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REVIEW ARTICLE

Review of Drinking Water Quality in Nigeria: Towards Attaining the Sustainable Development Goal Six

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Abstract

Access to potable water is a major problem confronting most developing nations particularly with the overwhelming health burden posed by polluted water and its sources. In this review, studies on the level of contamination of drinking water sources in different geopolitical zones in Nigeria were assessed. The anthropogenic activities eliciting the pollutions were extensively discussed. Overall, the level of Nigeria preparedness in meeting the sustainable development goal number 6 (SDG no 6: to ensure availability and sustainable management of water and sanitation for all) was evaluated. Cogent methods that could enhance the achievement of SDG no. 6 were suggested. From our analysis of published literature, pre- and post- SDG implementation in Nigeria, it is clear that no significant progress has been made in providing potable water for all in Nigeria. All implementing partners must therefore rejig the process to ensure the availability of potable water, in order to achieve the sustainable development goal six.

Keywords: Potable water; Contamination; Anthropogenic; Sustainable Development Goal; Nigeria

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1.0 Introduction

An important environmental component is water, which is an essential ingredient for sustainability and survival of every life form on earth. Therefore, need for water is constantly increasing due to high rates of population growth, urbanization and other anthropogenic factors. Water is also a necessity to humans who need plenty of water intake per day for survival (Nester et al., 2004). Ideally, drinking water should be safe and acceptable to all. Guidelines on the quality of drinking water by the World Health Organization (WHO) (WHO, 2011) provided standards in terms of microbial, chemical and radionuclide content, as well as physical properties for safe drinking water. More so, in a bid to transform our world and ensure better lives for humans, the United Nations, of which Nigeria is a member, is guided by 17 sustainable development goals (SDGs). The SDGs came into effect in January 2016 with a Global agenda till 2030. Goal number six of the SDGs is targeted towards clean water and sanitation (UN, 2020). Four years into the implementation of the SDGs globally, it is important to examine how Nigeria is faring towards achieving the goal of access to clean potable drinking water with respect to quality and quantity.

Nigeria is located in west Africa and located between 3°E and 14°E of the Greenwich Meridian and 4°N of the equator, and with great geographical variation. Its topography range from the coastal plains to the savannah in the North and reaches an elevation of 600 to 700 meters. It is surrounded in the South-West by Benin Republic, South-East by Cameroun, South-South by the Atlantic Ocean (Gulf of Guinea) and in the North by Niger Republic. There are six Geo-Political Zones in Nigeria namely: South-West, North-West, South-East, North-East, South-South and North-Central.

In Nigeria, less than one-third of urban and rural dwellers have access to piped water supply connections in their yards (WHO/UNICEF, 2014) for drinking, and those with piped water may still experience unreliable, poor quality service (Kumpel et al., 2016). Most households rely on public standpipes and non-piped water supplies, such as hand-dug wells, boreholes, springs and water vendors (WHO/UNICEF, 2014). These sources of drinking water are all classified as "improved drinking water sources" (WHO, 2011). Improved drinking water source can be defined as a source that is adequately constructed in such a way that the source is protected especially from fecal matters and other contaminations from outside (WHO/ JMPR, 2013). Other sources like rivers, streams, lakes and ponds from surface water and bottled water are classified as "unimproved drinking water sources (WHO, 2011)". Streams and rivers which have become important sources of water for cooking and drinking in remote villages and slums are faced with environmental contaminations from discharges or effluents from abattoirs or sewage especially downstream (Omole and Longe 2008) and from industrial waste (Bello-Osagie and Omoruyi, 2012; Ifelebuegu et al., 2017). In urban and metropolitan cities where ground water sources (boreholes and deep wells) constitute major sources of drinking water, contamination via leachates from municipal solid waste dumpsites (Aboyeji and Eigbokhan, 2016) and industrial wastewater (Bello-Osagie and Omoruyi, 2012) remains of major public health concern. Drinking water contamination by different microorganisms such as coliforms (Kumpel et al., 2016), *Staphylococcus aureus* and *Pseudomonas* species (Igbeneghu and Lamikanra, 2014) have been reported in Nigeria. Also, the presence of metals like iron, calcium, chromium and aluminum have been found in surface water (Titilawo et al., 2018) and sachet-packed water (Emenike et al., 2018), including cadmium, lead, manganese and nickel in groundwater (Ayedun et al., 2015) above permissible levels for drinking water. Other contaminants such as fluoride (Emenike et al., 2018) and light polycyclic aromatic hydrocarbons have also been reported to be present in groundwater in levels above permissible limits in some locations in Nigeria (Adekunle et al., 2017).

The risk of contamination of these drinking water sources by pathogens and harmful chemicals is high due to increasing population densities, lack of adequate sanitation infrastructure and poor hygiene. It is estimated that there are about 1.1 billion people with limited access to adequate water supplies, which has resulted in the outbreak of diarrhoea (about 4 billion cases) and death (about 5 million per annum) worldwide (WHO, 2015). Over the years, studies have shown that shortages of clean water are associated with improper management, alarming population growth, unfavourable policy implementation of water-related projects and upsurge in industrial activities (Sibanda et al., 2014; Kora et al., 2017). These dynamics are also known to unpleasantly affect the access, availability, distribution, provision and quality of water and associated resources (Igbinosa and Okoh, 2009; Liang et al., 2013). There is need for urgent interventions to prevent water shortages, particularly in developing countries like Nigeria where significant reports of waterborne infections and diseases such as diarrhoea, cholera and typhoid occur as a consequence of poor sanitation and poverty (Coleman et al., 2013; Igbinosa and Aighewi, 2017). Over 66 million Nigerians in the cities and rural areas lack access to potable drinking water supply, and this has resulted to an increase in the consumption of contaminated or polluted water (WHO, 2015; Ologbushere et al., 2016; Beshiru et al., 2018) with potential detrimental public health effects.

Guidelines for quality of drinking water by WHO (WHO, 2011) recommended up to ten water treatment methods, which are chlorination, activated carbon adsorption, oxonation, chemical coagulation, filtration, aeration, ion exchange, chloramination, oxidation processes and membrane. Vigorous data on existing water services and water quality are necessary for guiding infrastructure development and management priorities in Nigeria. In the literature, information is available on the drinking water sources in Nigeria (Beshiru et al., 2018), however, limited information is generally available regarding the prevalence of different types of water sources, water treatment methods employed and the risks these sources pose to consumer health in Nigeria.

Sustainable development goals

In 2012, the United Nations set in motion seventeen SDGs to replace the Millennium Development Goals. All UN member States finally adopted the 17 SDGs in 2015, with the goal of tackling some (if not all) of the pressing challenges facing the world by 2020 (UN, 2020).

Of particular interest in this review is the SDG no. 6: Ensure availability and sustainable management of water and sanitation for all. The nexus between water, sanitation and good health can therefore not be over emphasized. In 2019, the United Nations reported that "billions of people" are without access to safe drinking water (UN, 2019), most of whom are in developing countries (including Nigeria). This review

further put into perspective, Nigeria's progress so far in achieving SDG no. 6 judging by 2 of its major indicators, thus:

i. to achieve equitable and universal access to affordable and safe drinking water for all by 2030; and
ii. to improve water quality by reducing all forms of pollution, eliminating, dumping and minimizing release of hazardous chemicals and materials (including heavy metals), halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally by 2030.

