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Original Research Paper

Urban Informality and Safe Water Situation in Southwestern Nigeria

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This work studies the effects of informality on drinking water quality in selected informal settlements of Southwestern Nigeria. Both primary and secondary data were used. Primary data were obtained through observation, interview and photo snaps. Water samples were collected from the most used drinking water sources and analyzed to ascertain their safety levels. The work discovered that unprotected hand-dug-wells are the main drinking water sources of the residents. When the laboratory analysis results were compared with WHO, SON and NAFDAC standards, all the samples failed safety tests. The work recommends a coordinated interventionist approach that would break the chain of poverty, and hurt the existence and spread of informality in our cities. Free distribution of water treatment pills, gadgets and other products, provision of water schemes and environmental education were also suggested.

Keywords: Urban Informality, Slum nieghbourhood, Safe Water, Southwest and Intervention.

INTRODUCTION

Human settlements of the twenty-first century are more urban than rural as a result of partial knowledge and erroneous notion of what urban centres hold in wait for rural migrants. A World Bank Report (2022) put the percentage of rising number of people living in cities at 56 percent as against 44 in semi-urban and rural areas, The rapid in-flow of untrained rural dwellers into the cities multiplies the number of urban poor, crates more problems and escalates the existing ones resulting in series of almost irreversible social and environmental challenges. Hence, the growth of cities has defeated planning efforts by outpacing existing urban planning and regulatory activities in the developing world. There are also declining and degenerating neighbourhoods of inner/core of traditional cities that existed before the introduction of urban planning that have become slums or decayed.

Onditi 2021 and Soliman 2021 in their individual submissions described these unregulated or uncontrolled settlements as problematic, illegal and informal because they fall outside the legal sanction of the state. Urban informality is therefore “a state of exception from the formal order of urbanization”, it’s the process whereby a society changes from a rural to an urban way of life, ‘urban informality’ involves urbanization activities and practices that fall outside the purview of the state and policies that moderate the urbanization process Roy, 2005. Urban informality is more pronounced in the cities of the developing world, it forms most part of urban landscapes. Most times, it constitutes a disorganized and chaotic situation manifesting in slums and sanities, characterized by illegal occupation, deviation from urban planning and building code regulations as well as an informal economy Arefi, 2018 and Safiya *et all* 2021. Urban informality is identified and measured by the condition of; housing, living space, sanitation, land tenure and safe water.

Slums located at the core of city centers are the most common informal urban neighbourhoods in Nigeria cities, they came to be as a result of urban decay. Core city centers are oldest urban neighborhoods with the lowest quality of housing, highest population density and traditional landmarks such as kings’ palaces, local marketplaces, shrines and other worship centers, and town squares among others. In a nutshell, they are centers of human activities with attendant social and environmental challenges. Life in informal settlements is precarious because of access to basic necessities of life most especially safe water. No water, no life, the safer the water, the healthier the consumers. Informal urban neighbourhoods are unplanned, resident depend on self-help for sanitation, housing, and safe water among others. Human lives in informal settlements are susceptible to the consequences of sourcing drinking water from traditional, unsanitary environments. They source drinking water from sources like hand-dug and unprotected wells, buy water from unverified sources, and

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consume raw/untreated water among others that expose the poor residents to associated safe water-related risks. The researcher is therefore spurred by the plight of residents of informal neighbourhoods in selected capital cities of southwestern Nigeria. The study considers the effect of urban informality on the drinking water quality of the selected informal environments of selected major cities in southwestern Nigeria.

LITERATURE REVIEW AND THEORETICAL UNDERPINNING

Water is not just a top priority it is an absolute necessity, yet, The World Health Organisation (WHO) in 2018 announced that two billion people are drinking water contaminated by faeces and 3.4 million die annually from consumption of contaminated water. According to the Multiple Indicator Cluster Survey (MICS) by the National Bureau of Statistics (NBS), Nigeria constitutes a significant percentage of these two billion people, since an overwhelming majority of 163 million households are in informal settlements and they drink water contaminated by faeces and E.Coli. United Nations Children's Fund, (UNICEF) in 2021 reported that over 57 million Nigerians still lack access to potable water, most residents of informal settlements drink water from unprotected hand-dug-wells, rivers, lakes, ponds, streams and irrigation canals resulting in water-related infections that claims about 130,000 lives of Nigerian children.

Water in an unsanitary environment of informal settlements is contaminated by waste water, sludge, seepage from nearby latrines as well as contamination from dumping sites.

Others are the use of the effects of pesticides for insect control purposes on drinking water sources, surface/flood water gaining entrance into water sources during heavy rains Omotoso et al 2016. Free-ranged animals are common in informal settlements: goats, sheep, dogs, fowls, and pigs share drinking water sources with residents and sometimes pass nights on wells and their dung and urine get into the drinking water sources directly. Burial sites of dead family members buried within the compounds are among the respiratory filths in the informal living environment. Natural sources whereby water gets contaminated include but are not limited to iron and manganese contamination which results in aesthetic issues and rejection of the water source.

Scholars have embarked on the study of drinking water quality and some of the studies have focused on single informal settlements but this study is covering a region. Elizabeth and Augustine 2007; Omotoso and Oyeniyi 2015; Hannah *et al* 2019; WHO 2020; and Oyeniyi 2022 concluded that there are strong links between the environmental and sanitary conditions and the safe water situation of poor informal settlers. Subbaraman *et al* (2013) discovered seasonal variations in slum residents' safe water conditions and the cost of assessing safe water is difficult to bear resulting in residents sourcing drinking water from unsanitary places leading to outbreaks of safe water-related diseases.

