in water of these areas was a very common phenomenon, a direct indication of high hardness of the water. These results clearly revealed that total hardness value of the wells were above the threshold of [13] standards and could be harmful to the local inhabitants because it has been reported by [21], [22], and [23] that excessive hardness may cause diarrhea, gas trouble, kidney stones and heart problems.

Chloride

Chloride is a useful and reliable chemical indicator for surface and groundwater, as chloride is a non-reactive solute and ubiquitous to sewage and potable water [24]. The concentration of chloride across the wells varied in the range of 7.0 for well 2 to 171 mg/l for well 11. Chloride content value of water samples varied from 7.0 to 48 mg/l in Ambar quarter, 76 to 87 mg/l in Chicoco, 34 to 52 mg/l in Low beach and 10 to 171 mg/l in Okorodudu quarter respectively. These levels recorded may be attributed to seawater intrusion. The high values of chloride in the water samples may be due to the aquifer which is prone to seawater in the coastal area. Thus, the high value of chloride from the samples can increase the electrical conductivity of the water and also increases its corrosivity [25]. However, the results indicated that chloride content in the water sources were within the acceptable limit of 250 mg/l [13]. Excessive chloride in potable water is not particularly harmful but the criteria set for this anion are based primarily on palatability and its potentially high corrosiveness [24], [2]. The relatively high values of chloride in the samples confirmed the work of [26] that 40.00 mg/l chloride indicates saltwater intrusion and groundwater with greater than 100 mg/l is classified as a diffusion zone, thereby suggesting that only about 6.3 percent of the well water under investigation may be free from saltwater intrusion. The result also agreed with the report of [27] that the reflection of relatively high values of chloride in well water maybe due to retention of ions from salts trapped at the time deposition of seawater solution of minerals occurred. This study also confirmed the work of [28].

Sulphate

Sulphate is mainly derived from the dissolution of salts of sulphuric acid and is abundantly found in almost all water bodies. Sulphate concentration in natural water ranges from a few to a several hundred mg per liter but no major negative impact of sulphate on human health has been reported. In this study, mean values of 20, 6 and 40 mg/l for Ambar, 150, 25 and 30 mg/l for Chicoco, 40, 200 and 40 mg/l for Low beach and 200, 20 and 21 mg/l for Okorodudu were recorded for the sampled wells respectively. Although, samples from well numbers 8 and 10 had the highest values; these values are lower than the 250 mg/l of [13] permissible standard for drinking water quality. The relative high values of sulphate recorded in some of the wells could be traced to the geology of the soil. Interaction of sand and clay soil could also encourage sulphide such as pyrite from stratified matter reacting with water to produce SO_4 [29]. The values recorded for wells 8 and 10, suggests a likely characteristic taste of somewhat bitter. Based on the results, sulphate level is not likely to cause health hazard. But with continuous increase of sulphate in the samples can cause noticeable taste. Sulphate level in wells sampled from Ambar quarter in the study was lower than that reported by [30] and Niger study [31]. That of well 4 (Chicoco), 8 (Low beach) and 10 (Okorodudu) quarters however, were higher than the reports of [32], Abeoukuta study [33], [29].

Nitrate

The concentration of nitrate above 10 mg/L in natural waters was reported by [12] to indicate man made pollution and is one of the most important disease causing parameters of water quality particularly blue baby syndrome in infants. In this study, it was revealed that the lowest nitrate value was recorded in well 2 (0.50 mg/l) and the highest value of 12.20 mg/l in well 10. The nitrate values in the different wells in Ambar quarter were found to be below the permissible limit of [13] for drinking water. The values of nitrate obtained in samples from Chicoco quarter varied between 5.05 to 6.50 mg/l which was also below the drinking water standard of [13] but higher than values obtained from Ambar quarters. The higher nitrate values recorded for these samples may be a reflection of the organic material loads that settled at the bottom of the wells. Nitrate values for Low beach quarter were lower than the values for Chicoco but higher than that of Ambar quarter, reflecting the level of good hygiene practice and environmental sanitation around the wells. The absence of basic sanitation, as well as dropping of food particles by children, (since the wells were not properly covered) can contribute significantly to nitrate levels in the water. This shows that water pollution is more to do with the way water is handled or managed and not only the storage material. Although, the values recorded for samples from Chicoco quarter were below [13] guideline for potable water. The most alarming value of nitrate recorded across the four quarters in Burutu was sample number 10 from Okorodudu quarters which was above [13] standard. The high mean value recorded can be attributed to the presence of organic materials such as leaves, run-offs carrying organic materials and bird droppings in and around the well area. Reference [34] in his study on the variability of run-off quality established that nitrates present in run-offs may be due to organic materials and bird droppings.

