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Research Article

COMPARATIVE ANALYSIS OF DRINKING WATER QUALITY IN SELECTED SLUMS OF SOUTHWESTERN STATES OF NIGERIA

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Abstract

Poor quality of drinking water has killed and sickens millions of slum residents in developing countries. This work compares drinking water. quality in the selected slums across South-western Geo-political zone of Nigeria. Six states exist in the zone, the six were grouped into three and one in each group was purposively chosen. Worst slum in each state capital was then chosen to represent the state. Water samples were obtained from 5 most used drinking water sources in each selected slum into sterilized bottles between 6-8 am and immediately taken to laboratory for analysis and the results compared with WHO, NAFDAC and SON approved standards and across the study areas too. The results reveal poor quality of drinking water across the region and therefore recommend intervention of international organizations, attitude by individuals residents.

Keywords: Slums, Drinking Water Qaulity, Comparative Analyses, South-west and WHO

INTRODUCTION

Slum is as an overpopulated living environment with inadequate access to water and sanitation, it is a place where housing is very poor and made from low quality materials. Over the years, slums have been a consistent part of our urban development, from pre through post-industrial Europe and America in particular, long before it became a phenomenon predominantly associated with the developing regions Heather (2020). Worldwide, nearly 1 billion people live in slums and the number is expected to continue to increase John *et al* (2020). Globally, an estimated 663 million people remain without access to improved drinking water within a reasonable distance from home and 2.5 billion lack improved sanitation facilities Joseph *et al* (2020) citting WHO/UNICEF (2019). The countries which still have limited access to water for drinking purposes are mainly those in the Sub-Saharan region Paola *et al* (2020) sitting WHO (2017).

According to Heather *et al* (2019), slum residents are frequently unable to access sufficient safe drinking water because their drinking water access change over multiple timescale, the authors concluded that access to clean drinking water is woefully inadequate despite the United Nations' declaration that access to safe water is a fundamental human right. Oyeniyi and Oloyede (2016) sitting (Water and Sanitation Coverage 2000) reported that safe water provision is still not top priority for Africa governments, cacophony of excuses were given for their failure to provide the people with safe water and adequate sanitation, among which are; insufficient fund, inadequate human capacity, insufficient private sector and civil society interest in water provision, inability to collect revenue for water, in sustainability, inadequate human capacity, inadequate accessibility to donor funds, and slowness in mobilizing financing as well as inadequate necessary laws.

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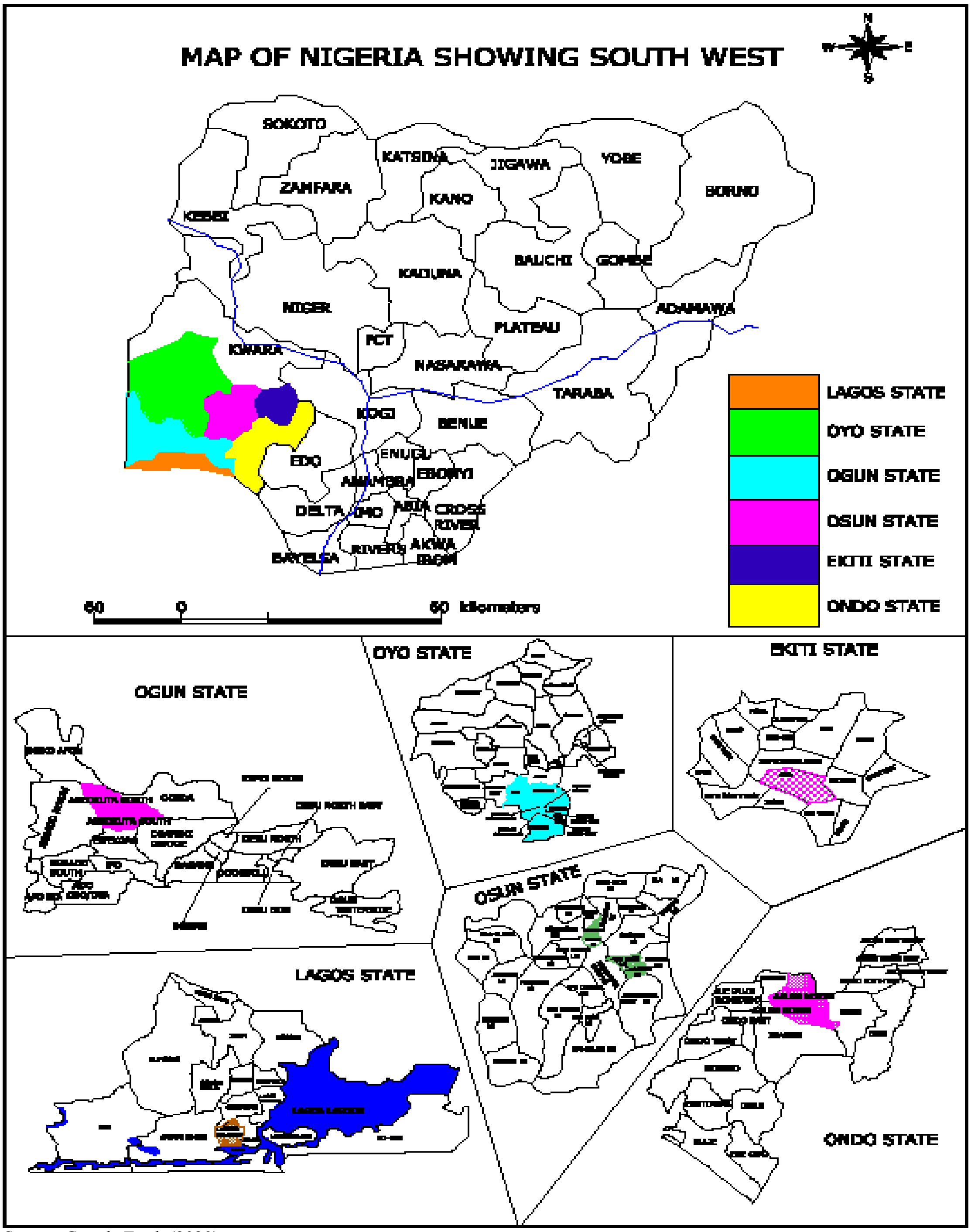
Literature review