The works of Ukpong 2006; Ashaso and Agbomisishie 2006; Ushie and Amadi 2008; Afiuwa and Eboatu 2013; Stefan-Kharich *et al* 2018 and Verlicchi and Grillini 2020) studied and compared drinking water quality, they discovered a 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 e*t al* 2019 and Heather, 2020 focused their studies on the drinking water quality of slum residents. They concluded that the safety level is poor when the samples are compared with WHO and other national standards as regards the microbiological components.

As reported by El Ghmari and Zabadi in 2021 the genesis of '*urban informality'* dates back to 1972 at the *International Labor Organization* (ILO). The neologism was coined and first used by a renowned anthropologist Keith Hart who theorized approaches to '*urban informality*' as a situation of underemployed immigrants in the outskirts cities using Ghanaian capital as a template. In the authors' translation of Western political economy as duality; the contrast and distinction between two local economies which he called: *"formal and informal".* He believes that the formal economy is modern while the informal economy is traditional and informality is the initial stage of all workers and informality is central to the functionality of human settlements. Bromley, (1978) faulted the claims of Hart on the grounds of the description of formal and informal as separate rather than interdependent, informality is seen as an exclusively urban phenomenon, economic activity is confused with places so that entire neighbourhoods are described as informal, informality and poverty are considered one and the same.

Castells and Portes in (1989) led theorists of like minds to consider informality as a way of contestation by the marginalized against the inequalities and capitalism, a reaction to over-regulation and bureaucracy. He suggested the reactivation of informal capital; informal activities and micro-operations in the market ecosystem and formalizing how to do things on a small scale. Kevin Hart (1972) believes that informality is any activity outside the formal framework, distinct and dissociated from the formal economy. This exclusion originally is due to bad urban policies and management in which legislative and legal structures rarely consider the rights of less privileged urban populations. The researcher therefore opinioned that urban informality is a reaction not only to socio-economic segregation and poverty, imbalanced distribution of national wealth, globalization, uneven distribution of social and infrastructural facilities but also lopsided and secluded legal and socio-political structure.

METHODS AND MATERIALS

Capital cities of six southwestern states were purposively selected for the study. Five informal settlements (mainly slums) were identified in each city and one of them was statistically selected. Adopting 'Indices Scoring Method' of Dung-Gwom and Oladosu (2004). Combining the definition of slum given by the National Sample Survey Organization (NSSO) (2000) of India as a "compact settlement with a collection of poorly built tenements, mostly of temporary nature, crowded together usually with inadequate sanitary and drinking water facilities in unhygienic conditions" and that of United Nations Habitat (2012) also identifies these indices while giving a definition to slum as any living space with two or more of the above. The criteria were used to evaluate and rank informal settlements (slums) on the aggregate of 10. The least represents the worst slum in the selected cities and were selected.

Primary data obtained were through observation, drinking water was sampled from the five most used sources into sterilized water bottles between 8-10am from the study areas and immediately taken to a Federal Government Laboratory for immediate analysis. The results of the analysis were then placed side by side with the World Health Organisation (WHO) recommended standard and the National Food and Drug Law

Enforcement Agency (NAFDAC) and Standard Origination of Nigeria to ascertain the level of their safety.

THE STUDY AREA

Oyo, Osun, Ogun, Ondo, Ekiti and Lagos, are the Southwestern states of Nigeria. The region falls 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 36, 216,127 persons by 2023 (Projection from NPC census results of 2006). This is the most urbanized region in Nigeria and it's populated mainly by Yorubas who are farmers, artisans, traders and office workers, they cohabit peacefully with other ethnic groups and nationalities.

Drinking Water Sources in the Study Areas

Iberekodo, Ikereku, Ikija, Ijemu areas of Abeokuta have access to standpipes from the nearby Ogun State Water Cooperation. Other parts of the study areas do not have similar access but they need to buy water from the same source for (200 naira per 25liters); the water scheme does not have the technical and financial capacity to pump water through farther and fairly rugged relief of Odo-Itoku, Mokola and Ilugun areas. The chosen slum in Osogbo also has a water scheme at Oke-bale owned and managed by Osun State Government. The issue with this scheme is inconsistency in supply and low capacity according to the interviewed residents, the water may not run for a whole week and when it funs, it does not flow for many hours when the tap water flows, only Oke-Bale axis has free access to it via public standpipes.

Other places are not connected just like Abeokuta because this situation has remained the same for many years now. The majority of dwellers therefore are left with hand-dug-well options. Poorly protected hand-dug-wells are the drinking water sources of Oja-Oba, palace areas, Isale Agbara, Kajola, Ibokun Road. From observation, there exist a good number of boreholes overhead tanks but they are mere shadows of their old self. Findings revealed that they don't function; some functioned for about six months after their commissioning because no provision was made for their maintainance. At Ibadan, the situation is different, at Oja-Oba, Mopo etc., the drinking water sources are boreholes stored in overhead tanks, Ibadan slum residents seem to have no other options. They buy 25-liter keg for 200-250 naira. At Ibadan, many boreholes are functioning perfectly well.

