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Level of arsenic in potable water sources in Nigeria and their potential health impacts: A review

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Abstract

Arsenic is one of the metalloid found in Nigeria environment including soil and water especially in the Northern region were it contaminates water. This paper reviews the concentration of arsenic in potable water sources (i.e ground, surface and rain water) and their potential human health effects. The study found that the level of arsenic in potable water is usually above the permissible limit of 0.01 mg/l recommended by Standard Organization of Nigeria (SON) and World Health Organization (WHO) in the Northern and Southwestern Nigeria. This has been attributed to the geological and industrial activities in the region such as mining. High exposure of arsenic could cause diseases such as cardiovascular, hematological, neurological, respiratory, gastrointestinal and birth disorders, dermatitis and cancer. The paper suggests the use of iron oxide filter and iron based sorbents as the suitable physico-chemical technologies for arsenic removal from potable water sources. Also, research on the use of biological materials such as leaves of *Musa* species and sea shells should be conducted for determining their removal efficiency and economic feasibility of arsenic removal. Industrial wastes monitoring and water surveillance should be improved by the Government monitoring agencies.

Keywords: Arsenic, Disease condition, Drinking water contaminants, Health impacts, Nigeria

1 Introduction

Nigeria is one of the richest nations in the world with several renewable (biomass, wind, solar, geothermal etc) and non-renewable (crude oil) resources. The country also have abundance of mineral resources including natural gas, tin, iron ore, coal, lead, zinc limestone, niobium and fertile arable land for agricultural purposes. In addition, Nigeria has several water bodies including estuarine, fresh and brackish water scattered all over the country. The water bodies are relatively abundant in the coastal region of the country and more especially the central Niger Delta region. Generally, aquatic ecosystems harbor several numbers of biodiversity including planktons (phytoplankton, zooplanktons and algae), fishes, aquatic mammals, sea birds etc. Nigeria is a country that rivers divide into three and over 10 states out of the 36 states excluding federal capital territory are named after water bodies. Yet, potable water supply remains one of the greatest hardships of the country. Despite, the abundance of water resources, the government has not been able to successfully harness them into sustainable, equitable, adequate, improved and affordable water supply [1]. With an increasing population, the demand and use of water is also leading to pressure on water resources and tension among users. Presently, Nigeria's population is about 170 million making it the most populous nation in Africa and one of the most populous black nations in the world. On a global perceptive, the increase in population above 6 billion has resulted in an increasing demand of clean water [2].

Water is a vital resource for life and it's also crucial for the socio-economic development and maintenance of the ecosystems [1]. The supply of fresh water in Nigeria for domestic and drinking purposes are from three sources including surface water (river, stream, pond, lake etc), groundwater (borehole, hand dug well) and rainwater [3 – 5]. Typically, Groundwater is a major source of water used for domestic purposes in Nigeria because it is seeming to be clean [6], while surface water vulnerable to pollution than groundwater [7]. The distribution of the various water sources depend on the location, topography and geology of the area. In the coastal region, water supply is mostly from the ground, rivers, lakes, swamps, and sea. While, in the non-coastal regions ground water is the main source of water supply. Though, the distribution of rivers in non-coastal areas is relatively lesser when compared to coastal regions especially the Niger Delta region, due to industrialization, water supply is mostly from boreholes. The borehole water often goes untreated especially by independent water distributors. The government supplies water in some states and where these schemes are available, it is often epileptic.

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Water pollution often occurs in Nigeria due to discharge of wastes including municipal waste materials into the environment which are washed into the aquatic ecosystem via soil erosion. According to Galadima et al. [8], the wastes are mainly from homes, local markets, abattoirs, oil and agricultural activities. In the processing of agricultural products into finished products, several waste streams are generated which are discharged into the environment without proper treatment. In northern Nigeria, mining of metals from the ores often leads to pollution. Muhammad et al. [9] ascribed arsenic as one of the potential heavy metal pollutants released during mining activities. Some of these agricultural processing wastes are generated during oil palm and cassava processing. Also, water pollution occurs during crude oil and gas exploration, drilling and production, shipping, refining, storage, distribution and marketing. Other major toxic wastes that are discharged into the environment are hospital generated wastes. Through the action of oxidative processes, microorganisms decompose these wastes [8], releasing toxic substances into the environment. Heavy metals such as arsenic could be leached into the environment through natural processes and anthropogenic activities (burning of industrial generated solid wastes) [10, 11].

