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Physicochemical Characteristics of Hand-dug Well Water Conditions and Hygiene Practices among Households in Selected Areas of Ado-Odo/Ota, Ogun state, Nigeria

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ABSTRACT: Water resources characterization is an essential component of quality water deliveries to the populace. Hence, the objective of this paper was to assess the physicochemical characteristics of hand-dug well water conditions and hygiene practices among households in selected areas of Ado-Odo/Ota, Ogun State, Nigeria using appropriate standard methods. Data obtained showed that the mean pH concentrations ranged from 2.2 – 7.26; temperature 27.2 – 35.5°C; TDS 46.33 – 442 mg/L and EC 21.67 – 128.33 µS/cm, respectively. Significant variations ($p<0.05$) were observed in the water concentrations sampled across the study area. About 70% of the wells are of medium risk and 56% of the well owners indicated that their well water suffers a colour change, especially during the wet season and 58% reported typhoid as illness suffered most in the last six months. We observed housefly infestation and human excreta odour, including unhygienic activities around the well heads which mostly have cracked casings. Well owners displayed low knowledge about their well water quality and well sinking standards. The study concluded that, wells in the area may be exposed to faeco-oral disease pathogens.

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Water, sanitation and hygiene (WaSH) practices form an important aspect of Environment and Public Health considerations in disease prevention and control, especially water and sanitation-related diseases. Water serves as a medium through which many illnesses are spread in the human population (Orimoloye *et al.,* 2015). Sanitation and hygiene practices help to maintain and promote health while preventing the spread of diseases through proper hand washing with soap or other agents, food hygiene, overall personal hygiene, including laundry, and environmental cleaning (Kaoje *et al.,* 2019). An improved sanitation facility is one that hygienically separates human excreta from human contact, and it generally involves physically closer facilities, less waiting time, and safer disposal of excreta (Adedeji *et al.,* 2017). The WHO estimated that around 94% of global diarrhoea and 10% of the total disease burden are due to contaminated drinking water, inadequate sanitation, and poor hygienic practices (Ahmed *et al.,* 2013). In 2012, the World Health Organisation claimed that about 1.1 billion people globally lacked access to safe water, and 2.4 billion lacked adequate sanitation resulting in widespread water- and sanitation-related diseases (WHO, 2012). Sanitation refers to the provision of improved facilities and services for the safe collection, storage, and appropriate disposal of wastes ranging from domestic, industrial, commercial, medical, and hazardous wastes (Adedeji *et al.,* 2017). Approximately 250 million cases of water and sanitation-related diseases are reported yearly, with more than 3 million deaths annually and about 10,000 a day (WHO/UNICEF, 2012). Human populations exploit groundwater as an alternative source of water supply for domestic use in Nigeria due to inadequate water supply from public water sources (Oguntoke *et al.,* 2013; Ifabiyi, 2013). Although households widely

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own shallow wells in urban Nigeria because of the simple technology and low cost involved, water from many of them contained contaminants (Oguntoke *et al.,* 2013). Common contaminants included the content of septic tanks, leachates from dumpsites, open drains, agricultural wastes and runoff from storms. Water from these wells is hardly tested, even though well owners are responsible for maintaining their wells. Hence, an average of 6 to 20 persons per well are exposed to the risks of using contaminated water for domestic purposes (Orebiyi *et al*., 2013). According to Hutton *et al.* (2007), lack of good sanitation varies from place to place; it is more pronounced in urban centres, especially in developing and under-developed countries. In major cities in sub-Saharan Africa, most people do not have access to a hygienic toilet, and large amounts of faecal waste are discharged to the environment without adequate treatment, with the likelihood of major impacts on infectious disease burden and quality of life. The increase in the population of urban centres has been a major contributor to an unsanitary environment; continuous use of unimproved sources of water increased the risk of environmental health problems such as cholera incidence (Adedeji *et al.,* 2017; Ayeni, 2014). Consumption of contaminated water by human communities in developing countries is responsible for the prevalence of gastrointestinal diseases such as diarrhoea, cholera, typhoid, dysentery and viral hepatitis (Oguntoke *et al.,* 2013). Out of 1.8 million cases of mortality attributed to diarrhoea diseases globally in 2004, more than 80% were children from developing countries (WHO, 2013). About 90% of these diarrhoea diseases were attributed to unsafe water supply, inadequate sanitation and poor personal hygiene. The scarcity of piped water has made communities find alternative sources of water, such as groundwater sources and rainwater (Obiri-Danso *et al*., 2009). Water contamination has increasingly become an issue of serious environmental concern after years of pollution (Akpoveta *et al*., 2011; Silderberge, 2003). Natural water contains many dissolved substances: contaminants such as bacteria, viruses, heavy metals, nitrates and salt have polluted water supplies due to inadequate treatment and disposal of wastes from humans and livestock, industrial discharges and over-use of limited water resources (Singh and Mosley, 2003). The increasing population pressure and rising demand for food and other services have increased the demand for water (Rodak and Silliman, 2011). Wells are termed shallow if the groundwater is tapped over the first impermeable stratum. If this stratum is near the surface, the water lying upon it has little protection from surface pollution. If deep, the surface water, as it sinks, has the impurities drained out of it by the thick layer of soil. Hand-dug wells are typical examples of shallow wells. A dug well may be 0.9 - 1.8 m in diameter and 4.5-10 m deep, depending on the water-bearing formation or groundwater is encountered to protect a dug well from contamination, watertight casing of concrete or brick set in cement, or large diameter close jointed piping is installed. The casing is usually carried up to form a platform 0.4 - 1.2 m high around the well mouth. A rounded or rectangular concrete slate is also used to cover the well, usually made to grow into a made-to-grow. Most of the inhabitants in developing cities have used hand-dug wells as an alternative source of water supply. Hand-dug wells also provide a cheap and low-technology solution to rural and urban water supply challenges. Well construction allows community participation during all phases of the water supply process (Seamus, 2000). Hand-dug wells could either be protected, unprotected or semi-protected. A protected well is equipped with a dedicated pump, concrete lining and platform, head wall, cover and drainage channel (Murcott, 2007; Oluwasanya *et al*., 2011). An unprotected well is without any of the features stated above, and a semi-protected one may have one or more features found in a protected well (Oluwasanya *et al*., 2011). Households within developing countries usually own shallow wells because of the simple technology and low cost. Most hand-dug wells are shallow, although wells as deep as 120 metres have been reported (Oyetayo *et al.,* 2007; Oguntoke *et al.,* 2013). Hence, the objective of this paper is to assess the physicochemical characteristics of hand-dug well water conditions and hygiene practices among households in selected areas of Ado-Odo/Ota, Ogun State, Nigeria.

