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Physicochemical and Microbiological Examination of Hand-dug wells, Boreholes and Public Water Sources in selected areas of Ibadan, Nigeria

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ABSTRACT: This study examined some physicochemical and microbiological characteristics of some water sources and evaluates their health implications in selected areas of Ibadan, Nigeria. Forty (40) water samples were collected into 1-litre plastic kegs from hand-dug wells, boreholes and public water points between June 12 and July 11, 2014. Samples were analysed for physical, chemical and microbial parameters using standard procedures. Well-structured questionnaires were used to elicit information on sanitation conditions in the areas. Electrical conductivity in many of the sampled water were higher than the recommended limit, while TDS were within the desirable limit of 200 mg/l except for the borehole at Ita-Baale Borehole (IB) and hand dug well at Oke-Aare (OAH). Microbial assessment of water samples in most areas confirmed the presence of vibrio species due to faecal pollution. Bacterial isolates identified in some of the water samples were *Enterobacter cloaca, Escherichia coli, Klebsiella oxytoca, Pseudomaonas fluorescens* and *Salmonella spp*. The study revealed that sanitary facilities including toilets and improved latrines are lacking in many areas. Hand dug wells had the highest frequency of occurrence pollutants and bacteria due to their close proximity to pit latrines. The study concluded that residents in the study area are exposed to polluted water sources, which pose serious threat their health. This study added to the existing data on the inadequacy of sanitation in urban centres in the country hence the need for increased effort in the provision of more cleaner and well protected water sources such boreholes and piped-borne water. ©JASEM

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Worldwide, about 1.1 billion of the population lacked safe water and 2.4 billion lacked adequate sanitation (WHO, 2012) resulting in widespread of water- and sanitation-related diseases. Sanitation generally 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. (Oke *et al.,* 2013). 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 (Hutton and Haller, 2004). Nearly 250 million cases of water- and sanitation-related diseases are reported every year, with more than 3 million deaths annually—about 10,000 a day (WHO/UNICEF, 2012). The report by the Joint Monitoring Programme further revealed that as at 2011 in Nigeria, only 31 % of the population has access to improved sanitation facilities such as flush toilets, 24 % uses shared facilities while 22 % uses unimproved facilities and 23 % defecate in the open (WHO/UNICEF, 2012). This problem is exacerbated by high population density, which results in overcrowding, inadequate planning and poor urban governance.

Although lack of good sanitation varies from place to place, it is more pronounced in the 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. This is likely to have major impacts on infectious disease burden and quality of life (Hutton *et al*., 2007). Ayeni (2014) reported that increasing population of urban centres has been a major contributor to unsanitary environment, continuous use of unimproved sources of water increased the risk of environmental health problems such as cholera incidence. Inadequate access to safe water and

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sanitation services, coupled with poor hygiene practices, kills and sickens thousands of children every day, and leads to impoverishment and diminished opportunities for thousands more (Allen *et al*., 2006; WHO, 2009). In view of the importance of water in our daily life and state of sanitation of the sources of water supply, it is imperative to conduct thorough microbiological and physico-chemical examinations especially in low-income urban settlements. The aim of the study is to examine some physicochemical and microbiological characteristics of some water sources and evaluate their health implications in selected areas of Ibadan, Nigeria.

MATERIALS AND METHODS

Description of the Study Area: Ibadan, the capital of Oyo state, is Nigeria's second largest urban agglomeration, with a population of 3.3 million people (Brinkhoff, 2010). Ibadan is located on longitude 7°2' to 7°40'E and latitude 3°35' to 4°10'N (Figure 1).

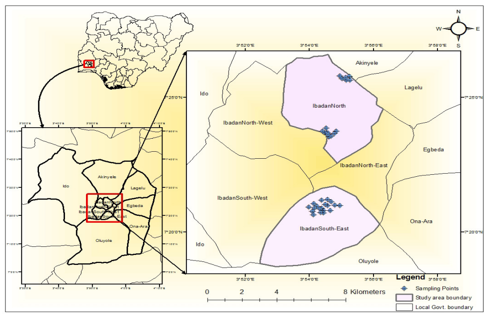

Fig 1: Ibadan North and Ibadan Southeast Local Governments Areas showing Sampling points