This is the result of users' private arrangements to manage and maintain them and because water from shallow/hand-dug-wells is hard and tasty. Ado Ekiti slum residents do not have access to any form of supply; even boreholes are rare. Dwellers basically drink well waters these wells are shallow, not well protected and the water is hard. Water samples are full or particles; they are highly turbid. Although, some claim they buy water from kiosks/tanks, neither of them is safe for consumption according to WHO. Places like the back of Fayose Market, Atikankan, Igbeyin, Ologoro, Okeisa Market and Irona have only one functioning public borehole.

The situation in Akure is similar to that of Ado-Ekiti; the hand–dug-well is the major source of drinking water. Public boreholes are not seen in the slum neighbourhood but tanks/water selling points are feasible. Ajegunle slum dwellers do buy their drinking water. Storex tanks in kiosks or selling points receive their water supply from tankers. It must be borne in mind that the tanker owners and operators brought water from unknown sources. The tanker owners are businessmen/women; they do use their tankers to supply non-potable water to building sites. Ajegunle residents do not have hand-dung-wells, because of some limitations; stagnant waters cover the surface, besides, canals from the lagoon will not allow hand-dug-wells to function.

Rainwater is recognized by WHO as an improved or safe drinking water source. Rainwater collection bowls and drums were seen in many Ajegunle dwellings and residents confirmed the collection and storage of rainwater as their fair alternative considering the quantity of rainwater in Lagos as a result of its closeness to the ocean. Some residents in the other study areas do use rainwater but the ability to collect, preserve and store it in large quantities is simply not there because of the limitation posed by inadequate space in their dwellings, inability to procure sizeable storage facilities as well as adequate knowledge of preservation for reasonable length of time.

Table 2: relates the laboratory results of water sampled from Ajegunle, the chosen slum area of Lagos with the National Agency for Food and Drug Administration (NAFDAC), Standard Organisation of Nigeria (SON) and importantly, the World Health Organization (WHO) recommended standard. Although, (NAFDAC) and (SON) standards are for treated bottled/mineral water, those recommendations are deliberately included to reveal the gaps that exist between the raw/untreated water the residents consume. The samples are Colorless, Odorless (ODL) and of average temperature (^oC) expected of natural water where organisms can easily survive and multiply. Conductivity, Total Dissolved Solid (TDS), Total Hardness (CaCO3), the right quantity of Sodium (Na), Nitrate (Ne) and Alkaline. WHO did not attach any expected quantity to Calcium (Ca), Magnesium (Mg^{2+}) and Bicarbonate (HCO_3); this implies that their presence does not pose any risk but has positive rather than negative effects on drinking water.

Sample one, two and three are turbid (6.00, 2.00 & 2.00) higher than the maximum permissible of 0.5. They are capable of affecting the aesthetic quality of drinking water, hosting organism, hence raising health, safety and drinking water availability concerns. All samples possess excessive Calcium (Ca^{2+}) and Magnesium Hardness ($CaCO_3$).

All samples show the presence of total coli form that should not be in drinking water (i) 48, (ii) 33, (iii) 29, (iv) 21 & (v) 18) which is a large collection of bacteria found in environment, intestine and faeces of warm-blooded animals. Total coli form on its own may not indicate health risks but it is an indication of pollution. Test result for coli form is one very important test for drinking water quality and in this case, it indicates an unhealthy sanitary condition of all water samples (US EPA, 2010 and Jacob *et. al.,*2001). To further confirm this result, sample (i) has E-coli; the major species in the coli form group. This micro-biological drinking water condition is a clear indication of the vulnerability of consumers of the drinking water sourced from the water sources.

Not unlike Table 2, Table 3 compares the recommended standards of the stated Organizations with the results obtained from drinking water samples taken from Araromi/Odo-Ikoyo chosen slum of Akure. The Appearance of water samples, Odour, Temperature, Conductivity, Total Dissolved Solids (TDS), Total Hardness ($CaCO_3$), Calcium (Ca^{2+}) and Bicarbonate (HCO_3) are favourably compared with WHO, NAFDAC and SON recommended standards 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 protect the organism during treatments and provide food for them too.

