



Environmental Implications of Increased Discharge of Pollutants into Nigeria's Fresh Water Resources

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Authors' contributions

This work was carried out in collaboration between all authors. Author SMM designed the study and wrote the first draft; author ACE managed literature searches; author JDD handled the section on human health risk assessment of Nigeria's water quality; while author MZO drafted the recommendation and typed the work. All authors read, edited and approved the final manuscript.

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ABSTRACT

The paper has appraised the implications of abuse of water in Nigeria. Through critical review of related works the paper has discovered that Nigeria's water resources are getting polluted daily as a result of such increased anthropogenic activities like modern agriculture, mining, fishing, livestock farming, manufacturing and household rubbish which release organic and inorganic pollutants into aquatic environment. The paper noted such adverse consequences of water pollution to include increased debilitating water-borne diseases which affect human health, fauna and flora negatively. Human health risk assessment of water quality from different parts of the country has shown that both surface and shallow groundwater are not safe for human consumption hence, some treatments are urgently required before ingestion. The paper therefore, recommended reduction in the discharge of pollutants into water bodies by reutilization and recycling of waste water, removal of pollutants before discharging waste into the environment, creation of public awareness and

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enforcement of environmental laws in order to safeguard this life-supporting resource from degradation.

Keywords: Environmental; implications; pollutants; freshwater; human health risk.

1. INTRODUCTION

Nigeria is located between latitudes 3°15' and 13°30' North of the Equator; and between longitudes 2°59' and 15°00' East of Prime Meridian. It has a total area of 923, 768 km² in which land comprises 910, 768 km², water 13,000 km², land boundaries 4,047 km long and a coastline of about 853 km [1]. The country is surrounded to the North, East, West and South by Niger, Cameroun, Benin and Atlantic Ocean respectively. The relief is dominated by plains, generally less than 600 m with the exception of Jos Plateau (1200 m), Udi Plateau (600 m), Western Highlands (700 m) and Eastern Highlands; Where Chappal Waddi is the highest point, being 2419 m above mean sea level [2]. These highland areas constitute the country's hydrological centres. Most of Nigeria's river systems with the exception of the Cross, Niger and Benue originate from these watersheds and flow either directly into the Atlantic Ocean or into the Niger and Benue rivers.

Adefolalu [3], identified four hydro-climate zones in Nigeria: The Sahel, Sudan-Sahel, Guinea Savanna and Forest zones. Rainfall decreases generally from the coast, where it ranges from 2000 mm to over 4000 mm, to northeastern extreme which receives less than 500 mm of annual rainfall. The country has a variety of soils, vegetation and climate types extending from Mangrove Swamps and Rainforest of the coastal lowlands to the Savanna Woodlands of the High Plains of Hausaland and the Semi-arid Sahelian lands in the Northeast [4].

NEST [5] stressed that water surplus varies from 379% of the national figure in Delta to less than 38% around Lake Chad. In other words, as rainfall decreases northwards from the coast, evaporation and transpiration rates increase thus, worsening the water balance. Although Nigeria is well endowed with water resources, both surface and underground estimated at about 267.3 billion cubic meters and 52 billion cubic meters respectively, with only less than 10% of these enormous amounts of water being currently exploited [1], there is need to safeguard it from deterioration arising from anthropogenic

activities like mining, agriculture, transportation, fishing, industrial and domestic uses that readily yield pollutants which get into freshwater bodies to contaminate them.

The country has one of the fastest growing populations of 3.3% in the world where census results of 1991 and 2006 indicated that there were as many as 88.5 million and 140 million people respectively [1]. It is arguably too that, it is the most urbanized country in Africa where in 1991 there were 359 urban centres which rose to 680 in 2002 as against 23 urban centres in pre-colonial period. The inequality in the level of development and distribution of economic and social infrastructure between the urban and the rural areas (to the disadvantage of the latter) is leading to high rate of rural-urban migration. Less than 40% of Nigerians are living in urban areas but the rate is increasing rapidly with consequent acute problem of sewage and waste disposal, pollution and general land degradation [6].