Inadequate access to safe drinking water is one of the most serious challenges of developing countries and has aggravated socio-economic, psychological and health problems of the poor slum dwellers. The situation is worsened by ever-increasing urban population growth, poor sanitation and recessed economy UNICEF, WHO (2019). Access to safe drinking water is measured by the percentage of the population having access to and using improved drinking water sources. Improved drinking water sources should, but do not always, provide safe drinking water, and they include: piped household water connections, public standpipes, boreholes, protected dug wells, protected springs, rainwater collection while unprotected sources are: unprotected dug wells, unprotected springs, surface water (river, dam, lake, pond, stream, canal, irrigation channels, vendor-provided water (cart with small tank/drum, tanker truck), bottled water, tanker truck water (Water and Sanitation Summary Sheet, WASH 2012). A number of studies have been carried out on water quality assessment and some of the studies have focused on informal settlements among them are those carried out by (Elizabeth and Augustine 2007; Omotoso and Oyeniyi 2015; and; WHO 2018; Hannah and Max 2019). These studies have established a strong link between the environments, socio-economic status as well as sanitation and safe water situation of the residents. Subbaraman *et al* (2013) added that there are seasonal variation in slum residents' safe water condition and the cost of assessing it is leading to the wide spread of water related diseases. Studies carried out by John 2003; Ashaso and Agbomisishie 2006; Ukpong 2006; Ushie and Amadi 2008; Afiuwa and Eboatu 2013; Stefan-Kharich *et al* 2018 and Verlicchi and Grillini 2020) investigated and compared drinking water quality, they discovered variance in physical, chemical and microbiological, components pointed out associated risks as well as consequences on the health and economy of the consumers. Elizabeth, 2007; Hannah, 2018; Sri *et al* 2018; Adediran, 2018; Sri *at al* 2019 and Heather, 2020 are among the scholars who focused their studies on



Source: Google Earth (2020)

Fig 1. Nigeria, Southwest and Southwestern States

drinking water quality of slum residents. They discovered low safety level because the water samples did not compare with WHO and other national standards especially as regards the microbiological components of water samples. To say the least, contaminated drinking-water is estimated to cause more than 500 000 diarrhoeal deaths each year WHO (2020). Unsafe drinking water has also continued to transmit diseases such as diarrhoea, cholera, dysentery, typhoid and polio. The health costs associated with waterborne and contaminated diseases such as malaria, diarrhoea, and worm infections represent more than one third of the income of poor households in Nigeria and other sub-Saharan African countries. Despite this huge global concerns, none of these studies compared drinking water quality across different slum environments in a vast region like Southwestern Nigeria so as to be able come up with robust and sustainable safe water provision strategies.

Besides, the researcher is of the opinion that slums differ not only in origin, outlook, characteristics deprivation and susceptibility to unsafe drinking water, but works on comparison of challenges of slum dwellers are few, hence, the comparative analysis of safe drinking water situation in selected slums of Southwestern Nigeria.

The Study Area

Lagos, Ogun, Oyo, Osun, Ondo and Ekiti are the states in Southwestern Geo-political zone of Nigeria. The region lies between Latitude 6^0 21^1 and 9^0 15 North and longitude 20 311 and 60 001 East (Fig. 1). The total population of the five states was put at about 34, 266,257 persons by 2020 (as projected from National Population Commission census results of 2006). The region is the most urbanized in Nigeria and populated mainly by Yorubas are who are farmers, artisan and office workers, they cohabit peacefully with other ethnic groups and nationalities.