Goal of this review

This review is aimed at putting into perspective, the efforts made thus far in the attainment of clean water for all by 2030, four years after its implementation in Nigeria. In this review, we provided the contamination level in sources of drinking water available in the literatures before and after year 2016 post implementation of the SDGs; we also provided indirect indicator of the attainment of the SDG goal on clean water by considering number of water-borne disease outbreaks before and after year 2016. Finally, we made recommendations on how Nigeria can reposition herself towards the attainment of the SDG goal 6 on clean water and sanitation.

2.0 Drinking water quality in Nigeria: pre-sustainable development goal six (6) implementation/pronouncement

Water as a universal solvent is indeed a necessity of life and as such maintaining the quality of drinking water cannot be over-emphasized. This is because poor quality of drinking water can predispose citizens to many food and water-borne diseases. Prior to the SDGs promulgation in Nigeria, a lot of researches were carried out in the area of quality drinking water supply. The findings of these studies revealed poor quality of the drinking water sources in Nigeria as depicted with these few examples. Generally, groundwater quality in Nigeria has been reported to be influenced by the geology and geochemistry of the environment, rate of urbanization, industrialization, landfill/dumpsite leachates, heavy metals, bacteriological pollution, and seasonality (Ocheri, 2014). A study conducted to determine the level of some chemical parameters in samples of five (5) potable water sources namely, tap, borehole, open well, sachet water, and bottled water encouraged the need for periodic and unannounced monitoring of the quality of potable water especially the sachet-packed and bottled water sources by the Nigerian National Agency for Food and Drug Administration and Control (Alhassan, 2012). Fascinatingly, water packaging into polyethylene sachets (as a form of water vending) has assumed an innovative status which has spread from its origin in Nigeria to other West African countries (Omole et al., 2015). Most studies on the safety of this sachet-packed and bottled water samples revealed them to be contaminated with pathogenic bacteria and coliform (Edema et al., 2011), heavy metals (Edema et al., 2011) and estrogens (Ignatius et al., 2010; Omoruyi et al., 2014).

Despite the growing dependence on sachet-packed and bottled water, the majority of Nigerians still rely on ground water as their major source of drinking water. Christiana and Amobichukwu (2014) conducted a research to determine the presence of geogenic contaminants (arsenic and fluoride), and the level of awareness of their presence in groundwater in Ibadan, Nigeria. Their results showed arsenic concentration exceeding the WHO (2011) recommended concentration for drinking water over 98-fold and 100-fold increase during the dry and wet seasons respectively. Equally, the concentration of fluoride also exceeded the recommended limits of 13-fold during the dry season and 100-fold increase during the wet season. Interestingly, 85% of subjects using underground water sources had never tested their water sources, 55% had no knowledge of geogenic contamination, while 92% never heard of arsenic or fluoride.

3.0 Chemical contamination of drinking water sources in Nigeria

Exposure of several individuals to unsafe levels of chemical contaminants in drinking water has been reported (WHO, 2010). This lends credence to the importance of monitoring the level of metals in surface or ground water sources in other to determine their potability (UNEP, 2007). Chemicals are among the major ground and surface water contaminants affecting groundwater quality. This is possible through vertical migration of chemical contaminants to the aquifer and extending to the borehole, or by horizontal migration through permeable soils to water supplies that are poorly constructed (MacDonald and Calow, 2009). Heavy metals and organics such as polyaromatic hydrocarbon (PAH), polychlorinated biphenyls (PCB), polybrominated diphenyl ethers (PBDE) etc. are also major chemical contaminants of drinking water sources, and of course, a potential threat to public health.

Sources of chemical contaminants in drinking water

Chemical contaminants are derived from different sources (industrial, geological and anthropogenic). The surge in anthropogenic activities and natural processes such as erosion, precipitations, weathering and degradation have made most water sources unsuitable for purpose (Furhan et al., 2004). Below are some of the major sources of chemical contamination of drinking water sources in Nigeria**.**

Agricultural activities

Chemical contaminants can be released from agricultural run-offs which contain nitrogen compounds and phosphorus from livestock waste, fertilizers and pesticides used during agricultural practices. In Nigeria, agriculture is a major occupation for a large majority of the populace. Lack of good laws guiding indiscriminate disposal of agricultural wastes has led to significant contamination of the water bodies which serve as sources of drinking water to different communities. Livestock production activities and waste have been implicated as a major source of pollution to river bodies, especially when poorly managed (Kato et al., 2009). Additionally, open grazing is still the major mode of raising livestock in Nigeria and these farm animals are usually led in their numbers to the water bodies (rivers, streams, well and boreholes) for drinking at least twice a day. In the process, animal faeces and urine are released, which contaminate the water bodies and thus, render the water body unsafe for consumption by the surrounding communities. This problem is aggravated since in many communities in Nigeria, there are no access to treated pipe-borne water for drinking and as well as for other domestic uses. The

runoff of animal waste into surface water is reported to pose great risk of pollution (Kwadzah and Iorhemen, 2015).

Rim-Rukeh et al. (2006) evaluated how agricultural activities impacted on the quality of Orogodo River in Delta State, Nigeria. This was carried out in a research study that involved 100 farmers' from Agbor and Owa communities. These farmers were asked questions on the frequency and method of irrigation practices they have adopted during different farm practices, most especially the use of fertilizers which normally result in water pollution. The sampling of the river was carried out at five different sampling stations along the river selected by testing the physicochemical properties of the river. The authors reported that the method adopted by the farmers constituted a major reason why the selected river was highly polluted. The difference in the selected parameters tested was linked to the runoff from farmlands and the capability of the river to undertake self-purification. The study also suggested that the contamination of Jakara River at both upstream and downstream and its use for irrigation purposes on vegetables could lead to the bioaccumulation of such heavy metals along the food chain (Rim-Rukeh et al., 2006).

Orheruata and Omoyakhi (2008) also reported agricultural waste from poultry as an important source of pollution affecting the quality of drinking water in Nigeria. Adegbola and Adewoye (2012) assessed the effect of some sources of pollution on groundwater quality in wells from Gambari community in Ogbomosho, Nigeria. They reported that the most polluted wells that shown minimal satisfactory level were linked to their proximity to cassava processing and milling industry.