Ibadan North and Ibadan Southeast chosen as study area contain the largest slum areas in the city and the characteristics of these two LGAs, which fit the criteria for slums, include high density of population, poor sanitation, inadequate health, education and social facilities, inaccessible road network, lack of potable water, and erratic electricity supply (Olusola *et al.,* 2012). The areas selected for the purpose of this study (Table 1) were carefully selected based on the varying sanitary conditions. The present features of sanitation practices in most parts of the study area are poorly managed solid-waste and drainage, poor transportation facilities, inadequate public utilities and social infrastructure, poor housing conditions as well as foul odour

Table 1: Selected locations within the two local governments

Local Government	Selected Areas
Ibadan North	Beere, Bodija, Oke-Are, Kara, Ashi
Ibadan South East	Kobomoje, Oja-Oba, Eleta, Olubi, Elekuro, Agbongbon, Ita-Baale

Water Sampling: Specific areas were selected from the two local governments based on their rather bad sanitary conditions. The areas also represent the core of ancient Ibadan metropolis. Forty (40) water samples were collected into 1-litre plastic kegs from hand-dug wells, boreholes and public water points between June 12 and July 11, 2014 in the selected areas. The water was left to run from the source for about 4 min to equate the minimum number of well volume and to stabilize the electrical conductivity (Mor *et al*., 2006). Samples for microbiological analysis were aseptically taken in 50ml sterile universal containers. All samples were transported to the laboratory on ice to stop reproduction and bias that may occur at ambient temperature. A handheld GPS devise was used in determining the coordinates of the sampling points for this study.

Chemical analysis: Three water samples each were taken from the boreholes, hand-dug wells and stream used by the people were analysed for physical and chemical properties. Water samples were stored at 4°C in the fridge prior to analysis. Temperature, pH, and electrical conductivity (EC) were measured *in situ* using Hanna combo portable meter (APHA, 2005). It was rinse with distilled H_2O, inserted into the sample, and allowed several minutes to stabilize before record reading. DO was determined by Winkler Azide Modification Titrimetric, while the DO method was used after five days for BOD. Chemical oxygen demand (COD) was determined using a strong oxidizing agent (potassium dichromate) $K_2Cr_2O_7$ and sulphuric acid at 148°C with back titration (APHA, 2005). Ammonia was determined following the procedure used by Hendriksen *et al*. (2012) while nitrate was determined using the Ion Chromatography Method (APHA 4110B).Total Dissolved Solids (TDS) was determined gravimetrically (APHA, 2005) and chloride by Argentometric Titration (Mohr's method).

Microbial properties: Microbial properties of water samples including thiosulphate Citrate Bile Salt (TCBS), total bacteria count (TBC), and Escherichia coli (*E. coli*) were recovered and enumerated via culture-based most probable number (MPN) techniques in compliance with EPA guidelines (EPA, 2009). Salmonella concentrations for well water samples were determined by the method described by Krometis *et al*. (2010). The media were boiled using Electro thermal bath. Plate count analysis was conducted using McConkey agar and the plates were incubated at 37°C for 24h to detect red colonies on the incubated Petri dishes. The plate were examined, then left for another 24h at room temperature and re-examined. all analyses were performed by the membrane filtration technique with Millipore filters and equipment (Millipore Corp., Bedford, Mass.). All samples were transported to the laboratory on ice to stop reproduction and bias that may occur at ambient temperature.

Identification of isolates: The bacteria isolates were identified by cultural features (i.e. colour, shape, edge, etc.), morphological characteristics (motility, Gram-reaction, cell arrangement and shape) and biochemical features (indole, lactase oxidase, coagulase, catalase, sucrose, citrate etc.).

Statistical analysis: Descriptive statistics (mean and standard deviations) were analyzed using Statistical Package for Social Sciences (SPSS 17.0) while other results were presented using graphs prepared using Microsoft Excel.