MATERIALS AND METHODS

Six states exist in Southwestern Nigeria; they are Lagos, Ogun, Osun, Oyo, Ekiti and Ondo, these six states were grouped into three, (two in each group), one out of each group was chosen. (Ogun, Oyo, and Ondo states) Capital cities of these states were purposefully chosen, three slum areas were identified and one considered as the worst is chosen. The core / city center exhibits the worst physical attributes like poor housing, sanitation and safe water availability; hence, they were considered as sample frame. Primary and secondary data ware used for the work; reconnaissance survey was combined with interview of women in randomly selected families to identity and chooses major drinking water sources. Google Earth was also employed to map/delineate the area (see Fig 1) Data on quality of drinking water was accessed by purposively selecting strategically located drinking water sources that serve many slum residents in the selected slum environments, the water samples collected between 6-8am into a sterilizes plastic bottles and was immediately taken to a laboratory (Federal Government Zonal Water Resources Laboratory, Akure) for laboratory analysis. The results were compared with international and national safe water standards; World Health Organization (WHO), National Food and Drug Administration Commission (NAFDAC) and Standard Organization of Nigeria (SON) of Nigeria where necessary and then compared among the three study areas since water sources are different, the qualities may also be different. Table 3 compares recommended standards of the stated Organizations with the results obtained from drinking water samples taken from Araromi/Odo-Ikoyi chosen slum of Akure. The constituents of drinking water samples show that, their Appearance, Odour, Temperature, Conductivity, Total Dissolved Solids (TDS), Total Hardness ($CaCO_3$), Calcium (Ca^{2+}) and Bicarbonate (HCO_3) are acceptable judging by WHO recommended standard as well as NAFDAC and SON but all the water samples are full of suspended particles; i 8.00, ii 600, iii 10.00, iv 8, 00, v 10.00 NTU as against 1.5 NTU. The particles provide food and shelter for organisms and protect them against disinfectants during water treatments since the organisms can hang on the particles. Presence of particles can make water samples physically unattractive for drinking consumers. This will naturally raise concern which can result in stress as well as seeking drinking water from more doubtful sources.

Chloride (Cl-) in samples i & v (300mg/L) is above the WHO recommended 250mg/L. This may have implication on taste, it can also corrode plumbing fixtures and thereby raise maintenance cost of water equipment and the consumers will naturally prefer water of better taste, this also denies the residents expected accessibility and add to the risk the water consumers are exposed to. Magnesium (Mg^{2+}) is found to be higher than recommended quantity samples i and v 24mg/L each as against recommended 20mg/L. Overdose of Magnesium (Mg^{2+}) do results in death of young children and ailment in young girls and women, impaired renal function, causes hypertension, convulsion, slowed heart and respiratory rate, vomiting and nausea (Stefan-Kharicha *et al* 2018; and WHO 2020). Magnesium (Mn) is 0.8 in sample i, 0.6 in ii, 0.6 in iii and 0.6 in iv above, against WHO 0.5 maximum permissible. The effects are usually Odour and taste.

The presence of Total Coliform in all the samples and E-coli in one sample (i) is an indication of pollution most likely fecal pollution. This is another important indication of vulnerability to problems related to unsafe drinking water problems. Bacteria, viruses, and parasites do cause dysentery, cholera, fever, typhoid and infections hepatitis (Upkong, 2006, Adebola *et al.,* 2010, Nwankawoala, 2013, and USGS, 2017). Consumers of the water sources are therefore susceptible to the aforementioned water related problems. Table 3 lays out and compares laboratory analysis result of drinking water samples collected from Iberekudo area of Abeokuta with NAFDAC, SON and very importantly, WHO recommended drinking water quality standards. The samples taken and analysed reveals that the water is clear, Odourless (ODL), possesses expected average temperature, turbidity, pH, conductivity, Total Dissolved Solid (TDS), Total Hardness (CaCO3), Calcium Hardness (CaCO3), and Nitrate NO_3. Others like Magnesium (Mg^{2+})' Chloride (Cl^-), Sodium (Na) and Bicarbonate (HCO_3). Turbidity is higher than maximum permissible of WHO of 1.5 NUT in samples (ii 2.00, iii 3.00, iv 2.00 and 4.00 in sample v) hence, water may have pathogen and unsafe for drinking. Magnesium Hardness ($CaCO_3$) is excessive in all the samples (i 36.0, ii 32.0, iii 42.0, iv 64.0 & v 26.0 mg/L) against 20mg/L, this has effects on taste/ hardness. The main issue about samples taken from Abeokuta is the presence of Total Coliform (i 17, ii 23, iii 14, iv 19, and v 20). The presence of Total Coliform is an indication of presence of pollutants in the drinking water samples. Abeokuta samples without E-coli and they have lowest number of Total Coliform; a proof that the water sources are better and safer. Table 4 presents the analysis and compares of the results obtained from samples taken from Beere and Monpo slum area of Ibadan. The samples compared with NAFDAC, SON and WHO recommended standards. The appearance, Odour, Temperature, pH, conductivity, TDS, Nitrate NO_3, Alkalinity, Magnesium (Mn) and Chromium (Cr^6+) are in line with WHO recommendation. In the contrary, all samples are highly turbid; they are full of suspended particles capable of increasing the chances of the presence and survival of microorganisms and then make the appearance of water not too appealing.