Indeed most of the fresh water bodies in Nigeria are daily taking in a variety of organic and inorganic pollutants which result from chemical and biochemical interaction between water and surrounding lands. As these activities increase, more pollutants including untreated, partially treated sewage, agricultural and industrial effluents are generated and indiscriminately disposed of. Hence this is seriously affecting the quality of surface and underground water, not just in heavily populated and industrialized cities of Lagos, Kano, Port Harcourt, Jos and Kaduna alone but in almost all the rural settlements of the country.

The paper therefore provides an in-depth overview of the nature and sources of pollutants that cause water pollution, the hazards which such polluted water poses to human health, fauna, flora and other abiotic components of the environment, with the aim of proffering solutions in order to safeguard Nigeria's fresh water resources from total deterioration. In order to achieve the objectives, the rest of the paper is organized into ten sections in the following order: introduction, study methodology, theoretical

framework, nature and sources of pollutants, causes of water pollution, profile of Nigeria's water resources, implications of water pollution on the components of the environment, human health risk assessment of Nigeria's water quality, recommendation and conclusion.

2. STUDY METHODOLOGY

Although some inferences were drawn from different parts of the world, the study was done with special emphasis to Nigeria's fresh water resources. The data for the study were obtained mainly from secondary sources: though personal observation over the years concerning the situation being investigated gave some important insight. Many books and articles published in reputable academic journals were read by the authors. A lot of information and ideas derived from such materials were noted down and subsequently expanded according to the need of this paper. The authors are very grateful to all those sources of information obtained. Consequently, the writers whose materials were cited have been duly acknowledged in the bibliography.

3. ECO – DEVELOPMENT AS A THEORETICAL FRAMEWORK

The concept of eco–development which, according to Sachs [7] is a shorthand for an ecologically sound development strategy that emphasizes the need for harmonizing economic, social and environmental concerns in the process of development. Sachs further states that eco–development should be basic in all development endeavours because environmental awareness reinforces the belief that in spite of several development paths, they are all contained in ecological contexts.

The earth is made up of several eco–units, eco–groups and ecosystems which are delicately balanced and related; and each component part performs best in a relatively undisturbed environment [7]. Kemp [8], further supported that the sub–systems like aquatic and terrestrials environment are all intimately linked and in combination constituting the whole earth and atmosphere system. The relationship is such that once there is an interference with water, land, soil or air, the entire system will be affected. This explains why in Nigeria such pollutant–yielding anthropogenic activities like modern agriculture, livestock farming, industrial and domestic work are daily generating effluents and sewage which

eventually get into water bodies through running water and pollute the resources.

Huggett et al. [9] stressed that of all the natural resources, water demonstrates most fully the interdependence of the physical and human spheres where human societies have great impact on the hydrological cycle, diverting rivers, damming flow and abstracting water for human development. Anyaegbunam [5], stressed that: cow requires about 3.5 – 5.5 litres of water to be able to produce 1 liter of milk; a chicken depends on about 7.75 litres of water for production of 1 dozen of eggs: About 165 kg of water must be available for production of 0.45 kg of dry matter in corn. Similarly, more than 10 kg of grains are required to produce only 1 kg of beef and about 60% of all grains grown in the world are used to feed livestock [10]. It is an undeniable fact that about 70% of human body weight consists of water and many of the body functions depend mostly on water. It has been estimated that each person in the United States of America uses more than 260 litres of water daily, industry uses 60 billion litres and it takes 375 billion litres of water per day to irrigate farmlands in the Southern and Western United State of America [10].

Indeed water has been the backbone of human civilization process. The place of water in shaping the early histories of Egypt and Mesopotamia can never be overlooked. Of immense historical relevance to water resources are such names like Nigeria and Niger State, derived from River Niger; Benue State, derived from River Benue; Ogun State, derived from River Ogun; Sokoto State, derived from River Sokoto; and former Gongola State, derived from River Gongola.

The demand for water is diverse in Nigeria. The first is household demand for basic needs like drinking and food preparation. The second purpose is non–basic needs like washing, swimming, gardening and agriculture, especially irrigation requirements. Besides, there are commercial and industrial needs including large quantities demanded by government and other public institutions. In general, water is needed in various quantities to meet the demand of urban centres and the rural settlements: for fishing, mining, irrigation, navigation, energy generation, livestock and wildlife. However, the concept of eco–development which believes that the environment has a maximum load which a particular project can carry should be respected

in order to safeguard water resources. Indeed, the application of the principle of eco-development in Nigerian society seems an impossible task because exploitation of the resources for the benefit of all appears to be a moral imperative by which all the available water should be exploited to the fullest extent possibly with all the means possible. Thus, the position of this paper is that Nigerians should pursue development on the environment but in a respectful manner to establish a lasting symbiosis between man and water, without polluting the latter that sustains the present and incoming generations.