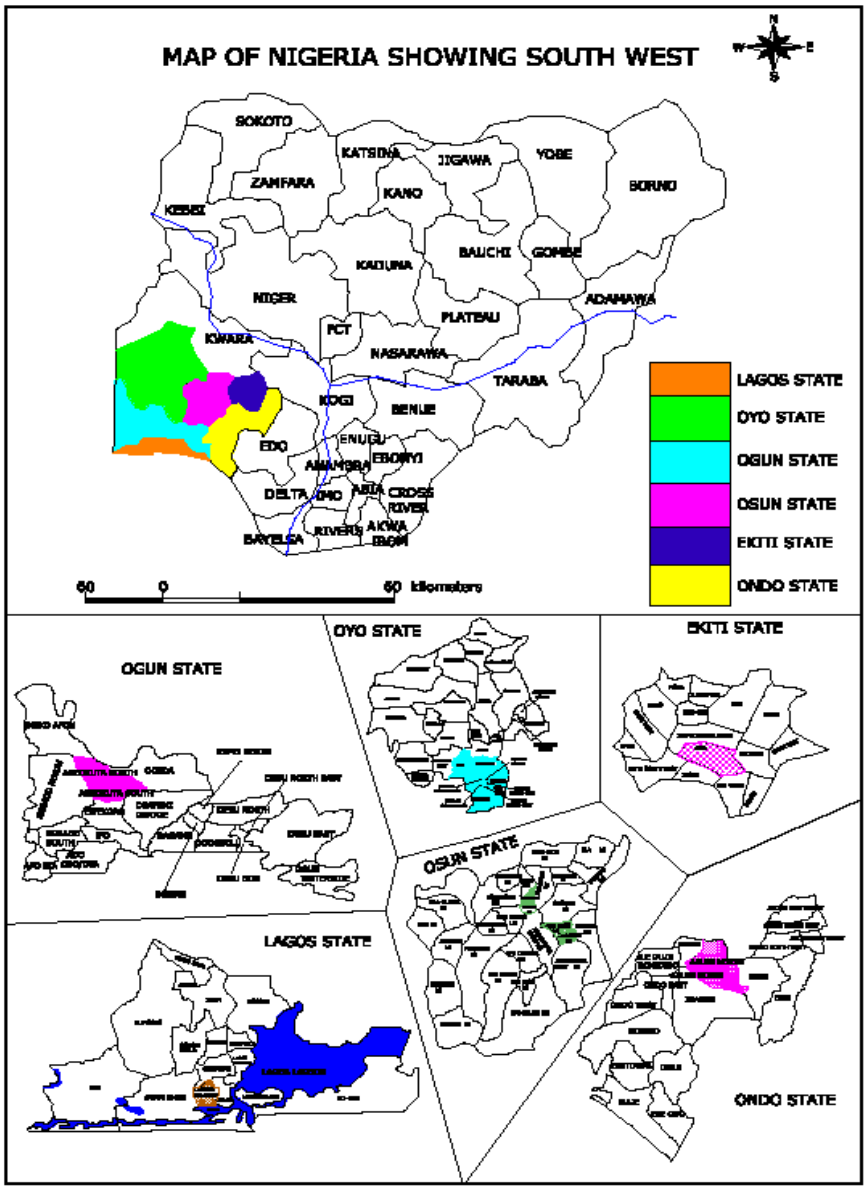

Fig: 1 Nigeria, Southwestern states and selected informal settlements

The presence of particles can make water samples physically unattractive for drinking consumers. This will naturally raise concern / fear which can result in stress. Chloride (Cl-) in samples i & v (300mg/L) is higher than WHO recommended 250mg/L. This may have implications on taste, corrode plumbing fixtures and raise maintenance cost of water equipment. Magnesium (Mg^{2+}) is higher than recommended in samples (i) and (v) 24mg/L each as against recommended 20mg/L.

Overdose of Magnesium (Mg^{2+}) kills and causes sickness in young children; impaired renal function, convulsion, hypertension, slowed heart and respiratory rates as well as vomiting and nausea (Adamu *et al* 2012). Magnesium (Mn) is 0.8 in sample (i), 0.6 in (ii), 0.6 in (iii) and 0.6 in four above the recommended the WHO 0.5 maximum permissible with effects on Odour and taste. Total Coliform is present in all the samples while E-coli found in sample (i) are indications of pollution most likely fecal pollution. Consumers of the water sources are therefore susceptible to the effects of the presence of Bacteria, viruses, parasites that cause dysentery, cholera, fever, typhoid, infections hepatitis (Upkong, 2006, Nwankawoala, 2013, and USGS, 2017).

Table 1 Lagos Water Samples Compared With NAFDAC, SON and WHO Recommended Standards

SN	PARAMETERS	UNITS	I	II	III	IV	V	NAFDAC MAX.ALD	SON STANDARD	WHO MAX.PERM	REMARK
1	Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Unobjec	15TCU	Unobjec	✓
2	Odour	ODL	ODL	ODL	ODL	ODL	ODL	Unobjec	Unobjec	Unobjec	✓
3	Temperature	^{0}C	26.1	26.2	26.3	26.3	26.3	NS	NS	NS	✓
4	ph. 20^0 C	pH	6.53	6.49	6.16	6.45	6.49	6.50-8.5	6.50-8.5	8.2-8.8	✓
5	Turbidity	NTU	6.00	2.00	2.00	0.00	0.00	5.0	5.0	1.5	
6	Conductivity	µs/cm-1	835	452	143	725	448	1000	1000	1200	✓
7	Total Dissolved Solid	mg/L	560	303	95.8	486	300	1000	1000	1500	✓
8	Total Hardness $CaCo_3$	mg/L	218	112	248	178	112	100	150	500	✓
9	Calcium Hardness $CaCO_3$	mg/L	180	76.0	200	148	78.0	150	150	NS	
10	Mag. Hardness $CaCO_3$	mg/L	38.0	36.0	68.0	30.0	34.0	20	20	20	×
11	Nitrate (NO_3	mg/L	3.98	5.23	4.47	3.38	5.22	10	50	50	✓
12	Irion (Fe)	mg/L	0.06	0.04	0.05	0.03	0.05	0.3	0.1	0.1	✓
13	Alkalinity	mg/L	20.0	13.0	18.0	17.0	20.0	100	100	100	✓
14	Magnesium (Mn)	mg/L	0.22	0.26	0.30	0.31	0.35		0.2	0.5	×
15	Calcium. Ca^{2+}	mg/L	72.1	30.5	80.2	59.3	31.3	75	NS	NS	
16	Magnesium (Mg2+)	mg/L	9.27	8.78	15.6	7.32	8.30	20	20	20	✓
17	Chloride (Cl-)	mg/L	108	50.0	270	76.6	250	100	100	250	✓
18	Sodium (Na)	mg/L	70.2	32.5	176	50.0	40.0	----------	200	NS	
19	Bicarbonate (HCO_3)	mg/L	200.	13.3	18.0	17.0	20.0	---------	----------	270	✓
20	Chromium (Cr^6+)	mg/L	0.01	0.01	0.01	0.01	0.02	---------	0.5	01	×
21	Total coliform	Cfu/100	48	33	29	21	18	0	10	0	×
22	E-coli	Cfu/100	1	0	0	0	0	0	0	0	×