The level of hardness is also high as evident by the result obtained from Magnesium Hardness ($CaCO_3$), iron and chloride. All these are capable of discouraging consumers and compel them to seek drinking water from other sources. Samples i and ii has 300 and 280mg/L above 250 mg/L maximum permissible. Microbiological conditions of drinking water samples are appalling, all the samples contain total coliform; (25) in samples i (31) in ii, (43) in iii, (28) in iv & (12) in v. Samples i even contains E-coli, a clear evidence of pollution and contaminants. The principal issues of drinking water quality are microbiological. They are Total coliform and E-coli (Escherichia coli): Total coliform is a large collection of bacteria/organisms found in the environment, intestine and feaces of warm blooded mammals. They may be found in drinking water without causing illness but their presence is a clear indication of the water source contamination by more harmful microorganisms (WHO, 2016). Total coliform is present in all the samples; this implies that all the drinking water samples' sources are susceptible to pollution by harmful pathogen thereby exposing the lives of water consumers to danger. E-coli (Escherichia coli): are special member of bacteria found in well waters; it is the only member of coliform bacteria that is found only in human intestine. It is an used to measure the level of pollution and sanitary quality of

Table 1. Comparison of laboratory analysis of Akure water samples with NAFDAC, son and WHO recommended standards

S.N.	Parameters	Unit	i	ii	iii	iv	v	NafdacMax. All.	Son Standard	Who Max.perm	Remark
1	Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Unobje	15TCU	Unobje	✓
2	Odour	ODL	ODL	ODL	ODL	ODL	ODL	Unobjec	Unobjec	Unobjec	✓
3	Temperature	^0C	28.4	28.6	28.7	28.3	28.1	NS	NS	NS	✓
4	ph.	pH	6.73	6.67	6.74	6.48	6.83	6.50-8.5	6.50-8.5	8.2-8.5	✓
5	Turbidity	NTU	8.00	6.00	10.0	8.00	10.0	5.0	5.0	5.0	×
6	Conductivity	µs/cm-1	163	749	116	668	157	1000	1000	1200	✓
7	Total dis. Solid	mg/L	109	502	77.7	448	105	1000	1000	1500	✓
8	Total Hard. $CaCo_3$	mg/L	330	186	340	186	179	100	100	500	✓
9	Cal. Hardness $CaCO_3$	mg/L	230	132	274	98.0	80.0	150	150	NS	
10	Mag. Hardness $CaCO_3$	mg/L	100	54.0	66.0	88.0	99.0	20	20	20	×
11	Nitrate (NO_3	mg/L	1.78	22.2	3.21	0.93	1.76	10	50	50	✓
12	Irion (Fe)	mg/L	0.03	0.06	0.02	0.04	0.03	0.03	0.03	0.1	×
13	Alkalinity	mg/L	82.0	36.0	48.0	18.0	60.0	100	100	100	✓
14	Magnesium (Mn)	mg/L	0.8	0.6	0.4	0.6	0.6	---------	0.2	0.5	×
15	Calcium Ca^{2+}	mg/L	92.2	59.9	110	39.3	32.1	75	NS	NS	
16	Magnesium(Mg2+)	mg/L	24.0	13.2	16.1	21.5	24.2	20	20	20	×
17	Chloride (Cl-)	mg/L	300	240	220	150	300	100	250	250	×
18	Sodium (Na)	mg/L	200	156	143	97.5	200		200	NS	
19	Bicarbonate (HCO_3)	mg/L	82.2	0.00	0.01	0.00	0.00	---------	---------	270	✓
20	Chromium (Cr^{6}+)	mg/L	0.00	0.00	0.01	0.00	0.00	---------	0.5	0.1	✓
21	Total coliform	Cfu/100	19	25	32	14	22	0	10	0	×
22	E-coli	Cfu/100	1	0	0	0	0	0	0	0	×

✓ Acceptable; × Not Acceptable

Source: Ground Water Akure Samples (2020)

Table 2. Comparison of laboratory analysis of Abeokuta water samples with NAFDAC, son and WHO recommended standards

