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Contamination of Dioxins in Nigerian Inland Waters: A Review

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Abstract

The rise of anthropogenic activities in Nigeria has contributed greatly to dioxin emission, where the aquatic environment remains the ultimate environmental sink to all pollutants such as polychlorinated dibenzo-p-dioxin (PCDDs). Thus, this paper reviewed the various impacts of dioxin in the water, sediment and organisms in inland waters. Literatures of relevant and previous studies on dioxins in the water, sediment and organisms within and outside Nigeria were reviewed. The impacts of dioxin place human health at risk; dioxin causes endocrine disruption, decreases fertility in shellfish, finfishes and mammals, decreases hatching success in fish, decreases offspring survival, alteration of immune and behavioral function in birds and mammals in the aquatic environment. Dioxins have been observed to cause different effect on the body of aquatic organism base on the concentration level in the aquatic environment. The ultimate impact of dioxins is biomagnification and it result in destruction of man on consumption of aquatic resources such as fish. Therefore, efforts should be made to reduce dioxins entrance in the aquatic environment. replace hydrocarbon product engines with the following; solar energy, biogas, wind energy and water energy sources, replace chlorinated compound with other compound that will function to reduce environmental risk, ban vehicles with smoke. Also, anthropogenic activities that release dioxins into the aquatic environment should be under surveillance.

Keywords: Pollution; Sediment; Organisms; Inland waters; Dioxins.

1. Introduction

Dioxins are chlorine related aromatic hydrocarbon with similar physical and chemical structure. World Health Organization [1], defined dioxins as a group of toxic chemical unintentionally produced persistent organic pollutant (POP) which include polychlorinated dibenzo-p-dioxin (PCDD), polychlorinated dibenzo furan (PDDFs) and certain dioxin-like polychlorinated biphenyl (PCBs) compound. Dioxins are naturally and intentionally activated organic compound that are colourless, odourless, invisible binding with oxygen, chlorine, hydrogen and carbon in any space given to them. According to Carey, *et al.* [2] suggested that dioxin is transported long distances in the atmosphere, circulating toward the polar region of the earth due to volatilization and cold condensation properties. EPA [3], further explained that smoking of cigarette, some home heating systems, and exhaust from vehicles using leaded and unleaded gasolines as well as diesel fuels also produce dioxins. According to World Health Organization [1], dioxins are produced naturally from wild forest fires and volcanic eruption, while the anthropogenic activities are divided into primary and secondary sources: the primary sources include industrial and thermal combustion processes.

Dioxins are found in the aquatic environment as a result of waste discharges from runoff, atmospheric deposit from human activities on the biota. Once in water, dioxins bind with substrate, settle in the sediment as sinkand sequestered for a long period of time as well as accumulating in the surface of organisms in the first trophic level of the food chain in the aquatic environment thus dioxins are being take up by organisms while others accumulate in the sediments in water bodies because they are hydrophobic and lipophilic in the body of fishes and human.

FAO [4], reported dioxin uptake is through gills, diet and accumulate in the fatty tissue and liver of fish. Other primary pathways for the dioxin to enter the ecologicalfood chains and human diet are from air-to-plant-to-animal and water, plankton/sediment-to-fish. Kulkarni, *et al.* [5], suggested the ultimate environmental sink of PCDDs/PCDFs is believed to be the aquatic sediments. Aquatic live exposure to dioxin is chronic depending on the level of sequestered pollutant and the time of exposure is a function of species sensitivity to dioxin, with regard to differences in body lipid composition or differences in body metabolism of species.

Contamination is the introduction of unwanted substances by man into the environment in a very low concentration that are not toxic to biotic organisms but change the natural structure. The demersal fish species are more exposed to contaminated sediments than pelagic fish species. Thus, these levels are not always higher than those in pelagic fish depending on the size, diet and physiological characteristics of the fish [4]. It is clear that every living thing that has fatty tissues is exposed to dioxin around world because of advance in industrialization.