Abattoir activities

Other important source of water pollution in Nigeria is the indiscriminate discharge of untreated abattoir effluents directly into ground or surface water bodies, resulting in serious surface and ground water contamination. Abattoirs are located indiscriminately in Nigeria and usually near water sources since the process requires a lot of water and for ease of disposal of wastes (Omoruyi et al., 2011). Abattoir effluents have been reported to markedly increase the amounts of nitrogen, phosphorus and total solids in contiguous water bodies (Bello-Osagie and Omoruyi, 2012). The high biochemical oxygen demand (BOD), nutrients and pathogen content in abattoir waste poses pollution risk to water bodies (Matsumura and Mierzwa, 2008; Keskes et al., 2012). In Nigeria, study of Omole and Longe (2008) showed that the quality of a surface water was impacted negatively by the activities of abattoir, with water quality parameters including Total Suspended Solid (TSS), dissolved oxygen (DO), BOD, chemical oxygen demand (COD), and heavy metals including cadmium (Cd), lead (Pb) and copper (Cu) above the permissible limits by regulatory authorities. In another study in Nigeria, animal processing and trading activities at Tudun Wada abattoir altered River Kaduna water quality (Kwadzah and Iorhemen, 2015). The study found higher concentrations than normal of BOD, COD, nitrate-nitrogen, ammonia-nitrogen, total nitrogen and total phosphorus in the river water. In addition, higher concentrations of these parameters were found downstream than upstream, an indication of the negative impact of the abattoir wastewater discharge into the river. However, dilution factor in the high-strength abattoir wastewater was not sufficient to mitigate the parameters to acceptable levels in the river water (Kwadzah and Iorhemen, 2015).

Industrial effluents

Industrial effluent is another major source of chemical contaminants of drinking water sources in Nigeria. Industrial effluents mostly contain heavy metals, hydrocarbons, and atmospheric deposition (Alam et al., 2007). Industrial effluents loaded with heavy metals and harmful microbes can be hazardous when it gets into the food chain through the soil and water bodies and can affect plants, animals and humans adversely (Deshmukh et al., 2011; Bai et al., 2012). Wastewaters from most industries in Nigeria are disposed into water bodies (Kanu and Achi 2011). Interestingly, many of these industrial effluents are discharged untreated into water bodies, partly because of weak regulations, thereby contaminating the receiving surface and ground waters. Reports have shown that effluents from pharmaceutical industry (Bakare et al., 2009; 2011), hospitals (Iyekhoetin et al., 2011), universities (Alabi et al., 2012), tobacco industry (Alabi et al., 2014), automobile workshops (Alabi et al., 2016) and cocoa industry (Alabi et al., 2017) contained heavy metals and other chemical constituents in high concentrations capable of contaminating drinking water sources and lead to public health detrimental effects.

Leachates

Dumpsites and landfills are major sources of leachate which contributes to chemical contaminants of surface and ground waters. Leachates are known to contain contaminants such as organic matters, ammonium, magnesium calcium, sodium, sulphate, potassium, iron, heavy metals (e.g. Cr, Cd, Cu, Pb, Ni, Zn) etc. These contaminants not only have the potential to penetrate and pollute soils but can significantly impact surface and ground water. The magnitude of the threat posed by leachates is a function of the concentration and toxicity of the constituents, depth of water table, and direction of groundwater flow. Phthalate esters (PAEs) from landfill have been reported to significantly contribute to the contamination of groundwater (Liu et al., 2010). Also, groundwater around a municipal landfill site has been reported to contain inorganic contaminants to the extent that shallow ground water near landfill sites are considered unsuitable for drinking (Han et al., 2014). Porowska (2015) used stable carbon isotopes to determine the source of inorganic carbon in groundwater near a reclaimed landfill and found 47-80% of dissolved inorganic carbon reportedly from the biodegradation of organic matter in the landfill and then positioned that the surrounding groundwater was contaminated by leachate from the landfill.

Oil spill

Oil spill has polluted Nigeria water sources with chemical contaminants. Crude oil is a mixture of many different hydrocarbons which is known to be highly toxic, causing damage to natural and semi-natural ecosystems including aquatic systems (Dawes, 1998). During oil spill, pollutants such as benzene, polyaromatic hydrocarbon (PAHs), grease, oil, heavy metals etc are introduced into aquatic ecosystems. In southern Nigeria, Ifelebuegu et al. (2017) showed alteration of the physicochemical parameters of drinking water sources due to pollution by petroleum hydrocarbon. These studies

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indicated significant alteration of water quality in some rivers due to oil exploration and other related activities. For example, turbidity, total suspended solid, total dissolved solid, dissolved oxygen, electrical conductivity and heavy metals (e.g. Cu, Pb, Ni, Cd, Cr and Zn) were all higher than the recommended limits for drinking water. Because of the constant oil spillage in Nigeria, many rivers and streams have been chemically polluted and rendered unsuitable for drinking, cooking and other domestic uses. Many aquatic lives have been lost and human consumption of organisms from these contaminated waters pose serious health problems due to bioaccumulation of chemical contaminants in the food chain. Due to the persistent nature of oil spillage, contamination of water sources remains a serious problem which would persist for a long period of time, thereby causing quality water shortage.

In the Niger Delta region, many studies have documented the effects of oil spillage on water sources (UNEP, 2011; Linden and Palsson, 2013; Alinnor et al., 2014; Onyegeme-Okerenta, 2017). A study by Lindén and Pålsson (2013) reported high level of petroleum hydrocarbon contamination of rivers, creeks, and ground waters in Ogoni land. This is of serious negative impact on human health and the ecosystem. It is not uncommon that a plethora of petroleum hydrocarbon spills sometimes occur due to leaks from decrepit infrastructure, aged facilities and pipelines as well as oil spillage during transportation, and other man-made causes (Ite et al., 2013; Lindén and Pålsson, 2013). A recent study by Onyegeme-Okerenta (2017) showed that water quality of some rivers and streams in Uzere, a community in Niger Delta, is impaired following the incidence of crude oil spillage in the community.

Similarly, Ifelebuegu et al. (2017) investigated the impact of crude oil spills on the physicochemical, microbial and hydro biological properties of the Nun River and reported that the physicochemical parameters and heavy metals (e.g. Cr, Cd Pb, Cu, Ni and Zn), total dissolved solid, turbidity, total suspended solid, dissolved oxygen, electrical conductivity, of the river failed to meet the adequate and recommended limits for drinking water. Also, the water quality parameters were seriously compromised due to oil exploration and other related activities.

In another recent study, Tongo et al. (2017) showed that acenaphthylene, naphthalene, and fluoranthene were common pollutants in Ovia river in Edo State, Nigeria. Furthermore, the concentrations of individual PAHs recorded in Ovia river were significantly higher than the recommended or permissible concentration [0.05 μg/l].

Due to contamination of drinking water sources, especially in the southern parts of Nigeria, most locals resort to drilling borehole as their drinking water source. However, discharged petroleum hydrocarbons often sink into groundwater thereby polluting these ground waters (Frynas, 2000; Yakubu, 2017). Alinnor et al. (2014) collected and analysed groundwater from five communities in the Niger Delta region and reported that the water samples from varying depth were contaminated with petroleum hydrocarbons.

Following an analyses of some drinking water samples from wells, also in the oil rich Niger Delta region, the United Nations Environment Programme detected high levels of benzene concentrations. The benzene levels were about 1800 fold higher than the drinking water tolerable limit set by the United States Environmental Protection Agency (USEPA) (UNEP, 2011; Kponee et al., 2015) and over 900 fold higher than the acceptable limit set by the WHO for drinking water (UNEP, 2011). In sum, the review of the existing but scattered literature suggests that most of the drinking water sources are contaminated due to oil spillage, and other oil exploration activities or issues. Therefore, we recommend the provision of potable and clean drinking water for communities in the Niger Delta region where exploration activities are concentrated.