RESULTS AND DISCUSSION

Physical and chemical properties of water samples: Physical and chemical properties of water samples collected from boreholes, hand dug wells and stream in the study area with their standard values as prescribed by WHO are presented in Table 2. The pH ranges between 8.06 in water from a hand dug well at Kobomoje to 9.03 in water from a borehole in Agbongbon. Water pH recorded for the borehole in Agbongbon was slightly higher than the range of 6.0-9.0 standard limit of World Health Organization (WHO, 2011a). Temperature varies from 27.09 to 29.01°C. Electrical conductivity (EC) ranged from mean ± SD of 255.32±45.04 μScm^{-1} at Elekuro Borehole in Ibadan South East LGA to 657.06 ± 32.74μScm^{-} at the Ita-Baale Borehole also in Ibadan South East LGA (Table 2). EC in many of the sampled water from different parts of the study areas were higher than the recommended limit of 500 mg/l (WHO, 2011). Electrical conductivity indicates that the content of soluble and high conducting salts present in the water samples. Total dissolved solid (TDS) varies proportionately as the EC. Highest TDS of 132.1±0.55 mg/l was recorded at Ita-Baale Borehole, which incidentally had the highest EC. Studies have shown that some TDS act as conductors and thus contribute to conductance (Harilal *et al*., 2004). All samples contains TDS within the desirable limit of 200 mg/l except for the borehole at Ita-Baale Borehole (IB) and hand dug well at Oke-Aare (OAH), which were 227.1 mg/l and 217.0 mg/l respectively. High TDS makes water make it unpalatable and potentially unhealthy (Barnes *et al*., 1998). Nitrate concentration in the water samples varied from 23.03 in borehole at Elekuro to 60.01mg/l in Kobomoje Hand dug well. The 60.01mg/l recorded in Kobomoje exceeded the 50 mg/l stipulated for nitrate in drinking water (WHO, 2011). Oxidation of vegetable and animal debris and animal excrement mainly from agricultural, domestic and industrial discharges and improperly managed municipal wastewaters and septic tanks were reported as the main sources of nitrate and nitrite into drinking water (Fewtrell, 2004; WHO, 2011b). Although the occurrence of infantile methaemoglobinaemia to nitrate in drinking water (Dzwairo *et al*., 2006), recent evidence from research suggests that diarrhoea and/or gastrointestinal infection, not ingested nitrate, are the principle causative factors in infantile methaemoglobinaemia or the blue-baby syndrome (Avery, 1999; Addison and Benjamin; 2004; WHO, 2011a; Abou El-Gheit *et al*. (2012).). According to IARC (2005), ingested nitrate or nitrite under conditions that result in endogenous nitrosation is probably carcinogenic to humans. A minimal risk level (MRL) of 4 mg/kg/d was quoted for acute-duration oral exposure (1 to 14 days), intermediate-duration oral exposure (15 – 364 days) and chronic-duration oral exposure (>364 days) for nitrate (ATSDR, 2015). Ammonia concentrations in the water samples were all within the limit of 1.5 mg/l according to WHO (WHO, 2011b).

Table 2: Physical and chemical properties of Borehole and hand dug well water from selected areas

Location	pH	Temp (^{0}C)	EC (µScm^{-1})	TDS (ppm)	Nitrate (mg/L	Chloride (mg/L)	Ammonia
Ibadan South East							
EH	8.75±0.19	28.47±1.36	479.00±15.19	89.6±8.13	36. 12	42.05	0.33
AH	8.89±0.23	28.03±0.45	619.67±72.86	123.7±14.7	40. 05	46.24	0.67
OH	8.26±1.17	27.8±0.36	492.33±92.09	99.3±4.05	32.45	36.03	0.56
EB	8.56±0.57	28.30±0.88	255.32±45.04	48.3±0.72	23.03	45.09	0.23
KbH	8.06±0.70	28.10±1.22	607.00±27.08	120.9±3.02	60.01	46.24	1.25
IB	8.19±0.36	29.00±0.08	657.06±32.74	227.1±0.55	52.07	50.05	1.45
OOB	8.45±0.24	29.20±0.04	559.03±26.03	334.1±0.31	48.04	47.03	1.21
OOH	8.23±0.16	28.23±0.05	537.02±22.54	327.3±0.48	50.03	43.07	0.65
IH	8.06±0.21	28.62±0.17	608.02±12.63	231.1±0.48	47.05	47.03	0.67
AB	9.03±0.07	28.40±0.73	523.18±20.13	104.6±5.06	48.04	56.03	0.82
Ibadan North							
BdH	8.65±0.23	27.09±1.22	388.32±23.76	72.9±1.04	33.02	28.05	0.12
BdB	8.48±0.54	28.32±1.03	456.02±45.21	102.1±0.52	43.06	47.05	0.20
BH	8.59±0.22	28.33±0.88	502.56±82.11	124.6±1.21	53.27	50.04	0.25
BS	8.31±1.02	29.01±0.45	556.21±13.04	115.6±0.61	56.05	47.01	0.45
OAH	8.62±0.35	27.98±1.02	625.02±32.03	217.0±1.04	53.08	53.47	1.06
OAB	8.71±0.62	28.35±0.66	445.63±35.26	100.1±0.65	34.8	28.02	0.27
KH	8.29±0.29	28.22±1.36	574.04±32.06	104.1±0.38	37.07	28.23	0.96
KB	8.43±0.17	28.47±0.53	495.12±18.48	98.4±1.02	29.05	27.04	0.15
AsB	8.64±0.34	28.30±0.43	373.04±24.67	78.3±0.58	26.05	28.03	0.34
AsH	8.42±0.51	29.03±0.48	346.06±25.53	84.3±0.54	34.03	37.04	0.56
WHO Standards*	6.0-9.0	Ambient	500	200	50	250	1.50