MATERIALS AND METHODS

Study Area: Ogun state has a population of 3,728,098, according to National Population Commission (NPC, 2006). The state is in the rainforest vegetation belt of Nigeria within longitude 2°45’ and 3°55'E and latitudes 7° 01 N and 7° 8' N in the tropics. The rainy season starts around the middle of March and continues until late October. The dry season starts in November and lasts until February in most locations in the state. Rainfall ranges between 1600 and 900 mm annually. The state is warm throughout the year, with a temperature of between 28 and 35°C. Humidity is between 85 and 95% (Oloruntoba and Adegbite, 2006). Ado-Odo/Ota Local Government Area is one of the 20 Local Governments and the third largest Local Government Area of Ogun State. The capital of Ado-Odo/Ota Local Government is Ota at Latitude 6°41'00"N and longitude 3°41'00"E which borders on by the metropolitan Lagos to the south and

Ifo Local Government to the west. Ota is an industrialised town. It has an area of 1,460km^2 and a population of 526,565 at the 2006 census.

Field investigation and selection of hand-dug well water: Twenty-five (25) hand-dug wells were randomly selected from six communities (Dalemo, Sango, Itele, Atan, Sokoto road, Kooko- Ebiye and Alapoti road), and subsequently classified as a well with low risk, medium risk and high risk based on the results obtained from the study.

Measurements of depth and age of selected wells: The depths of the selected wells were determined by multiplying the number of rings in a well by the length of the ring. A measuring tape was used to measure the length of the ring. The length of a ring varies from 0.5 - 1.0 m. The number of rings was determined by visual counting and by the house owner through direct interviews.

Water Samples Collection and Water Quality Analysis: Water samples were collected from twenty-five (25) wells using a white plastic with an in-situ measurement carried out on-site to take the readings. The in-situ physical parameters such as pH, Temperature, Electrical Conductivity (EC) and Total Dissolved Solid (TDS) were determined using a Hanna Combo Sampler Meter and a Global Positioning System (Garmin version 72H) for geo-referencing. The Hanna Combo Meter was rinsed with distilled water for some minutes. The Hanna combo meter was dipped into the container, and the actual temperature values were taken and recorded. The mode button was pressed after reading the TDS, which was to take and record the EC value.

Questionnaire Administration: One hundred and twenty copies of the questionnaire were administered to the respondents in Ado-Odo/Ota communities. The questionnaire was administered randomly at each of the sampling sites to men and women from the ages of 18 years and above. A set of structured questionnaires was used to elicit information on various issues, such as Socio-demographic characteristics of the respondents; Sources of water supply and treatment for households; Sanitary and hygiene convenience and attitude towards the use of sanitary convenience by households; Health condition of the households.

Checklist Administration: A validated observational checklist was employed for risk assessment of the sanitary status of hand-dug well waters in the selected areas. The risk factors analysed are in three parts; the location and site characteristics, construction and the condition of the well and the maintenance and testing of the well using a scale of 1-3 for each item (Swoveland *et al.,* 2001). The physical factors that were assessed include the texture of the soil, surface runoff, potential pollution source, the well's casing, cracks and holes. The detailed checklist was used to score and rate the wells based on field measurement, personal interview or direct observation of conditions of individual hand-dug well into three (categories), namely, low risk, medium risk and high risk. The checklist was administered to twenty well-owners who were the respondents selected from the different communities. The ex-situ features or parameters were examined, and it includes well profile (the depth, age, cover, well-head and type of users), use of pump or bucket and rope, geo-referencing (exact locational coordinates of the well), sanitary inspection, and maintenance practice of the selected wells. The field investigation was done to identify the well with low, medium, and high risk. Questions were asked on the separation of the distance between the well and sewer inlet, septic tank, outdoor privies, nearest streams, pond, nearest dwelling, chemical storage, nearest property line such as petroleum pipeline, how old the well is, how the well was constructed, the depth of the well, casing of the well, the connection between their water supply line and a potential source of contaminated water, how many faucets and house connection have anti-backflow devices and does the well meet the federal quality standard.

Scale for the coding of the checklist; 1 represents a low risk; 2 represents a moderate risk and 3 represents a high risk

Data analysis: Data obtained were analysed using the descriptive and inferential methods of statistical analysis. Data from copies of the checklist were transferred into Microsoft excel spread sheets and exported into the Statistical Package for Social Science (SPSS 20.0). Frequency-run, percentages and other descriptive statistical tools were used to summarise the data collected. Data for physical parameters in water samples were subjected to Analysis of Variance (ANOVA) and Duncan Multiple Range Test (DMRT) to evaluate the significance level. Water quality results were compared with World Health Organization (WHO) Standards.

RESULTS AND DISCUSSION

Socio-economic Characteristics of the Respondents: The respondents' information concerning their gender, age group, marital status, educational status, occupation and tribe is presented in Table 4. This study's male respondents (63.3%) were higher than the female respondents (36.7%). The age distribution reveals that most of the respondents (38.3%) fall between the ages group of 36 - 45 years, followed by the age group 25-35 years (22.5%), while between the age group 46-55 years had several respondents below 20%. Furthermore, the study reveals that married people constitute the bulk of the respondents, 68%, a development that could lead to higher population density and negatively impact the environment/green space areas (Fuwape and Onyekwelu, 2011). Ninety percent of the respondents is from the Yoruba region. The study also indicates that the respondents with a secondary education accounted for 46.7%, about 20% of the respondents had primary education, and those with tertiary and no formal education accounted for 17.5% and 15.8%, respectively. The majority (64.2%) of the respondents' income source is their personal earnings. Despite this level of education, the most common occupation groups were farmers/ petty traders and artisans (59.1%), followed by the unemployed (23.3%). In comparison, civil servants and students were about 17.5% which implied that the respondents are knowledgeable enough to provide reasonable answers (Table 4).

