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Emphasis on Effects of Storm Runoff in Mobilizing the Heavy Metals from Leachate on Waste Deposit to Contaminate Nigerian Waters: Improved Water Quality Standards

N. I. Onwughara, U. C. Umeobika, P. N. Obianuko and I. M. Iloamaeke

***Abstract*-The alarming increase, in water pollution has been reported in a number of cities, throughout the world because of its overwhelming environmental significance. Due to the decomposing nature of the open dumps and industrial discharges, urban storm-water runoff, and agricultural drainage, the resultant leachates which are mobile, can pollute surface and underground waters. This work emphasized more on heavy metals from leachate which were known to accumulate in selected tissues of the human body and have the potential to be toxic even at minor levels of exposure. Effective water resources management programmes, improved water quality standards, effluent and site control guidelines and effective monitoring of industrial discharges in Nigeria were discussed.**

***Index Terms*-Contaminants, Heavy Metals, Legislation, Nigeria, Sound Management, Toxicity, Water Pollution and Water Resources,**

I. Introduction

The global community is becoming increasingly aware of the values of an ecosystem, as well as the implications of man's activities on sustainable development; an advocate of a balanced and quality environment. A balanced and quality environment in-turn sustains biodiversity, healthy biophysical domain, promotes socio-economic and public health sectors. What is yet to be fully known by a generality of the society particularly in the developing world are the ecological and toxicological implications of increased releases and discharges of heavy metals into the environment. David, 1996 [1], noted that about 150 million tons of municipal solid waste and 240 million tons of industrial solid waste are deposited in 16,400 landfills in the United States yearly. Some hazardous waste materials are deposited in municipal landfills, and underlying groundwater may become contaminated. Municipal solid wastes management in Nigeria and other developing countries reveals a poor state of disposal methods in urban areas.

Heavy metals are elements having atomic weights between 63.546gramme and 200.590gramme and a specific gravity greater than 4.0 i.e. at least 5 times that of water. They exist in water in colloidal, particulate and dissolved phases [2] with their occurrence in water bodies being either of natural origin (e.g. eroded minerals within sediments, leaching of ore deposits and volcanism extruded products) or of anthropogenic origin (i.e. solid waste disposal, industrial or domestic effluents, harbour channel dredging) [3]. Some of the metals are essential to sustain life-calcium, magnesium, potassium and sodium must be present for normal body functions. Also, cobalt, copper, iron, manganese, molybdenum and zinc are needed at low levels as catalyst for enzyme activities [2], however, excess exposure to heavy metals can result in toxicity.

Municipal and industrial discharges, urban storm-water runoff, and agricultural drainage can result in heavy metals, nutrients, pesticides, and organic wastes being transported into aquatic ecosystems. In aquatic ecosystems, contaminants are often rapidly removed from the water column via sorption processes [4]. Given that heavy metals are not subjected to degradation processes, they tend to accumulate in benthic sediments [5]. However, heavy metals are not necessarily fixed permanently to sediments; rather they may be remobilized via chemical, physical, and biological processes. The geochemical processes that control the metal mobility and its availability are dissolution, adsorption into mineral and organic particles, mineralization, complexation by biogenic or nonbiogenic ligands, and subsequent uptake by biota [6].

The development of the electronics industry has led to an increase not only in the production of new goods but also in the scrap generation and the volume of waste material left after lifetime of these goods. This electronic waste (e.waste) has toxic heavy metals that pose a serious environmental threat unless proper treatment of these wastes is carried out [7]. In Nigeria and other developing countries, these hazardous materials are disposed of with municipal solid waste into open dumps and surface water bodies, often used for domestic purposes [8]. When disposed through these routes, toxic substances can leach and eventually

N. I. Onwughara is with the Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University Awka, P.M.B. 5052 Awka, Anambra State, Nigeria (Corresponding Author: Phone: +2348063781088, e-mail: onwugharankwachukwu@yahoo.com).

U. C. Umeobika is with the Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University Awka, P.M.B. 5052 Awka, Anambra State, Nigeria (e-mail: ugowens84@yahoo.com).

P. N. Obianuko is Raw Material Research and Development Councils, Okpuno Road, Anambra State., Nigeria. (e-mail:ucheobianuko@yahoo.com).

I. M. Iloamaeke is with the Department of Pure and Industrial Chemistry, Nnamdi Azikiwe University Awka, P.M.B. 5052 Awka, Anambra State, Nigeria (e-mail: ifeomailoamaeke@yahoo.com).

contaminate surface and groundwater. In Nigeria, open dumping of municipal solid wastes, is mainly the existing method of waste disposal used even in capital cities except perhaps among few and affluent institutions [9].They have become the simplest, cheapest and most cost-effective method of disposing municipal solid waste [10]. In many developed countries, most solid wastes are landfilled or buried [11].