***WHO (2011a)**

Note: AB=Agbongbon Borehole; AH=Agbongbon Hand dug well; AsB=Ashi Borehole; BdH=Bodija Hand dug well, BdB=Bodija Borehole; BH=Beere Hand dug well, BS=Beere Stream; EH=Eleta Hand dug well; EB= Elekuro Borehole; IB=Ita-Baale Borehole; IH= Ita-Baale Hand dug well; KB=Kara Borehole; KH=Kara Hand dug well; KbH=Kobomoje Hand dug well; OAB=Oke Aare Borehole; OAH=Oke Aare Hand dug well; OH=Olubi Hand dug well; OOB= Oja Oba Borehole, OOH= Oja Oba Hand dug well

Highest con concentration of ammonia was 1.45 mg/l found in water sample from Ita-Baale while the lowest of 0.12mg/l was found in Bodija Hand dug well. Ammonia can enter the well or borehole directly from nearby latrine waste or following denitrification of nitrate released from latrines (Ahmed *et al*. 2002; Dzwairo *et al*. 2006). Concentration of chloride in the water samples in this study varied between 27.04 mg/l in Kara Borehole in Ibadan North LGA and 56.03 in Agbongbon Borehole in Ibadan South East LGA. The values obtained for chloride in this study were all within the standard limit set by the World Health Organization (WHO, 2011b). High concentrations of chloride are common in soils closest to latrines, from where it can be transported with minimal retention during groundwater flow (Banks *et al*., 2002).

Microbial Characteristics: The result of the microbial analysis of water samples taken from the selected points is presented in Table 3. Thiosulphate Citrate Bile Salt (TCBS) is positive in the water samples taken from bore holes in Agbongbon (AB), Elekuro (EB), Elekuro Hand dug well (EH), and Oja Oba Hand dug well (OOH) in Ibadan South East LGA. TCBS was also positive in Bodija Hand dug well (BdH), Bodija Borehole (BdB), Oke Aare Borehole (OAB) and Ashi Hand dug well (AsH) in Ibadan North LGA. The positive value confirms the presence of *vibrio* species in the water samples. Total bacteria count (TBC) ranges from 1.85 x 10^1 in water sample from Oja-Oba Borehole (OOB) and 3.82 x 10^4 in Beere stream (BS) which is surface water exposed to direct dumping of domestic waste and faecal matter. Generally, the hand-dug wells showed greater contamination levels. Escherichia coli (*E. coli*) count ranges from zero to 6.93 x 10^2, while the total salmonella count ranges from zero to 9.11 x 10^2. *E. coli* belongs to the faecal coliform group and is specific to the intestinal tract of warm-blooded animals (Washington State Department of Health, 2012).