Heavy metal pollution such as Mercury and Arsenic is one of the essential water contaminants associated with health impacts. These heavy metals often occur as an oxide of other less poisonous metals. Specifically, arsenic is chemically similar to phosphorus, to the extent of partly substituting its biochemical reactions including its poisonous nature [12]. According to Garba et al. [10], arsenic could occur in a variety of minerals including Arseno pyrite (FeAsS), Realgar (As_2S_2), Orpiment (As_2S_3), Arsenolite (As_4O_6), nickel glance (NiAsS) or mispickel. Arsenic can also occur as ores in heavy metals such as copper, lead, cobalt, nickel, zinc, silver, tin etc [10, 13]. Some other forms arsenic could occur include arsenic trioxide (As_2O_3), arsenic pentoxide (As_2O_5), arsenic sulfide (As_2S_3), dimethylarsinic acid (DMA) [$(CH_3)_2AsO(OH)$], monomethylarsonic acid (MMA) [$(CH_3)AsO(OH)_2$], lead arsenate [$PbHAsO_4$], potassium arsenate [KH_2AsO_4], potassium arsenite [$KAsO_2HAsO_2$] [14]. According to WHO [14], arsenic exists in oxidation states of −3, 0, 3 and 5 and they are found throughout the earth's crust as arsenic sulfide or as metal arsenates and arsenides. Arsenic can also exist in elemental forms and they can also undergo sublimation upon heating [12]. Basically, elemental arsenic is not principally hazardous, but its oxide such as arsenic (III) oxide (As_2O_3) is the mostly used and is very poisonous [3, 4].

Arsenic is a trace element found at variable concentrations in the atmosphere, soils and rocks, natural waters. Several inorganic and organic compounds contain arsenic and they are relatively harmful to the environment and biological species. Common oxides of metal containing arsenic is used in the manufacture of pesticides and insecticides include sodium arsenite ($NaAsO_2$) used for locusts, arsenic (III) oxide (As_2O_3) used for rodents, calcium arsenate [Ca (AsO_4)] used for cotton boll weevil and the potato beetle [3]. Organic arsenic compounds such as arsenocholine and arsenobetaine are relatively nontoxic and rapidly excreted unchanged in urine and they account for about 64% of total arsenic consumed indirectly in food related products [15]. But according to Lesikar et al. [16], organic arsenic is usually less harmful than inorganic arsenic, although exposure to high levels of some organic arsenic compounds may cause similar effect to those from inorganic arsenic. Through the use of these arsenic containing chemicals, arsenic find its way to the environment including air, water, food and soil [14], hence they are ubiquitous. A long period of soil exposure could cause the infiltration into the ground water leading to contamination. Arsenic in water is colorless, odorless, and tasteless [17].

Arsenic is useful in the hide and tanning process and, to a limited extent, as pesticides, feed additives and pharmaceuticals [14]. The exposure to humans during processing of these products could be a potential source of pollution which could be hazardous to the human health. Also some of the foods produced with arsenic have a concentration above the standard limit and this could lead to health related effects. Maduabuchi et al. [18] reported the arsenic level of some canned foods consumed in Nigeria including Picnic Soymilk (Maeil) (0.161mg/l) produced in Seoul, South Korea, Remmy Rankky Orange (0.160mg/l) manufactured in Wuging, Republic Of China, Sprite Soft Drink (0.051mg/l) manufactured in Wadeville, South Africa, Star Pino Pineapple (0.030mg/l) and Star Mango (0.020mg/l) produced in Shariah, United Arab Emirates, Godys Malta Drink (0.023mg/l) manufactured in Germany, Chinchin malt milk drink (0.011mg/l) produced in Tianjin, China. Some un-canned foods containing high arsenic concentration include La Casera Orange Drink (0.261mg/l), Chelsea Teezer Gin and Pinneapple (0.012mg/l), Fine Merit Yoghurt (0.011mg/l), Delite Black Currant Drink (0.011mg/l), Chivita Orange Juice (0.020mg/l), Popcy Flavored Drink (0.017mg/l), Lulu Apple Juice (0.014mg/l) produced in Lagos, Nigeria, Sans Cream Soda (0.016mg/l), Ribena Black Currant (0.014mg/l), Lucozade Boost (0.038mg/l) produced in Ogun State, Nigeria, V. Roovers Orange Drink (0.012mg/l) Ogidi, Nigeria, Campina Yazzo Milk Drink (0.060mg/l) manufactured in Aalter, Belgium, Mighty Nice Chocolate Drink (0.038mg/l) produced in Cape Town, South Africa, Sheeza Mango (0.034mg/l) produced in Karachi, Pakistan, Vitamilk Soyamilk (0.030mg/l) produced in Thailand and Grape Joy Of Health (0.027mg/l) manufactured in Cansavay Bay, Hong Kong. Yet this food and drink products are widely consumed throughout Nigeria.

