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Polychlorinated Biphenyls Contamination in Aquatic Organisms if Nigerian Inland Waters

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ABSTRACT

Polychlorinated biphenyls (PCBs) are mixtures of up to 209 individual chlorinated compounds called congeners with no natural sources in the aquatic organisms (Plants and Animals), only anthropogenic sources exist. This research reviewed the sources, effects, control, preventive, mitigation and remediation methods of PCBs as well as some cases studies of contamination of PCBs of Aquatic Lives in Nigerian Inland waters. Literatures of relevant and previous studies on Polychlorinated Biphenyls in Nigerian Inland waters within and outside Nigeria were reviewed. Anthropogenic sources are usually by industrial and shipping activities which may be direct or indirect. PCBs have major routes which are through accidental spills and leaks during the transport of the chemicals, from leaks or fires in transformers capacitors and other products containing PCBs. They tend to influence the patterns of survival, reproduction, growth, endocrine, hormonal function, enzyme activities and accumulation in representative aquatic organisms. Polychlorinated Biphenyls can also cause mortality or lethality in aquatic organisms when exceeded the normal body dosage. The Environmental Protection Agency standard for PCBs in the aquatic ecosystem is 0.0005 ppm. PCBs have been reported for some aquatic organisms in Nigerian Inland waters which are C. gariepinus inOgun River and Ona River. Mitigation and preventive methods are traditional, advanced technology and multi technology methods. Polychlorinated biphenyls are toxic, persistent and bio-accumulate in and biota as well as affect the physiology of biota and biological integrity of the aquatic environment. Government agencies should regulate the use of PCBs in the manufacture of various substances due to its harmful effects and industries should adhere to proper waste treatment before disposal into the aquatic environment.

Keywords: *Polychlorinated biphenyls, Sources, Control, Preventive, Mitigation, Control, Aquatic Organisms Nigerian Inland Water.*

INTRODUCTION

Polychlorinated biphenyls (PCBs) are mixtures of up to 209 individual chlorinated compounds known as congeners (Fig. 1). The compounds are man-made with non-natural sources and they appear as colorless to light yellow oily liquids or waxy solids. They have no known taste. The positions of chlorine atoms attached to the benzene ring are denoted by numbers assigned to the carbon atoms. They are utilized as coolants and lubricants in transformers, capacitors and electrical equipment because they do not burn easily and are good insulators[1].

They represent a class of chlorinated aromatic compounds which have found widespread industrial application because of their ability and inertness, excellent dielectric properties and their excellent solventcharacteristics[2]. These substances have the tendency to bio-accumulate in organisms. Bioaccumulation is a process by which certain toxic substances (such as heavy metals and polychlorinated biphenyls) accumulate and keep on accumulating in living organisms, posing a threat to healthy life and environment. It is also called bio-concentration, biological concentration or biological magnification[3].The aquatic environments are made up of abiotic (non-living such as physical and chemical features) and biotic (life/flora and fauna /comm-unities of organisms) properties.

Aquatic organisms mean any species or hybrid of animal or plant, including fish, shellfish and marine organisms. These aquatic lives are also known as the biological properties of the aquatic environments. The biological properties are all indispensable plants (flora) and animals (fauna)

in the dynamic waters. The flora are phytoplankton (primitive, unicellular passively drifted plants/micro algae), periphyton (attached, uni cellular algae), sea weeds (sessile, micro algae or plant-like organisms) and macrophytes (larger aquatic plants). The fauna are divided into invertebrates and vertebrates. The invertebrates are zooplankton (primitive passively drifted animals though some are vertebrates such as larvae of fin fishes), coelenterates (Sea anemones, jelly fishes), echinoderms (sea star/star fish, sea urchins and sea cucumber), molluscs (periwinkles, oysters, bloody cockles, clams, rock snails), and crustaceans (shrimps, prawns and crabs) while the vertebrates are the Agnata, jawless fish (sea lamprey), Gnastomata (jawed fishes, Chondrichthyes [cartilaginous fishes such as sharks) and Osteichthyes (bony fishes such as cat fishes, tilapias, carps, etc)], amphibians(frogs), reptiles (sea turtles, alligators, crocodiles, monitors), aves (birds, ducks) and mammals (whales, dolphins, etc). Aquatic organisms can be classified into four major groups, each varying in adaptations, but linked within a complex network of ecological roles and relationships. An overview of each group is found within the following sections: microorganisms, plants, invertebrates and vertebrates[4-5].

Microorganisms

Microorganisms include members of the plant kingdom, protozoa, bacteria and fungi.

Plants Invertebrates

Macrophytes are individual aquatic plants that can be seen by the un-aided eye. They can be categorized based on how they grow as rooted macrophytes and floating aquatic macrophytes

Invertebrates

Invertebrates include all animals without back bone.