4. NATURE AND SOURCES OF WATER POLLUTANTS

It is not very easy to define pollution in a single sentence because of the complex nature of the pollutants that cause environmental pollution. Kemp [8] has defined environmental pollution as the contamination of physical and biological components of the earth- atmosphere system to such an extent that normal environmental processes are adversely affected. This means pollution occurs only when the environment's capacity for dealing with additional materials is surpassed. Santra [11], sees pollution as the presence of undesirable substance in any segment of the environment (land, air, water, soil), primarily due to human activity, discharging by-products, waste products or harmful secondary products which are harmful to man and other organisms. This means environmental pollution is said to occur when the undesirable substances which are admixtures and impurities are present in substantial quantities in the environment, sufficient enough to cause appreciable harm to any component (Land, air, water or soil) or all the components of the environment.

On the other hand, water pollution is simply defined as 'the presence in water of foreign substances which could be organic, inorganic, biological or radiological in quantity high enough to lower the water quality and constitute a health hazard; because of the presence of microbiological agents, chemical agents, oxygen-depleting substances, nutrient materials and suspended matter [12].

Tripathy and Panda [13] also see water pollution as physical or chemical change in water that can adversely affect living organisms. The USA Public Health Services [13] defined water pollution as the presence of any toxic substance

in water that degrades the quality to constitute a hazard or impair its usefulness. This means any extraneous enrichment of chemicals which alter the physico-chemical aquatic environment, changing the community composition and compelling some species to disappear from the natural ecosystem with negative consequences on human beings can be considered water pollution.

Huggett et al. [9] identified two groups of pollutants: insoluble and soluble. The two main pathways for these chemicals to enter the water system are via transport of suspended particles, in the case of insoluble chemicals and dissolution of minerals and chemicals in water, in the case of soluble chemicals. The materials get to surface water systems through point and diffuse sources. Point sources refer to a point in space such as an effluent or outflow pipe like discharge of wastes from industries of definite identity with fixed volume and composition while diffuse sources refer to non- point introduction such as water flowing over field or forest surfaces, entering streams along their widely scattered and discharged margins over some considerable distance. Consequently, diffuse pollution sources are much more difficult to identify, isolate and treat [9].

A number of scholars across the world [10-17] have similar views about the major water pollutants and sources highlighted as follows:

- **Disease- causing agents:** which include bacteria, viruses, protozoa and helminths;
- **Oxygen – demanding wastes:** most of which are biodegradable like domestic sewage, animal manure and other organic wastes that do not persist in the environment;
- **Water soluble inorganic chemicals:** which include acids, salts and toxic heavy metals;
- **Sediments or suspended matter:** which include insoluble particles of soil, silt and other materials which can remain suspended in water;
- **Radio- active substances:** from nuclear testing; and
- **Heated water:** from nuclear plant discharged back into water bodies can raise the temperature beyond tolerant levels of most fauna and flora.

5. CAUSES OF WATER POLLUTION

The amount of water we consume through drinking and cooking is not the problem but the

used water we release into the environment daily at home, factories and in the field. Seymour and Girardet [14], stressed that almost every litre of water is usually polluted before is thrown into the environment. There are many ways in which water get polluted in Nigeria. They prominent causes are discussed as follows:

Agricultural Wastes: Water which is used for irrigation and flooding occasionally results in the transfer of pollutants into water bodies. Advanced agricultural technology has resulted in large- scale use of fertilizers, insecticides, pesticides, herbicides, weedicides and fungicides. Seymour and Girardet [14], argued that up to half of the artificial fertilizers used by today's farmers is washed out of the soil into water bodies annually to cause pollution which does not only affect aquatic life forms but even human beings. Livestock farming also produces huge volumes of liquid manure concentrated in small areas which easily get into water bodies and pollute the life-support system.