Table 4: Socio-economic characteristics of residents

Socio-economic variables	No. of respondents	Percentage
Gender		
Male	76	63.3
Female	44	36.7
Age		
Below 25	15	12.5
25-35	27	22.5
36-45	46	38.3
46-55	21	17.5
56 and above	11	9.2
Marital status		
Married	81	67.5
Single	39	32.5
Educational status		
No formal education	21	17.5
Primary	24	20.0
Secondary	56	46.7
Tertiary	19	15.8
Occupation		
Artisan	34	28.3
Civil servant	21	17.5
Farmer/Petty trader	37	30.8
Unemployed	28	23.3
Tribe		
Yoruba	108	90
Hausa	4	3.3
Igbo	8	6.7
Source of income		
Salary	16	13.3
Pension	13	10.8
Allowance	14	11.7
Others (Personal)	77	64.2

Source of water supply and water treatment for the households: The major sources of water supply mentioned by the respondents were well water from pipe/rainwater (57.5%), community tap (24.2%) and borehole with a hand pump (18.3%), as depicted in Table 5. The respondents that got their water supply from a borehole with a hand pump have access to potable water; this reason was also given by Inah *et al*. (2020). Of the 120 respondents, 52 (43.3%) indicated that they have access to potable water. This result is similar to that of Inah *et al.* (2020) on the assessment of water supply and hygiene practices among households where access to potable water was perceived to be the greatest issue in the study. This study clearly stated that access to potable water at the sampling sites is still a major challenge. Furthermore, about 50% of respondents attested that water is mainly stored in plastic containers. In comparison, 47.5% stored their water in drums, and most (60.8%) used permanent cups to obtain drinking water from their containers. About 46% indicated that they clean their water storage container fortnightly, showing poor hygiene practices among households. Cleaning water storage regularly helps to combat diseases or water contamination. Moreover, 35% and 28.3% use boiling and filtration method to treat water for easy household consumption and convenience to be carried out without any cost implication. About 28% asserted that they do not treat water before usage. This water treatment finding agrees with Venkatashiva *et al.* (2017), where most households assessed did not treat their water before usage. Fifty-seven per cent attested that their risk of contamination might be high due to septic tanks, canals, open pits or toilets close to the water source. The result in this study contradicts a finding by Kaoje *et al.* (2019), where river/stream was the major source of drinking water among households.

Sanitation and hygiene facilities used by households: Type of toilet facilities used in households as indicated by the respondents; majority make use of pit latrines (44%); water system closets (23%); swat flush latrines (21%), while some of the households make use of the bush or river to dispose of their excreta waste as an alternative place for defecating (Fig. 2). This result contradicts the study by Orimoloye *et al.* (2015), where the pour water system closet was the most used type of toilet facility. In this study, pit latrines are mainly used due to their cost-effectiveness and maintenance. Furthermore, at the time of the study, the hygiene standard of most pit and swat flush latrines in most households was very poor, making some defecate in the bush, affecting the environment and polluting the water bodies. Fig. 3 shows the method of solid waste disposal among the respondents, as stated, mainly open dump sites and burning (56%), private agencies (33.4%) and government agencies (19.2%). This finding is in line with the work done by Inah *et al.* (2020) and Girsha *et al.* (2016), whereby most households dispose of their waste openly. Disposing of waste in open dumpsites promotes flies and rodents' infestation. About 62% stated that they do maintain and use the toilet properly, 62.5% indicated that the availability of drainage system is open, while few respondents stated that the drainage system in their area is concealed. Forty-four per cent of the respondents complained of the sanitary condition of the drainage system in their community and the presence of fly infestation and odours from defecation or human excreta waste. 41% of the respondents stated that the levels of vector infestation in and around the toilet are less severe, while 33% stated that the infestation of vectors in their toilet is severe (Table 6).

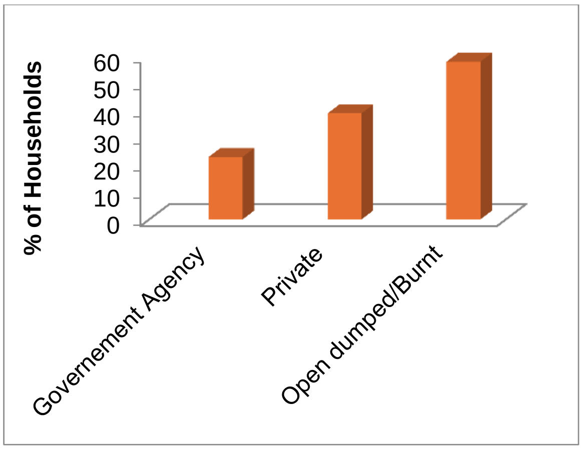

Fig. 3: Method of waste disposal collection among households

Table 5: Source of water supply and water treatment for the households

Variables	No. of respondents	Percentage
The main source of water supply		
Piped water/community tap	29	24.2
Borehole with a hand pump	22	18.3
Well water with pipe	69	57.5
Accessibility to potable water		
Have access	52	43.3
Do not have access	68	56.7
Method of water storage		
Plastic container	60	50.0
Clay pot	3	2.5
Drum	57	47.5
The method used in taking water from the stored container		
Permanent cup	73	60.8
Any cup	32	26.7
Pouring	15	12.5
Frequency of cleaning water storage container		
Every week	39	32.5
Every two weeks	55	45.8
Every three weeks	26	21.7
Method of water treatment		
Filtration	34	28.3
Boiling	42	35.0
Chlorination	11	9.2
No treatment use	33	27.5
Risk of contamination		
Yes	68	56.7
No	52	43.3