Scrap yards

Scrap yards contain unwanted, dumped metal parts from different sources. In most of the scrap yards in Nigeria, car parts, electronic wastes, etc are the major constituents. Different informal recycling activities are very common at the scrap yards with scavengers picking different metal parts for repair or sale. The scrap yards contaminate the soil due to leaching and can contaminate water bodies during raining season especially as run-offs. Also, acid bath used by scavengers during informal recycling at the scrap yards can cause the release of chemical contaminants. The study of Ojekunle et al. (2016) revealed that there could be significant discharge of hazardous heavy metals in the water bodies as a result of seepage and uncontrolled activities in Ikorodu, Lagos State and Lafenwa scrap yards in Abeokuta Ogun State respectively. In furtherance, their study reported of high concentrations in the physicochemical parameters and heavy metals assayed in surface water from most of sampling locations. On comparison of the results to the limits set by Standard Organization of Nigeria (SON), their results exceeded the permissible limits.

Municipal waste

Kayode et al. (2018) evaluated the effects of municipal waste dumpsite on the quality of drinking water obtained from groundwater around Oke-Afa, Oshodi/Isolo area of Lagos state, Nigeria. They assayed water samples from two boreholes and eighth hand-dug wells using standard procedures. The results showed high levels of heavy metals especially barium (Ba) and aluminum (Al) which occurred in high values when compared to the stipulated limits for potable drinking water by World Health Organization.

Aboyeji and Eigbokhan (2016) also evaluated the effect of leachates generated from municipal solid waste dumpsites on the water qualities from fifteen boreholes and five wells along downslopes of the dumpsite around Olusosun in Lagos metropolis. The quality of the water sources were evaluated using water quality index rating and geospatial techniques. The results obtained from the heavy metal and physicochemical parameters revealed that the water quality were unfit for human consumption because the values obtained fell below the range recommended by WHO for potable drinking water. By virtue of the results obtained, it is clear that there are no impervious soil structures that could prevent the seepage of the leachates into the aquifer that are close to the dumpsite. In another study conducted by Usman et al. (2016) on the influence of liquid and solid wastes on groundwater quality, they obtained water samples from different boreholes at some specific distances from dumpsites and assayed its physicochemical and heavy metals concentrations. The distance ranged from 55, 25, 16, 15, 8, and 12m. The physicochemical

parameters / heavy metals assayed include: dissolved oxygen, total hardness, heavy metals, turbidity, temperature, total dissolved solids, pH, nitrate, nitrite, chloride and calcium. The results obtained indicated the absence of Lead (Pb) from all the samples while Chromium (Cr) and manganese (Mn) were above the WHO standard limit for drinking water sources. The microbiological analyses showed the presence of *E. coli* and other coliform bacteria in the tested samples.

Olagunju et al. (2018) reported on the environmental impact assessment of soil and ground water around Ilokun waste dumpsite. Soil samples (7 around the dumpsite) were collected and 7 water samples from the waste dumpsite; 5 water samples from hand dug well; and 2 water samples from boreholes were obtained. In all the samples investigated, the results obtained exceeded the permissible limits from World Health Organization and Nigerian standard for quality drinking water.

The study by Karshima (2016) detailed more on the consequence of poor municipal waste management on human health. In the report, the author highlighted sources of potential hazards which included flooding from drain obstructions, water pollution by feces, direct wounds, and heavy metal constituents from municipal solid waste. The author advocated for government policies on public education, its implementation and legislation on sanitation. Additionally, the author opined for improvement of funding for observation and monitoring, recycling of waste and adequate construction and management of landfills to enhance proper handling of solid waste management in Nigeria.

In 2012, Akinbile reported on the influence of dumpsite on the groundwater and soil quality by determining the bacteriological, physical and chemical evaluation of the ground water and soil samples (Akinbile, 2012). He obtained samples from different boreholes located at 50, 80, and 100 m distance from the landfill and twelve soil samples obtained at 10, 20, and 30 m away from the refuse dump. Some of the parameters determined included total dissolved solids, turbidity, dissolved oxygen, temperature, pH, total hardness and total iron, nitrite, calcium, chloride, nitrate and heavy metals like Zn, Cu and Pb. The author observed that most of the evaluated parameters which were present in the water fall below the stipulated limit by the World Health Organization for human consumption. The results showed that the boreholes were contaminated thus it becomes pertinent to treat the water while the soils are unfit for crop production. The author suggested proper designing of the sanitary landfills to avert leachate from seeping into the aquifer, proper implementation of clean technology for re-utilization of greenhouse gases and land management.

In a study carried out by Akinbile and Yusoff (2011), they evaluated the environmental impact of leachate on groundwater in Akure, Ondo State, Nigeria. The authors carried out their assessment on three boreholes located at 50m, 80m, and 100m to the landfill. Some of the parameters assessed included: temperature, dissolved oxygen, total hardness, turbidity, total dissolved solids, total iron, nitrate, nitrite, chloride, calcium and heavy metals such as Cu, Zn and Pb. The results obtained from the parameters assayed were not within the regulatory standards of the Nigerian Standard for Drinking water quality and World Health Organization. Additionally, it was observed that the presence of Cr in one of the boreholes was linked to its proximity to an abattoir. The results revealed that two of the borehole water tested was heavily polluted. Thus, there is a need for adequate treatment of the water before use. The authors therefore recommended the need for public education on waste management to avoid further pollution of ground water. Similarly, Okpanachi (2009) studied the impact of solid waste dumpsites on groundwater quality in Samaru-Zaria, Kaduna State, Nigeria. The author examined water samples from twenty-four different wells over two seasons (twelve in dry and twelve in the raining seasons). Author's results revealed that wells within 50m distance to the dumpsite exhibited high levels of heavy metal contamination, especially the shallow wells. Also, the wells were reported to be more contaminated during the wet season.

Furthermore, Omofonmwan and Eseigbe (2009) evaluated the impact of solid waste disposed into water bodies (e.g. river) and the impact of water runs offs on the quality of underground water in Benin metropolis, Edo State, Nigeria. Their results showed that the majority of parameters evaluated fell below the WHO recommended standard. This result was similar to the study carried out in Nnewi, Anambra State (Okeke et al., 2018) and Oke Afa, Lagos State (Salami et al., 2014).

4.0 Physicochemical parameters of drinking water sources in Nigeria

In Nigeria, many sources of drinking water have been reported to be contaminated due to anthropogenic sources. Thus the physico-chemical properties of these waters if compared with the regulatory guidelines fall below recommended standard and are therefore not suitable for consumption. Below, we appraised the current situation across the different geopolitical zones in Nigeria (Table 1).

5.0 Microbiological contamination of drinking water sources in Nigeria

Microorganisms are major contaminants of drinking water sources, especially in developing countries like Nigeria, and their presence could have deleterious effect on her citizenry.

Below is the recommended guideline for drinking water quality in Nigeria (Table 2). Additionally, we reviewed published literature from the different geopolitical zones in Nigeria (Table 3), to ascertain if the microbiological quality of their drinking water sources met the Nigerian standard.