Industrial Discharge: Industries like textile, paper and pulp, chemical, rubber, plastic, leather and pharmaceutical usually release their toxic effluents into water bodies. Sometimes the buried industrial metals and solvents can seep through the ground to reach water bodies and cause havoc to aquatic communities. Besides, these factories use huge quantities of water for processing of products, washing and cooling and once discharged into the environment it can reach water bodies to cause havoc to life forms.

Domestic Sewage: In urban settlements, the domestic sewage is directly released into nearby water bodies while some domestic rubbish buried in landfill sites produce soluble pollutants which can seep through porous ground to reach and pollute local water bodies too. Most sewage and effluents usually contain high quantities of organic matter which easily consume dissolved oxygen of water thereby make aquatic habitat uninhabitable to organisms [13].

Mineral Exploitation: To obtain petroleum beneath water surface, oil wells have to be constructed and if precaution is not taken during construction, oil can spill to pollute water bodies. Oil spills also occur when tankers carrying oil are damaged, causing

their oil to leak into the surrounding water [10]. Besides, oil refineries situated near the river banks and sea shore readily cause oil spills by way of releasing some quantities of oil. Mining of solid minerals also release some toxic metals like lead into water bodies that can kill sensitive aquatic life forms, especially fish.

Fishing with Harmful Substances: In some localities, children and even adults ignorantly use some harmful chemicals and spread it over surface water to suffocate the fish for easy catch. Unfortunately, such toxic materials dilute with water, degrade its quality hence, capable of harming water communities. People who drink water from such polluted sources also risk their health.

Surface Run-off: During heavy rains, the surface run-off gathers minerals, top soil and many other organic impurities as it moves down and joins larger water bodies to dilute. Hence, renders such fresh water unsuitable for drinking and for other economic and social uses.

Heat: Water discharged from certain industries like iron and steel plants, petroleum refineries, nuclear reactors and electric power plants always carry a lot of heat. When the thermal water is introduced into water bodies, it causes thermal pollution, killing substantial life forms.

Radio-active Wastes: When radio-active wastes containing different isotopes are discharged into aquatic system, they do not only pollute the water bodies but adversely affect aquatic life and human beings who consume both water and aquatic animals.

Human Excreta: In cosmopolitan cities of Nigeria, particularly slum areas where there is acute shortage of toilet facilities, people simply resort to open defecation thereby giving rise to land, soil and water pollution directly, as observed in urban areas that have streams passing through them. Yet, there are other people who decide to pass their excreta in the bush, not minding how near it is to their dwelling place. However, when such excreta is disposed of on land or stream, it eventually gets to the larger water bodies and pollute the resources. This has adverse environmental consequences especially to animals and human beings.

6. PROFILE OF NIGERIA'S WATER RESOURCES

Nigeria has an estimated total surface area of about 94,185 000 hectares of land mass of which 12,244,050 hectares (13%) is made up of inland waters in lakes, rivers and dams [12]. The Federal Ministry of Information and Communication gave estimates of surface and underground water as 267.3 billion m³ and 52 billion m³ respectively, with just 10% of these enormous amounts of water being currently exploited [1].

A good number of these water resources have been dammed for some specific purposes. According to Akinbode [18], the total water income of Nigeria is derived from two major sources namely: Rainfall and surface water. Rivers Niger, Benue and Cross bring in water from neighbouring countries while part of the rain that falls is returned back to the atmosphere through the process of evapo-transpiration; yet the last part sinks into the ground to become part of underground water.

The bulk of the water resources are found in numerous rivers dissecting the country. There is indeed, no part of the country without at least a major river. There are mainly four major hydrological centres serving as watersheds of Nigerian rivers: the North Central Highlands, Eastern Highlands, Western Highlands and Eastern Scarpland. The major rivers from the North Central highlands are Kaduna, Yobe, Zamfara, Sokoto and Gongola; from the Eastern Highlands are rivers Donga and Katsina-Ala; from Eastern Scarpland are rivers Imo and Anambra and from Western Highlands are rivers Ogun, Osun and Osse.