✓ Acceptable × Not Acceptable
Source: Author's Compilation (2023)

Table: 2 Akure Water Samples compared With NAFDAC, SON and WHO Recommended Standards

SN	PARAMETERS	UNIT UNITS	I	II	III	IV	V	NAFDAC MAX.ALD	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	^{0}C	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 coli form	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, (2023)

Table 3: Ado-Ekiti Water Samples compared with NAFDAC, SON and Who Recommended Standards

SN	PARAMETERS	UNITS	I	II	III	IV	V	NAFDAC MAX.ALD	SON STANDARD	WHO MAX.PERM	REMARK
1	Appearance	Clear	clear	clear	Clear	clear	Clear	Unobje	15TCU	Unobjec	✓
2	Odour	ODL	ODL	ODL	ODL	ODL	ODL	Unobje	Unobje	Unobjec	✓
3	Temperature	^{0}C	29.0	27.9	28.9	28.9	28.1	NS	NS	NS	
4	ph.	pH	7.32	7.15	7.12	6.69	7.13	6.50-8.5	6.50-8.5	82-8.8	✓
5	Turbidity	NTU	0.01	12.0	6.00	4.00	2.00	5.0	5.0	1.5	×
6	Conductivity	µs/cm-1	154	132	138	162	199	1000	1000	1200	✓
7	Total Dis. Solid	mg/L	120	82.1	99.1	125	110	1000	1000	1500	✓
8	Total Hardness $CaCo_3$	mg/L	374	268	311	658	334	100	100	500	×
9	Cal. Hardness $CaCO_3$	mg/L	284	240	220	544	166	150	150	NS	
10	Mag. Hardness $CaCO_3$	mg/L	91.1	39.0	91.0	114	158	20	20	20	×
11	Nitrate (NO_3	mg/L	3.00	7.00	2.45	4.38	3.21	10	10	50	✓
12	Irion (Fe)	mg/L	0.06	0.02	0.04	0.06	0.07	0.3	0.3	0.1	×
13	Alkalinity	mg/L	122	71.0	75.0	65.0	82.0	100	100	100	×
14	Magnesium (Mn)	mg/L	0.08	0.09	0.12	0.09	0.10	03	0.2	0.5	✓
15	Calcium	mg/L	114	95.2	89.2	219	65.5	76	NS	NS	
16	Magnesium(Mg2+)	mg/L	2.0	9.27	22.0	27.8	38.6	20	20	20	×
17	Chloride (Cl-)	mg/L	281	301	121	235	218	100	250	250	×
18	Sodium (Na)	mg/L	182	200	78.0	156	142	-------	200	NS	
19	Bicarbonate (HCO_3)	mg/L	112	70.0	76.0	66.0	80.0	250	250	270	✓
20	Chromium (Cr^{6}+)	mg/L	0.01	0.00	0.00	0.00	0.01	0.5	0.5	01	✓
21	Total coliform	Cfu100	31	46	26	18	21	0	10	0	×
22	E-coli	Cfu100	1	0	0	1	0	0	0	0	×

✓ Acceptable × Not Acceptable

Sample Source: Underground Water Ado- Ekiti Samples (2023)

Table 4: Abeokuta water samples compared with NAFDAC, SON and WHO recommended standards

SN	PARAMETERS	UNITS	I	II	III	IV	V	NAFDAC MAX.ALD	SON STANDARD	WHO MAX. PERM	REMARK
1	Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Unobje.	Unbje.	Unobje	✓
2	Odour	ODL	ODL	ODL	ODL	ODL	ODL	Unobjec	Unbj	Unobje	✓
3	Temperature	^{0}C	26.3	26.3	26.3	26.3	26.3	NS	NS	NS	
4	pH.	pH	6.82	5.33	6.17	6.16	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 4: Tap Water Abeokuta Sample (2023)

Table 5 compares the laboratory results from water samples taken from Atikankan, Igbeyin, Olorogbo, and Irona slum areas of Ado-Ekiti with NAFDAC, SON and WHO recommended standards. All the samples are clear, they are without odour (ODL), they have an average temperature that that can support life, the samples are with adequate conductivity as well as Magnesium $CaCO_3$ Total Dissolved Solids (TDS), Nitrate (NO_3), Magnesium (Mn) and Chromium (Cr^{6+}). Samples (ii 12.00, iii 6.00, iv 4.00, & v 2.00) are highly turbid; when compared with 1.5 NTU and WHO maximum permissible the samples are turbid. The samples suspended particles provide food and shelter for pathogens and reduce the potency of disinfectants. Excessive iron samples i, iii, iv and v) do not actually pose any danger but affect water taste, aesthetic and or colour that is capable of discouraging and seek drinking water from other sources possibly with clearer colour and taste.