Magnesium

Magnesium is the eighth most abundant natural element. It makes up 2.5 percent of the earth's crust and is commonly found in such minerals as magnesite, dolomite, olivine, serpentine, talc and asbestos [17]. Mg values in the studied wells varied in the range of 11.08 to 14.87mg/l, the lowest being observed in well 2 and highest in well 10. Mg values of water from Ambar, Chicoco, Low beach, and Okorodudu quarters varied in the range of 8.45, 4.94, 46.05, 16.65, 14.85, 12.95, 5.25, 11.25, 12.85, 20.85, 18.16 and 6.25 mg/l respectively. These values were found to be within the 150 mg/l of [13] guideline for drinking water. The relative mean values of magnesium recorded across the samples may be due to seawater intrusion since the water table is very high, dissolved minerals and run-offs laden with magnesium. The values of magnesium recorded may also be attributed to the geological locations of the area. This finding is similar with the report of [35], [17].

Calcium

Calcium is a determinant of water hardness, because it can be found in water as Ca^{2+} ions. Also, high deficiency of calcium in humans may caused rickets, poor blood clotting and bones fracture, but excessive concentration of calcium produced cardiovascular diseases. The results of this study showed that the concentration of calcium ranged from 8.64 to 85.95 mg/l for Ambar wells, 28.95 to 68.85 mg/l for Chicoco wells, 17.66 to 48.64 mg/l for Low beach wells and 8.96 to 76.84 mg/l for Okorodudu wells respectively. The relatively high values of calcium recorded across the samples except wells 2 and 12 may be attributed to the various construction materials, such as cement, brick lime and concrete used for the well construction as well as the geology of the area. The values recorded may be attributed to seawater intrusion and run-offs containing dissolved minerals. However, these values were within [13] guideline for drinking water.

Zinc

Zn is naturally found in air, water and soil. Zn concentrations are rising due to additions of Zn to the environment through industrial activities and waste combustion [36]. The most significant zinc ores include sphalerite (ZnS) and smithsonite ($ZnCO_3$). These compounds end up in water on locations where zinc ores are found. Zinc concentration in the analysed water samples were 0.342, 3.190 and 3.285 mg/l for samples 1 to 3 (Ambar), 5.120, 0.000 and 6.680 mg/l for samples 4 to 6 (Chicoco), 1.025, 0.000 and 6.680 mg/l for samples 7 to 9 (Low beach) and 0.000, 0.024 and 0.000 mg/l for samples 10 to 12 (Okorodudu) quarters respectively. Some of these values were within 5.0 mg/l acceptable limit of [13] except wells 4, 6 and 9 which had mean value that exceeded the standard. The relatively high values of zinc recorded in some of these wells may be attributed to point and non-point sources of pollution. The variations in zinc values across the sampled wells maybe adduced to poor environmental hygiene and the presence of zinc compounds since zinc is present in fungicides and insecticides and human feaces [12].