S.N.	Parameters	Units	I	II	III	IV	V	Nafdac Max.ald	Son Standard	Whoma.perm	Remark
1	Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Unobj	Unbj	Unobje	✓
2	Odour	ODL	ODL	ODL	ODL	ODL	ODL	Unobj	Unbj	Unob	✓
3	Temperature	^0C	26.3	26.3	26.3	26.3	26.3	NS	NS	NS	
4	pH.	pH	6.92	5.33	6.18	6.18	5.52	6.50-8.5	6.50-8.5	8.2-8.8	✓
5	Turbidity	NUT	0.00	2.00	3.00	2.00	4.00	5.0	5.0	1.5	×
6	Conductivity	µs/cm-1	253	269	262	256	240	1000	1000	1200	✓
7	Total dis. Solid	mg/L	170	180	176	172	161	100	100	500	✓
8	Total Hardnes $CaCo_3$	mg/L	116	92.0	122	140	108	100	100	500	✓
9	Cal.Hardness $CaCO_3$	mg/L	80.0	60.0	80.0	76.0	82.0	75	75	NS	✓
10	Mag. Hardness $CaCO_3$	mg/L	36.0	32.0	42.0	64.0	26.0	20	20	20	✓
11	Nitrate (NO_3	mg/L	2.68	3.12	1.78	4.00	3.32	10	10	50	✓
12	Irion (Fe)	mg/L	0.02	0.02	0.04	0.06	0.03	0.03	0.3	0.1	×
13	Alkalinity	mg/L	12.0	30.0	14.0	12.0	8.0	100	100	100	✓
14	Magnesi (Mn)	mg/L	0.02	0.03	0.03	0.04	0.06	20	20	0.5	✓
15	Calcium Ca^{2+}	mg/L	32.1	24.1	32.1	30.5	32.9	75	NS	NS	
16	Magnesium (Mg2+)	mg/L	8.80	7.01	10.2	15.6	6.34		20	NS	
17	Chloride (Cl^-)	mg/L	34.0	26.0	42.0	38.0	27.0	100	100	250	✓
18	Sodium (Na)	mg/L	22.1	16.9	27.3	24.7	17.6		200	NS	
19	Bicarbonate (HCO_3)	mg/L	12.0	30.0	14.0	12.0	8.0		200	250	✓
20	Chromium (Cr^{6}+)	mg/L	0.02	0.01	0.02	0.03	0.02		------	0.1	✓
21	Total coliform	Cfu100	17	23	14	19	20	0	10	0	×
22	E-coli	Cfu100	0	0	0	0	0	0	0	0	×

✓ Acceptable; × Not Acceptable

Sample Source: Tap Water Abeokuta Sample (2020)

Table 3. Comparison of Laboratory Analysis of IBADAN Water Samples with NAFDAC, Son and WHO Recommended Standards

S.N.	Parameters	Units	i	ii	Iii	iv	v	Nafdac Max.ald	son standa.	Who Max.	Rmk
1	Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Unobje	15TUC	Unobje	✓
2	Odour	ODL	ODL	ODL	ODL	ODL	ODL	Unobje	Unobj	Unobje	✓
3	Temperature	^0C	26.2	26.2	26.0	26.2	26.2	NS	NS	NS	
4	pH.	pH	7.20	7.16	6.80	6.74	6.23	6.50-8.5	6.5-8.8	8.2-8.8	✓
5	Turbidity	NTU	2.00	6.00	2.00	4.00	2.00	5.0	5.0	1.5	×
6	Conductivity	µs/cm-1	118	159	162	155	138	1000	1000	1200	✓
7	Total dis. Solid TDS	mg/L	79.1	107	107	104	92.5	100	100	500	✓
8	Total Hardness $CaCo_3$	mg/L	186	276	156	300	118	100	100	500	✓
9	Calc. Hardness $CaCO_3$	mg/L	140	212	92.0	248	92.0	75	75	NS	
10	Magn. Hardness $CaCO_3$	mg/L	46.0	64.0	64.0	62.0	26.0	20	20	20	×
11	Nitrate (NO_3	mg/L	8.04	6.23	2.21	4.23	2.00	10	10	50	✓
12	Irion (Fe)	mg/L	0.02	0.03	0.02	0.05	0.05	0.03	0.03	0.1	×
13	Alkalinity	mg/L	60.0	54.0	66.0	54.0	22.0	100	100	100	✓
14	Magnesium (Mn)	mg/L	0.01	0.01	0.02	0.02	0.02		0.5	0.5	✓
15	Calcium	mg/L	56.1	85.0	36.9	99.4	36.9	75	NS	NS	
16	Magnesium(Mg2+)	mg/L	11.2	15.3	15.6	12.7	6.34	20	20	20	✓
17	Chloride (Cl-)	mg/L	300	265	216	174	145	100	250	250	×
18	Sodium (Na)	mg/L	200	172	138	113	94.3	-------	200	250	
19	Bicarbonate (HCO_3)	mg/L	60.0	54.0	66.0	54.0	22.0	--------	-------	250	✓
20	Chromium (Cr^{6}+)	mg/L	0.01	0.01	0.00	0.00	0.01	---------	0.5	0.1	✓
21	Total coliform	Cfu/100	25	31	43	28	12	0	0	0	×
22	E-coli	Cfu/100	1	0	0	0	0	0	0	0	×