Of the total water surface in Nigeria, only about 853, 600 hectares (0.9%) constitutes inland water: 13 lakes and about 200 dams of varying sizes like Lakes Chad, Pandam, Tiga, Bakolori, Kiri, Oyan, to mention but a few [12]. Lwahas et al. [12] gave startling statistics of Nigeria's water situation thus: total water withdrawals for domestic, industrial and agricultural is 13.11 km³ per year; annual budget allocation to water sector is less than 5%; of the 150 million people only 43% have access to safe water (which translates to only 64.089 million people); of the 64.089 million people that have access to clean and safe water, 39.731 million (62%) are urbanites and only 24.358 million (38%) people are in rural areas, enjoying the facility.

The above analysis clearly shows that most Nigerians have no access to clean and safe water and by implication, they drink and prepare food daily with water that is already polluted. However, the advent of European colonialists did not help in improving Nigeria's water problem significantly. They deliberately embarked upon water supply schemes in just some selected urban centres to facilitate administration throughout the country. Although, successive administrations by Nigerians themselves made efforts by establishing eleven River Basins & Rural Development Authorities and Directorate of Food, Roads and Rural Infrastructure (DFRRI) in 1976 and 1986 respectively, where new phase of rural water supply schemes were embarked upon, yet the problem of safe water supply to the masses have not yielded the desired dividend [18]. Admittedly, pipe-borne water is being supplied to an increasing number of rural communities yearly, yet the supply cannot keep pace with the demand. It is observable that poorer people who live in the rural areas and in the poorer parts of the urban areas are either spending more time each day in search of water or spending more money to purchase this life-supporting resource.

The major problem of buying water lies in the fact that the sources of such water are usually not known to the consumers, as some unscrupulous water vendors could simply fetch water from polluted streams or even gutters and sell to innocent consumers and endanger their health.

The position of this paper is that there is urgent need for the relevant authorities and the general public to do everything possible to safeguard these fresh water resources from further degradation as there cannot be realistic development when the health of the citizenry is being endangered by what Webb and Iskandarani [9] described as:

- Water-borne diseases—typhoid, cholera, dysentery, gastro – enteritis and infectious hepatitis;
- Water-washed infections of the skin and eyes – trachoma, scabies, leprosy, conjunctivitis and ulcers;
- Water-based diseases – schistosomiasis and guinea-worm;
- Diseases from water-related insect vectors such as mosquitoes;
- Infections caused by defective sanitation.

7. DETRIMENTAL EFFECTS OF CONTINUED FRESH WATER POLLUTION

Various pollutants entering surface water either naturally or through human beings have human and environment consequences. Apart from the economic implications like spending money to buy water from water vendors, medical expenses incurred for treating patients of water-borne diseases and the hours dissipated in search of safe water, there are many negative effects. According to Eziashi [19], the effect of uncontrolled pollution as seen all over Nigeria renders stream channels and waterways unsafe for human, agriculture and recreational uses; destroys biotic life, poisons the natural ecosystems, poses a threat to human life and is therefore, against the principles of sustainable development. The human and environmental consequences of the increase discharge of pollutants into Nigeria's fresh water resources are generally discussed, thus.

Health Hazards: Water polluted with human and animal faeces often contain different forms of bacteria, viruses, protozoa and helminths which can cause diseases like dysentery, typhoid, and infectious hepatitis. The implication of contracting the diseases is that one becomes sick, debilitated, and weak and may even die. Effluent flowing from factories and fields containing cadmium, mercury, lead, nickel, antimony and arsenic can get to the natural water and be assimilated at low concentrations by aquatic organisms over time. Fish caught and eaten from such contaminated body of water pose health hazards to both children and adults. Infants often suffer severe brain damage and nervous system damage from methyl mercury when passed from the fish to the mother through placenta to the foetus [17]. The symptoms include breathing difficulty, blue skin, colouring and suffocation while lead poisoning in human beings generally range from anaemia, headache, sore muscles (when in small concentrations), to malfunctioning of kidney, reproductive system, liver and central nervous system.

Death of Aquatic Fish: Organic matter which includes dead leaves, human and animal excreta are mainly from fields, homes and factories. The presence of these pollutants in water results in reduction of dissolved oxygen, leading to an increase in

the amount of oxygen needed to break down oxygen demand. The resulting anaerobic condition produces foul smell due to the accumulation of ammonia and hydrogen sulphide. This can eventually lead to the death of many aquatic fauna not adapted to low oxygen concentration.