Iron

Iron is objectionable because of the bad taste associated with it in water. High concentration of iron in water stains laundry, sanitary ware, gives an undesirable taste and develops turbidity as well. Iron concentration below 0.2 mg/l is safe, but the taste of water is affected when it exceeds 0.3 mg/l [13]. The observed mean Fe concentrations were in the order of well 1<well 2<well 3 (Ambar quarter), well 5<well 4<well 6 (Chicoco quarter), well 7<well 8<well 9 (Low beach quarter) and well 12<well 10<well 11 (Okorodudu quarter) respectively. Samples from Ambar quarter had mean Fe concentrations that were above [13] standard value of 0.3 mg/L. Also, the mean values for samples from Chicoco quarter still exceeded the standard. In addition, the mean values for samples from Low beach and Okorodudu quarters exceeded the standard guideline except well 7 and 12 which were within the standard. The high iron concentrations recorded in majority of the wells suggest dissolved iron by rainwater from soil particles into ground water [36]. It may also be attributed to run-off that carried sediments containing iron or intrusion of seawater since Burutu is an Island. The high concentration of iron recorded in the samples is validated by the level of pH and total hardness of the water samples recorded. A study by [37] on the quality of ground and rainwater indicated that the occurrence of iron in borehole could be due to the dissolution of iron from metallic wastes and scraps and lateritic iron within the soil particles. The iron concentration recorded for wells 7 and 12 may be attributed to dissolved particulate matter that found their way into the wells. Wells across the four quarters had mean iron concentrations that were above the acceptable level except wells 7 and 12. Hence, ulceration of the gastrointestinal tract and black stools of consumers can be anticipated in the study area. Reference [31] reported that elevated Fe levels in water over time could cause severe lungs disease.

Lead

Lead is one of the oldest metals known to man and is discharged into surface water and percolates into ground water through paints, solders, pipes, building material and gasoline. Combustion of oil and gasoline account for about 50 percent of all anthropogenic emissions, and thus form a major component of the global cycles of Pb [38]. In this study, the values of lead recorded were below detectable levels and were within limits of [13] standard for drinking water. However, the presence of lead in ground water may be attributed to run-offs from industrial activities and the corrosion, or wearing away of materials containing lead. It may also be attributed to particulate matters from industrial flares or corrosion of lead materials, sediment load of the well and poor environmental sanitation [36].

B. Microbiological characteristics of the different hand dug wells

The microbiological results showed that the sampled wells were contaminated with total and faecal coliform organisms because they exceeded [13] standard of 10MPN/100ml and 0MPN/100ml respectively. The wells had a mean of total coliform 175.16±155.73 MPN/100ml from twelve samples with a range of 67 to 576 MPN/100ml. Values across the wells varied as follows: 67, 86.00, 70 for (Ambar); 110, 360, 294 for (Chicoco); 112, 111, 114 for (Low beach) and 102, 576 and 100 for (Okorodudu) quarters respectively. This indicates that microbiologically, none of the wells were fit for drinking. This result corroborates the finding of [37] that the MPN coliform index per 100ml of water samples collected from selected areas in the oil producing region of Nigeria had 23 to 45 MPN/100ml. Reference [39] in a related study isolated some members of coliform in stored well water samples. Reference [40] also obtained high total coliform from wells and boreholes water in some peri-Urban communities in Kumasi, Ghana.

The analysis of faecal coliform revealed a mean value of 58.42±76.33 mpn with a range of 18 to 282 mpn in the various wells across the four quarters. Reference [13] standard for faecal coliform in potable water is 0 cfu/ml. The presence of counts exceeding [13] limits indicates that the samples contain high concentration of bacteria that could make the water unsafe for drinking. The result showed that the values of faecal coliform varied as follow: 22, 18.00, 29 for (Ambar); 18, 120, 60 for (Chicoco); 48, 20, 18 for Low beach and 224, 1218 and 273 for (Okorodudu) quarters. These values exceeded [13] permissible limit for drinking water. This high level of contamination may be attributed to the high level of biological activities resulting from animal wastes, improper waste disposal management and non practice of good hygiene in and around the well areas. This finding agrees with similar studies by other scholars who reported that the sources of faecal coliform in water are human and animal wastes, runoffs, pasture, natural soil or plant bacteria, sewage and other unsanitary practices [12], [41]-[42]. It also corroborates the findings of [43], and [15]. Reference [44] in a separate study also obtained a range of faecal coliform that are unacceptable by WHO from hand dug wells in Benin City, Nigeria.