✓ Acceptable; × Not Acceptable

Sample Source: Underground Water Ibadan Samples (2020)

Table 4. Compares of the Ranges of Water Samples Results by City with WHO Recommended Standard

S.N.	Parameters	Units	Akure	Abeokuta	Ibadan	Who	RMK
1	Appearance	Clear	Clear	Clear	Clear	Obj	✓
2	Odour	ODL	ODL	ODL	ODL	Obj	✓
3	Temperature	^0C	28.1-28.7	26.3	26.3-26.4	NS	
4	pH.	pH	6.48-6.83	5.33-7.20	5.35-6.04	8.28.8	✓
5	Turbidity	NTU	6.48-6.67	0.00-4.00	0.1110.0	1.5	×
6	Conductivity	µs/cm-1	116-749	240-269	113-790	1200	✓
7	Total Dis. Solid	mg/L	77.7-502	161-180	75.7-529	500	×
8	Total Hard. $CaCo_3$	mg/L	179-340	92.0-116	152-590	500	×
9	Calciu.Hard.$CaCO_3$	mg/L	80.0-274	76.0-82.0	93.0-328	NS	
10	Magn.Hardn $CaCO_3$	mg/L	54.0-100	26.0-64.0	90.0-216	20	✓
11	Nitrate (NO_3	mg/L	0.93-3.21	1.78-4.00	2.09-3.65	50	✓
12	Irion (Fe)	mg/L	0.2-0.6	0.2-0.6	0.2-0.5	0.1	×
13	Alkalinity	mg/L	18.0-82.3	6.34.-15.6	8.00-20.0	100	×
14	Magnesium (Mn)	mg/L	0.4-0.8	0.02-0.06	0.09-0.16	0.5	×
15	Calcium Ca^{2+}	mg/L	32.1-110	24.1-32.9	37.3-63.3	NS	
16	Magnesium(Mg2+)	mg/L	13.2-24.2	6.34-15.6	14.4-27.3	20	✓
17	Chloride (Cl-)	mg/L	150-300	26.0-42.0	95.0-240	250	×
18	Sodium (Na)	mg/L	97.5-200	16.9-27.3	61.8-156	NS	
19	Bicarbonate (HCO_3	mg/L	18.0-82.0	8.00-30.0	8.00-20.0	270	✓
20	Chromium (Cr^6+)	mg/L	00-01	0.01-0.03	0.00-0.1	0.1	×
21	Total coliform	Cfu/100	19-32	14-23	22-41	0	×
22	E-coli	Cfu/100	0-1	ND	0-1	0	×

✓ Acceptable; × Not Acceptable

Source: Fieldwork (2020)

Table 5. Total number of issues by city/study area and number of parameters leading to the issues

S.N.	Parameters	units	Akure	Abeokua	Ibadan	Total (a)
1	Appearance	Clear				
2	Odour	ODL				
3	Temperature	^0C				
4	ph.	pH				
5	Turbidity	NTU	5	4	5	14
6	Conductivity	µs/cm-1				
7	Total dissolved Solid	mg/L				
8	Total Hardness $CaCo_3$	mg/L				2
9	Calcium Hardness $CaCO_3$	mg/L				
10	Magnesium Hardness $CaCO_3$	mg/L		5	5	24
11	Nitrate (NO_3	mg/L				
12	Irion (Fe)	mg/L	5			5
13	Alkalinity	mg/L				1
14	Magnesium (Mn)	mg/L	4			4
15	Calcium Ca^{2+}	mg/L				
16	Magnesium(Mg2+)	mg/L	3			10
17	Chloride (Cl-)	mg/L	2		2	7
18	Sodium (Na)	mg/L				
19	Bicarbonate (HCO_3)	mg/L				
20	Chromium (Cr^6+)	mg/L				
21	Total samples with coliform	Cfu/100	5	5	5	30
*	Total coliform	Cfu/100	112	93	160	365
22	E-coli	Cfu/100	1	0	3	8
23	TOTAL (B): NUMBER OF PROBLEMS IN EACH CITY		137	107	177	

Source: Author's Compilation (2020)

water source and its presence indicates resent fecal contamination and presence of disease causing pathogen such as bacteria, viruses and parasites United States Government (USGS, 2015), New York City Department of Health (NYSDH, 2016). One of the really harmful pathogen is E.*coli* 0157:H7 that has led to epidemic in Europe and North America in the past (US-EPA, 2015). The sources of these bacteria are septic tanks or pit latrine, leaching of animal manure/droppings as well as runoff entering into the wells because of poor construction or maintenance. By any standard, E-coli and total coliform should not be in drinking water. Only SON allows10cfu/100 of a Total Coliform in drinking water but did not allow/permit E-coli in drinking water. The water borne illness caused by these bacteria vary because the parasites also vary and they include diarrhea, nausea, vomiting, eyes, skin and nervous system or liver and the effects may be severe, chronic or fetal, it can even be epidemic in nature. Sample(s) in each study area reveals the presence of E-coli, an evidence of presence of disease causing pathogen in the drinking water samples (USGS, 2015).