Water contamination by Leachate can transmit bacteria and disease, typhoid fever is a common problem for the people of developing nations, many of them cannot afford to dig wells deep enough to reach fresh aquifers [8]. There is need to simulate the effect of storm runoff in mobilizing the metals to contaminate surface waters used for domestic purposes and also in making these metals bio-available to soil biota. Most non-functioning electronics and electrical equipments donated for 'charity' have been a means of disposing waste electronic devices in the developed countries. The proliferation of urban settlements and slum in the cities also meant increased human pressure and the generation of domestic effluents, which eventually find their way into the water bodies such as rivers, etc. These bodies receive a complex mixture of domestic and industrial waste and have served as the ultimate sink for the disposal domestic sewage since the latter part of the 19th century.

Lee et al [12] noted that landfilling and incineration are not accepted as option in the management of waste computer monitors. This is because when landfilled, the lead they contain could pose a threat to the environment, due to the acidic leaching of high concentrations of heavy metals to the ground water [13].

Similarly, considering that the components contain brominated flame retardants in the plastic and PWB components, the incineration process of these materials could produce dioxins and furans in the gas mixture, which are indeed very toxic compounds. This cocktail of toxins could be transported long distances in the fly ash particulates (which could be inhaled) and significant quantities left in the ash and cinder. The results of this study indicate that storm runoff could easily wash these toxins to contaminate surface and ground water sources.

From Nnorom et al [14] study test on evaluation of heavy metal release from the disposal of waste computer monitors, provides valuable information on the leachability/mobilization of heavy metals especially lead from broken computer monitors at waste disposal points. Of much concern is the observation that deionized water extracted as much as 10% of the lead content of the CRT glass indicating the extent storm runoff could mobilize toxins from inappropriately disposed CRTs [14].

The aim of this paper is to examine and emphasized more on the surface water and groundwater pollution which results from wastes generated by industrial, commercial and household activities in several urban centers of Nigeria. The various efforts made at promoting standards are described and their effectiveness in achieving desired objectives is evaluated. Other response strategies for reducing the health risks from water contamination are presented. The paper emphasizes the need for (a) improved water quality standards and criteria; (b) effluent and site control guidelines; (c) effective monitoring of industrial discharges; and (d) effective water resources management programmes.

A. The Study Approach And Study Locations

Nigeria is located approximately between latitude 4° and 14° North of the Equator, and between longitudes 2° 2' and 14° 30' East of the Greenwich meridian Fig. 1 [15]. It is bordered to the north by the Republics of Niger and Chad, to the south by the Atlantic Ocean, to the east by the Republic of Cameroon and to the west by the Republic of Benin. The population is more than 100 million, spread unevenly over a national territory of 923,770 km^2. Nigeria has the eighth largest national population in the world and about a quarter of the total population of all the countries in Sub-Sahara Africa [15].

The climate, which affects the quality and quantity of the country's water resources, results from the influence of two main wind systems: the moist, relatively cool, monsoon wind which blows from the south-west across the Atlantic Ocean towards the country and brings rainfall, and the hot, dry, dust-laden Harmattan wind which blows from the north-east across the Sahara desert with its accompanying dry weather and dust-laden air. The mean temperature is generally between 25°C and 30 °C (77°F and 86 °F), although because of the moderating influence of the sea the mean daily and annual maximum temperatures increase from the coast towards the interior. In the dry season the temperatures are more extreme, ranging between 20 and 30 °C (68 and 86 °F) [15].

Based on the degree of industrialization, cities in West Africa can be divided into four basic categories: very highly industrialized, highly industrialized, moderately industrialized and poorly industrialized [16]. The very highly industrialized cities are Lagos, Kaduna and Port Harcourt and the highly industrialized urban centers of Kano, Ibadan and Jebba. Lagos is the commercial capital of Nigeria and the most rapidly urbanizing center in West Africa. It also is a center for indiscriminate dumping of refuse. Refuse dumps usually approach the size of large mounds or hills and remain uncollected for several months. The present study evaluates the impacts of industrial establishments on water quality. In addition, results are presented on the quality and possible contamination of groundwater in areas close to refuse tips (landfills) in the Lawanson and Ikeja industrial areas of Lagos [16]. According to the Lagos State Waste Disposal Board, domestic, industrial and commercial wastes constitute about 35 %, 38 % and 20 %, respectively of the total wastes gathered in the Lagos metropolitan area. In all the urban centers of Nigeria, the high density traditional, or old-core, areas normally generate more solid wastes than the newer areas. Indeed, in these areas, it is a common sight to see solid wastes blocking sections of streets and open spaces. Such dumps emit offensive odors and constitute health hazards to neighborhoods [8]. In addition, the leaching of solid wastes into groundwater poses growing health risks for the large urban population that relies on groundwater for domestic use. Worse still, during the rainy season, damaging floods often occur as a result of solid waste blocking gutters and river channels in urban areas [8], [7], [16].