Table 3: Microbial properties of water samples

Location	TCBS	TBC (CFU/ml)	*E. coli* CFU/ml)	Salmonella (CFU/ml)
Ibadan South East				
EH	+	7.25 x10^{2}	6.93 x10^{2}	0
AH	-	8.55x10^{2}	0	0
OH	-	6.20 x10^{3}	1.00 x10^{1}	1.13 x10^{1}
EB	+	2.00 x10^{2}	0	0
KbH	-	1.78 x10^{3}	3.25 x10^{2}	2.26 x10^{1}
IB	-	6.30 x10^{1}	2.50 x10^{2}	0
IH		3.05 x10^{2}	1.50 x10^{2}	0
AB	+	2.75 x10^{2}	2.50 x10^{2}	0
OOB	-	1.85 x10^{1}	0	0
OOH	+	3.16 x10^{6}	9.40 x10^{1}	6.67 x10
Ibadan North				
BdH	+	1.02 x10^{4}	1.63 x10^{2}	6.67 x10
BdB	+	4.97 x10^{3}	6.85 x10^{2}	3.72 x10^{2}
BH	-	3.29 x10^{3}	6.33 x10^{1}	7.00 x10^{1}
BS	-	3.82 x10^{4}	6.13 x10^{2}	4.42 x10^{1}
OAH	-	3.30 x10^{4}	4.89 x10^{2}	3.48 x10^{1}
OAB	+	2.95 x10^{3}	2.33 x10^{2}	1.67 x10^{2}
KH	-	1.16 x10^{4}	1.55 x10^{2}	1.06 x10^{2}
KB	-	2.34 x10^{4}	9.83 x10^{1}	9.11 x10^{2}
AsB	-	9.18 x10^{3}	3.04 x10^{1}	4.44 x10^{2}
AsH	+	3.23 x10^{3}	6.02 x10^{2}	3.65 x10^{1}
WHO Standards*	-	1.00 x10^{2}	0/100CFUml^{-1}	0/100CFUml^{-1}

***WHO (2011a)**

Note: AB=Agbongbon Borehole; AH=Agbongbon Hand dug well; AsB=Ashi Borehole; AsH=Ashi Hand dug well, BdH=Bodija Hand dug well, BdB=Bodija Borehole; BH=Beere Hand dug well, BS=Beere Stream; EH=Eleta Hand dug well; EB= Elekuro Borehole; IB=Ita-Baale Borehole; IH= Ita-Baale Hand dug well; KB=Kara Borehole

Epidemiological evidences have shown that total coliforms and Escherichia coli are good indicators of water quality (Wade *et al*. 2003; Verhille, 2013). In majority of the cases in this study, TBC and Escherichia coli were in concentrations far higher than the recommended limits due to possible leaching of excreta from the many not well-constructed pit latrines into groundwater sources. The use of unprotected pit latrines may cause severe human and ecological health impacts including diseases associated with microbiological and chemical contamination of shallow groundwater sources (Blackburn *et al.,* 2004; Caincross, 2004; Pedley *et al*. 2006) as well as inadequate personal hygiene (Olowe *et al*., 2005). Bacterial isolates identified in some of the water samples were *Enterobacter cloaca, Escherichia coli, Klebsiella oxytoca, Pseudomaonas fluorescens* and *Salmonella spp* (Table 4).

Table 4: Bacteria Isolates in water samples

Samples	Gram	Motility	Glucose	Lactose	Mannitol	Maltose	Indole	Methyl Red	Voges proskauer	Citrate	H_2S	Sucrose	Urea	Oxidase	Coagulase	Catalase	Isolate
AH	GNB	-	+	-	-	-	-	-	-	+	-	+	-	-	-	+	*Klebsiella oxytoca*
KbH	GNB	+	+	+	-	-	-	+	+	+	+	+	+	-	NA	+	*Pseudomaonas fluorescens*
KH	GNB	+	+	+	+	+	-	-	-	+	-	+	-	-	-	+	*Enterobacter cloaca*
OH	GNB	+	+	+	+	+	+	+	-	-	-	NA	-	-	NA	+	*Escherichia coli*
OOB	GNB	+	+	-	-	-	-	+	-	+	+	+	-	-	NA	+	*Salmonella spp*
OOH	GNB	+	+	-	-	-	-	+	-	+	+	+	-	-	NA	+	*Salmonella spp*
IH	GNB	+	+	+	+	+	+	+	-	-	-	NA	-	-	NA	+	*Escherichia coli*
BS	GNB	+	+	+	-	+	-	+	+	+	+	+	+	+	NA	+	*Pseudomaonas fluorescens*

Note + = Positive, - = Negative, GNB= Gram Negative Bacilli, NA= Not Applicable AH=Agbongbon Hand dug well; BS=Beere Stream; IH= Ita-Baale Hand dug well; KH=Kara Hand dug well; KbH=Kobomoje Hand dug well; OH=Olubi Hand dug well OOB= Oja Oba Borehole, OOH= Oja Oba Hand dug well

The isolates were characterized based on their cultural, morphological as well as biochemical features. Bacterial isolates were mostly positive based on morphological feature (motility) and biochemical features (glucose and catalase), while oxidase is mostly negative. These organisms are largely responsible for some of the sanitation-related diseases highlighted in Table 3. Coliform group density is a criterion of the degree of pollution and sanitary quality (Benjamen and James, 2014). The presence of *E. coli* is an indicator of faecal contamination which could increase the susceptibility of the residents to several infections e.g. meningitis, acute renal failure and diarrhoea which is one of the leading cause of morbidity and mortality among young children (NIS, 2007). Faecal coliforms are a smaller group in the total coliform family that inhibit the intestines of mammals and have a relatively short lifespan.