Table 5 Compares the quality of water in a clearer terms; it shows cities representing the study areas and below them, the number of samples elements WHO recommended values. For instance, under Lagos (3) samples have high turbidity, (5) under Akure and (4) under Abeokuta The total marked 'A' shows total number of samples with high turbidity (14) out of (15), ditto to other elements under each city. According to this table, all samples have common problem; high turbidity and iron concentration. Total coliform is also common; three samples taken from Akure and one from Lagos contain Magnesium (Mg^{2+}) higher than recommended values. In the same vein, one sample from Lagos shows the presence of excessive Chromium (C^{r6+}). All samples possess microorganism in form of Total Coliform and one sample each from Lagos, Akure and two from Ibadan show the presence of most unexpected and harmful E-coli (Escherichia coli).The data made it clear that only Abeokuta samples are free from the presence of E-coli and contain the lowest number of Total Coliform (93), by implication, Abeokuta samples are far better than samples from other study areas. It should also be noted that drinking water sampled from Abeokuta study area is tap; (public stand taps) the water is treated, still, it has some issues, particularly the presence of Total Coliform. Similarly, high turbidity which must be due to improper water treatment or contamination during distribution processes in the channels, this discovery is similar to that of Amos *et al.* (2014).

Summary

Only Abeokuta slum residents drinking treated water sourced from Ogun State Water Cooperation close to them. The water scheme has just been resuscitated by the present administration in the first quarter of the year (2020) hence, the issues found in the samples. Ibadan slum residents source their drinking water from deep wells mechanically pumped into overhead tanks. The water sources are expected to be safe but a lot of issues were discovered when the samples were subjected to laboratory analysis. All the samples are highly turbid, hard and contain coliform while two samples contain excessive chloride. This could be as a result of poor water source protection and on spot pollution at the water source area. More importantly, overhead tanks are left unkempt for years as reported by residents and a whole lot of issues might be from the tanks. The result of laboratory analysis of water samples drawn from drinking water sources of Akure is the worst; all samples contain high turbidity (NTU), high Iron (Fe) concentration and four has high Magnesium (Mn) concentration, three has Magnesium Mg^{2+}), two has high concentration of Chloride (Cl) while all the samples has the total coliform of (112). Slum residents of Ibadan and Akure consume raw water, raw water is natural water found in the environment and has not been treated, nor have any minerals, ions, particles or living organisms being removed. Drinking raw water make the slum residents vulnerable to waterborne diseases, stressors and psycho-socio effects. It causes among many others: vomiting or diarrhea, a sick stomach, skin rashes, leukemia after drinking bad water for a long period of time, reproductive problems, like infertility can happen after drinking polluted water for a long period of time, developmental problems (Some kinds of learning disabilities can happen after drinking dirty water for a long period of time). It also influences mood negatively and increases stress. When water comes from improved and more accessible sources, people spend less time and effort physically collecting it, meaning they can be productive in other ways. This can also result in greater personal safety by reducing the need to make long or risky journeys to collect water. Better water sources also mean less expenditure on health, as people are less likely to fall ill and incur medical bills that further burden the already impoverished slum residents.

Conclusion

From the summary of results of analysis it is clear that the problems discovered in the drinking water samples can be categorized into;

i. Physical contaminants; these primarily impact on physical appearance or other physical properties, water sediments or organic materials as shown by the occurrence of turbidity.
ii. Chemical contaminants are elements or compounds that may be naturally occurring or introduced into the drinking water by man which include chloride (Cl-), Chromium ($Cr^{6+,}$), Calcium and Magnesium Hardness ($CaCO_3$), Magnesium (Mg2+), Sodium (Na), Bicarbonate (HCO_3) etc.
iii. Inorganic contaminants; Total Dissolved Solids (TDS) and
iv. Biological / microbiological contaminants as occur in the samples and indicated in the samples Total Coliform and E-coli (Escherichia coli).

These four classes of contaminants can be easily put under three headings for simplification purpose; (a) Physical i (b) chemical ii & iii and (c) microbiological iv

Having identified the groups of contaminants found in the water samples, it will be thoughtful to seek diligently the available, acceptable and affordable ways, methods, materials and gadgets that can be used to remove the contaminants at community and household levels so that the available and assessable drinking water will be safe.