II. Water Resources

Nigeria has abundant water resources although they are unevenly distributed over the country. The highest annual precipitation of about 3,000 mm occurs in the Niger Delta and mangrove swamp areas of the south-east, where rain falls for more than eight months a year. There is a progressive reduction in precipitation northwards with the most arid north-eastern Sahelian region receiving as little as 500 mm a -1 precipitation from about 3-4 months of rainfall. Widespread flooding occurs in the southern parts of the country, while the northern parts experience chronic water shortages during the dry season when rainfed springs, streams and boreholes dry up. There are four major drainage systems in the country Fig. 2.

• The Niger River Basin Drainage System with its major tributaries of Benue, Sokoto-Rima, Kaduna, Gongola, Katsina-Ala, Donga, Tarabe, Hawal and Anambara Rivers.

• The Lake Chad Inland Drainage System comprising the Kano, Hadejia, Jama'are Misau, Komadougou-Yobe, Yedoseram and Ebeji Rivers.

• The Atlantic Drainage System (east of the Niger) comprising the Cross, Imo, Qua Iboe and Kwa Rivers.

• The Atlantic Drainage System (west of the Niger) made up of the Ogun, Oshun, Owena and Benin Rivers.

A. Water Pollution

Water pollution in Nigeria occurs in both rural and urban areas. In rural areas, drinking water from natural sources such as rivers and streams is usually polluted by organic substances from upstream users who use water for agricultural activities [15]. The most common form of stream pollution associated with forestry activities is increased concentrations of soil particles washed into the stream by land disturbance. The large particles sink to the bottom and increase the bed load while, depending on the stream velocity, smaller particles remain in suspension. In the river Niger, for example, studies have shown that the suspended matter can obstruct the penetration of light and limit the photosynthetic zone to less than 1 m depth. Suspended sediments in watercourses have become a serious concern for the water supply authorities because they lead to increased water treatment costs [15].

Many factories in Nigeria are located on river banks and use the rivers as open sewers for their effluents. The major industries responsible for water pollution in Nigeria include petroleum, mining (for gold, tin and coal) wood and pulp, pharmaceuticals, textiles, plastics, iron and steel, brewing, distillery fermentation, paint and food, of all these, the petroleum industry presents the greatest threat to water quality [8], [15]. From time to time accidental oil spillages occur which endanger local sources of water supply and freshwater living resources, especially in the rural areas. The have shown that the suspended matter can obstruct the penetration of light and limit the photosynthetic zone to less than 1 m depth. Suspended sediments in watercourses have become a serious concern for the water supply authorities because they lead to increased water treatment costs. Surface water and groundwater contamination, air pollution, solid waste dumps and general environmental degradation, including the loss of land and aquatic resources, are major environmental problems caused by industrialization in Nigeria. Improper disposal of untreated industrial wastes has resulted in coloured, murky, odorous and unwholesome surface waters, fish kills and a loss of recreational amenities. A significant proportion of the population still rely on surface waters for drinking, washing, fishing and swimming. Industry also needs water of acceptable quality for processing [8], [9], [15].

Some of the long term impacts of dredging have been associated with heavy metal pollution from abandoned dredged spoil, which have been implicated in the pollution of both surface and ground water, toxicity and bioaccumulation phenomena resulting from the leaching of heavy metals from spoils. Dredge spoils in the Niger Delta are rich in pyrite (FeS) and principally contaminated by heavy metals [17]-[19]. Dredging has been reported to cause the re-suspension of sediments, which is linked to the re-mobilization of contaminants particularly heavy metals and increasing their bioavailability [17], [20]. Re-suspension of sediment causes the oxidation of sediment leading to the mobilization of metals into the water body [17], [19], [21]. It has been variously reported that sediments are sinks for heavy metals and their disturbance through dredging could cause the re-mobilization of metals [20], [22].