Table 6: Sanitation and hygiene facilities used by households

Variables	No. of respondents	Percentage
Type of toilet facility used among household		
Water system closet	28	23.3
Pit latrine	53	44.2
Swat flush latrine	25	20.8
Community latrine/Bush/Waterside	14	11.7
Toilet facility maintenance		
Yes	74	61.7
No	46	38.3
Availability of drainage system		
Open drainage	75	62.5
Concealed drainage	28	23.3
None	17	14.2
Sanitary condition of drainage		
Sanitary	50	41.7
Unsanitary	53	44.2
None	17	14.2
Sanitary condition of the bathing facility		
Sanitary	65	54.2
Unsanitary	55	45.8
Odour of excreta/Infestation of flies in the surrounding		
Present	67	55.8
Absent	53	44.2
Levels of vector breeding within the toilet		
Severe	39	32.5
Less severe	49	40.8
Not severe	32	26.7

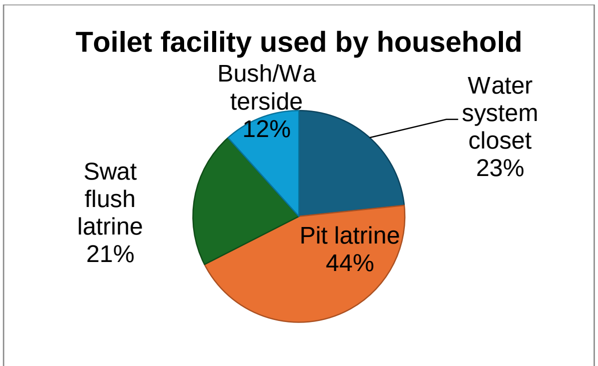

Fig. 2: Toilet facility used among the households

Health Conditions of Household Facilities and Hygiene Practices: Fig. 4 shows the results on hand washing practice among respondents; about 51% indicated that they use their general toilet properly, while 39.2% said they do clean up sometimes. A reasonable number of respondents (60%) practice hand washing with soap mostly after daily activities. Since hands are used in most cases for eating/feeding, both hands must be clean. Seventy-one per cent of respondents indicated that they always practised hand washing with soap after defecation, and the majority (73.3%) practised hand washing before and after food preparation. About 45% of the respondents do not secure or cover their garbage bins, while 35.8% said their garbage had been securely covered. These results are similar to the findings of Inah *et al.* (2020).

Most households (91.7%) indicated they always cover their food while 55% attested that they provide better cleaning materials for cleaners who clean their toilet and immediate surroundings. At the same time, 50.8% of the respondents practice regular toilet sanitation, while about 33% do not care for their toilets. This result is corroborated by Orimoloye *et al.* (2015). According to Mumuni *et al.* (2017), hygiene behaviours include proper hand washing, regular bathing and laundering, proper waste disposal method and proper use of toilets to help combat diseases.

Majority of the households (57.5%) complained that they suffered from typhoid due to water borne diseases during the last six months, followed by vomiting (17.5%) and diarrhoea (11.7%) within the last six months as at the time of the study (Fig. 5). About 46% stated that water-borne diseases only occur once, while 35% of respondents indicated that they had water-borne diseases twice, and about 19% frequently experienced water-borne diseases (Fig. 6).

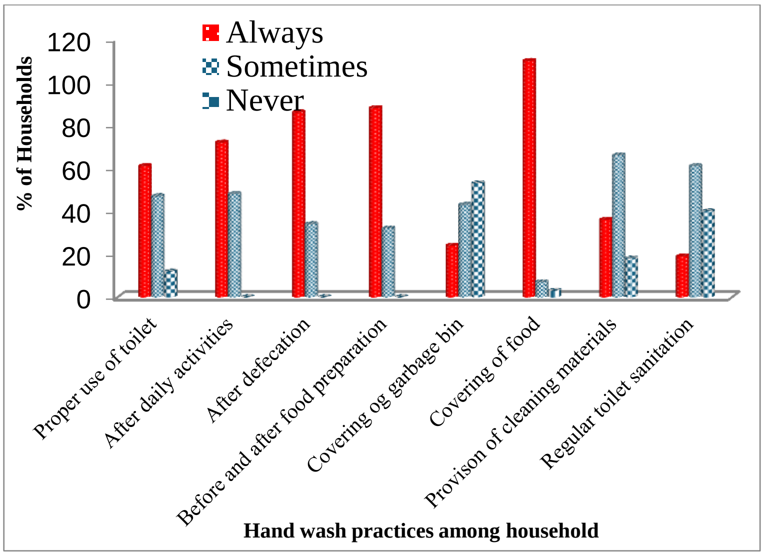

Fig. 4: Hand washing practices and hygiene behaviour

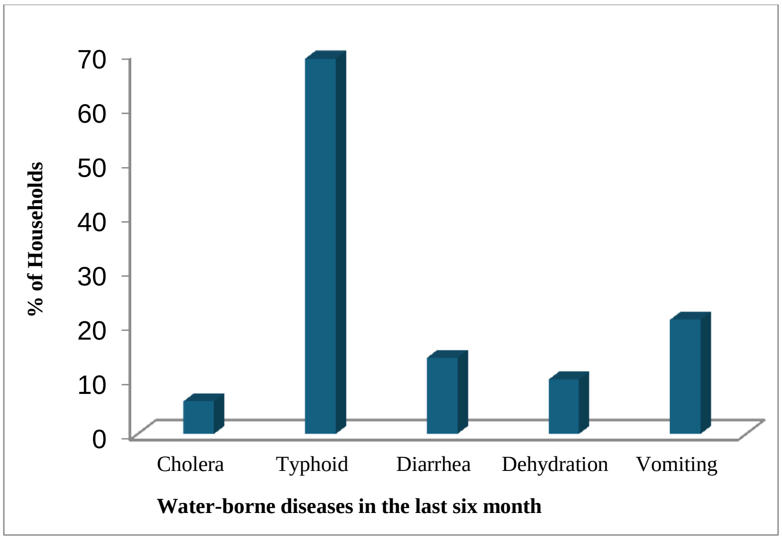

Fig. 5: Perceived water-borne diseases suffered by households

Most of the respondents used different sorts of medication to treat these problems. About 50% of the respondents depend on self-medication. About 28% utilised modern healthcare services/hospitals (orthodox) to treat water-borne diseases suffered by households. Some respondents (8%) used herbal preparation, while 10% consulted pharmacist/chemist shops for some of their water-borne ailments due to water pollution (Fig. 7). Some of the respondents that suffer from water-borne diseases without support from proficient medical specialists may be due to inaccessible health care facilities and low sources of income which may incapacity the respondents to approach or utilise adequate measures for their health challenges.