Water is an essential resource utilized by all humans as well as biodiversity. Water pollution is one of the challenges of developing countries like Nigeria. Hence, this paper focuses on the challenges of potable water supply, level of arsenic in water quality in Nigeria and potential health effects. The study concludes by suggesting options for removing arsenic in drinking water sources in Nigeria.

2 Challenges of Water Supply in Nigeria

Water is a limited resource which is very crucial for the survival of humans and also, an important tool to industries, agriculture and producers at large. Poor water supply with regard to quantity and quality will adversely affect sustainable development [19]. Drinking water supply in Nigeria is challenging, with more intense situations in

the Northern region of the country. Generally, the potable water problems include concentration of heavy metals such as arsenic, microbial isolates and counts and water monitoring and surveillance policy.

2.1 Water Monitoring and Surveillance Policy

According to Galadima et al. [8], adequate supply of safe and sanitized fresh water is an inevitable factor for human and economic development of the country. The authors attributed water crisis in Nigeria to lack of education, low budgetary funding, inefficient government policies, corruption, drought and other anthropogenic factors as the leading factors that lead to poor quality supply. The major challenge of water supply include inadequate policy, legal, regulatory and institutional framework, high population growth, low investment level in operation and maintenance leading to recurrent break down of water facilities, non – participation of intended water users during initiation/conception of the schemes or funding, execution and monitoring, insufficient public awareness toward water conservation and management [1]. In Nigeria, potable water supply policy favors ground water, and a significant number of the population is still getting their drinking water from stream, rivers and lake. Hence, the surveillance of water sources of significant importance is lacking and grossly inadequate.

2.2 Microbial challenge

Generally, the quality of drinking water is determined based on the appearance, taste, color and odor of the water, but this does not indicate that the water is free from hazardous compounds [4]. In addition, microbial contamination also occur in water used in Nigeria. According to SON [20], water microbial quality should not exceed maximum permissible limit of 10cfu/ml for total coliform count which indicates faecal contamination, 0cfu/100ml for thermo tolerant coliform or *E.coli* which indicates urinary tract infections, bacteraemia, meningitis, diarrhea (one of the main cause of morbidity and mortality among children), acute renal failure and haemolytic anaemia and 0 cfu/100ml for Faecal streptococcus which is an indication of recent faecal contamination and 0cfu/100ml for *Clostridium perfringens* spore which is the intermittent faecal contamination index for drinking water. Yet the water quality distributed and consumed in Nigeria often exceeds this limit. Ige and Olaifa [21] has reported *E.coli* in ground drinking water around waste dump sites in parts of Lagos state, Nigeria in the range of 4 – 50 x/100ml count which is an indication of contamination. Olaoye and Onilude [22] has reported microbial contaminations in drinking water from western Nigeria as 2.86 -3.45 log colony forming unit (cfu/ml) and 1.62 log cfu/ml as total bacteria count and highest coliform count respectively. The authors also identified *E.coli, Staphyloccocus aureus, Pseudomonas aeroginosa, Enterobacter aerogenes, Klebsilla* species, *Proteus vulgaris, Alcaligenes faecalis, Bacillus cereus, Streptococcus lactis, Aeromonas* species and *Micrococcus luteum* as the bacteria diversity found in drinking water. These microorganisms are pathogenic and are known to cause variety of diseases.