Specific regulations to protect groundwater from pollution have also been issued by the Federal Environmental Protection Agency of Nigeria (FEPA) [23], [24]. Industrial sites have to meet concentration limits for their effluents, as given in Table I. These are specified in facility permits issued to the industries and enforcement takes place by compliance monitoring.

TABLE 1 Maximum permitted concentrations of toxic substances in industrial effluents in Nigeria for the protection of groundwater.

Variable	Maximum Concentration (Mg/l)
Arsenic	0.05
Barium	1.0
Cadmium	0.01
Chromium	0.05
Lead	0.05
Mercury	0.002
Selenium	0.01
Silver	0.05
Endrin	0.0002
Lindane	0.004
Methoxychlor	0.1
Toxaphene	0.005
2,4-D	0.1
2,4,5-TP Silvex (tree killer)	0.01

Source: FEPA, 1991c [25].

B. Surface Water Contamination

Health risks from surface water contamination can also be illustrated with the effects of textile industries in Kaduna, Kano and Lagos. In all these cases, the effects on the receiving rivers and streams include coloration, high pH, high total solid contents and relatively high values of

sodium, magnesium, calcium, manganese and iron. Because much of the population in the country depends upon streams and rivers for their daily water requirements, there is clearly a need to ensure the monitoring of the effluents discharged into these streams and river. However, because the volume of most effluents is small compared with the volume of the river, the adverse effects of the effluents are localized to the immediate vicinity of the discharge point. The effects of the effluents of this plant were devastating on both surface water and groundwater.

C. Groundwater Contamination

The risk of groundwater pollution has become one of the most important environmental concerns. Considering that, groundwater is a major source of drinking water for more than half of the world's population. When waste is landfilled, the lead they contain could pose a threat to the environment, due to the acidic leaching of high concentrations of heavy metals to the ground water [13].The leaching of solid wastes into groundwater poses growing health risks for the large urban population that relies on groundwater for domestic use. Water contamination by Leachate can transmit bacteria and disease, typhoid fever is a common problem for the people of developing nations, many of them cannot afford to dig wells deep enough to reach fresh aquifers [8]. Leachate from the landfill can enter ground water systems, leading to increase in nutrient levels that cause eutrophication, [26], [27].

Leachates have been reported to possibly cause growth retardation and haematological abnormalities [28]. Carla, 1997 [29], argued that in the next few decades, more polluted aquifers will be discovered, new pollutants will be identified, and more polluted groundwater will be discharged into wetlands and streams as groundwater passes through the hydrological circle. There is need to simulate the effect of storm runoff in mobilizing the metals to contaminate surface and groundwaters used for domestic purposes and also in making these metals bio-available to soil biota. Federal Ministry of Water Resources, 2004 [30], estimated that 150,000 to 200,000 children are lost to diarrhea related deaths each year; cholera, typhoid, paratyphoid, guinea worm, bilharzias and shistosomiasis are all common nationwide. Pink, 2006 [31], suggested, that it is the leading worldwide cause of deaths and diseases, and that it accounts for the deaths of more than 14,000 people daily. An estimated 700 million Indians have no access to a proper toilet, and 1,000 Indian children die of diarrheal sickness every day [32]. In recent years, the widespread reports of pollutants in groundwater have increased public concern about the quality of groundwater. In addition, acidification and nitrification of groundwater have been linked to dumpsite around their outlets in Philippines [33]. While a number of dumpsites in Germany, have been implicated for bacterial contamination of drinking water. Due to the decomposing nature of the open dumps, the resultant leachates from the dumps are mobile and can pollute groundwaters in distant areas. When the waste dump site is located on the recharge area of an aquifer, that aquifer is liable to leachate pollution. Lee et al 1993 [34], have provided a general discussion of the potential for municipal dump leachate to pollute groundwater, rendering them unstable for domestic water supply purposes. Fig. 3 shows typical picture of water which runs over the solid waste dump, infiltrates from the solid waste extracts dissolved and suspended constituents and thus becomes a contaminated liquid called **leachate** spring.

D. Toxicity

The pollution of aquatic ecosystems by heavy metals is a significant problem, as heavy metals constitute some of the most hazardous substances that can bio-accumulate. Heavy metal can cause serious health effects with varied symptoms depending on the nature and quantity of the metal ingested [36]. They produce their toxicity by forming complexes with proteins, in which carboxylic acid (–COOH), amine (–NH2), and thiol (–SH) groups are involved. These modified biological molecules lose their ability to function properly and result in the malfunction or death of the cells. When metals bind to these groups, they inactivate important enzyme systems or affect protein structure, which is linked to the catalytic properties of enzymes. This type of toxin may also cause the formation of radicals which are dangerous chemicals that cause the oxidation of biological molecules.