Physicochemical Characteristics of Sampled Wells: Table 7 presents the results of the physical characteristics of well water samples for all the twenty (25) locations in Ado-Odo/Ota. The pH measures the concentration of hydrogen ions and is the scale of intensity of acidity and alkalinity of water (Sheshe and Magashi, 2014). The pH values for all the twenty-five water samples ranged from 2.27±.0.15 to 7.26±0.47. A high concentration of pH was assessed at Sokoto W1 (7.26), followed by Itele W1 (7.03) and Kooko W4 (6.56), while the least was recorded at Adalemo W1 (2.27). The pH of the well water samples falls within the permissible limit set by the World Health Organization (WHO, 2011) standard of 6.5-8.5 in potable water, except that some of the samples had lower pH values. The pH values obtained signified majority was slightly alkaline, and such water samples were unlikely to cause health problems such as acidosis, as revealed by previous work done by Asamoah and Amorin (2011); Ojekunle and Lateef (2017). These findings were similar to the work done by Yakasai *et al*. (2010).

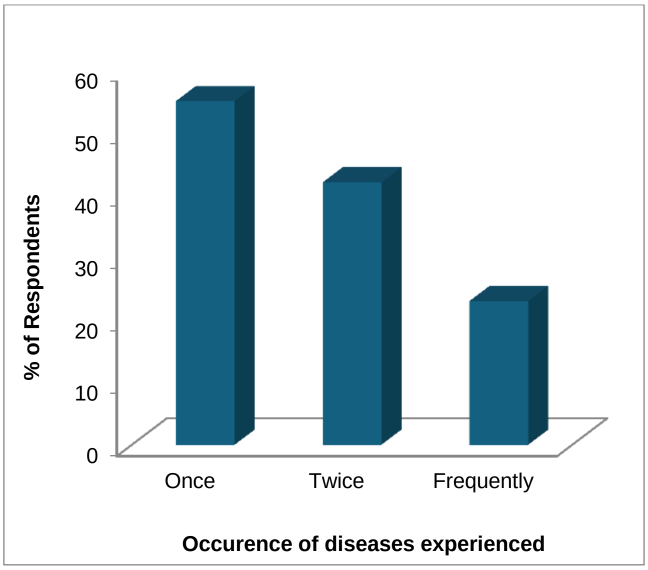

Fig. 6: Occurrence of water-borne disease experienced by households

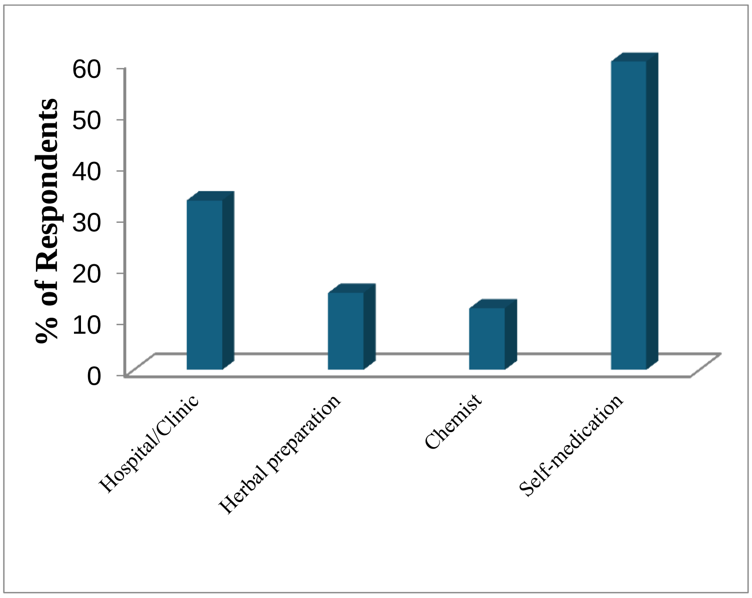

Fig. 7: Health facility patronised for treatment by household

Table 7: Physicochemical Characteristics of Sampled Wells

		Parameters			
Location		**pH**	**Temp°C**	**TDS (mg/L)**	**EC (µs/cm)**
Dalemo1	WELL1	2.27±0.15^{a}	31.1±0.2^{efg}	246±172.34^{def}	50.33±13.61^{abcde}
Dalemo2	WELL2	3.66±0.15^{b}	29.4±0.3^{cd}	91.67±51.63^{abc}	33.33±32.62^{abc}
Dalemo3	WELL3	3.96±0.41^{bc}	30.6±2.3^{def}	183.33±64.65^{bcd}	65±5.56^{bcde}
Atan1	WELL4	4.4±0.17^{cd}	29.6±0.5^{cde}	367.67±3.21^{fgh}	54.33±3.05^{abcde}
Atan2	WELL5	3.96±0.31^{bc}	30.8±0.4^{defg}	129±14^{abcd}	50±57.16^{abcde}
Atan3	WELL6	5.76±0.33^{efg}	28.9±0.8^{bc}	103.33±13.57^{abc}	30±18.24^{ab}
Atan4	WELL7	6.1±0.52^{fghi}	35.5±0.3^{k}	347.67±100^{fgh}	39.67±13.32^{abcd}
Sango1	WELL8	5.86±0.21^{efg}	32.5±0.7^{fghi}	131±2.64^{abcd}	35.33±6.81^{abc}
Sango2	WELL9	6.33±0.32^{ghi}	33.7±0.1^{hij}	127.33±90.18^{abcd}	30.33±0.57^{ab}
Sango3	WELL10	5.96±0.32^{efgh}	33.2±1.2^{gh}	330.67±0.57^{fgh}	50.67±21.73^{abcde}
Sokoto 1	WELL11	5.9±0.2^{efgh}	31.6±0.2^{efg}	130.33±14.15^{abcd}	40.33±0.57^{abcde}
Sokoto str2	WELL12	7.26±0.47^{k}	31.7±0.1^{efg}	51.67±3.21^{ab}	28.33±30.43^{ab}
Sokoto str3	WELL13	6.46±0.21^{jk}	28.1±1.2^{hij}	306±1.73^{def}	49.33±10.11^{cde}
Itele W1	WELL14	7.03±0.11^{ghi}	33.8±0.6^{efg}	253.33±147.21^{abc}	71.67±19.5^{a}
itele W2	WELL15	6.23±0.23^{ghi}	31.7±0.1^{defg}	108.67±28.45^{abcd}	21.67±2.08^{abcde}
Itele W3	WELL16	6.23±0.15^{ghi}	30.9±0.1^{hij}	137.67±0.58^{h}	41.67±2.1^{e}
Itele W4	WELL17	6.26±0.28^{ghi}	33.5±0.01^{ijk}	442±1.0^{a}	78±33.87^{a}
Itele W5	WELL18	5.56±0.4^{cd}	27.2±0.7^{efgh}	412.33±168.29^{abc}	57.67±21.38^{abcde}
Alapoti str W1	WELL19	6.26±0.81^{e}	34.1±2.4^{ghij}	25.67±0.58^{abc}	24.67±2.08^{de}
Alapoti str W2	WELL20	4.26±0.05^{ef}	32.2±1.1^{ghij}	98.33±52.17^{a}	41±1.73^{a}
Alapoti str W3	WELL21	5.43±0.15^{ef}	32.8±0.01^{jk}	95.67±57.44^{abcd}	73.67±5.51^{abc}
Kooko-E W1	WELL22	5.56±0.15^{d}	32.8±0.1^{efg}	46.33±9.86^{abcd}	23.67±15.04^{abc}
Kooko-E W2	WELL23	5.6±0.26^{ef}	34.2±0.1^{a}	127±4.0^{gh}	34±22.53^{abcde}
Kooko-E W3	WELL24	4.8±0.1^{hi}	31.7±0.1^{abc}	135±12.16^{efg}	34.67±8.62^{abcde}
Kooko-E W4	WELL25	6.56±0.12^{ij}	27.7±0.6^{ab}	205.67±21.46^{cde}	128.33±2.08^{f}
WHO		6.5-8.5	<40	<1200	500/<900

Values are Means ± Standard Deviation; Different superscripts in the same column indicate significant differences at $p < 0.05$ according to Duncan Multiple Range Test (DMRT).