Death of Water-related Birds: Aquatic organisms are greatly affected, including birds of the air. When water bodies are polluted with oil, fish-eating birds may swallow oil or have their feather soaked with oil and would not be able to fly; hence may be easily caught by their predators. Because oil usually excludes oxygen from water, water-dwelling organisms get suffocated and die too. The hazards of oil on organisms are noticeable on oil-spoiled beaches where all kinds of aquatic life forms on rocks or in mud are often seen dead and washed onshore.

Joblessness among Fishermen: Fishing is a popular activity in Nigeria where many ethnic groups in riverine areas engage in it for livelihood. Pollution of water bodies implies reduction in fish catch and may put the local fishermen out of business as it happened sometime in 1980 at Akassa, Rivers State when Oil spill killed large number of fishes in the area and neighbouring creeks [16].

Reduction in Fish Supply: The presence of toxic pollutants in water bodies often soften the exo-skeleton or carapace of fish-like creatures and expose them to various disease conditions and a considerable number may die. The death of aquatic organisms does not only throw fishermen and other water-related business activities out of jobs but reduces fish supply generally. The absence of these proteinous foods from people's table has direct effect on their health by exposing them to protein-deficiency disease conditions.

Change in Species Composition: Some industries such as thermal power plants and nuclear reactors withdraw water from fresh water for cooling purposes but return same at higher temperature with deleterious consequences. The heated water dissolves oxygen at the faster rates than cool water and increase the rate of chemical reaction including decomposition, thereby leading to depletion of oxygen. In a thermal-polluted

water, oxygen is depleted but the growth of thermophilic species is enhanced hence upsets species composition.

Floral Photosynthesis Impaired: The presence of insoluble particles suspended in water bodies make water cloudy and murky. These solid particles which are mostly derived from cultivated lands, overgrazed lands, degraded stream banks, strip mines and construction sites make the water dark hence reduces light penetration. As a result of light reduction, the normal photosynthesis of under-water plants will be impaired to the disadvantage of aquatic animals that depend on such plants for livelihood. Impaired photosynthesis by aquatic plants reduces the concentration of dissolved oxygen in the water body. Under conditions of low dissolved oxygen, anaerobic reactions for the degradation of pollutants begin to occur hence, may lead to the deterioration of the water body beyond recovery.

Ecological Succession: The concentration of nutrients in natural water from wash-down sources usually increases the growth and number of aquatic organisms. The presence of these pollutants, particularly nitrogen compounds, sulphur, phosphorus and metal ions create a new environment hence the physical, chemical and biological properties change; leading to new organisms getting into the system while others will disappear. Since there is dense growth in algae bloom and other aquatic plants that now cover the water surface, photosynthesis is prevented thus, the feeding habits of aquatic animals may change from simple autotrophic to heterotrophic mode known as eutrophication, which is a natural process of ecological succession.

Loss of Aesthetic and Recreational Value of Water Fronts: In the economically developed nations, there is increasing pressure on the water resources as well as public concern about social uses of rivers, such as swimming, recreation which ought to be considered when surface water is being allocated [19]. Indeed, water sites like rivers, lakes, lagoons and reservoirs are very useful for recreation purpose where a lot of Nigerians and expatriates visit such areas on public holidays, weekends and other festive occasions. Many of them undertake swimming either for pleasure or as an

exercise or both. However, a polluted water body that emits bad smell and is clogged with debris or covered with algae bloom can be offensive, hence unpleasant to visit. The stench can also arise from decaying organic matter and sewage which may replace the natural state of water. The implication is that such a body of water that emits foul odour to cause noxious smell will certainly lead to loss of the beautiful sites for recreation and tourism development.

8. HUMAN HEALTH RISK ASSESSMENT OF NIGERIA'S WATER QUALITY

Nigeria's water is being impregnated daily with pollutants from such sources as industries, farms, cities and oil spills. For instance, industries pour into rivers, lakes and ocean a vast array of contaminants such as lead, asbestos, detergents, solvents, acid and ammonia; farmers' agro-chemicals like pesticides, herbicides, fertilizers and animal waste drain into streams and lakes; city dwellers dispose of their wastes including sewage and microorganisms into rivers to end up downstream in other people's drinking water sources; and oil spills caused by tanker accidents or leaks in offshore drilling pollute water bodies. Water is indeed, the most immediate problem in less developed countries where about 80% of their national industrial and domestic wastes are discharged untreated into rivers to cause pollution and water scarcity [20]. Eitzen and Zinn, further argued that 'shortage of water' led to the tripling of demand between 1950 and 1990 and that the demand is expected to even outstrip supply by 56% in 2025.