Sanitary Conditions: Many households in the study areas cannot afford to build improved latrine as corroborated by other similar studies (Songsore and McGranahan, 1998; Osumanu, 2007) that revealed that poor households are often unable to afford a toilet facility at home. In some parts such as Beere, Eleta, Kara and Kobomoje some people defecate in open areas in areas without latrines and faeces could be seen dotting some spots in the neighbourhood. There is hardly any public toilet and where the public toilets area available, such facilities area in various state of disuse. In some instances, people avoid public toilets for fear of contacting diseases and therefore defecate in the open. Osumanu *et al*. (2013) stressed that public toilet is an unavoidable option for sanitation in many low-income towns and cities of developing countries because in the absence of public toilet facilities people may be forced to defecate in the open (Ayee and Crook, 2003; MLGRD, 2010). Although 25% of the households surveyed had access to public piped water source of drinking water, they resort to other sources when the pubic tap water is not available. Public piped water service is erratic in majority of the areas. Investigation in the study area also indicated that household also depends on water purchased from water vendors whose source and quality of water sold cannot be guaranteed. Many existing water sources were not functioning thus increasing poor hygiene conditions in the area. The quality and quantity of water available for drinking and other domestic uses are grossly inadequate within the areas; thus leading the residents to adopt unimproved sources of water which pose serious danger to their health. In Olubi area, it was discovered that a former soak away pit is now being used as a well. Unsanitary condition of the environment also lead to breeding sites for vectors of diseases like mosquito which transmit malaria, with open refuse dumps serving as hiding and breeding sites for rats which transmits various kinds of infections. Although 38 % of the households surveyed indicated that they dispose wastes using government approved agencies while about 28 % of the households dispose wastes on undeveloped/abandon plots nearby (Figure 2).

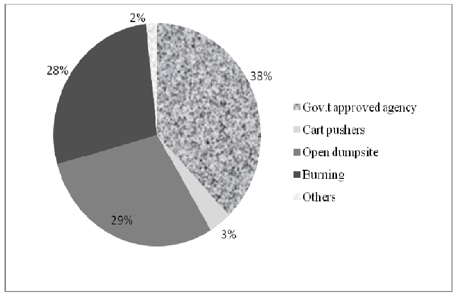

Fig 2: Means of waste disposal

Medical Records: Although available medical records between 2009 and 2012 a steady reduction in the number of reported cases of sanitation related diseases (Table 5) properly due to the adoption of improved sanitation methods and water supply. Incidences of typhoid and diarrhoea were very high in 2009, 2011 and 2012 although no mortality was reported.

Table 5: Epidemiological Records of Oyo state

Year	Cholera		Typhoid		Diarrhoea	
	Cases	Mortality	Cases	Mortality	Cases	Mortality
2009	1025	1	19,961	74	NA	NA
2010	NA	NA	NA	NA	NA	NA
2011	978	3	7546	89	22,129	NA
2012	433	1	NA	NA	16,942	NA

***Source**: Oyo State Ministry of Health, Statistics Division)*

There is paucity of epidemiological data on sanitation related diseases as shown in Table 5 as no data was available for 2010 and the data gathered was for the entire state, hence not location specific. In many instances, such cases are not reported because people seek alternative medical care, which are not recorded in the government hospitals.

Conclusion: Groundwater sources in the study area are mostly unprotected and close to the pit latrines thus increasing susceptibility to contamination. Water quality parameter such as electrical conductivity in many areas were higher than the recommended limit while microbial assessments of the water used in some of the areas were positive confirming the presence of vibrio species due to faecal pollution. There is a need for to prioritizing sanitation and hygiene by the provision of cleaner and well-protected water sources, and adequate waste disposal to reduce associated health implications.

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