Review of literature from the different geo-political zones in Nigeria as shown in Table 3, shows that drinking water sources in Nigeria, are frequently contaminated with microorganisms above the permissible limit and are therefore unfit for consumption. This is evident in the number of documented outbreaks of water-borne diseases such as cholera, diarrhea, dysentery, typhoid etc. It is worthy of note that the Nigerian Center for Disease Control (CDC) reported outbreaks of cholera in 20 different states out of 36, between January and October 2018, with a fatality rate of 1.95% (Elimian et al., 2019; NCDC, 2019).

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Table 1: Water quality indices for Surface-water across Nigeria

Geopolitical Zones	WQI Range (dry Season)	For Drinking	WQI Range (wet Season)	For Drinking	Reference
South-West (Lagos) 10 sampling site around Owode-Onirin Scrap yard	ND (physicochemical parameters of water from sample site is above permitted limits)	Unsuitable			Ojekunle et al. 2016
South-West (Ogun) 5 sampling site around Lafenwa Scrap yard	ND (physicochemical parameters of water from sample site is above permitted limits)	Unsuitable			Ojekunle et al. 2016
South-West (Osun) 10 out of 10 rivers	ND (Metal Contaminants above Permitted limit)	Unsuitable			Titilawo et al. 2018
South-South (Edo)					
River Osolo	585.015	Unsuitable	120.225	Unsuitable	
River Foreign	587.833	Unsuitable	200.474	Unsuitable	
Ijoh River	512.498	Unsuitable	105.261	Unsuitable	Beshiru et al. 2018
Ole River	489.992	Unsuitable	150.114	Unsuitable	
South-South (Bayelsa) Nun River	ND (turbidity, TDS, TSS, DO, conductivity and heavy metals) above permitted limits.	Unsuitable			Ifelebuegu et al. 2017
North-West (Kaduna)					
Samaru Stream	ND (physicochemical parameters of water from sample site is above permitted limits)	Unsuitable	ND (physicochemical parameters of water from sample site is above permitted limits)	Unsuitable	Chigor et al. 2012
Kubanni Dam	ND (physicochemical parameters of water from sample site is above permitted limits)	Unsuitable	ND (physicochemical parameters of water from sample site is above permitted limits)	Unsuitable	Chigor et al. 2012
Kubanni River	ND (physicochemical parameters of water from sample site is above permitted limits)	Unsuitable	ND (physicochemical parameters of water from sample site is above permitted limits)	Unsuitable	Chigor et al. 2012

Key: ND = Not determined

Table 2: Microbiological indicator for potable water

Parameter	Unit	Maximum Permitted Level	Health Impact
Total coliform count	cfu/100mL	10	Indication of faecal contamination
Thermo tolerant coliform of *E. coli*	cfu/100mL	0	Urinary tract infections, bacteraemia, meningitis, diarrhea, acute renal failure and haemolytic anaemia
Protozoa-giardia *Cryptosporidium oocyst*		3 log reduction and/or inactivation	Commonly associated with gastrointestinal upset (nausea, vomiting, diarrhea); less common health effects can include respiratory systems, central nervous system infection, liver infections and muscular syndromes
Faecal Streptococcus/Enterococcus	cfu/100mL	0	Indication of recent faecal contamination
Clostridium perfringens spores	cfu/100mL	0	Index of intermittent faecal contamination

Source: Nigerian Industrial Standard (2015)

Table 3: The bacteriological contamination of drinking water sources in Nigeria in selected states from the different geo-political zones in Nigeria

States	Sources	THC	TCC (Cfu/ml)	Organisms (MPN/100ml)	Reference
NORTH CENTRAL					
Nasarawa	Well	8.3×10^6	40.5	*S. aureus, P. mirabilis, K. pneumoniae, P. aeruginosa, S.* Typhi, *S. dysentriae, E. coli* and *E. faecalis*	Makut et al., 2015
Niger	Sachet-packed	$0 - 2.8 \times 10^8$	0 -150	*Klebsiella* sp. and *E. coli*	Bala et al., 2016
Kwara	Tap	$0 - 1.6 \times 10^3$	0 – 210	*S. aureus, E. coli, B. licheniformis, B. circulans, L. brevis, E. coli, P. aeruginosa,*	Sule et al., 2011
Kogi	Stream	ND	0.98	*E. coli*	Obeta et al., 2015
NORTH EAST					
Adamawa	Sachet-packed	ND	0 – 1966.7	*E. coli, Enterobacter* sp., *P. aeruginosa, Citrobacter* sp.	Tula et al., 2018
Bauchi	Tap	ND	106.04	*Pseudomonas* spp., *Salmonella* sp. *E. coli*	Isikwue and Chikezie, 2014
Borno	Sachet-packed	ND	0-16	*Escherichia coli*	Muazu et al., 2012
Taraba	Well	$0.9 - 3.0 \times 10^4$	$0.2 - 1.8 \times 10^2$	*S. aureus, Pseudomonas* sp., *E. coli, Klebsiella* sp., *Enterococcus* sp., *Salmonella* sp., *Enterobacter* sp. and *Proteus* sp.	Agwaranze et al., 2017