2.3 Heavy metal – Arsenic challenge

Leaching of heavy metals such as arsenic causes water pollution. Most heavy metals are toxic on exposure especially on a prolong state. Some of these harmful elements include arsenic, beryllium, cadmium, mercury, lead, radon, and uranium [23]. In recent time, monitoring of heavy metals in drinking water sources as been a major concern to environmental scientists [24]. Arsenic in one of the major pollutant that is deleterious to the environment and humans that consumes the contaminated water. Arsenic has the potential to undergo a sequence of changes such as oxidation-reduction reactions (an arsenic atom taking electrons from another atom or losing them to another atom), ligand exchanges (electron exchanges involving other atoms which are combined with a central arsenic atom), and biotransformations (chemical changes to arsenic atoms within the body of living things) [16]. During oxidation and oxidation-reduction reactions the transport process in ground water is affected due to the water pH, total iron level, temperature, salinity, and suphate in water [16].

3 Concentration of arsenic in potable water sources in Nigeria

Arsenic concentrations in water depends much on the source of arsenic contamination which may be as a result of natural processes, industrial or agricultural activities and increase in human activities in the area where the wells are located [3]. Table 1 present the level of arsenic concentration in drinking water sources in Nigeria mainly from wells, boreholes/ground water and surface water. However, arsenic have been detected above the permissible limit of 0.01mg/l in Northern Nigeria with a concentration of 0.02 to 0.80mg/l. Northern regions with high concentrations include Biu Volcanic, North-Eastern Province of Nigeria [23], Kano state [10, 12], Zaria and environs [11], Kaduna [3, 4], Borno states [25], Sokoto [26] and in south western Nigeria it has been detected in Osun state [227], Ogun state [28, 29]. Information of arsenic contamination of water pollution is not severe in the Southern region when compared to the Northern Nigeria. In the Niger Delta, the concentration in Bayelsa state specifically is below the permissible limit [30, 31], apart from the recent studies in 2013 that the concentration of arsenic was reported as 0.03 mg/l in Yenagoa, Bayelsa state [5]. Similarly, in Abia state the concentration is below the permissible limit for potable water source [32, 33].

High arsenic concentrations can occur locally in surface waters (as well as ground waters) in areas of bedrock sulphide mineralization or mining activity, industrial contaminations, or areas affected by geothermal activity and in surface waters that are fed by high-arsenic groundwater [34]. This could be the reason why arsenic concentration is often high in the Northern Nigeria due to the abundance of rock deposits. Similarly, the deposition of arsenic in potable water sources in southwestern Nigeria could be attributed to anthropogenic activities such as industrialization and mineral richness of the region.

Table 1: The arsenic concentration level of drinking water sources in Nigeria

Water source	Concentrations	Location	References
Surface water, mg/l Groundwater, mg/l	0.03 - 0.477 0.006 - 0.424	Biu Volcanic, North-Eastern Province of Nigeria	[23]
Hand dug wells, mg/l	0.40 - 0.60	Karaye Logal Government area, Kano state.	[12]
Tap pumped water, mg/l	0.09 – 0.16		
Hand pump operated borehole, mg/l	0.12 – 0.16		
Well Water mg/l	0.765 highest level 0.809 highest level	Getso in Gwarzo Local Government area, Kano State. Kutama in Gwarzo Local Government area, Kano State.	[10]
Borehole, mg/l	0.002 – 0.008	Zaria and environs	[11]
well water, mg/l	0.02 – 0.51		
Well water, mg/l	0.34	Jeba, Jemaa, Kachia, Kagarko, Kauru, Kaura, Sanga and Zangon Kataf local government area in Kaduna state	[3]
Borehole water, mg/l	0.14		
Well water, mg/l	0.20 – 0.40	Ikara, Kubau, Kudan, Lere, Makarfi, Sabongari, Soba and Zaria local governments area of Kaduna	[4]
Borehole water, mg/l	0.03 – 0.14		
Borehole, mg/l	0.02 – 0.04	Maiduguri, Borno state	[25]
Sachet water	0.17-0.25	Sokoto metropolis	[26]
Well water	0.21-0.38		
Tap water	0.22-0.28		
Ground water	0.00 – 0.38 (dry season) 1.03 – 3.06 (Rainy season)	Ibadan, Oyo state	[6]
Borehole, mg/l	0.00 – 0.05	Odeda region, Ogun state	[29]
well water, mg/l	0.00 – 0.07		
Borehole, mg/l	0.03 – 0.47	Ijebu land, Ogun state	[28]
Ground/surface water, mg/l	0.01 – 0.70	Igun-ijesha, Osun state	[27]
Groundwater	0.00	Yenagoa, Bayelsa state	[30]
Groundwater	0.01 – 0.03	Yenagoa, Bayelsa state	[5]
Groundwater	0.00 – 0.01	Yenagoa, Bayelsa state	[31]
Groundwater	0.00	Osisioma, Abia state	[32]
River	0.001 – 0.014	Aba, Abia state	[33]
Limit, mg/l	0.01	WHO, SON	[3, 4, 11, 12, 17, 20, 25]