C. Water Quality Index

In this study, the analytical results for each parameter were used to calculate the WQI. The data was first converted to a non-dimensional sub-index values rating from 10 (worse case) to 100 (ideal) depending on the parameter's contribution to water quality impairment (see Tables 5 and 6).These sub-indices were then combined to give a single water quality index rating value ranging from 10 to 100. The unweighted harmonic square mean formula used to combine sub-indices allowed the most impacted parameter to impart the greatest influence on the water quality index as described by [10]. Thus, the calculated result revealed that the Water Quality Index was reported to approach 61.33 and some samples > 61.33, indicating that the water is in very poor category to fair category (not suitable for human consumption).

The WQI graph for the comparison of mean values between the wells in Burutu community is shown in figure 3. Table 3 displays the water quality rating (qn) of different parameters of the samples at different wells. The sub-index (q_nW_n) values of the different parameters of the samples at different wells is shown in Table 4, whereas Tables 5 and 6 contain information on drinking water guidelines, unit weights and classification scheme for water quality index scores. The statistical summary for each well sample and quarter as per their quality rating (WQI) are shown in Table 7.

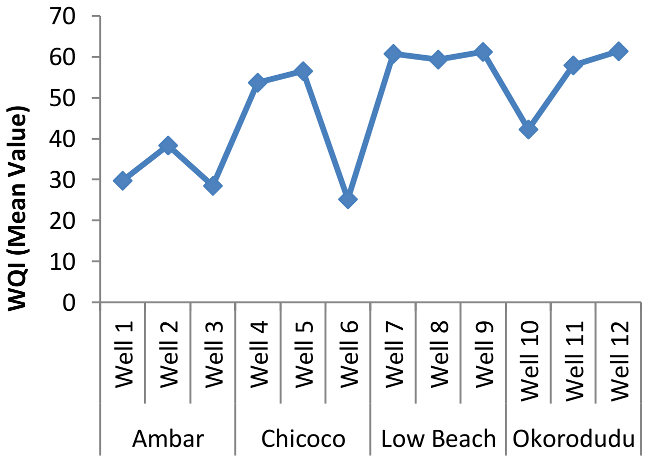

Figure 3: Comparison of WQI mean values sampled wells in Burutu Community, Delta State

Table 3: Water quality rating (*qn*) of different parameters of well water at different stations