Vertebrates

Vertebrates include all animals that have back bone[4].

The Nigerian inland waters is the second largest length of water ways in Africa having a total of 8,600 kilometers (km) of inland water ways and an extensive coast land about 852 kilometers. The major components of the water ways which cuts across the country into the Cardinal east, west and North sections, are the River Niger and North sections, are the River Niger and River Benue. The two rivers run into each other at Lokoja and flows into the Atlantic Ocean[6].

This paper reviews the Sources, effects, control, preventive, mitigation and remediation as well as some case studies of contamination of Polychlorinated biphenyls in Aquatic Organisms of Nigerian Inland Waters.

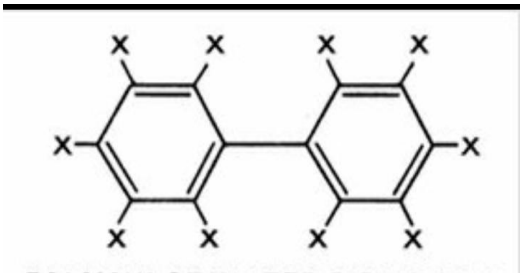

Figure1. *Chemical structure of Polychlorinated biphenyls molecule*[7].

Source: *Agency for Toxic Substances and Disease Registry (ATSDR)* [7].

Sources and Routes of Polychlorinated Biphenyls on Aquatic Organisms

There is no existence of natural sources of Polychlorinated biphenyls in aquatic Organisms, only anthropogenic sources exist.

Anthropogenic Sources in Aquatic Organisms

There is a trend for the highest chlorinated congeners to accumulate preferentially while a large proportion of the PCBs are adsorbed onto particulates in sediment. It is still bio-available to organisms and will continue to be accumulated in the higher trophic levels[8].

Sources of Polychlorinated Biphenyls in Aquatic Animals

PCBs are taken up by small organisms and fish in sediments and water. They are also taken up by other animals that eat these aquatic animals as food. PCBs accumulate in fish and marine mammals, reaching levels that may be many thousands of times higher than in sediments and water[1].

Marine invertebrates accumulate Polychlorinated Biphenyls 52, 101, 128, 138, 151, 1153, 180, 194, 206 and 209 from Polychlorinated Biphenyl contaminated sediments[9]. In the aquatic environment, concentrations will thus be greater in shellfish than in the plankton on which they feed, and even greater in animals at the top of the food chain such as large predatory fish or mammals (seals, dolphins, and Zebra mussels

(Dreissenapolymorpha) accumulates Polychlorinated biphenyl from their diets and from surrounding lake sediments[10].

Sources of Polychlorinated Biphenyls in Aquatic Plants

Most plants (terrestrial and aquatic plants) do not bio-accumulate PCBs from contaminated soil due to the presence of a waxy layer, or cuticle, which binds the PCBs and prevents them from being absorbed into the plant. Some plants in the squash family appear to be able to accumulate PCBs from soil via their roots. Studies of tomatoes grown downwind from a PCB-contaminated sediment site demonstrated that lighter, more volatile, congeners released into the atmosphere can be taken up by the leaves and transported into edible portions of the plant. Generally, however, most of the PCBs remain on the surface of fruits and vegetables, often as part of the soil deposited by wind or rainwater splash clinging to the plant[11].

Effects of Polychlorinated Biphenyls on Aquatic Organisms

PCBs influence patterns of survival, reproduction, growth, enzyme activities and accumulation in representative aquatic organisms[12]. PCB can also cause mortality or lethality in aquatic organisms when exceeded the normal body dosage. PCBs especially those with 2, 3, 7, 8-Tetra Chloro Dibenzeno Dioxin (TCDD) type activity adversely affect reproductive sources success of spawning female Chinook salmon. PCBs can also impair the reproductive capacities of marine mammals.

Mixtures of planner PCBs and Dioxins, however produces synergism of Aquatic Animal Health (AAH) activity in fish liver at low rate and antagonism at high dose[13]. These substances have the tendency to bio-accumulate in organisms. Bio-accumulation is a process by which certain toxic substances (such as heavy metals and polychlorinated biphenyls) accumulates and keep on accumulating in living organisms, posing a threat to healthy life and environment. It is also called bio-.concentration, biological concentration or biological magnification[3] (Fig. 2). Fig.3 also indicates the transfer of Polychlorinated biphenyls across the food chain.