4 Impacts of Arsenic on Water Quality in Nigeria

Arsenic compounds have a relatively higher density than water. Some of the densities of arsenic containing compounds include: As (5.727g/cm^3 at 14 °C), As_2O_3 (3.738 g/cm^3), As_2O_5 (4.32 g/cm^3), As_2S_3 (3.43g/cm^3), $PbHAsO_4$ (5.79g/cm^3), KH_2AsO_4 (2.867g/cm^3) [14]. Some metals act as catalysts in the oxidative reactions of biological macromolecules causing toxicity that could damage tissues [35].The gastrointestinal tract is exposed to environmental pollutants such as arsenic from contaminated foods and water which may have toxic effects on the body [18]. Arsenic enters the body through the skin (dermal) and also through parental routes (placental transfer of the arsenic to the unborn fetus). But the central port of arsenic entry is by oral ingestion of contaminated foods and water and also through inhalation [18]. Figure 1 shows the route of contraction of arsenic through systems; tissues and organs etc. which absorbs them thereby causing disease conditions. Dermal contamination can occur through prolong exposure to water bodies with high arsenic levels including rivers, ponds and lakes. Generally in Nigeria, most rural dwellers often bath and wash in open rivers. However, the absorption of arsenic through the skin is minimal; therefore, hand-washing, bathing and laundering etc. with arsenic containing water does not pose significant human health risks [36]. Similarly, over exposure to arsenic contaminated air can cause respiratory diseases induced by arsenic. These usually occur as occupational arsenic toxicity, especially in individuals who work with arsenic compounds, though the type of effect and severity is relatively depended on the level of exposure.

The degree of non-occupational exposure to arsenic varies greatly, and this is dependent on the local geochemistry as well as the level of anthropogenic activity [36]. Arsenic is one of the major water pollutants that need adequate public health attention due to the variety of diseases that they cause.