Metals that are deposited in the aquatic environment may accumulate in the food chain and cause ecological damage while also posing a risk to human health. Surface water and groundwater contamination, air pollution, solid waste dumps and general environmental degradation, including the loss of land and aquatic resources, are major environmental problems caused by industrialisation in Nigeria. Improper disposal of untreated industrial wastes has resulted in coloured, murky, odorous and unwholesome surface waters, fish kills and a loss of recreational amenities. A significant proportion of the population still rely on surface waters for drinking, washing, fishing and swimming. Industry also needs water of acceptable quality for processing.

The abandonment of unconfined dredged materials in the fringes of canals, in the Niger Delta where annual rainfalls exceed 2800mm often causes the leaching of metals into the environment, i.e. releasing the metals that were bound in the spoils into solution, making them bioavailable, more mobile and toxic. These metals are known to accumulate in selected tissues of the human body and have the potential to be toxic even at minor levels of exposure. Chronic exposure to heavy metals at high enough levels can lead to toxic effects and a variety of health problems such as hypertension in individuals exposed to lead and renal toxicity in individuals exposed to cadmium [37]. The most common heavy metals that humans are exposed to are Aluminum, Arsenic, Cadmium, Lead and Mercury. Aluminum has been associated with Alzheimer's and Parkinson's disease, senility and presenile dementia. Arsenic exposure can cause among other illness or symptoms cancer, abdominal pain and skin lesions. Cadmium exposure produces kidney damage and hypertension. Lead is a commutative poison and a possible human carcinogen [38] while for Mercury, toxicity results in mental disturbane and impairment of speech, hearing, vision and movement [39]. In addition, Lead and Mercury may cause the development of autoimmunity in which a person's immune system attacks

its own cells. This can lead to joint diseases and ailment of the kidneys, circulatory system and neurons. At higher concentrations, Lead and Mercury can cause irreversible brain damage.

In Nigeria today, the use of ground water has become an agent of development because the government is unable to meet the ever increasing water demand. Thus, inhabitants have had to look for alternative ground water sources such as shallow wells and boreholes. The quality of these ground water sources are affected by the characteristics of the media through which the water passes on its way to the ground water zone of saturation [40], thus, the heavy metals discharged by industries, traffic, municipal wastes, hazardous waste sites as well as from fertilizers for agricultural purposes and accidental oil spillages from tankers can result in a steady rise in contamination of ground water, [41], [42].

According to the WHO, the Maximum Contaminant Level (MCL) for Aluminum, Cadmium and Lead are 0.2, 0.003 and 0.01mg/L respectively [43], through Momodu et al 2009 [44] the analysis of heavy metal content of the groundwater in middle class neighbourhood of Lagos State, the metal was found to be present in 93.88% of the samples analysed. Over 38% of the samples had Cadmium present in them and 32.65% of the samples had Cadmium concentrations above the MCL. Almost 60% of the samples had detectable level of Lead while 36.73% of the sample had Lead concentration above the MCL [44]. In general 97.96% of all samples analysed contained one or more of the three heavy metals studied each in varying concentrations. The results obtained from this study suggest a significant risk to this population given the toxicity of these metals and the fact that for many, hand dug wells and bore holes are the only sources of their water supply in this environment [44]. In order to confirm this, a field survey was carried out on medical records from General Hospital, Onitsha, It shows that the incidence of Cholera, dysentery, typhoid and diahorea in the last five years has been on the increase as revealed in Table II and Fig. 4 below.

III. Reducing Health Risks From Water Contamination

It is essential to regularly evaluate and efficiently dispose of wastes, in order to reduce contamination of drinking water [16]. In West Africa in general, and Nigeria in particular, private and public efforts have been made to develop programs for tackling the waste management problems. Unfortunately, none of these efforts have been adequate. In the public waste management disposal systems, the establishment and use of different varieties of waste disposal units have been established in different cities of Nigeria. The units also are responsible for ensuring that collected wastes are disposed of. However, these arrangements generally break down or are completely non-functional. Theses waste disposal units face serious operational problems, such as lack of sufficient funds for operations, high costs of collection and transportation of wastes to final disposal sites, shortage of personnel and use of obsolete equipment for collection [16].