Table 5: Analysis of Osogbo Water Samples compared with NAFDAC, SON and WHO Recommended Standards

SN	PARAMETERS	UNITS	I	II	III	IV	V	NAFDAC. MAX. ALD	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	Unobje	Unobje	Unobje	✓
3	Temperature	^0C	26.4	26.4	26.3	26.3	26.3	NS	NS	NS	
4	ph.	pH	5.35	5.88	5.71	5.90	6.04	6.50-8.5	6.50-8.5	8.2-8.5	✓
5	Turbidity	NTU	4.00	10.0	8.00	4.00	0.11	5.0	5.0	1.5	×
6	Conductivity	µs/cm-1	162	113	687	140	790	1000	1000	1200	✓
7	Total dis. Solid	mg/L	109	75.7	460	93.8	529	100	100	500	✓
8	Total Hardness $CaCo_3$	mg/L	260	374	152	590	196	100	100	500	✓
9	Calcium Hardness $CaCO_3$	mg/L	142	158	93.0	328	106	75	75	NS	
10	Magn. Hardness $CaCO_3$	mg/L	112	216	59.0	262	90.0	20	20	20	✓
11	Nitrate (NO_3	mg/L	3.65	4.12	2.65	2.09	3.13	10	10	50	✓
12	Irion (Fe)	mg/L	0.03	0.03	0.02	0.05	0.02	0.03	0.03	0.1	×
13	Alkalinity	mg/L	10.0	13.3	8.00	20.0	10.0	100	100	100	✓
14	Magnesium (Mn)	mg/L	0.09	0.16	0.13	0.11	0.10	2.0	0.1	0.5	×
15	Calcium	mg/L	59.3	63.3	37.3	131	42.5	75	NS	NS	✓
16	Magnesium(Mg2+)	mg/L	27.3	52.7	14.4	63.9	22.0	20	20	20	×
17	Chloride (Cl-)	mg/L	240	154	100	270	95.0	100	250	250	×
18	Sodium (Na)	mg/L	156	98.6	65.0	176	61.8		200	NS	
19	Bicarbonate (HCO_3)	mg/L	10.0	13.3	8.00	20.0	10.0		--------	250	✓
20	Chromium (Cr^6+)	mg/L	0,01	0.00	0.00	0.01	0.01	0.5	0.5	0.1	✓
21	Total coliform	Cfu100	37	41	22	36	24	0	10	0	×
22	E-coli	Cfu100	1	1	0	1	0	0	0	0	×

✓Acceptable ×Not Acceptable Source: Underground Water Osogbo Samples, (2023)

High alkalinity in the sample (i), does not potent any risk, but when it is found in association with high pH values, total dissolved solids and hardness causes corrosion on water distribution infrastructure. High Magnesium (Mg^{2+}) samples (iii 22.0, iv 27.8, v 38.6) may lead to death in children with impaired renal function among others. Higher than expected Chloride (Cl-) in samples (i 280 and ii 300mg/L) as against (250mg/L), implies that the water from such sources may be too tasty and consumers may doubt the sources and prefer water of better taste even if they are from unsafe sources. Total Coliform in all samples implies the presence of pollutants but that of E-coli in two of the samples raised a red flag as they confirm the presence of pathogen and sure susceptibility of the consumers to waterborne/related diseases.

The laboratory analysis reveals that the water samples are clear, Odourless (ODL), possess expected 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 by WHO which is 1.5 NUT in samples (ii) 2.00, (iii) 3.00, (iv) 2.00, (v) 4.00 hence, water may have a pathogen and is 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 and the forming of soap. Presence of Total Coliform (i 17, ii 23, iii 14, iv 19, and v20) is the main issue with Abeokuta samples. The presence of Total Coliform implies the presence of pollutants in the water samples. No Abeokuta sample containings E-coli. They are also the only set of samples with the lowest number of Total Coliform; the reason for this is not far-fetched; “the water sources”

Table 5: **Analysis of Osogbo Water Samples compared with NAFDAC, SON and WHO Recommended Standards**

SN	PARAMETERS	UNITS	I	II	III	IV	V	NAFDAC. MAX. ALD	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	Unobje	Unobje	Unobje	✓
3	Temperature	^{0}C	26.4	26.4	26.3	26.3	26.3	NS	NS	NS	
4	ph.	pH	5.35	5.88	5.71	5.90	6.04	6.50-8.5	6.50-8.5	8.2-8.5	✓
5	Turbidity	NTU	4.00	10.0	8.00	4.00	0.11	5.0	5.0	1.5	×
6	Conductivity	µs/cm-1	162	113	687	140	790	1000	1000	1200	✓
7	Total dis. Solid	mg/L	109	75.7	460	93.8	529	100	100	500	✓
8	Total Hardness $CaCo_3$	mg/L	260	374	152	590	196	100	100	500	✓
9	Calcium Hardness $CaCO_3$	mg/L	142	158	93.0	328	106	75	75	NS	
10	Magn. Hardness $CaCO_3$	mg/L	112	216	59.0	262	90.0	20	20	20	✓
11	Nitrate (NO_3	mg/L	3.65	4.12	2.65	2.09	3.13	10	10	50	✓
12	Irion (Fe)	mg/L	0.03	0.03	0.02	0.05	0.02	0.03	0.03	0.1	×
13	Alkalinity	mg/L	10.0	13.3	8.00	20.0	10.0	100	100	100	✓
14	Magnesium (Mn)	mg/L	0.09	0.16	0.13	0.11	0.10	2.0	0.1	0.5	×
15	Calcium	mg/L	59.3	63.3	37.3	131	42.5	75	NS	NS	✓
16	Magnesium(Mg2+)	mg/L	27.3	52.7	14.4	63.9	22.0	20	20	20	×
17	Chloride (Cl-)	mg/L	240	154	100	270	95.0	100	250	250	×
18	Sodium (Na)	mg/L	156	98.6	65.0	176	61.8		200	NS	
19	Bicarbonate (HCO_3)	mg/L	10.0	13.3	8.00	20.0	10.0		--------	250	✓
20	Chromium (Cr^{6}+)	mg/L	0,01	0.00	0.00	0.01	0.01	0.5	0.5	0.1	✓
21	Total coliform	Cfu100	37	41	22	36	24	0	10	0	×
22	E-coli	Cfu100	1	1	0	1	0	0	0	0	×