Sample Location	Sample Code	pH	EC	TDS	TSS	TH	Cl^+	Sulphate	Nitrate	Magnesium	Ca	Manganese	Cu	Zn	Fe	Pb	Total Coliform
Ambar	Well 1	4.6231	16.2915	11.3402	0.6667	12.3601	9.0320	6.2316	0.5098	4.6517	17.1333	0.0637	0.0264	0.0296	0.0218	0.000	12.3587
	Well 2	4.2850	13.2305	9.2618	0.6667	5.2519	2.0816	1.2066	0.0135	2.2902	4.5924	0.0000	0.0859	0.0653	0.0562	0.000	12.4315
	Well 3	4.1038	22.6689	16.3265	0.6667	24.3213	13.1606	11.1646	0.6219	14.7566	28.6526	0.0384	0.0436	0.0679	0.0590	0.000	9.5699
Chicoco	Well 4	4.8732	24.7624	16.6800	0.6667	16.3471	11.1210	15.1934	2.0176	9.8074	22.6955	0.0457	0.0544	0.0835	0.0613	0.000	13.6436
	Well 5	4.8123	22.9021	16.4514	8.6273	11.2433	13.0709	8.2651	3.4268	7.1293	13.8543	0.0389	0.0561	0.0000	0.0587	0.000	18.9123
	Well 6	4.9406	25.6214	18.7656	8.7722	13.6203	13.0709	9.2228	3.6171	5.7923	19.2956	0.0397	0.0633	0.0846	0.0619	0.000	16.8061
Low Beach	Well 7	4.0369	16.9248	11.9220	0.9432	7.4316	7.0604	11.1646	0.5164	3.1286	8.2432	0.0000	0.0323	0.0829	0.0093	0.000	9.9147
	Well 8	4.0152	22.2375	13.4319	9.0621	13.3411	8.1445	20.4660	0.6872	5.3085	18.3612	0.0000	0.0467	0.0635	0.0227	0.000	12.4035
	Well 9	4.0084	16.1091	12.2393	0.0000	12.9672	3.2574	11.1646	0.5395	6.1716	17.3803	0.0000	0.0852	0.0828	0.0293	0.000	12. 2520
Okorodudu	Well 10	4.5825	27.1303	18.6750	9.9761	17.3583	16.3881	17.2404	7.0156	8.3727	18.0432	0.0483	0.0000	0.0000	0.0571	0.000	12.1106
	Well 11	4.5902	17.9894	13.3425	8.6548	18.4566	11.1333	6.2316	2.0248	7.1456	21.1651	0.0359	0.0698	0.0876	0.0992	0.000	20.8542
	Well 12	4.5900	14.1011	6.2603	0.6667	9.8141	4.5807	6.4858	0.0191	2.1800	3.7937	0.0096	0.0000	0.0000	0.0276	0.000	12.3117

Table 4: Sub-index (q_nW_n) values of different parameters of well water at different stations

Sample Location	Sample Code	pH	EC	TDS	TSS	TH	Cl^+	Sulphate	Nitrate	Magnesium	Ca	Manganese	Cu	Zn	Fe	Pb	Total Coliform
Ambar	Well 1	4.0001	0.7247	0.1345	0.0546	0.1490	0.0295	0.0934	0.0196	4.2216	0.0309	0.0423	0.0128	0.0228	0.0262	0.0000	4.1184
	Well 2	3.2922	0.7618	0.0758	0.0875	0.2065	0.0641	0.4046	0.0753	4.2163	0.0144	0.0000	0.0634	0.0482	0.0538	0.0000	4.3766
	Well 3	3.1189	1.3093	0.0625	0.0426	0.1994	0.0259	0.1865	0.0432	6.7674	0.0446	0.0146	0.0227	0.0592	0.0523	0.0000	2.8501
Chicoco	Well 4	3.5174	0.5355	0.0842	0.0435	0.1168	0.0488	0.1376	0.0322	4.5459	0.0182	0.0206	0.0356	0.0617	0.0610	0.0000	5.6317
	Well 5	4.1709	0.6043	0.1653	0.1552	0.2462	0.0173	0.3163	0.0203	6.1264	0.0373	0.0141	0.0353	0.0000	0.0527	0.0000	7.9680
	Well 6	4.6715	0.4762	0.6394	0.0294	0.1453	0.0168	0.1469	0.0431	5.2881	0.0145	0.0163	0.0461	0.0573	0.0631	0.0000	6.8415
Low Beach	Well 7	4.0914	0.5429	0.0581	0.0588	0.0910	0.0351	0.1885	0.0261	2.6697	0.2145	0.0000	0.0136	0.0636	0.0057	0.0000	2.9691
	Well 8	3.2955	0.0692	0.2105	0.0712	0.1624	0.0164	0.1743	0.0518	4.7255	0.0651	0.0000	0.0224	0.0417	0.0118	0.0000	4.9847
	Well 9	3.4076	0.4743	0.0587	0.0215	1.0222	0.0376	0.1489	0.0382	2.6573	0.0376	0.0000	0.0699	0.0649	0.0137	0.0000	4.8452
Okorodudu	Well 10	4.4885	0.5435	0.0562	0.0648	0.0183	0.0528	0.1987	0.0174	2.3516	0.1845	0.0215	0.0000	0.0000	0.0015	0.0000	4.7618
	Well 11	4.2427	1.1371	0.0674	0.0476	0.1315	0.0423	0.0918	0.0269	3.4512	0.0224	0.0133	0.0468	0.0638	0.0815	0.0000	9.3686
	Well 12	4.2865	0.6940	0.0584	0.0572	0.1652	0.0526	0.1117	0.0241	3.2216	0.0824	0.0019	0.0000	0.0000	0.0023	0.0000	4.8170