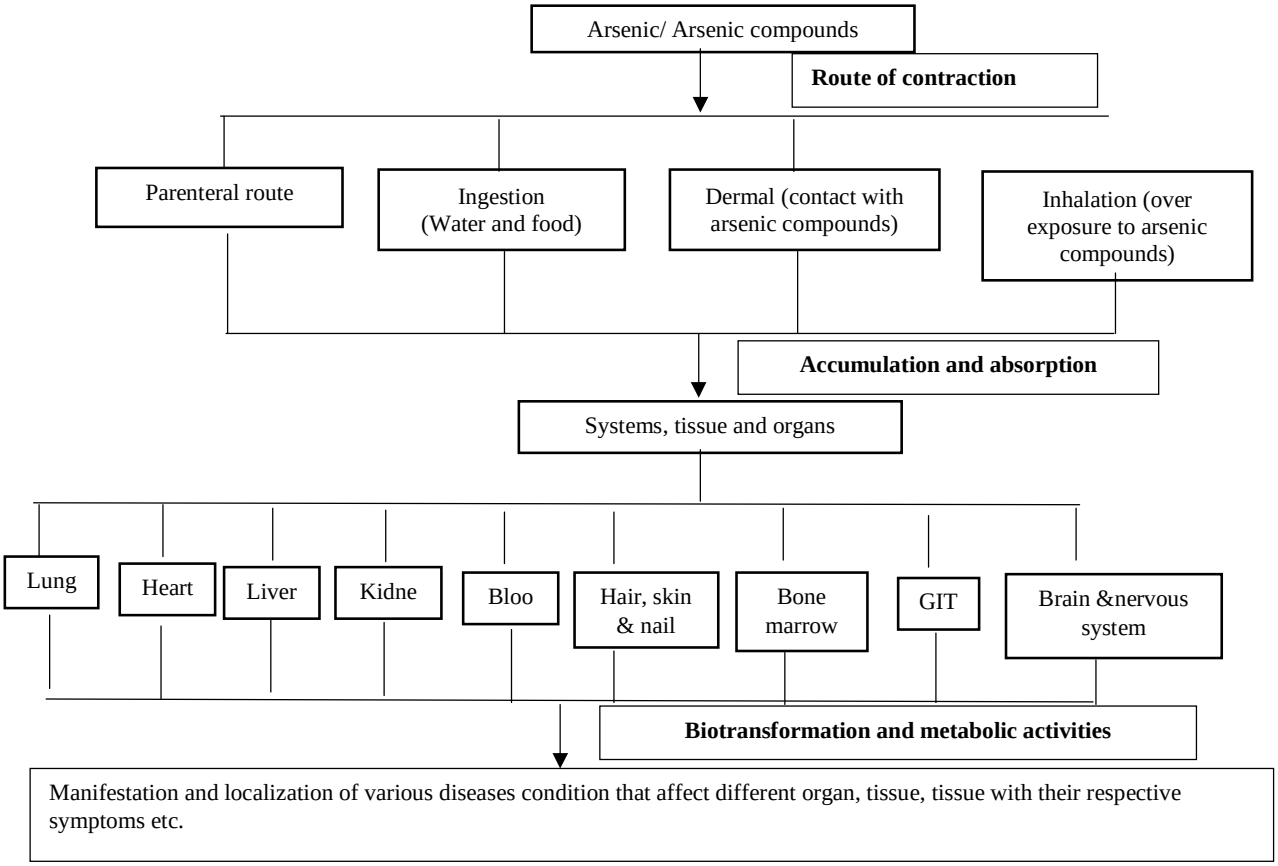

Figure 1: Possible route of contracting the arsenic related disease conditions (GIT = gastrointestinal tract)

Quality water supply is vital for the existence of humans and other biological species. Basically, quality analysis of drinking water quality offers essential information about the sources of water pollution and guidelines for health protection [37]. Water pollution and /or shortage could cause adverse reduction in productivity and even deaths of living species [10, 12]. The impact of arsenic on human health is often severe causing several types of diseases. Table 2 presents various diseases caused or induced by over exposure to arsenic. These diseases affect the younger generation which could be attributed to the fact that they are prone to exposure as against older people. Usman and Lar [23] reported that in some rural communities of Biu Volcanic Province in North-Eastern Nigeria, arsenic related diseases are common among adults, youths and children. Arsenic pollution has also been reported in the northern Nigeria [3, 4, 10, 12]. According to the British Geological Survey [34], the latent period of arsenic related diseases usually takes several years before clinical symptoms of arsenic-related skin disorders and cancer become apparent. Garba et al. [4] reported that chronic arsenic poisoning can take 5-15 years to reveal themselves depending upon the amount of arsenic ingested. This could be the reason why it only surfaced in Northern Nigeria some decades ago despite the use of the same water several centuries ago. Arsenic toxicity is real, and health implications have been recorded across the globe [36] in Countries like Bangladesh, India, China, Taiwan, Thailand, Chili, Romania [13, 34].Ground water pollution from arsenic has a correlation in the development of cancer and other chronic diseases as a result of ingestion of high-arsenic drinking water [34].

The severe toxicity of arsenic compounds in humans is mostly a function of their rate of removal from the body [14]. Arsine is in its toxic form as arsenites [arsenic (III)], the arsenates [arsenic (V)] and organic arsenic compound [14]. The symptoms of arsenicosis or arsenic induced diseases visibly show is different form depending on the localization center and level of exposure. Arsenicosis is a disease caused as a result of arsenic induced water through long term consumption. The symptoms that appear after a few weeks of exposure often included fever, insomnia, and anorexia [18], abdominal pain, vomiting, diarrhoea, muscular pain and weakness, with flushing of the skin [14, 45]. Other symptoms include brittle nails, nausea, chronic

anemia, burning in mouth/esophagus/stomach/bowel, confusion, drowsiness, enzyme inhibition, and garlicky odor to breath/stool, hair loss, headaches and low grade fever [45]. At advanced stages of arsenicosis its clinical symptoms are incurable, however mild and early symptoms can be alleviated by supply of low-arsenic drinking water [34]. According to Lesikar et al. [16], the manifestation of arsenic causes gastrointestinal diseases, diabetes, anemia, cardiovascular, neurological effects and liver disease include noncirrhotic portal hypertension, bleeding esophageal varices, splenomegaly, hyperspenism, metallic taste in mouth, Mee's lines in nail beds, bone marrow depression and peripheral neuropathy.