Sediments are composed of particles from rocks, biological activities, chemical process within the water and even from space. Garrison [6], reported sediments as loose particulate materials that have been deposited or

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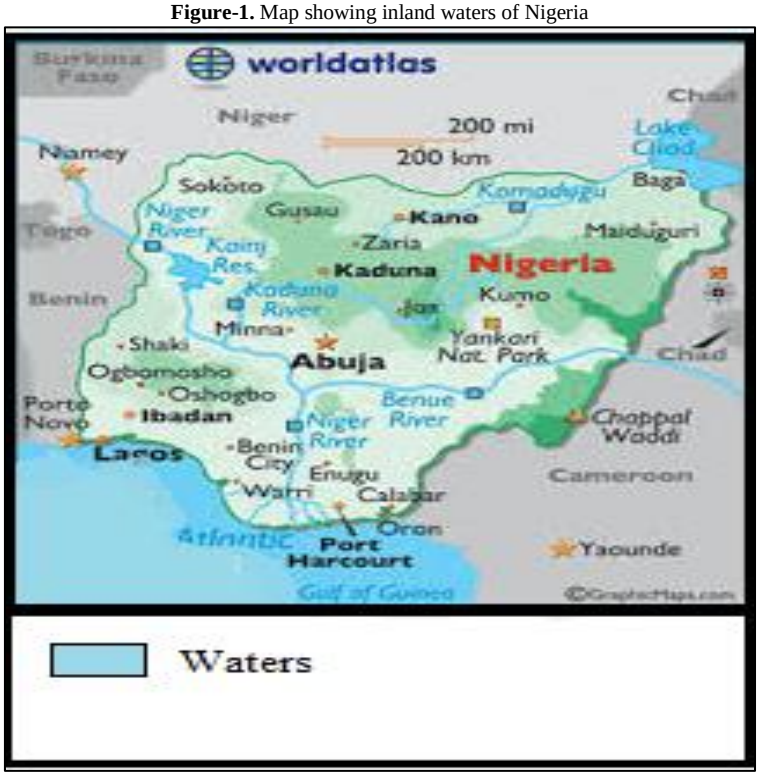
precipitated from liquid, particles originate from the weathering and erosion of rocks from the activities of living organisms, from volcanic eruptions, from chemical processes within the water itself and even from space. Juttner, *et al.* [7] identified considerable amounts of PCDD/F in the sediments lakes in Germany, America and Europe in a very low concentration (below 10 ng/kg) in 1860 to1990 and increases 1920- 1930s and attained maximum during 1970s (750 ng/kg) and started declining (375 ng/kg) thereafter.. Although the trend was almost same in advanced countries, the peak time was differing and may be correlated with the industrialization in the respective countries [8].

Water is the essential part of life that encompasses the physical and chemical composition of all living organism in the biota. Davies [9], reported water constitute tasteless, odourless, colourless and transparent form by which aquatic organism inhabit such as lakes, swamps, lagoons, creeks, rivers, ocean. Thus, organism in the water interact with whatsoever that comes around the medium aquatic environment. The major rivers in Nigeria are River Benue and River Niger which makes up the inland waterways and cuts across the country forming the cardinal north, east and west sections, and flows into the Atlantic Ocean [10]. (Fig 1)

Figure-1. Map showing inland waters of Nigeria

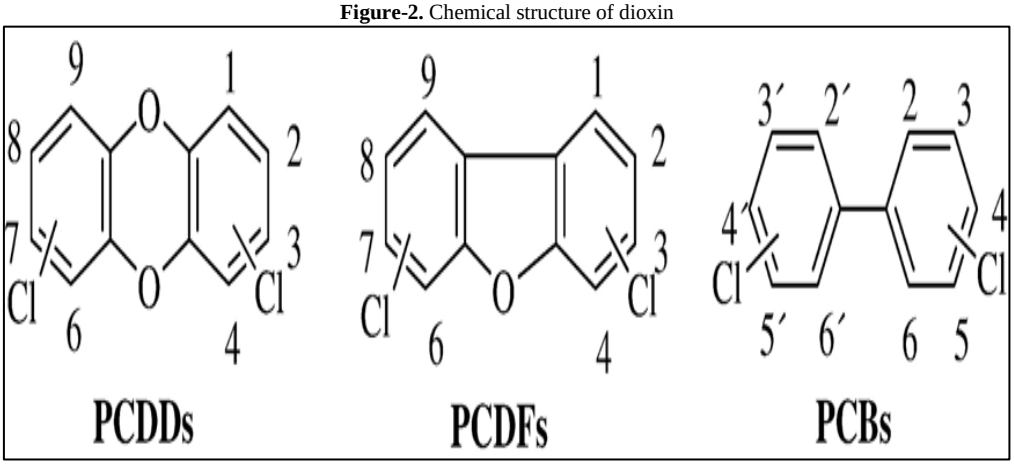


Source: Map at google 2019

1.1. The Structure of Dioxin

The PCDDs include 75 individual compounds; PCDFs include 135 different compounds. These individual compounds are referred to as congeners. Only 7 out of the 75 congeners of PCDDsare thought to have dioxinliketoxicity; these are ones with chlorine/bromine substitutions (Fig.2) Kulkarni, *et al.* [11].