✓Acceptable ×Not Acceptable Source: Underground Water Osogbo Samples, (2023)

Table 6: **Comparison Laboratory Analysis of Ibadan Water Samples With NAFDAC, SON and WHO Standards**

SN	PARAMETERS	UNITS	I	II	III	IV	V	NAFDAC MAX. ALD	SON STANDARD	WHO MAX. PERM	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	^{0}C	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, 2023

Table 7: Comparison of the Ranges of Laboratory Results by City with WHO Recommended Standard

SN	PARAMETERS	UNITS	LA**G**OS	AKURE	ABEOKUTA	IBADAN	OSOB**GO**	ADO-EKITI	WHO	RMK
1	Appearance	Clear	Clear	Clear	Clear	Clear	Clear	Clear	Obj	✓
2	Odour	ODL	ODL	ODL	ODL	ODL	ODL	ODL	Obj	✓
3	Temperature	^{0}C	26.1-26.3	27.1-28.6	26.3	26.3-26.4	26.0-26.2	28.8-29.6	NS	
4	ph.	pH	6.16-6.53	6.48-6.83	5.33-7.20	5.35-6.04	6.23-7.20	6.74-7.35	8.28.8	✓
5	Turbidity	NTU	0.00-6.00	6.48-6.67	0.00-4.00	0.1110.0	2.00-6.00	0.00-12.0	1.5	×
6	Conductivity	µs/cm-1	143-835	116-749	240-269	113-790	118-162	122-179	1200	✓
7	Total Dis. Solid	mg/L	95.8-560	77.7-502	161-180	75.7-529	790-109	81.7-120	500	×
8	Total Hard. $CaCo_3$	mg/L	112-248	179-340	92.0-116	152-590	118-300	278-658	500	×
9	Calciu.Hard.$CaCO_3$	mg/L	76.0-200	80.0-274	76.0-82.0	93.0-328	92.0-248	220-554	NS	
10	Magn.Hardn $CaCO_3$	mg/L	30.0-68.0	54.0-100	26.0-64.0	90.0-216	26.0-64.0	38.0-158	20	✓
11	Nitrate (NO_3	mg/L	3.89-5.23	0.93-3.21	1.78-4.00	2.09-3.65	2.00-8.04	3.00-7.00	50	✓
12	Irion (Fe)	mg/L	0.03-0.06	0.2-0.6	0.2-0.6	0.2-0.5	0.02-0.05	0.02-0.07	0.1	×
13	Alkalinity	mg/L	13.0-20.0	18.0-82.3	6.34.-15.6	8.00-20.0	22.0-66.0	66.0-112	100	×
14	Magnesium (Mn)	mg/L	0.22-0.35	0.4-0.8	0.02-0.06	0.09-0.16	0.01-0.02	0.8-0.12	0.5	×
15	Calcium Ca^{2+}	mg/L	30.5-80.2	32.1-110	24.1-32.9	37.3-63.3	36.9-89.4	66.5-218	NS	
16	Magnesium(Mg2+)	mg/L	7.32-15.6	13.2-24.2	6.34-15.6	14.4-27.3	6.34-15.6	2.0-38.6	20	✓
17	Chloride (Cl-)	mg/L	50.0-270	150-300	26.0-42.0	95.0-240	145-300	130-300	250	×
18	Sodium (Na)	mg/L	32.5-176	97.5-200	16.9-27.3	61.8-156	113-300	78-200	NS	
19	Bicarbonate (HCO_3	mg/L	17.0-20.0	18.0-82.0	8.00-30.0	8.00-20.0	22.0-66.00	66-112	270	✓
20	Chromium (Cr^{6}+)	mg/L	0.0-0.2	00-01	0.01-0.03	0.00-0.1	0.00-0.01	0.00-0.1	0.1	×
21	Total coliform	Cfu/100	0-1	19-32	14-23	22-41	12-43	18-46	0	×
22	E-coli	Cfu/100	18-48	0-1	ND	0-1	0-0.1	0-1	0	×

✓Acceptable, ×Not Acceptable Source: Authors' Fieldwork, 2023

Table 8: Number of Issues By City And Number of Parameters Leading To The Issues.

SN	PARAMETERS	UNITS	LAGOS	AKURE	ABEOKUA	IBADAN	OSOGBO	ADO	**TOTAL (A)**
1	Appearance	Clear							
2	Odour	ODL							
3	Temperature	^{0}C							
4	ph.	pH							
5	Turbidity	NTU	3	5	4	5	4	4	24
6	Conductivity	µs/cm-1							
7	Total dissolved Solid	mg/L							
8	Total Hardness $CaCo_3$	mg/L					1	1	2
9	Calcium Hardness $CaCO_3$	mg/L					1		
10	Magnesium Hardness $CaCO_3$	mg/L	5		5	5	5	4	24
11	Nitrate (NO_3	mg/L							
12	Irion (Fe)	mg/L		5					5
13	Alkalinity	mg/L						1	1
14	Magnesium (Mn)	mg/L		4					4
15	Calcium Ca^{2+}	mg/L							
16	Magnesium(Mg2+)	mg/L		3			4	3	10
17	Chloride (Cl-)	mg/L		2		2	1	2	7
18	Sodium (Na)	mg/L							
19	Bicarbonate (HCO_3)	mg/L							
20	Chromium (Cr^{6}+)	mg/L							
21	Samples with Coli form	Cfu/100	5	5	5	5	5	5	30