Table 5: Drinking water standards by WHO and unit weights

S/N	Parameters	Units	Std (S_n)	Recommended Agency	Unit Weights (W_n)
1	EC	µS/cm	1000	WHO	0.0019748
2	TDS	mg/l	500	WHO	0.096894118
3	Sulphate (SO_4)	mg/l	250	WHO	0.003524
4	Chloride (Cl)	mg/l	250	WHO	0.003524
5	Sodium (Na^+)	mg/l	200	WHO	0.0041182
6	Potassium (K^+)	mg/l	200	WHO	0.0041182
7	Calcium (Ca^{2+})	mg/l	200	WHO	0.0041182
8	Total Hardness	mg/l	100	WHO	0.0058633
9	Nitrate (NO_3)	mg/l	50	WHO	0.0066893
10	Colour	TCU	15	WHO	0.0087346
11	Total Coliform	MPN/100 ml	0 - 10	WHO	0.0135682
12	pH	-	6.5 – 8.5	WHO	0.096894118
13	Turbidity	mg/l	5.0	WHO	0.082748531
14	Zinc (Zn)	mg/l	3.0	WHO	0.046285911
15	Ammonia	mg/l	0.5	WHO	0.847391672
16	Iron (Fe)	mg/l	0.3	WHO	0.618149295
17	Magnesium (Mg)	mg/l	0.2	WHO	0.422695319
18	Nitrate (NO_3)	mg/l	0.2	WHO	0.422695319
19	Lead (Pb)	mg/l	0.01	WHO	0.138491845
20	Copper	mg/l	2.0	WHO	0.031947212
21	Manganese	mg/l	0.4	WHO	0.425318327

Table 6: Classification Scheme for Water Quality Index Scores

WQI Range	Class	Statement
< 45	VI	Very Poor
45 – 60	V	Poor
61 – 69	IV	Fair
70 – 79	III	Good
80 – 90	II	Very Good
91 – 100	I	Excellent

Table 7: Water Quality Index (WQI) of well water from different stations

Sample Location	Sample Code	WQI	Status
Ambar	Well 1	29.75	Very Poor
	Well 2	38.35	Very Poor
	Well 3	28.56	Very Poor
Chicoco	Well 4	53.66	Poor
	Well 5	56.46	Poor
	Well 6	25.18	Very Poor
Low Beach	Well 7	60.75	Fair
	Well 8	59.42	Poor
	Well 9	61.28	Fair
Okorodudu	Well 10	42.35	Very Poor
	Well 11	57.91	Poor
	Well 12	61.33	Fair

The highest WQI value was observed in well 12 (61.33) at Okorodudu quarter, while the lowest value was observed in well 6 (25.18) at Chicoco quarters. The three sampled wells at Ambar quarters had very poor WQI values (29.75 for well 1, 38.35 for well 2 and 28.56 for well 3) respectively. Generally, wells from Chicoco quarter throughout the studied wells had WQI values that were at the very poor to poor category. For wells in Low beach quarter, the highest value of WQI was observed at well 9 (61.28), while the lowest value was observed at well 8 (59.42). In general, the WQI values for the wells at Low beach quarter were below 70 indicating from poor to fair category. For wells from Okorodudu quarter, the lowest WQI value was recorded at well 10 (42.35), while the highest value was recorded at well 12 (61.33). The wells revealed WQI range of very poor to fair category. When compared with the WQI values for samples from Ambar and Chicoco quarters, samples from Low beach were found to have higher WQI value than the others. Figure 3 revealed that the water sources from Ambar quarter are the most contaminated. We observed that well 5 from Low Chicoco quarter had the poorest water quality (25.18), followed by wells 8 and 11 from Low beach and Okorodudu quarters (open wells with concrete walls and simple open wells). Since the WQI values of samples from wells 7, 9 and 12 were in the category of fair (60.75 – 61.33) over the others, the water can be recommended for treatment before it can be used domestically. On the basis of the calculated WQI result, the water quality of the samples revealed that 94% were found as very poor to poor indicating that the water is not suitable for both domestic purpose and direct consumption. However, wells 7, 9 and 12 should be treated before they can be used for other domestic purposes.