A. Legislation

Poor management of sewage, municipal wastes, toxic metallic wastes, industrial effluents, poor water management and poor regulation of pesticide use have all combined to degrade water quality in Anambra State, Nigeria [45], [46]. For the protection of human health, guidelines for the presence of heavy metals in water have been set by different International Organisations such as USEPA, WHO, EPA, European Union Commission [3], [47], thus, heavy metals have maximum permissible level in water as specified by these organisations. Maximum contaminant level (MCL) is an enforceable standard set at a numerical value with an adequate margin of safety to ensure no adverse effect on human health. It is the highest level of a contaminant that is allowed in a water system.

Economic development can be compatible with environmental conservation and the present problems of environmental resource degradation need not arise within the framework of sustainable development. Failure to halt further deterioration of environmental quality might jeopardize the health of a large proportion of the population, resulting in serious political and socio-economic implications. Ideally, the siting of industries should achieve a balance between socio-economic and environmental considerations. Relevant factors are availability and access to raw materials, the proximity of water sources, a market for the products, the cost of effective transportation, and the location of major settlements, labour and infrastructural amenities. In developing countries such as Nigeria, the siting of industries is determined by various criteria, some of which are environmentally unacceptable and pose serious threats to public health. The establishment of industrial estates beside residential areas in most state capitals and large urban centres in Nigeria is significant in this respect.

Drinking water quality standard ensures the safety of the drinking water supplies and the protection of public health. The establishment of Nigerian Standard for Drinking Water Quality (NSDQW) will ensure the protection of the consumers. It is expected that the Nigerian Standard for Drinking Water Quality will speed up the process of upgrading non-protected water systems and improving the management of all drinking water systems in the country. In developing this Standard, references were made to the Nigerian Industrial Standards for Potable Water and Natural Mineral Water, the National Guidelines and Standards for Water Quality in Nigeria, the World Health Organization (WHO) guidelines for drinking water quality (3rd Edition) and International Organization of Nigeria (ISO).

IV. Conclusion

Heavy metals in municipal solid waste incineration bottom ash (MSWIBA) or from burnt waste may leach into soil and groundwater and pose long-term risks to the environment [48]. Incineration, which aims to reduce the volume, the toxicity and the reactivity of the waste [49], is a viable management strategy throughout the world for treating the increasing combustible municipal solid waste (MSW) that cannot be recycled [50], [51]. Although incineration reduces greatly the volume (by about 90%), the

mass (by about 75%) of MSW and provides energy [8], [52], it is not the final solution of managing MSW [51]. Since the solid residues (bottom ashes (BA), fly ashes) it generates still amount to roughly 17 Mt per year world-wide, which must subsequently be disposed of in an environmentally acceptable manner [49], [52]. This amount is expected to double within the next 10 or 15 years [49], [52]. Moreover, the advance of air pollution control measures in municipal solid waste incineration (MSWI) has resulted in a shift of constituents of concern from air emissions to the solid residues [48], [53], [54]. Heavy metals (after undergoing gasification, oxidation, chlorination, condensation, coagulation, and nucleation), which come from raw wastes, are condensed into incinerated residues and thus may pose a threat to the environment [55].

Adequate supply of good quantity of drinking water is a basic need for all human beings on the earth. United Nations Environmental Programme (UNEP), 1996 [56], and World Health Organization (WHO), 1996 [57], argued that it is not sufficient merely to have access to water in adequate quantities, the water also needs to be of adequate quality to maintain good health. Again, such water must be free from harmful biological and chemical contamination. However, it has been observed that millions of people worldwide are deprived of such portable and wholesome water. Finally, it may be noted that considerable progress can be achieved through collaboration, cooperation and coordination among researchers, policy makers, planners and the public. All arms of the governments must recognize the need for effective implementation of their policies and programmes. They must recognize the need for an environment of a quality that will permit a life of dignity and well being for the present and future generations.