Figure-2. Chemical structure of dioxin



1.2. Sources of Dioxins in Inland Waters

There are two different sources of dioxin into the environment which are the natural and anthropogenic sources. Natural sources include biological transformation of inorganic chlorine to complex organic chlorine compounds such as forest fires[4]. Thus, USEPA. [12] acknowledges volcanic eruptions, as other natural sources of dioxins.

1.3. Anthropogenic Sources

These are Man-made sources that can be divided into primary and secondary sources. The primary sources include industrial and thermal combustion processes while the secondary sources are from some domestic activities. **Industrial Primary Sources**: Industrial activities including certain chemicals production and combustion processes. Innocent, *et al.* [13], reported total emissions of dioxin are far higher for manufacturing than for combustion, with values of 77.12317563gTEQ/A and 14.962688gTEQ/A respectively (Fig 2).

2. Chemical Processes

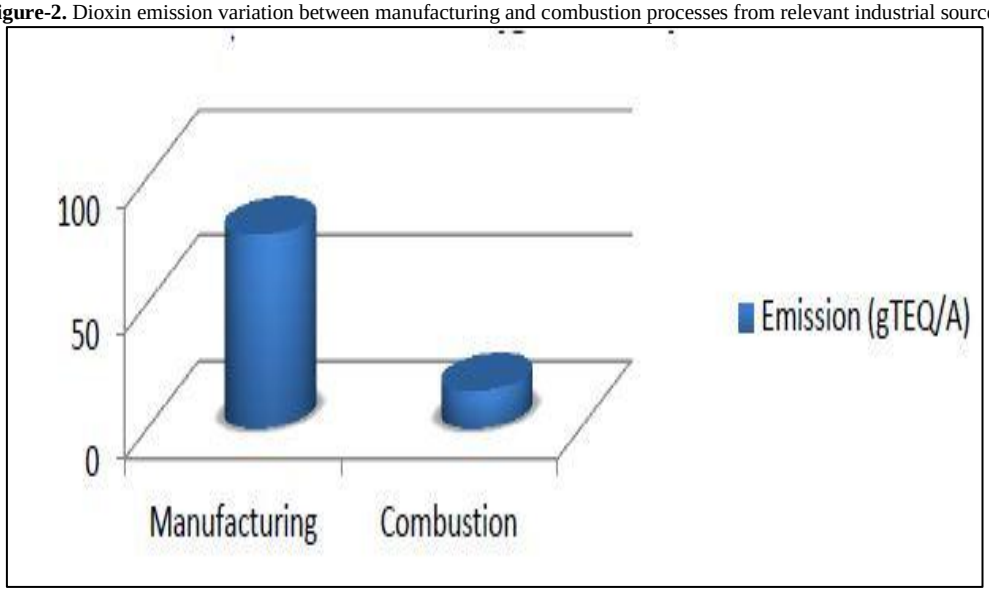
Chemical processes include the synthesis of chlorophenols, chlorobenzenes, chlorobiphenyls, polyvinyl chloride, dyes, pigments,printing inks and halogenated pesticides emit dioxin as a by-product Kri`zanec and Marechal [14]. Chemical industries that releases dioxin (Table 1).

Table-1. Chemical industries of PCDD/Fs sources

Chemical Industries	Products with the potentialfor formation and/or releaseof PCDD
Bleached chemical Wood pulp	Bleached pulp, Wastewater sludge, Wastewater effluent.
Manufacture of chlorine, Chlorine derivates, and metal Chlorides	Chlorine, Chlorine dioxide, Metal chlorides
Manufacture of halogenated Organic chemicals	Chlorophenols, Chlorobenzens,Chlorobiphenyls, Polyvinylchloride, Aliphatic chlorine compounds,dyes, pigments,printing ink

Source: Kri`zanec and Marechal [14]

Figure-2. Dioxin emission variation between manufacturing and combustion processes from relevant industrial sources



Source: Innocent, *et al.* [13]

The contaminant PCDD/PCDF were also produced with the use of chloro-organic chemicals (including the pulp and paper industry) Fiedler and Hutzinger [15], Fiedler, *et al.* [16]. It is further explained that accidents in chemical factories are known to release high emission of the contaminant to the rural areas [4].