In Nigeria, fresh water is being saturated with bacteria, viruses, protozoa and parasitic worms coming from domestic sewage, human excreta and animal wastes. World Health Organization [21] maintained that these microorganisms are the greatest cause of sickness and death of 25,000 people every day worldwide. Most of the studies revealed that bacteriologically, most of the water, particularly rivers and streams are heavily polluted due to the high numbers of coliform organisms found in them, with total coliform counts exceeding 1800 per 100 milliliters of water sample against the WHO recommendation of zero colony per 100 milliliters for drinking water [21].

Similarly, available work on oxygen demanding wastes in Nigerian surface water showed a

generally very low amount of dissolved-oxygen (DO) in them. Eziashi [21] reported that Martin's water quality study of the Ogun River at Olokomeji has revealed that the dissolved oxygen ranged between 6 mg/l and 9 mg/l; indicating that the degree of pollution was slight to moderate.

Maigari et al. [22] carried out a health risk assessment for exposure to some selected heavy metals via drinking water from Dadin-Kowa dam and River Gombe, Northeast Nigeria. The concentration of iron, manganese, copper, lead, cadmium, nickel, cobalt and zinc were determined in water from Dadin-Kowa dam and Kwadon boreholes which are the major sources of drinking water for Gombe town. The human health risk assessment was performed and the hazard quotient of the metals from all the sampled sites were greater than unity and the total hazard index of water from all the sampled sites were of high risk to both children and adults.

In like manner, Jidauna et al. [23] conducted chemical water quality assessment in selected locations in Jos, Plateau State, Nigeria. Chemical parameters were tested and the results indicated that though pH, electrical conductivity, total dissolved solids, lead, arsenic, and cyanide appeared within the acceptable national standard for drinking water quality however, nitrate, tetraoxosulphate (vi) acid (H_2SO_4), iron and lime in some parts of Jos Metropolis fall outside acceptable standard. Hence the study concluded that well water quality through chemical assessment in Jos metropolis is not fit for drinking without treating it.

Adeniyi et al. [24] carried out classification and health risk assessment for borehole water contaminated by metals in selected households in Lagos-Ogun axis of Southwestern Nigeria. The analysis was for silver, iron, manganese, lead, nickel, magnesium, cadmium, zinc, sodium, potassium, pH, turbidity, dissolved oxygen, electrical conductivity, alkalinity, total hardness, chloride, nitrate and sulphate, following standard methods of water analysis. The results obtained were compared with global background values and WHO guidelines for drinking water. Health risk assessment for exposure to cancer and non-cancer indices was evaluated and it was found that 19 of the 20 household water samples fall short of the ideal water quality suitable for lifetime use because it was impregnated with pollutants.

Eno and Etuk [25] also conducted human health assessment of trace metals in water from Qua Iboe River Estuary Ibeno, Southeastern Nigeria. Trace metals in water from the river was measured using atomic absorption spectrophotometer and human health risk induced by the trace metals in dry and wet seasons was investigated using mathematic models recommended by US EPA. The results indicated that concentration of metals were far above US EPA limits for lead, cadmium, magnesium, volatile, chromium, nickel and iron but the target hazard quotient and hazard index values via ingestion of water were greater than one for cadmium only. The combined target hazard index from ingestion and dermal contact of water was greater than unity for cadmium, chromium and lead for wet and dry seasons. Therefore, it was concluded that lead, cadmium and chromium may contribute to health risk from dermal and oral exposure to water from the Quo Iboe River Estuary system.

Similar assessments of water quality in different parts of China have been carried out by several scholar [26-29] and their findings indicated that both surface and shallow groundwater were polluted; consequently, dangerous to people who ingested the water without treatment.

The foregoing water quality assessments from different parts of the country carried out by scholars, have clearly shown that many Nigerians do not have enough safe water and the situation is likely going to worsen, giving the fact that there is now increased urbanization, industrialization and agro-chemical usage on farms by Nigerian farmers. Hence, there is need to evolve high technology that would help in removal of pollutants from drinking water to curtail the risk of contracting water-borne diseases. Sensitization campaign on the importance of clean water and sanitation should be embarked upon by government, non-governmental organizations, educational institutions and individuals in order to protect Nigerian citizens from being exposed to undue health hazard arising from water pollution.