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States	Sources	THC	TCC (Cfu/ml)	Organisms (MPN/100ml)	Reference
NORTH WEST					
Zamfara	Sachet-packed	$6.0 – 40.0 \times 10^8$	1.8×10^7	*Pseudomonas maltophila, E. coli, Citrobacter freundii, P. pseudomollia, Salmonella* Typhi, *Shigella* sp.,	Fardami et al., 2019
Sokoto	Borehole	$100 – 1 \times 10^9$		*E. coli, Salmonella* sp., *Shigella* sp. and *Vibrio cholerae*	Raji et al., 2010
Kano	Tap	16.8 - 95.5	ND	*E. coli, P. vulgaris* and *K. pneumonia Citrobacter fruendii, E. aerogenes, Salmonella* Typhi, *Shigella sonnei*	Taura and Hassan, 2013
Kaduna	Sachet-packed	ND	2–18	*Klebsiella* spp., *Proteus* spp., *Pseudomonas* spp.	Ugochukwu et al., 2019
SOUTH EAST					
Abia	Stream	ND	Present	*S. aureus, P. aeruginosa, Proteus* sp., *Streptococcus* sp., *E. aerogenes, E. coli*	Onyemaechi and Nwachukwu, 2018
Ebonyi	Hand-pump Boreholes	107 – 261 119 – 275	0-11 0-23	*Aeromonas hydrophila, Serratia liquefaciens, Micrococcus luteus, K. oxytoca, S. marcescens, Proteus vulgaris, V. cholerae, Citrobacter freundii, P. aeruginosa* and *P. fluorescens.*	Onuorah et al., 2018
Enugu	Sachet-packed	7 -500	Present	*E. coli, S. faecalis, Clostridium* sp.,	Ohanu et al., 2012
Imo	Stream	$2.4 – 4.7 \times 10^7$	$0.6 - 5.8 \times 10^7$	*Staphylococcus* sp., *E. coli, Klebsiella* sp., *Pseudomonas* sp., *Bacillus* sp. *Proteus* sp., *Enterobacter* sp.	Okorondu and Anyadoh, 2015
SOUTH-SOUTH					
Cross River	Borehole	$0.4 - 5.8 \times 10^4$	9	*Bacillus cereus, S. aureus, Pseudomonas, E. coli, Proteus* sp, *Enterobacter* sp, *Streptococcus* sp, *Salmonella* sp., *Shigella* sp. and *Vibrio* sp.	Akubuenyi et al., 2013
Rivers	Sachet-packed	$0 - 4.5 \times 10^4$	0 - 28	*S. aureus, Bacillus* sp., *Pseudomonas* sp., *Enterobacter* sp., *Klebsiella* sp. and *E. coli*	Eze et al., 2013
Delta	Well	$1.9 – 2.5 \times 10^4$	9- 26	*Escherichia* sp., *Enterobacter* sp., *Alcaligenes* sp., *Klebsiella* sp., *Staphylococcus* sp. and *Bacillus* sp.	Eboh et al., 2017
Edo	Borehole	$1.0 – 2.01 \times 10^6$	1600 – 1800	*S. aureus, E. coli, Pseudomonas* sp.	Ehiowemwenguan et al., 2014
SOUTH WEST					
Ogun	Well	$0.1 – 6.5 \times 10^4$	20 – 180	*Klebsiella* sp., *E. coli, Salmonella* Typhi.	Idowu et al., 2011
Ondo	Stream	$0.1 – 9.9 \times 10^4$	$0 – 1.9 \times 10^4$	*S. aureus, B. subtilis, E. coli, Salmonella* sp. *Serratia* sp.	Aromolaran, 2013
Osun	Sachet-packed	$7.0 - 12.0 \times 10^1$	0 – 1	*E. coli, B. cereus, Proteus vulgaris, Streptococcus faecalis, S. aureus* and *Enterobacter aerogenes*	Olowe et al., 2005
Lagos	Well	ND	< 3 and 1,100	*Enterobacter gergoviae, E. coli, Klebsiella pneumoniae, Serratia liquefaciens,* and *Vibrio*	Deji-Agboola et al., 2017

Keys: ND = Not Determined; THC = Total Heterotrophic Count; TCC = Total Coliform Count

Table 4: Reported outbreaks of cholera in Nigeria pre- and post- SDG implementation

Year	Numbers affected	death	CFR (%)	City/region	Reference
1982	662	Nil	7.7	Katsina	Umoh et al., 1983
1991	59,478	7,654	12.9	Nation-wide	Elimian et al., 2019
1995-96	5,600	340	6.1	Kano	Hutin et al., 2003
1996	1,384	Nil	5.3	Ibadan	Lawoyin et al., 1999
1999	26,358	2,085	7.9	3 states	Elimian et al., 2019
2010	41,787	1,716	4.1	18 states	Kolawole et al. 2013a
					Dalhat et al., 2014
2018	43,996	836	1.9	20 states	Elimian et al., 2019

Key: CFR: case fatality rate

6.0 Drinking water quality in Nigeria post-SDG implementation

In 2015, the Nigerian President, Muhammad Buhari was among the leaders that endorsed the takeoff of the SDGs as a replacement for the millennium development goals (MDGs). Interestingly, the SDGs were said to be in tandem with the positive change mantra of the President Muhammad Buhari led administration. Efforts to attaining the SDGs led to a joint meeting of all relevant Nigerian stakeholders, with a view to planning and strategizing on possible implementable measures in actualizing the SDGs. Around that time and in another forum, it was reported that the Nigerian nation was far from achieving the MDGs for water and sanitation. Additionally, it was reported that access to water supply and sanitation stood at 69% and 29% respectively in 2015 (WHO, 2015). The figures, although questionable also cast doubt on the willpower of the Nigerian government in actualizing the SDGs, if the supposed MDGs could not be achieved within the stipulated time frame.

Furthermore, the findings of research works carried out on the quality of water sources in Nigeria post SDG implementation revealed little or no progress in the attainment of SDG goal six as exemplified in the following instances. Firstly, there are no functional government water supplies to residential homes in Nigerian major cities, with majority of them, having to depend on personal borehole as their major source of water supply (Anochie et al. 2018). The majority of such borehole water is also not further subjected to any form of purification, either because of ignorance or the high poverty burden (Anochie et al., 2018).

The high rate of inequality with respect to water and sanitation is unimaginably high in Nigeria, with a large part of the population also depending on sachet-packed and bottled water as their primary source of drinking water (Airaodion et al., 2019). Interestingly, and post SDG implementation, the majority of the vended water (sachet-packed and bottled) have been reported to be highly contaminated with microorganisms, including coliform and pathogenic bacteria (Atuanya et al., 2016; Omonigho and Daodu, 2016; Anochie et al., 2018; Opafola et al., 2020), heavy metal and potential Endocrine Disrupting Chemicals [EDCs] (Atuanya et al., 2016; Dada et al., 2018), with EDCs being mostly reported to be more prevalent in sachet-packed water samples compared to bottled water (Dada et al., 2018). It is worthy of mention that the sachet-packed vended water samples are consumed more because of its cheap price. The high bacterial load in water samples are reported from several major cities and states across Nigeria. In a very recent study, Opafola et al. (2020) reported different brands of bottled water sold within the premises of Federal University of Agriculture Abeokuta to be loaded with microorganisms. Interestingly, 100% and 29% of the samples contained total bacterial and coliform respectively.

Similarly, the microbial, heavy metal and estrogenic burden of borehole water in Nigeria are also high and of great concern (Adeghe and Emejulu, 2016; Samuel et al., 2019) post SDG implementation. Samuel et al. (2019) reported pathogenic bacteria and coliform (including *Salmonell*a Typhi) from borehole samples from Anambra State. Similar outcome was also reported in Rivers State (Obioma et al.,

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2017), Edo State (Foka et al., 2018), and other major cities across the country.

To date, majority of Nigerians do not have access to proper sanitation, with 25% of Nigerians still practicing open defecation (Federal Ministry of Water Resources, 2016). It is worthy of mention that the nexus between sanitation, potable drinking water and health cannot be over emphasized.

Finally, all Nigerian water policy frameworks for water resource management exist only at the federal level, with the most recent Nigerian policy on water dating back to 2004 (Federal Republic of Nigeria, 2004), far before the implementation of the SDG, with the recent draft still work in progress (Federal Ministry of Water Resources, 2016). Additionally, the government does not seem to put into cognizance, her huge human resource working in the area of water and sanitation.