Table 2: Diseases and localization associated with arsenic pollution in drinking water

Diseases	Localization	References
Cancer	skin, lung, bladder, colon liver and kidney	[13, 14, 17, 23, 36, 38 – 44]
Skin problems	Skin problems like: rashes, abnormal growth, skin lesion and roughness	[23, 36, 43]
	Changes in skin color and hard patches on the palms and soles of the feet	[38]
	Nails deformity- nail thickening and brittleness, Hyper-pigmentation of the skin and hand palms	[17, 23, 45]
	Hyperkeratosis and pigmentation changes	[14, 17]
	Dermatitis	[45]
	Melanosis (hyperpigmentation), spotted melanosis (spotted pigmentation), non-melanoma (depigmentation) and leucomelanosis in which white and black spots side by side is found in the skin	[13]
	Hypertension, heart disease, 'blackfoot disease' and related gangrene, Raynaud's syndrome	[14, 34]
Cardiovascular / Haematological/ pulmonary disorders	Increased mortality or prevalence of coronary heart disease, peripheral arterial disease, myocardial infarction and stroke, blood pressure	[14]
	Cardiovascular diseases	[12, 13, 16, 17, 39, 41 – 43]
	Diseases of the blood vessels	[16, 34, 38]
	Hematologic disorders (anemia, leukopenia and eosinophilia)	[41, 42]
	Hepatic diseases	[34]
	Decreased production of red and white blood	[16]
	Cells, Abnormal heart rhythms, Damage to blood vessels	
	Risk factor for atherosclerosis	[43]
	Vascular disease including arteriosclerosis - Peripheral vascular andischemic heart disease (ISHD), renal, chronic lung and cerebrovascular disease	[13]
Gastrointestinal diseases	Gastrointestinal tract	[15, 34]
	Gastrointestinal effects such as nausea, vomiting, abdominal pain and severe diarrhea	[16]
Nervous and immune system disorders	Neurological diseases, decrease motor co-ordination, nervous	[3, 13, 16, 34, 42]
	Peripheral neuropathy	[17, 39]
	Nervousness	[45]
	Convulsions and immune system disorder	[12, 45]
Diabetes	Diabetes	[13, 17, 23, 39, 41, 42]
Respiratory diseases	Respiratory tract infection,	[3, 45]
Hearing difunctioning	hearing loss	[23, 41, 42]
Organ inflammation or accumulation of arsenic compounds	Liver, kidney, spleen.	[12, 15]
	Liver disease.	[16]
Birth defects	Birth defects/ developmental abnormalities, neurologic and neurobehavioral disorders	[12, 41, 42]

Arsenic compounds are usually carcinogenic especially in their trivalent inorganic forms. According to WHO [14], the mechanism of carcinogenicity and the shape of the dose–response curve at low intakes have remained unknown, highly controversial and uncertain. Most of these diseases have been occurring in Nigeria since the 19th century. These diseases may have claimed several lives especially in the rural areas in the northern Nigeria were arsenic have been reported as the main cause of water pollution. Some of the diseases conditions include skin lesion, cardiovascular disorder, cancer, respiratory disorder, neurological and birth defects. Besides human, arsenicosis could also affect biodiversity (biological species) exposed to arsenic for prolong periods. Basically arsenic is found in living organisms in a minute form, but when the concentration is high it poses health effects for animal's species (arboreal, terrestrial and aquatic organisms). Like in humans, high arsenic concentration could trigger different forms of diseases occurring frequently in biological species. The mode of contraction could be from prolonging consumption of water polluted with arsenic.

5 Conclusion and the way forward

Potable water source is one of the most essential requirements for the existence of man and biodiversity. Yet its supply in Nigeria is challenged by high microbial counts, heavy metals such as arsenic and unfavorable water policies especially with regard to surveillance and monitoring. The concentration of arsenic in water is high especially in the northern Nigeria due to the anthropogenic activities such as mining and natural conditions such as the geology of the area. In the south west especially in Ogun state, concentrations have been detected above the permissible limits recommended by SON and WHO. However, in south-south region the limit is below the guideline values of 0.01 mg/l except for recent studies (2013) were arsenic concentrations are up to 0.03 mg/l in ground water in Yenagoa, the Bayelsa state Capital. The presence of arsenic in southern Nigeria is probably due to industrial activities in the region. Besides drinking, water is also used for bathing, washing; cooking etc. The routes through which arsenic enters the human body include ingestion from contaminated food and water, inhalation and dermal contact. To a large extent, ingestion remains the means through which arsenic toxicity occurs. Basically, the exposure to arsenic could causes several disease condition such as cardiovascular, hematological, neurological and immune system, respiratory, gastrointestinal birth disorder, dermatitis and cancer. To avoid the attendant health impacts of arsenic in potable water sources in Nigeria we suggests that drinking water should be adequately treated before consumption especially in region were arsenic pollution in high.