However, pH plays a significant role in determining bacterial population growth and diversity in water. An increase in the observed pH could be attributed to the production of basic metabolic waste products by increasing the bacterial population (Ojekunle and Lateef, 2017). Prescott *et al*. (1999) stated that microorganisms frequently change the pH of their habitat by producing acidic or basic metabolic waste products (Table 7).

Temperature (^{o}C): The temperature of the samples ranged between 27.2±0.7 to 35.5±0.3^{o}C (Tables 7). These ranges are contrary to the work done by Ojekunle and Lateef (2017) on the environmental impact of abattoir waste discharge on the quality of surface and ground water in Abeokuta. The temperature falls within the WHO standard of permissible limit of <40°C; temperature influences the amount of dissolved oxygen in the water, influencing the survival of aquatic organisms. Hence, the temperature of water samples in some selected areas in Ado-Odo/Ota may not pose any health problems for residents. These indicated that the temperature of the water samples is generally ambient and good for consumption that prefers cool to warm water and for the specific reason of water quality. Furthermore, a high water temperature impacts water quality, enhancing the growth of microorganisms, which may increase the water's odour, colour and taste (UNICEF, 2008). Also, temperature affects the biological, chemical and physical activities of water; it is important for well water temperature not to be too high in order not to have microbial proliferation.

Total dissolved solid (TDS): The TDS value of the result obtained from the analysis ranged from 25.67±0.58 to 442±1.0. Itele well 4 has the highest value of 442 mg/L, followed by Atan well 1 (367 mg/l), while Alapoti well 1 has the lowest value of 25.67 mg/L (Table 7). All value obtained falls below the WHO standard of <1200 mg/L. While water with low concentrations of TDS may also be unacceptable to the consumer because of its taste, and high TDS may be due to the presence of a large number of organic salts such as carbonate, sodium, potassium and calcium and some non-volatile substance which are solid at room temperature (Prasanthi *et al.,* 2012). Well water with high salt content and particle appearance indicate the intrusion of runoff from different sources into the well. Hence, the water contamination from some of the sampled shallow wells may be attributed to the fact that some wells do not have casing or fitted caps. These reasons were also highlighted by Oguntoke *et al.* (2013).

Electrical Conductivity (EC): Electrical conductivity is the ease with which a substance allows the free flow of electricity through the ions in electrolytes of water samples and the levels of dissolved solids in the water sample. The values of EC ranged from

21.67±2.08 to 128.33±2.1 µs/cm. Kooko well 4 has the highest value (128 µs/cm), while Itele (21.67 µs/cm) recorded the lowest (Table 7). All the samples were within the permissible limits of the WHO maximum permissible level for conductivity of 900 µS/cm. This level shows that the water samples are not saline, the concentration of salts dissolved in the water is minimal, and the salt content of a water body is determined by its ability to conduct an electric current the higher the salt concentration, the larger the current that can be conducted and the higher the EC of the water. Any electrical conductivity level above the WHO standards can pose a health risk of defective endocrine functions and total brain damage with prolonged exposure. All the water samples have EC values less than the highest tolerable values. The recorded high EC in unprotected wells may be due to direct water ingress due to poor well construction. However, all recorded values are below the recommended 1000 us/cm and 1.0 mS/cm (WHO, 2011; NDWQS, 2007). Generally, the more ions that are present, the higher the conductivity of water. Likewise, the fewer ions in the water, the lesser the conductivity.