7.0 Impact of drinking contaminated water on Nigerian populace

waterborne viral diseases

Given that freshwater bodies serve as the main water resources for the majority of Nigerian populace particularly those in rural areas, their pollution with viruses has resulted in epidemics with associated health burden. Although there is paucity of data on the prevalence of viruses in drinking water sources in Nigeria, partly because of the current limitations on the detection of viruses. However, waterborne viral diseases are reported to be prevalent, especially in Northern Nigeria (Nasir et al., 2016). Waterborne viral pathogen that are classified by the WHO as having moderate to high health significance include the adenovirus, astrovirus, rotavirus, norovirus, enterovirus etc (WHO, 2011)

The enterovirus for example, is an important cause of human diseases and is transmitted easily by water environments due to varied human activity. These viruses are usually present in inadequately treated drinking water, rivers, groundwater and seas (Rajtar et al., 2008). Poliovirus which is an enterovirus causes poliomyelitis, and was considered endemic in Nigeria for a very long time, up to 2015. In 2012, more than 50% of the world's cases of poliomyelitis occurred in Nigeria (Tara et al., 2014), but only with the help of oral poliovirus vaccines, the plague of poliomyelitis in Nigeria has been put under control.

Waterborne viral pathogens have also been implicated as causative agents of gastroenteritis and diarrhea, especially in children between the ages of 0 – 5 years. In one of such studies in North-Eastern Nigeria, Oyinloye et al. (2016) reported norovirus and astrovirus from diarrheic children (n = 600) with a prevalence of 6.7% and 5.0% respectively. The feces of 60 out of 161 diarrheic patients in Lagos State, Nigeria were also reported to harbor norovirus (Ayolabi et al., 2010). Interestingly, 3.7% of non-diarrheal children in that study also harbored norovirus. In a similar study, Aminu et al. (2008) reported waterborne rotavirus and astrovirus in 9% and 5% respectively from children in North-Western Nigeria.

Waterborne parasitic diseases

Waterborne parasitic diseases occur when humans ingest drinking water from source(s) contaminated with enteric pathogenic parasites. The most common waterborne parasitic diseases in Nigeria include giardiasis, amoebiasis and dracunculiasis. Among the known *Giardia* species, *Giardia intestinalis* is the species infecting humans, and is estimated to cause 280 million cases of intestinal diseases per year globally (Lane and Lloyd, 2002; Thompson, 2004). A high prevalence rate of giardiasis is often recorded in developing countries including Nigeria (Squire and Ryan, 2017). Chronic infection with *Giardia intestinalis* can lead to weight loss and malabsorption and is associated with stunting and cognitive impairment in children in developing countries (Berkman et al., 2002; Nematian et al., 2008; Al-Mekhlafi et al., 2013). Acute giardiasis may disable patients for extended periods and can elicit protracted post-infectious syndromes, including irritable bowel syndrome and chronic fatigue (Hanevik et al., 2014). Giardiasis is also associated with abdominal distension, vomiting, fever and weight loss mostly in children (Squire and Ryan, 2017). *Giardia* cysts have been detected in a variety of drinking water sources in Nigeria including water from wells and the Kano River in northern Nigeria (Squire and Ryan, 2017). In Nigeria, 37.2% prevalence was reported after 199 children (less than 15 years old) were examined (Squire and Ryan, 2017).

Dracunculiasis is among the diseases caused by drinking water contaminated by the parasite, *Dracunculus medinesis*. Humans are the only reservoir for this parasitic nematode. The symptoms of dracunculiasis may include fever, vomiting, nausea, diarrhea, and arthritis (Adeyinka et al., 2014). Adeyinka et al. (2014) reviewed the prevalence rates of dracunculiasis and found that in 2002, a total of 2588 cases of dracunculiasis were recorded. In 2003, 2004, 2005, 2006 and 2007, a total of 1234, 2202, 153, 36, and 1 case(s) were respectively recorded across Nigeria (Adeyinka et al., 2014). There was no record of cases of dracunculiasis for 2008. There were no recorded cases of deaths from this disease between 2002 and 2008 in Nigeria. The parasite, *Entamoeba histolytica* is the main cause of amoebiasis in humans. The disease is still considered a major public health problem in developing countries including Nigeria. Symptoms of amoebiasis may include abdominal discomfort, weakness, malaise, constipation, fever, amoebic colitis, liver abscess, dysentery with the passage of exudates, blood and mucus as well as colicky abdominal pain (Huston et al., 1999). Nyenke et al. (2008) found 11% prevalence rates of amoebiasis after 405 stool samples were collected from children within the age group of 1-14 years from three communities of Ileleme, Okpor and Usokun-Degema in River State. In Lafia, Nasarawa State, Rine et al. (2013) recorded 26.7% prevalence rate after 120 stool samples of students were examined for the cysts and/or trophozoites of *Entamoeba histolytica* using the direct smear and formol/ether concentration techniques. Simon-Oke and Ogunlewe (2015) studied the prevalence of amoebasis in school age children in Akure, Ondo State and found a 67.6% prevalence rate following the examination of 278 stool samples. As with other studies, we hypothesize that the incidence of waterborne diseases is due to the inability of the Nigerian citizenry to gain access to potable drinking water most especially people living in the rural areas.

Bacterial waterborne diseases

When there is no clean and safe water people consume whatever they have at their disposal since they cannot survive without water. Consumption of bacteria contaminated water results to many disease conditions such as diarrhoea, cholera, dysentery and typhoid fever (Omalu et al., 2011). In several regions of Nigeria, clean and safe water is far from the reach of the populace. This has led to the outbreak of waterborne diseases like cholera, typhoid and diarrhoea. There are usually more reports on the outbreak of cholera than the other diseases.

Cholera is a bacteria disease caused by the ingestion of food or water contaminated with the toxigenic strains of *Vibrio cholerae* (Clemens et al., 2017). It is a disease of poverty and poor sanitation and a major health problem in the developing countries. Cholera exists as a seasonal disease in Nigeria, occurring annually mostly during rainy seasons (Kolawole et al., 2013a). Contamination of the community water source is a common reason for community outbreaks (Adagbada et al., 2012). Prior to the year 2016, i.e pre-SDG, there have been several outbreaks of cholera as well as sporadic cases in different regions of Nigeria. However, there are still records of outbreaks and sporadic cases post SDG Table 4. The severity and spread of this outbreak is an indication that the journey of Nigeria in attaining the sixth SDG goal which is clean water and sanitation is still far from reach. The decrease in fatality rate of the most recent outbreak compare to the previous suggested a greater preparedness on the part of the health provider (Elimian et al., 2019). However, the cause should be dealt with to forestall future outbreaks. There is therefore the need for the Nigerian government to provide a clean and safe water system that would be in place throughout the year. A functional pipe borne water in both the rural and the urban centres will go a long way in helping to reduce the incidence of cholera.

Typhoid is also a bacterial disease which is transmitted by the ingestion of food or water contaminated with the bacterium *Salmonella enterica* subsp. *enterica*, serovar Typhi (Yusuff et al., 2014). *Salmonella* Typhi infection is endemic in Nigeria with varied morbidity and mortality rate. Unlike cholera, there are limited data on prevalence of typhoid in Nigeria in the public domain. Yusuff et al. (2014) reported 10,4154, 77,850 and 39,337 cases nation-wide in the year 2000, 2003 and 2004 respectively. Recent clinical investigations still reported high cases of typhoid fever amidst the Nigerian population (Ohanu, 2019).

Diarrhea is a waterborne disease and is caused by bacterial, viral or protozoan (Efunshile et al., 2019). Diarrhea remains a major killer of children worldwide although its mortality has reduced drastically. In Nigeria, mortality among children below the age of 5 years from diarrhea was 331.3 per 100,000 children in 2016 (Efunshile et al., 2019). This implies that the burden of diarrhea in Nigeria is still very high post SDG implementation.