IV. CONCLUSION

From the results of the physical, chemical and microbiological analysis as well as the calculated WQI of the water samples from the area under investigation, wells number 7, 9 and 12 are of better quality than the other sampled wells in the community, since they did not exceed some of the limit stipulated by WHO for most of the parameters measured and fell within the category of fair. However, they are not fit for direct consumption except treated. This study has revealed that water quality index and statistical tests are useful exploratory tool for understanding and interpreting complex water quality data sets, which generates information that are useful and effective for water quality management. The results of this study points to a need for an effective environmental pollution monitoring programme to ensure good water quality in the riverine areas.

V. RECOMMENDATIONS

In analyzing the findings of this study, several recommendations were identified that can help to improve the water quality of hand dug wells made available for use by the community indigenes.

➢ *Policy recommendations*

- Proper sanitary practices should be established and enforced to reduce level of contamination from various pollutants.
- The indigenes of the study area should be educated on the siting of wells away from liable sources of contamination.
- As a proactive mitigation measure, new alternative sources of water supplies in the form of treated water should be provided for the communities by the Federal and State Government as well as the multinationals.
- Proper disposal of urban and industrial waste should be carried out to avoid further degradation of groundwater.

➢ *Technical recommendations*

- A hand dug well can be protected by sealing the walls, pouring a concrete apron, putting a lid over the top, and installing a hand pump (see Figure 4). But these measures increase the cost of the well. This will ensure that the containers used for the collection of water will be kept in clean conditions as well as avoid introduction of contaminants.

Figure 4: A protected hand dug well with manual hand pump

- Pot chlorinators: - A pot chlorinator is a pierced container (clay pot or plastic bucket) of 8 to 10 holes of 5mm at the bottom of the container. The holes are covered with stone pebbles and then with a layer of pea gravel. A dry mixture of 1.5kg of chlorine powder and 3 kg of coarse sand are spread over the gravel. The pot is then filled with stones to the neck and hung in a well alone (see Figures 5). The chlorine slowly disperses from the pot into the water. The aim is to protect against direct contamination in the groundwater and provide protective chlorine residual. The number and size of holes, the type and quantity of chlorine used will determine the dose of chlorine released and left into the well. This method requires some level of monitoring to function effectively.

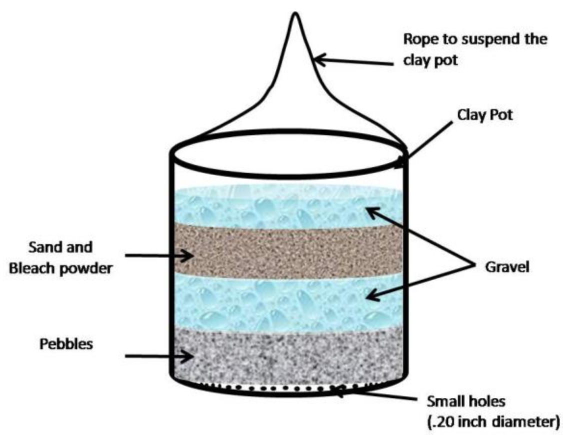

Figure 5: Diagram of a locally made pot chlorinator

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