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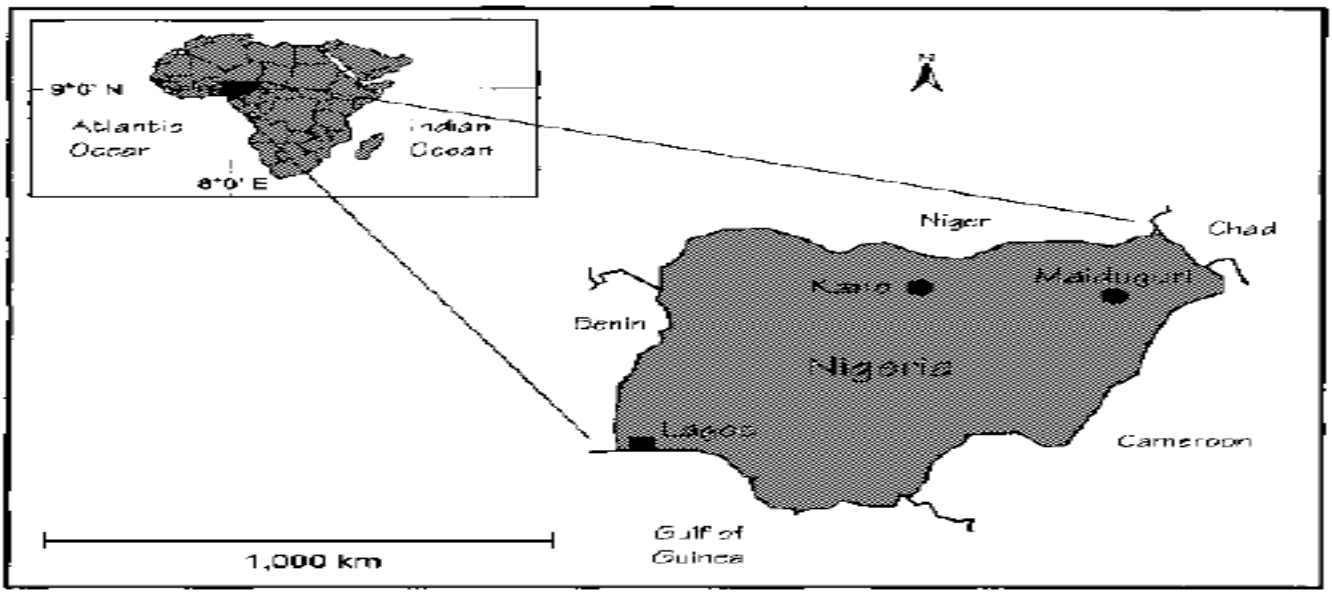

Fig. 1: Location map of Nigeria. (Source: Richard and Ivanildo, 1997) [15].

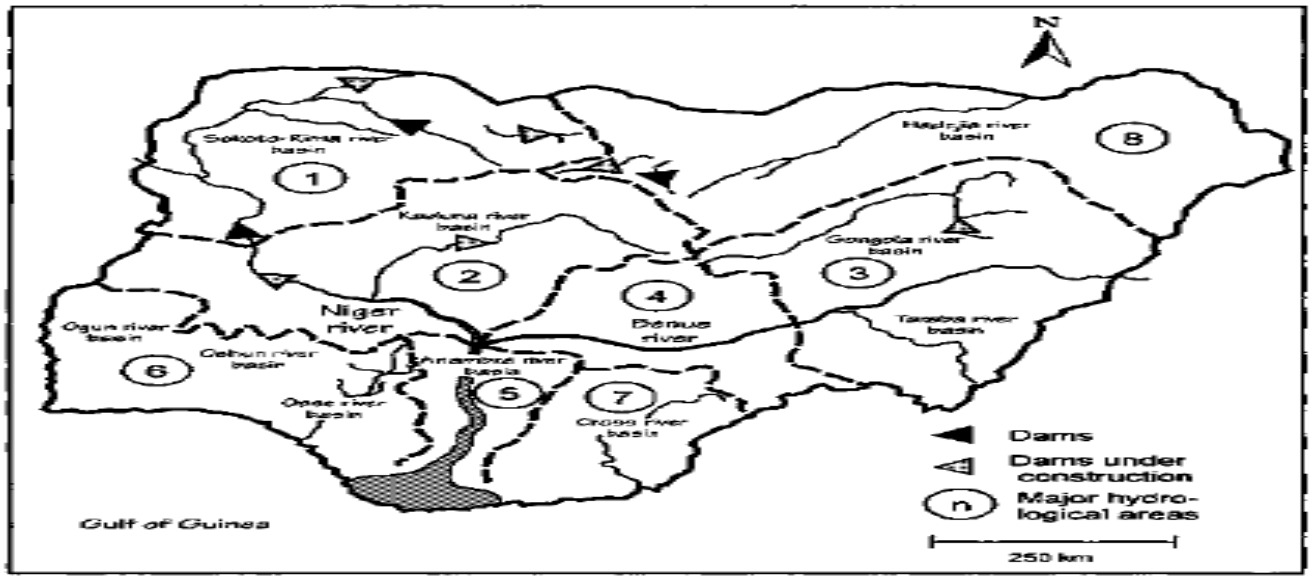

Fig. 2: Map of Nigeria showing major rivers and hydrological basins: 1 Niger North, 2 Niger Central, 3 Upper Benue, 4 Lower Benue, 5 Niger South, 6 Western Littoral, 7 Eastern Littoral, 8 Lake Chad. (Source: Richard and Ivanildo, 1997) [15].