2.1. Thermal Combustion

Saskatchewan Environmental Ministry [17], reported that hydrocarbons and chlorinated materials manufacture, during combustion processes under suitable temperatures and pH, promote the emission of a wide range of toxic substances including volatile organic compounds (VOC), hydrogen chloride, Dioxin, heavy metals, carbon monoxide, oxides of Sulphur and nitrogen.

2.2. Secondary Sources: Domestic Sources

Accidental fires from our living homes, domestic wood burning for cooking in the rural and urban areas and coal combustion, traffic emissions, home use generators, incomplete combustion of vehicle engines, domestic heaters and backyard burning of household wastes are sources of dioxin [4, 14]. Thus, the burning of wastes, incomplete combustion of fossil fuels, cooking stoves that have mixed colors of flame as a result of illegal refinery products in Nigeria use in our homes, vehicle and generator contribute to dioxin emittion (Plate. 1, 2, 3 and 4). The burning of agricultural residues also emits polychlorinated dibenzo-*p*-dioxins (PCDDs), and polychlorinated dibenzofurans (PCDFs), because of the presence of Chlorine in the residue as suggested [12]. This also reflects burning of wastes by the river sides and at the road side cause its point in the aquatic environment (Plate 4).

Plate-1. Mix color flame from kerosene stove

Source: Personal

Plate-2. Incomplete combustion from vehicle

Source: Personal

Plate-3. Incomplete combustion from generator

Source: Personal

Plate-4. Waste burning by the road side

Sources: Personal

2.3. Contamination

The release of effluent or emission of substance into the environment is by man's activities [18]. But substance present in the environment are of greater concentration as a result of human activities [19]. That is to say that the environment remains a dump site to every by product of man activities in sub lethal concentration. Dewailly [20], reported some of the highest body burdens of dioxins are from fish and marine mammals from a local food chain contaminated by dioxin from distant industrial sources. Dioxin in emission in some state in Nigeria (Table 2).

Table-2. Dioxins in the environment of some states in Nigeria

S/No.	States	Test Systems	Results	References
1.	Abuja	Human	High	Solomon-Wisdom and Ndana [21]
2.	Abuja Federal Capital Territory	Wastes Tyre burnt	High	Alhassan, *et al.* [22]
3.	Borno	Agricultural waste		Maina [23]
4.	Kano	Industries /wastes sites	High	Innocent, *et al.* [13]
5.	Lagos	Industries/waste site	High	Nigerian Environmental Society [24]

2.4. Dioxin in the Water

Transport of dioxins is deposited into the aquatic environment through wet and dry deposit from industrial effluent and run-off from soil which partition to organic matter and accumulate in sediments [3]. The hydrophobic nature of dioxin make it bind to surface of suspended particlesmaking it a universal cake to aquatic live indirectly. According to Frignani, *et al.* [25] reported that dioxin is sequestered in the environment for long periods of time. For this purpose, dioxin accumulation levels in the sediments have been used in so many literatures as a means to monitor anthropogenic activity over time [3].

2.4.1. Dioxins in Aquatic Organisms

Fish and other aquatic organisms in the waterbodies are situated were municipal contaminant like PCDD accumulate in their tissues, such as channel catfishes, yellow perches and suckerfish [26]. In organism, the concentration of dioxin in the tissue, muscle and liver tend to be higher in the liver indicating hepatic sequestration. Thus, Atkinson [27] suggested the concentration level of dioxin in the body of fishes and invertebrate have found to be in higher concentration than those in the water column, suggesting to be bioaccumulation.

2.4.2. Accumulation

The distribution of dioxin in the environment tend to bind with organic matter in the sediments and soil, accumulate in fatty tissue of living organism humans, and are found at higher concentrations at higher levels in the food chain, and are toxic to both humans and wildlife.Exposure to even low doses of dioxins can lead to cancer, damage the nervous system, result in immune system diseases and reproductive disorders [28].