Several treatment options of potable water are available including ion exchange, activated alumina, reverse osmosis, coagulation filtration and microfiltration, oxidative filtration, lime softening, iron based sorbent [46], iron oxide filter [47], pond-sandfiltration [3, 4], iron hydroxide precipitation [13]. The most widely used coagulants are alum and ferric chloride [34]. Of these, technologies, coagulation filtration and microfiltration have arsenic removal efficiency of 95% and work best when the pH of the water is 5.5 – 8.5 requiring high skill. Basically, most potable water sources with less contaminant have a pH of about 6 – 8. SON and WHO have reported that drinking water with a pH of 6.5 and 8.5 may not have health related effects. Of all the physico-chemical arsenic treatment technologies, the use of iron based sorbent is best due to its high removal efficiency (98%), requiring a water pH of 6 – 8.5 with minimal skills [46]. Low cost filtration and iron hydroxide precipitation system that are affordable, efficient and with low maintenance capacity can be also be used for treating potable water sources high in arsenic [13]. Also, iron oxide filters are a relatively new and hopeful technique for lowering arsenic levels in private drinking water systems [47].

Iron oxide media can be housed in small inline filter cartridges or in larger tanks like the ones used for ion exchange systems [47]. These filters can be used to enhance the performance of reverse osmosis systems that are not effectively removing As (III). Generally, Iron oxide filters are effective for both As (III) and As (V) removal, inorganic removal matters, simple to use and maintain [47]. However removal efficiency can be reduced when the water contains other materials such as iron, manganese, sulfate, silica or organic carbon [47].

Tech Brief [48] has reported that low cost arsenic removal can be done through a sequence of aeration/sand filtration, cation exchange softening and finally chlorination. Basically, adsorption column is modified from activated alumina and iron-based sorbents. The benefits of adsorption column technologies include simplicity of operation and maintenance, and cost effectiveness with high removal efficiency [16]. Reverse osmosis treatment technologies is mostly used when the water contain high amount of sulphates and phosphates. However, the treatment of As (III) in drinking water could undergo pre-oxidization and this enhances the complexity and cost of the treatment. Reverse osmosis treated water do have bland tastes due to inorganic substances removed from the treatment system.

Ion exchange process removes arsenic by passing the water under pressure through one or more columns packed with an exchange resin [16]. In distillation, the water is heated to its boiling point (100°C) in a condenser (i.e enclosed container) and the residues containing arsenic is allowed to evaporate. The water is subsequently allowed to cool and condenses back into a liquid [16].

Generally, 21hysic-chemical treatment technologies are limited by costs. In the recent years, biological approaches for remediating heavy metals including arsenic from potable water have been a cause for concern to biological environmentalists. Rowel [49] has reported that Musa species peel can be used up to 11 times during water treatment without replacement. Richard [50] reported that sea shells can also be used for remediating heavy metals from water due to the presence of aragonite (a form of calcium carbonate). In view of the cost required for treating arsenic in water through 21hysic-chemical methods, we hereby suggest that research should be carried out using biological materials such as sea shells and Musa species leaves to determine their potential arsenic removal efficiency from potable water sources and their economic feasibility. With regard to the water supply challenges, the

government should carry out thorough monitoring and surveillance of health impactable anthropogenic activities such as mining and discharge of industrial wastes to ensure that toxic materials containing arsenic are not dumped into the potable water sources. Also, industrial yards should be sited far from residential areas were potable water sources such as borehole are in abundance. The inhabitants of high arsenic communities should balance their diets with nutritious supplements and avoid diets low in protein, fats, vitamins and minerals, since they enhance the risk of arsenic-induced skin lesions and other malignant disease [13].

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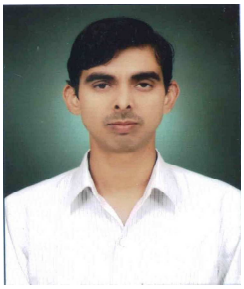

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