9. RECOMMENDATION

In view of the hazards arising from increased discharge of pollutants into Nigeria's fresh water resources, the following are measures that need to be taken in order to forestall further degradation.

Pollution Control at Source: The most common and easiest approach to restoring polluted water is to reduce or stop further input of water pollutants and wait for natural processes to remove or destroy those already in the system.

Dredging: Many water pollutants such as phosphates, toxic organic and heavy metals can attach themselves to fine sediments and accumulate at the bottom of water bodies for a long time. These can be removed by dredging which takes the entire pollutants out of the system. However, effort should be made during dredging to minimize the quantity of fine suspended sediments returning back into water as they may contain higher concentrations of pollutants.

Chemical Treatments: The addition of aluminum, calcium and iron salts can fix phosphorus in sediments. This reduces eutrophication, thus reducing algal bloom that might pollute fresh water. It is more economical to use these chemicals than using synthetic algacides to destroy algae bloom. Treatment with these harmless chemicals could be repeated every two or three years in order to keep the water source usable.

Physical Treatment: This can be done using physical barriers like impermeable plastic liners which can be placed on top of the sediments over a limited water body like a small useful reservoir and held in place by a layer of sand.

Waste Water Treatment: This is the treatment of sewage which has to undergo several processes of purification at the sewage treatment plant to prevent environmental and public health problems. It is done in such a way as to remove suspended and floating particles like sand, silt, solid, grease and scum before the waste is chlorinated to kill harmful disease-causing organisms. Different types of wastes including industrial effluents, sewage and sludge of municipal and other systems as well as thermally polluted water may be recycled to beneficial use. Urban waste may be recycled to generate cheaper fuel gas and electricity, thus recycling, reutilization, renovation and recharge of waste water reduces water pollution.

Removal of Pollutants through Suitable

Techniques: Appropriate methods for removing pollutants in water exist. Tripathy & Panda [13] have suggested adsorption, electro-dialysis, ion-exchange and reverse-osmosis, among others as appropriate techniques. They averred that ammonia in waste water could be removed by ion-exchange technique; mercury could be removed from chloro-alkali effluent plants through mercury selective ion-exchange resin; phenolics could be removed from waste water by the use of polymeric absorbents; decolourization of water could be corrected through electrolyte decomposition technique; and sodium salts could be removed through reverse-osmosis technique.

Public Enlightenment: Creation of public awareness on the causes and hazards of water pollution can have desirable effect at curtailing the problem. Educating farmers properly could help to make them shift from the use of chemical fertilizers to traditional manure that is less injurious pollutants than agro-chemicals. Measures should also be put in place to control soil erosion that usually transfer chemicals and other solid matter into water bodies to pollute them.

Fresh Water Pollution Abatement:

Government at Federal, State and Local levels should lay down restrictions for waste discharge into waterways, based on hygiene standards for water quality. Government, as a matter of urgency should enact and pass laws prohibiting industries and other institutions from discharging harmful pollutants into water bodies without treating to remove the pollutants. The enforcement of the law will help in controlling the pollution of water generally and fresh water pollution in particular.

10. CONCLUSION

It has been pointed out in this paper that water is one of the basic elements of human existence on planet—earth. Indeed, Nigeria is endowed with enormous quantities of both surface and underground water resources. In spite of this, many Nigerians do not have access to safe and clean water. This is because most of the surface water is being enriched with physical, chemical and biological pollutants arising from such anthropogenic activities like modern agriculture,

livestock farming, and mining, manufacturing, fishing and poor disposal of domestic and industrial sewage. The presence of these pollutants into Nigeria's fresh water resources have human and environmental consequences, including posing health hazards, death of aquatic animals, reduction in fish supply from people's table, change in species composition and upsetting the ecological balance. It is hope that controlling pollution at source, dredging of polluted water bodies, treatment of polluted water for recycling and reutilization of waste water, public enlightenment campaign as well as enactment and enforcement of water pollution laws will no doubt, help to prevent further degradation of Nigeria's fresh water resources.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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