Locational Characteristics of the selected sampled Wells: The texture of the soil around the twenty-five wells sampled showed that 52% of the wells were of sandy composition while 40% was clay, and about 8% of the soil around the sampled wells had a loamy formation. Sandy soils are easily prone to penetration of transported sediments and have a higher risk of contamination. About 60% had a depth less than 10 m from the ground surface; 60 per cent of the sampled wells showed signs of soil settlement in and around the well sites, and the water table was less than 10 m above the ground surface in about 56% of the sampled wells. Surface runoffs occasionally reach only 36% of sampled well, and few were upslope from all potential pollution sources. Some of the wells were sited less within areas of risk to sewer inlets, septic tanks, outdoor privies and a manure pit, respectively (Table 8). About 52% of wells were sited less than 15 m to outdoor privies, while 64% were sited more than 15 m to a manure pit. Furthermore, 64% of the assessed wells were sited greater than 10 and 30 m from the nearest stream and about 72% from underground chemical storage and fuel tanks, respectively. The nearness of the wells to the pollution source affects the water quality from the wells.

Construction and Condition of selected sampled Wells: In Ado-Odo/Ota, about 90% of wells were hand dug; and 60% had been in existence for about 20 years while 36% had been dug for over 60 years. The depth of the well in about 56% of the sampled wells was about 10- 30 m in depth. Eighty-four percent of the well had casing/concrete rings while 32% are not sure of the extension of the casing to full depth of the wells (Table 9). The height of concrete ring above ground level was between 0-30 cm in about 52% and 28% above 30 cm of the wells. 36% of the sampled wells had cracks on their casing. Between 32% of wells encountered in Ado-Odo/Ota had cracks on their caps while 20% of wells had loose cap fittings. According to Oguntoke *et al*. (2013) wells with loose cap fittings are prone to contamination from materials that can gain entrance from the surface. Moreover, 52% of the wells with no vent were attached with a fetcher/rope which could be a source of contamination to the water (Table 9).

Table 8: Locational Characteristics of the sampled Wells

Samples	Texture	Depth	Depression	Well site	Runoff	Upslope	Sewer	Septic	Privies	Pit	Stream	Chemical	**Total score**
WELL1	3	1	1	1	1	1	1	1	1	1	1	1	**14**
WELL2	1	1	1	3	1	0	1	1	1	1	1	1	**13**
WELL3	3	1	1	1	1	1	1	1	3	1	1	1	**16**
WELL4	1	1	3	3	3	1	3	3	3	3	3	1	**28**
WELL5	1	1	1	3	2	3	3	1	1	3	3	3	**25**
WELL6	1	1	1	1	1	3	1	1	1	1	1	1	**14**
WELL7	2	1	3	3	1	3	3	3	3	3	3	3	**31**
WELL8	3	1	1	3	3	1	1	1	3	3	3	1	**24**
WELL9	1	1	1	1	3	1	3	3	3	3	3	0	**23**
WELL10	1	1	1	3	2	3	3	3	1	1	1	1	**21**
WELL11	1	1	0	0	2	3	0	3	0	0	0	0	**10**
WELL12	3	1	1	3	3	1	1	1	1	1	1	1	**18**
WELL13	3	1	1	3	3	1	1	1	3	3	3	3	**26**
WELL14	3	1	3	1	2	1	1	1	1	1	0	0	**15**
WELL15	3	3	1	3	2	1	3	3	1	0	0	0	**20**
WELL16	3	3	1	1	3	3	1	3	3	1	1	1	**24**
WELL17	1	1	3	1	2	3	3	3	1	1	1	1	**21**
WELL18	1	1	1	3	2	1	1	3	3	1	1	1	**19**
WELL19	1	1	3	2	3	3	3	1	1	1	1	1	**21**
WELL20	1	1	1	3	3	1	1	3	3	1	1	1	**20**
WELL21	3	3	3	1	2	3	1	1	3	1	1	1	**23**
WELL22	3	3	3	1	3	1	3	3	3	1	1	1	**26**
WELL23	3	3	1	1	3	1	1	3	3	1	1	1	**22**
WELL24	3	1	1	3	3	1	1	1	1	1	1	1	**18**
WELL25	2	1	3	3	2	1	1	1	1	1	1	1	**18**

Maintenance and testing of wells: Table 10 shows the maintenance and testing of each well sampled at Ado-Odo; 40% of the wells had a connection between their water source and other potential sources which may contaminate the water and majority of the well owners were aware of the health risk from the contamination. Few wells which are not capped through a standard procedure were sited to be abandoned wells on some of the owner properties.

Table 9: Construction and Condition of selected sampled Wells

Location	Well dug	Old	Depth (no of ring)	Casing	Full depth	Height	Hole casing	Crack well cap	Fit cap	Contamination	Vent	**Total score**
WELL1	3	2	2	1	1	1	0	1	1	1	1	**14**
WELL2	3	2	3	1	3	2	1	0	1	1	1	**18**
WELL3	3	1	2	1	1	1	1	1	1	1	1	**14**
WELL4	3	2	1	3	3	3	3	3	3	3	3	**30**
WELL5	3	1	3	1	1	3	1	1	1	1	3	**19**
WELL6	3	1	1	1	1	1	1	1	1	3	3	**17**
WELL7	3	1	2	3	3	3	3	3	1	3	1	**26**
WELL8	3	1	2	1	1	3	1	1	1	3	2	**19**
WELL9	3	1	1	1	3	2	1	1	1	3	3	**20**
WELL10	3	1	2	1	1	2	3	3	1	3	1	**21**
WELL11	3	1	1	1	1	3	1	1	1	3	3	**19**
WELL12	3	2	2	1	1	2	1	1	1	1	3	**18**
WELL13	3	1	1	1	1	2	1	1	1	3	1	**16**
WELL14	3	1	2	1	1	2	1	1	1	3	2	**18**
WELL15	3	1	2	3	1	2	3	3	3	3	1	**25**
WELL16	3	1	2	1	1	1	1	1	1	1	1	**14**
WELL17	3	1	2	3	3	3	3	3	3	3	1	**28**
WELL18	3	1	1	1	3	2	3	1	1	1	1	**18**
WELL19	3	2	2	1	3	2	1	1	1	1	3	**20**
WELL20	3	2	2	1	1	2	1	1	1	1	1	**17**
WELL21	3	2	1	1	1	2	1	1	3	1	3	**19**
WELL22	3	2	1	1	1	2	3	3	1	3	2	**22**
WELL23	3	2	2	1	1	1	3	1	1	1	3	**19**
WELL24	3	1	2	1	1	2	1	1	1	1	3	**17**
WELL25	2	3	3	1	3	3	1	3	3	1	3	**26**