Health effect of drinking water contaminated with heavy metals

The World Health Organization estimated that 80% of diseases are waterborne. These contaminated water-associated diseases include cancer, respiratory disease, neurological disorder, cardiovascular disease and diarrheal disease (Ullah et al., 2014), which are caused by different chemical constituents among which are heavy metals. Cancer and blue baby syndrome are associated with nitrogenous chemicals in water (Krishnan and Indu, 2006) and drinking of different chemicals in contaminated water during pregnancy has been associated with increased rate of low birth weight which eventually affects the fetal health (Currie et al., 2013).

Drinking water contaminated with heavy metals has been reported to cause liver cirrhosis, hair loss, neural disorder and renal failure (Salem et al., 2000). They are also implicated for various illnesses like hemorrhage, nausea, skin irritation, ulceration and dermatitis which may be lethal (Abah et al., 2013). The ingestion of large quantities of Fe results in hemochromatosis. Nickel is a ubiquitous metal but its high concentration is frequently responsible for allergic skin reactions and has been reported to be one of the most common causes of allergic contact dermatitis (Kitaura et al., 2003), apart from being also carcinogenic (McKenzic and Smythe, 1998). Hexavalent Cr on the other hand is highly toxic, mutagenic, as well as carcinogenic (Lee et al., 2008). Copper on the other hand is an essential trace element for all organisms and can be used in metabolic pathways, however, young children are easily intoxicated by it. There have been records of kidney failure in young children exposed to elevated Cu concentrations. Lead is the most toxic heavy metal (Ferner, 2001) and Pb poisoning causes teratogenic, mutagenic, and carcinogenic effects as well as the inhibition of the synthesis of hemoglobin, dysfunction in the kidneys, joints, reproductive systems, cardiovascular system, chronic damage to the central nervous system and peripheral nervous system (Ogwuegbu and Muhanga, 2005).

8.0 How prepared/possible is it for Nigeria to achieve the SDG 6

The Sustainable Development Goal 6 centers on "ensuring availability and sustainable management of water and sanitation for all by 2030". Globally an estimated 30% of the people, which represent 2.1 billion people, still lack access to safe, potable water at home, while about 60%, or 4.5 billion people, lack safely managed sanitation (WHO, 2017)

Nigeria is the most populated country in Africa, with over 200 million people growing at a rate of around 3.2 percent annually. About half of the Nigerian population resides in urban areas. Nigeria possesses vast reserves of surface and underground waters; however, the country is crippled by a lack of water management infrastructure and distribution capacity. This is even exacerbated by highly variable rainfall patterns leading to water shortages across the country.

Below are some of the notable challenges faced by Nigeria in achieving the SDG 6

a) **Poor water service delivery**: In Nigeria, 37 publicly owned water boards that should provide water for her citizenry are dysfunctional.

b) **Institutional and governance constraints**: Nigeria's effort on sustainable management of water suffers from weak institutional framework to reduced financial and operational autonomy and thus is not financially or commercially viable.

c) **Gender inequality**: Statistically, women maintain about half of the electorate in Nigeria (Kolawole et al., 2013b), and due to biological and cultural factors have limited voice in how their local communities are governed. This influences their access to excellent water services.

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d) **Weather and water-related risks**: From a recent report from the International Food Policy Research Institute (2015), Nigeria's temperature could increase between 2-3^{o}C over the next 30 years. This temperature increase could cause changes in rainfall, storms, and sea levels, which could lead to water shortages in the country.

Way forward for the achievement of sdg6:

i. Nigeria's government will need to develop adequate physical infrastructure as well as to set up viable and accountable water agencies and systems

ii. Expand private-sector opportunities in Nigeria's management of water and sanitation development efforts. The government can introduce competition with potential efficiency gains when proper legal and regulatory frameworks have been put in place. Besides, there should be infrastructure investment and public-private participation ownership in the service operation of the water sector.

iii. The government must address gender inequalities by paying particular attention to the need of women and girls that are in vulnerable situations. Also, there must be concerted efforts to improve water quality by reducing pollution and indiscriminate dumping of hazardous chemicals. Efforts should be geared towards the reduction of untreated wastewater and protection and restoration of water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers, and lakes, substantially increasing recycling and safe reuse of waste in Nigeria.

iv. An excellent database to document or indicate government transparency on the pursuit of the SDG6 should be put in place.

9.0 Conclusion

Looking at the available information from published literature, pre- and post- SDG implementation in Nigeria, it is clear that no significant progress has been made in providing potable water for all in Nigeria. The implementation of any of the ten WHO recommended water treatment methods earlier reported in this study would translate to substantial reduction in the microbiological and chemical contaminants in the different drinking water sources, post- SDG implementation, which was not the case. The recent cholera outbreak in 55% of the states also calls for serious concern, with a number of other water-borne viral, bacteria and parasitic diseases going unreported. All implementing partners must therefore rejig the process to ensure the availability of potable water for all Nigerians.

10.0 Recommendations

Following the review of relevant publications viz a viz the efforts made so far by the Nigerian government towards achieving the sustainable development goal 6, we therefore, make the following recommendations:

General

1. The Governments at Local, State and Federal levels should implement and enforce her policies on treatment of industrial, abattoir and other contaminated wastes before release to the environment or water bodies through monitoring.
2. The Governments at all levels should relocate existing dumpsites and abattoirs located or present within human communities to areas outside of human communities and in situations where this is impracticable due to unavailability of land space, practice of controlled solid waste incineration should be done.
3. The National Agency for Food and Drug Administration and Control in collaboration with implementing partners should ensure regular and periodic monitoring of water sources meant for human consumption for its quality or potability'
4. Remediation of poor-quality water sources using any of the ten methods recommended by the WHO as appropriate.
5. The Government at all levels and implementing partners should carry out public education and enlightenment on anthropogenic sources of water pollution periodically.
6. The members of the communities should engage in responsible and sanitary disposal of faecal waste; and in sanitary installations in collaboration with implementing partners.
7. Continuous research on the availability and quality of drinking water from various sources should be encouraged.
8. Governments at all levels (local, state and federal) should provide funds for original research on drinking water quality assessment and for monitoring compliance to SDG6

Specifics

1. In Agrarian communities with high propensity of surface water contamination via run-offs, provision of clean water from ground water sources such as boreholes, deep wells and/or pipe borne water is recommended and such be sited away from potential sources of contamination by concerned local or state government and implementing partners
2. In oil communities' rift with contamination of water sources from oil spillage, leakages and pipeline vandalism, the Federal Government should enforce her policy on oil spillage and remediation; and carry out regular maintenance and protection of oil pipelines. Implementing partners can collaborate with the state and federal governments to install boreholes that will be regularly monitored for its water quality and remediation done when necessary.

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Declaration of Conflict of Interests

The authors declare that there are no potential conflicts of interest.

Authors' Contributions

Conception: [OCN, OU, EJA, ITO, AMU, AM, OAA, OIE, COA, IMO]
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