*	Total coli form of samples in each city		93	112	93	160	139	142	739
22	E-coli	Cfu/100	1	1	0	3	3	2	8
23	**TOTAL NUMBERPROBLEMS IN EACH CITY (B)**		**114**	**132**	**107**	**180**	**160**	**164**	

Source: Author's Compilation (2023)

The comparison reveals that water is Colourless, Odourless and of acceptable temperature, pH, and conductivity, Total Dissolved Solids (TDS), Magnesium Hardness$CaCO_3$, Nitrate (NO_3), Alkalinity, Calcium (Ca^{2+}) and Bicarbonate (HCO_3). Three of the samples are characterized by suspended particles (i) 4.00, (ii) 10.0, 8.00, (4).00NUT) beyond the maximum permissible of WHO of 1.5NUT. The indication is that, water may be unsafe and unappealing to consumers. The set of samples obtained from Osogbo are among the worst because they have the highest number of Total Coliform and total number of E-coli the pathogen that brings waterborne diseases.

The results show clear appearance, Odourless, average temperature, ph, conductivity, Alkalinity, Magnesium TDS, Nitrate NO_3, (Mn) and Chromium (Cr^6+) passed with WHO recommendation. All samples are full of suspended particles, encouraging the presence and survival of microorganism; this makes the appearance of water uncomely. High level of hardness is also noticed in the result obtained from Magnesium Hardness ($CaCO_3$), iron and chloride. This discourages consumers and forces them to source drinking water from possibly unsafe sources. Samples (i) and (ii) has 300 and 280mg/L above 250 mg/L maximum permissible. Microbiological conditions of drinking water samples are bad, 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 contain E-coli, a clear evidence of pollution and contaminants in the water samples.

Table 8: Compares the quality of water in clearer terms; it shows cities representing the study areas and below them, the number of sample elements above the WHO recommended values. For instance, under Lagos (3) samples have high turbidity, (5) in Akure and (4) Abeokuta etc. The total marked 'A' shows the total number of samples with high turbidity (25) out of (30), ditto to other elements under each city. All samples in Ado possess Magnesium Hardness beyond the recommended value but only one in Lagos exhibits the same. According to this table, all samples have certain features in common; turbidity, iron and total coli form are common problems to all but four samples in Osogbo, three samples in both Ado and Akure possess Magnesium (Mg^{2+}) higher than recommended values. One sample from Lagos and three from show the presence of excessive Chromium (C^{r6+}).

All samples possess microorganisms in the form of Total Coliform and one sample each from Lagos, Akure and Ado- Ekiti, two from Ibadan and three from Osogbo show the presence of the 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, by implication, Abeokuta samples are far better than samples from other study areas. To buttress this claim, Abeokuta samples have the lowest number of Total Coliform (93) and the total marked 'B'(19). With these, one can clearly see that Abeokuta slum residents are less vulnerable to consequences of unsafe drinking water than other slum areas.

It should be noted that the drinking water sampled at Abeokuta study area is tap; (public stand taps) the water is treated, still, it has some issues, particularly the presence of Total Coliform, high turbidity and which must be due to improper water treatment or contamination during distribution processes in the channels. This is also in line with the discoveries of (Amos *et. al.,*2014). Drinking water quality in Lagos closely followed that of Abeokuta. Residents of (Ajegunle) the study area of Lagos mostly buy their drinking water sourced from deep wells brought from other places devoid of the effects of concentrated human activities of slum environment. Akure slum residents drink well water which was discovered to be better than that of Osogbo, Ado-Ekiti. Drinking water in Ibadan chosen slum is the worst according to the laboratory results.

SUMMARY

Residents of the selected informal settlements in the study area drink raw/untreated water sourced from the environment with the exception of the Abeokuta. Results of the analysis revealed that drinking water consumed in the study areas is unsafe; they contain physical, chemical and microbiological contaminants including Total Coli form and E**-**coli (Escherichia coli). Studies have shown that drinking such raw water made the residents susceptible to waterborne diseases; 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 as well as stressors and psycho-socio effects.

RECOMMENDATION

A provision of water schemes is strongly recommended but where and when it is not feasible yet, other workable alternatives must be sought by the residents. Combination of sedimentation and filtration can help to improve drinking water quality 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). Secondly, the Principle of "ion exchange" could also be applied; (ion of hardness mineral will exchange for sodium). This effectively reduces the concentration of minerals to a tolerable level. Thirdly, 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.

Government at all levels must 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 the Standard Organization of Nigeria Governing Council. As the whole world stood together to fight Covid 19,

HIV/AIDS, and Malaria Scourge, "World Government" through United Nations (UN), the United Nation Human Settlement Programme (UN-HBITAT), theWord Health Organization (WHO), as well as the United Nation Agency for International Development (USAID) among others must come up with a systematic and sustain the fight against this ruthless killer by in-situ intervention and delivery of water treatment pills/equipment/filters to the poor in s residents of informal settlements. The communities need to forge a common front in protecting their water sources by promoting environmental sanitation; and personal and community hygiene and they fight to ensure the government does its bit.

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