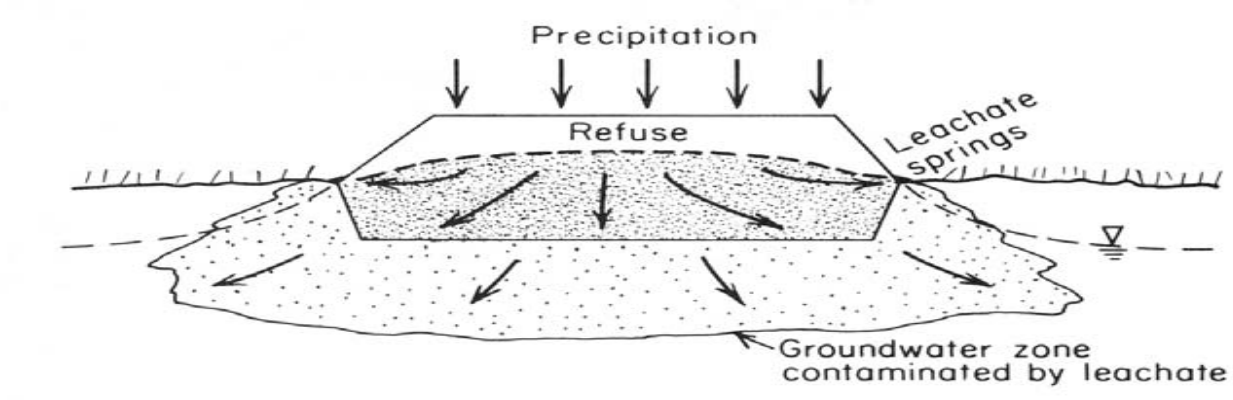

Fig. 3: Conceptual diagram of leachate migration from a landfill. (Source: Freeze and Cherry, 1979) [35].

TABLE II: MEDICAL RECORDS ON WATER BORNE DISEASES IN ONITSHA FOR FIVE YEARS.

Disease	2005	2006	2007	2008	2009 (Jan-April)
Cholera	34	69	151	184	237
Dysentery	51	87	104	122	251
Diahorea	77	121	193	232	319
Typhoid	179	266	378	457	774

(Source: General Hospital, Onitsha).

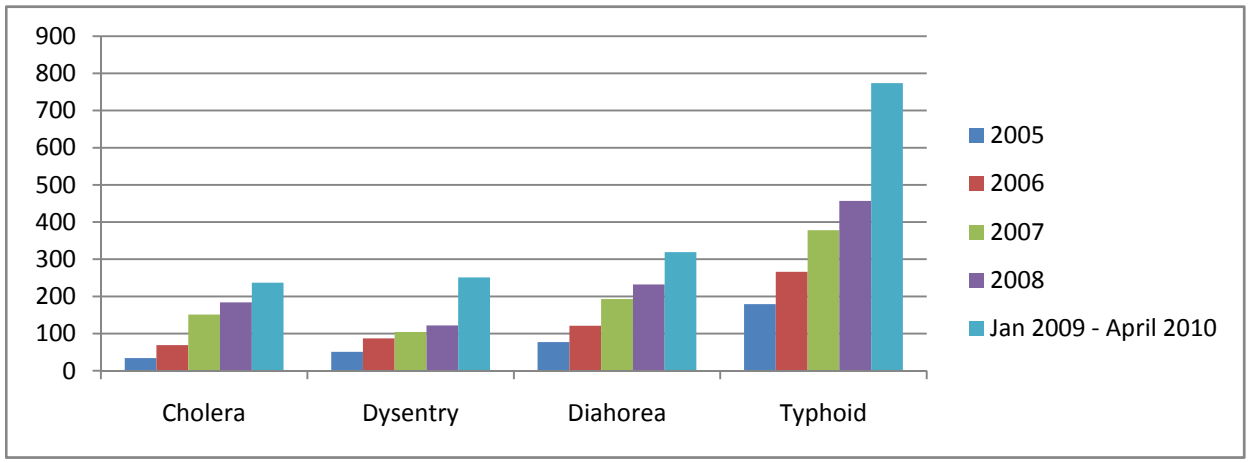

Fig. 4: A Compound Bar Chart Showing Water Borne Diseases in Onitsha for Five Years. (2005-2009). (Source: General Hospital, Onitsha).