Table 10: Maintenance and testing of wells

Location	**Cross connect**	**Aware**	**Abandon**	**Test**	**Standard**	**Colour**	**Taste**	**Clarity**	**Total score**
WELL1	1	1	3	2	3	1	1	1	**13**
WELL2	0	0	1	3	3	3	1	1	**12**
WELL3	1	3	3	3	3	3	3	3	**22**
WELL4	3	3	1	3	3	3	3	3	**22**
WELL5	3	3	3	3	3	3	3	3	**24**
WELL6	1	3	3	2	1	1	1	1	**13**
WELL7	3	3	1	3	3	3	3	3	**22**
WELL8	1	3	3	2	2	3	3	3	**20**
WELL9	3	3	3	3	3	1	1	1	**18**
WELL10	1	3	3	3	3	3	1	1	**18**
WELL11	3	3	3	3	3	3	1	1	**20**
WELL12	1	3	3	2	3	1	1	1	**15**
WELL13	1	3	3	3	3	3	1	3	**20**
WELL14	1	3	3	3	2	1	3	3	**19**
WELL15	3	3	1	3	3	1	1	1	**16**
WELL16	1	1	1	3	1	1	1	1	**10**
WELL17	3	3	2	3	3	3	1	1	**19**
WELL18	3	1	2	2	3	3	1	1	**16**
WELL19	1	3	2	3	3	3	1	1	**17**
WELL20	1	3	3	2	3	1	1	1	**15**
WELL21	1	3	3	3	3	1	1	3	**18**
WELL22	1	3	3	3	3	3	3	3	**22**
WELL23	1	3	3	3	3	1	1	1	**16**
WELL24	1	3	3	2	3	1	1	3	**17**
WELL25	3	2	3	2	3	3	1	1	**18**

Assessment of well owners' knowledge and practice on well treatment showed that 70% do not treat or test their well regularly, and their water does not meet any state or federal quality standard. About 56% of the well owner indicated that their well water quality changed in colour, especially during the rainy period, and 28% of the well owners stated that they had a noticeable change in taste and odour during wet periods. This may be due to runoffs seeping into wells, especially if there are defects or cracks in the well structure (Table 10).

Table 11 shows the aggregate risk assessment scores (high, moderate and low-risk categories) of the twenty-five sampled hand-dug wells in the Ado-Odo/ Ota local government area. The aggregate risk scores of the twenty-five sampled wells indicated that two of the wells were rated to be in the high-risk group (Well 4 and Well 7), while about five (5) were in the low-risk category (Well 1, 2, 3, 6 and 11) and the remaining eighteen wells were rated as moderate risk wells. Concerning construction risk, the wells sampled for water analysis in well 4 and 17 had the highest risk status (56 – 60 score), while the lowest risk (28 scores) was assessed in wells 1 and 3.

The highest location risk assessment was recorded at wells 7, 4 and 13 (78 – 93 score). While Well 11 had the lowest location risk status (30 scores). Meanwhile, the maintenance risk assessment status of the sampled wells was generally moderate. Moderate to high-risk scores of most sampled wells implies that their structural and maintenance conditions were below the acceptable standard. Water from such wells may be prone to contamination (Oguntoke *et al.,* 2013).

Table 11: Aggregate risk assessment scores for sampled water

Location	Location score	Construction Score	Maintenance	Aggregate	Risk Category
WELL1	42	28	13	83	Low
WELL2	39	36	12	87	Low
WELL3	48	28	22	98	Low
WELL4	84	60	22	166	High
WELL5	75	38	24	137	Moderate
WELL6	42	34	13	89	Low
WELL7	93	52	22	167	High
WELL8	72	38	20	130	Moderate
WELL9	69	40	18	127	Moderate
WELL10	63	42	18	123	Moderate
WELL11	30	38	20	88	Low
WELL12	54	36	15	105	Moderate
WELL13	78	32	20	130	Moderate
WELL14	45	36	19	100	Moderate
WELL15	60	50	16	126	Moderate
WELL16	72	28	10	110	Moderate
WELL17	63	56	19	138	Moderate
WELL18	57	36	16	109	Moderate
WELL19	63	40	17	120	Moderate
WELL20	60	34	15	109	Moderate
WELL21	69	38	18	125	Moderate
WELL22	78	44	22	144	Moderate
WELL23	66	38	16	120	Moderate
WELL24	54	34	17	105	Moderate
WELL25	54	52	18	124	Moderate

**TLC-Total location characteristic; TCS- Total construction condition; TMS- Testing and maintenance*

*Conclusions***:** This study concludes that the pH values obtained signified that the majority was slightly alkaline and that such water samples were unlikely to cause health problems. Most households suffered from typhoid due to water borne diseases during the last six months, and water-borne diseases only occur once or twice within six months. The presence of flies infestation and odours from defecation or human excreta waste is very common in the study and may pose faeco-oral disease outbreak. Buckets and ropes in abstracting water from hand-dug wells may contribute to increased water contamination, irrespective of the well classification. Hence, there is a need for periodic water quality monitoring and incorporation of household water treatment practices with hand-dug well water. The risk assessment survey of sampled wells showed that about 70% of the wells are of moderate risk.

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Data Availability: Data are available upon request from the first author or corresponding author or any of the other authors.

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