Recommendation

Physical characteristics of water in the slum areas could be improved upon by the combination of sedimentation and filtration i.e. drinking water should be allowed to settle and then filtered using commercially produced water filters or improvised ones. (Neat silk or cotton clothing materials made in 3-5 layers could be used to filter settled water).

(a) Softening of water by adding salt, this work with the principle of “ion exchange” in which ion of hardness mineral will exchange for sodium. This effectively reduces the concentration of minerals to tolerable level.
(b) Boiling of drinking water at a rolling point for between just three to five minutes will kill bacteria, boiled water can be allowed to settle and then filtered.

i) **Suggested levels of Intervention by Government**

Protecting lives and properties is a primary responsibility of any responsible and responsive governments at all levels but world has become a global village, in certain ways, lives especially are now been protected by “World Government” through United Nations (UN), Word Health Organization (WHO), United Nation Human Settlement Programme (UN-HBITAT), United Nation Agency for international Development (USAID) etc. have engaged in protection of human lives in the countries of the word by mediating in conflicts, providing relieve materials, setting standards enforcing compliance and where necessary.

- A provision of water schemes is the best option but where poor economy and lack of political will do not allow it, other workable alternatives must be sought.
- As these bodies fight common enemies like HIV/AIDS, Malaria scourge and the rampaging (COVID 19) corona virus pandemic so can they fight problems relating to safe water delivery in various fronts;
- As malaria scourge experiences and intensified and sustained fight through regular popular public campaign/enlightenment, provision and distribution of free mosquitos’ nets etc. Problems of poor quality of drinking water delivery especially to poverty ridden slum dwellers can also enjoy such attentions since both mosquitoes and bad water kill massively;
- Delivery of water treatment pills/equipment/filters to the poor in slum residents should also be provided.

The federal government of Nigeria along with states and local governments need to enforce the robust policy of Nigeria Standard for Drinking Water Quality (NSDWQ) as contained in Nigeria Industrial Standard (NIS) 554 of (2007) and approved by Standard Organisation of Nigeria Governing Council.

But it is observed that the existing structure is weak and cannot effectively do this, the work therefore suggest institutionalization of an agency to be named National Drinking Water Protection Agency (NDWPA). This Agency will have town / environmental planners, geologists, water engineers and community health workers as staffers. It will be saddled with the following responsibilities among others:

a) Approve the location and types of ground water to be sunk. This approval will be based on compliance with Town Planning Regulations as entrenched in the constitution of Federal Republic of Nigeria. The approval will also be based on what I will like to call Hydrological Sensitivity Assessment (HSA). Since all aquifers are not the same some are more porous than others. Deep wells will be strongly recommended in the porous aquifers and so on.
b) It will also coordinate and register contractors / water engineer that are involved in drilling of wells to ensure that quality jobs are done with quality materials. This is necessary because one major way by which hand-dung-well water gets contaminated is through infiltration of surface water into wells due to the use of poor materials and poor construction standards.
c) It will also be expected to monitor activities of water corporations in the country. Up till now, no one supervises the water corporations and the quality of water they circulate cannot be guaranteed. This is evident by the laboratory analysis results of Ogun State Water Corporation. The reasons for not too good result can be inadequate contact time of chlorine, maximum contaminant level violation, damages in distribution channel etc. proper monitoring would have put these under check.
d) Coordinate the activities of water vendors. This will be easily achieved by formalizing the business, register them, train them, facilitate the availability of good quality water treatment materials and equipment, monitor the sources of water they sell and regulate their prizes, serve as a link between the vendors and government and enforce environmental and hearth related laws.
e) Collaborate with International Organisations; Water Aid Agencies, Donor Agencies, development partners and other government parastatals and agencies at all levels to facilitate the development of effective, acceptable and affordable water disinfectants and filters to poor slum residents.
f) Ascertain the safety level of drinking water at the community sources and disseminate the information to the consumers.

ii) **Intervention of Community households and Individuals**

The communities also need to come together and forge a common front in protecting their water sources by promoting personal and community hygiene and sanitation as they fight to ensure government do her bit. Communities also need to come together and decide on maintenance and protective strategies of their drinking water sources. This may include protection of the well surrounding at least 15meter radius as clearly stipulated by town planning law, provision of motorized methods to replace manual and provision of the needed power, ensuring the wells are well covered and protected, occasional empting, flushing and washing of their tanks/reservoir to prevent excessive sediment and growth that can further contaminate the water and test drinking water quality at least once in a year. At household and individual levels, good sanitation; personal and domestic hygiene must be maintained, water fetchers must be hygienically kept, domestic animals feces, waste water must not be allowed to find its way into wells, wells must not be dunged close to septic tanks. Our drinking water must be treated at least by boiling and filtration before they are consumed.

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