2.4.3. Bioaccumulation

Dioxins dissolve easily in lipid compounds than water, because of this, dioxins tend to bioaccumulate in both animals and humans. When deposited on aquatic flora, contaminate the first level of the food chain in the aquatic

environment. The ingestion of contaminated sediments and the consumption of contaminated foods in the aquatic food chain have proven to be the major pathways in which fish uptake dioxins [29, 30].

Table-3. Bioaccumulation Factors for 2,3,7,8 TCDD in Freshwater Aquatic Organisms

Organism / species	Tissue/body part	Exposure Duration (day)	Bioaccumulation factor
Alga (*Oedogoniumcardiacum)*	Whole body	33	3094b
Alga (*Oedogoniumcardiacum*)	Whole body	32	2075c
Snail (*Physa sp.*)	Whole body	33	5471b
Snail (*Physa sp.*)	Whole body	32	3095c 3731
Cladoceran (*Daphnia magna)*	Whole body	30	7070c 7125
Cladoceran (*Daphnia magna)*	Whole body	32	3895b
Catfish (*Italurus punctatus)*	Whole body	28	4875
Mosquito fish (*Gambusia affinis*)	Whole body	14	4850c 4875

Notes: b – Arithmetic mean of several values reported. c – Tissue concentrations at equilibrium
Source: CPCB [26]

2.5. Toxic Effect on Organisms

Dioxin as organic chemical compound has the ability to binding physical and chemical properties such that, once released into the aquatic environment, they remain intact for along periods of time as they are partition in both biotic and abiotic factor in the aquatic environment. Thus, it becomes alarming that the safety of food supply (aquatic resources) fish has potentialadverse health effects on the exposure to dioxin because of their lipophilic nature together with their persistency in the environment which dioxin bioaccumulate in the food chain. This POPs dioxin persistent synthetic hormones bind effectively to specific aryl hydrocarbon receptors (AhR) in living cells and trigger a chain of reactions resulting in biochemical and cellular changes [30]. USEPA. [12] reported dioxin cause endocrine disruption, decreased fertility in shellfish, fish and mammals, decreased hatching success in fish, decreased offspring survival, alteration of immune and behavioral function in birds and mammals.

2.6. Control and Mitigation Measures

There is considerable public, scientific and regulatory concern over the negative effects on human health and on the environment of long-term exposure to even the smallest amounts of dioxins. In Nigeria, where environmental organization are established but not working to reduce the effect of environmental poisoning, the following measures to reduce dioxins contamination entering the food chain (aquatic resources) is aim to prevent or reducing contamination in the environment (air, soil and water);

- Aquatic resources monitoring systems must be put in place to ensure information about incidents of contamination in the aquatic environment.
- The Government should promote (fact-finding studies) Research work and development to improve the understanding and quantification of the fundamental transfer processes by which dioxins is transfer processes between the different environmental media, particularly the aquatic environment, and the degradation processes in the aquatic environment.
- The Government (Nigeria) should put in place a system for Public Information, up to the rural communities, ethnic groups, religion and culture on the concentration of dioxins and dioxin-like PCBs compounds in particular fishes and foodstuffs, providing information necessary to reduce their exposure to dioxins.
- To improving inspection system (monitoring) of dioxins and other related Persistent Organic Pollutants (POPs).
- Contributing to the international communities on new innovations
- Controlling the disposal of dioxins containing oils, wastes, domestics and agricultural by products.

3. Conclusion

Dioxins release from industrial and domestic activities is yet to be given sufficient attention, despite indications of possible emissions of dioxins (the local refinery ‘Kpo fire’) and Bunkers activities in the Niger Delta Nigeria that could lead to species endanger and other severe pollution regard the social impact, health impact in the aquatic environment is given less concern. However, it is believed that human response to dioxin action on a molecular level varies with sensitivity to dioxin toxicity in aquatic organism and human. Thus, since the pollutant bioaccumulate and biomagnified, research should be made to give daily intake of dioxins in Nigeria

Recommendations

The indicated impact of PCDD/Fs concentration in sediment and tissues of fishes requires further investigation extensively.The national authority (Nigeria) should banned the importation of generators and give light to every area in the country, replace hydrocarbon product engines with the following;

- Solar energy.
- Biogas
- Wind energy and water energy sources

- Replace chlorinated compound with other compound that will function to reduce environmental risk.
- Ban vehicles with smoke

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