Table1. *Effects of polychlorinated biphenyls in aquatic organisms*

S/No.	Effect of PCBs	Reference
1	Inhibit the growth of several algal species composition of algae in water	Mahantyet al.[15]; Swackhamer& Skoglund[16]
2	Influence patterns of survival, reproduction, growth, endocrine, hormone function, enzyme activities, and accumulation in representative aquatic organisms	Adeogunet al.[17]
3	Can cause mortality or lethality in aquatic organisms when exceeded the normal body dosage	Eisler[12]
4	Certain aquatic species can metabolize and bio-transform PCB	Sijmetal.[18]

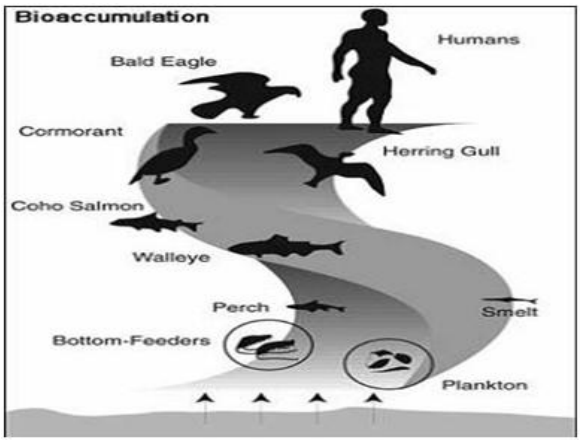

Figure2: *Bioaccumulation of PCBs from aquatic Organisms to human*

Source: *https://www.greenfacts.org/en/pcbs/l-2/2-biomagnification.htm#0*[19]

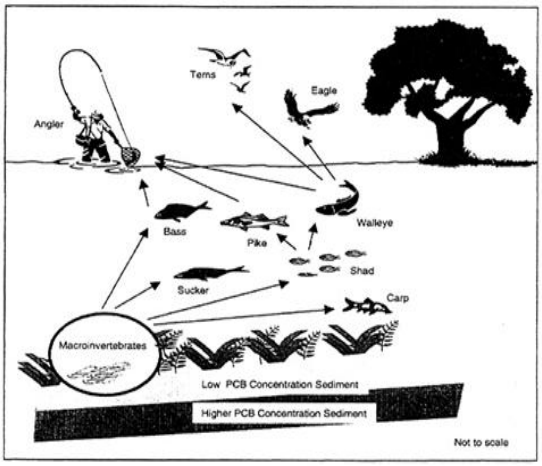

Figure3. *Transfer of Polychlorinated biphenyls in the food chain*

Source: *NAP*[20].

Igbo et al. stated that their lipophilic characteristics are responsible for their ability to bio-accumulate particularly in tissues and organs rich in lipids which lead to their consequent possible connection with carcinogenesis in living organisms[14]. Table 1 summarizes the effects of Polychlorinated Biphenyls on aquatic Organisms (Plants and Animals). Certain standard has been set aside to regulate the concentration of PCBs in water and aquatic organisms which are taken as food to man (Table 2).

Table3. *The standards, regulation and recommendations for PCBs in aquatic environments by EPA, FDA, WHO round the World*

Agency	Focus	Level	Comment
EPA	Drinking Water, Environment (Air, water & Land)	0.0005 ppm	Enforceable
FDA	Food, Environment (Air, water & land)	0.2-3.0 ppm (all foods), 2.0ppm(fish)	Enforceable, tolerance level
WHO and EPA	Food, Environment	6.0µg/kg per day	Allowable daily intake

Source: *http://www.atsdr.cdc.gov/csem/csem.asp?csem=30&po=8*[21]

Polychlorinated Biphenyls Contamination in Aquatic Life

The Concentration of polychlorinated biphenyl (PCB) congeners in the muscle of Clariasgariepinus and sediment from inland rivers (Ogun and Ona Rivers) of southwestern Nigeria and estimated potential human was assessed by Adeogun et al[17]. The effect of PCB congeners on condition factor (CF) and associated human health risk were also assessed by the use of muscle levels for a non-carcinogenic hazard quotient (HQ) calculation. Elevated concentrations of high-molecular-weight (HMW) PCB congeners were detected in fish downstream of points of discharge in both rivers. There was an observed significant reduction in fish body weight and condition factor (CF) which correlated with high PCB congener concentrations in the Ona River. Significant decreases in fish body weight; length and CF were observed downstream compared to upstream in the Ona River (Fig. 4 & 5).

Control, Preventive, Mitigation and Remediation Methods of Polychlorinated Biphenyls

In other to control and prevent polychlorinated biphenyls, fish should be poached and the broth discarded[22]. There is urgent need for a concerted effort to be made by the relevant authorities to address the environmental and health hazards posed by the exposure to e-waste[23]. There is need for Governments agencies to stop the manufacture of substances using Polychlorinated biphenyl compounds[1].

Mitigation & Remediation of Polychlorinated Biphenyls

In some areas like the U.S, the most common technology for remediation of polychlorinated biphenyl-contaminated soil or sediments are known as the incineration or disposal in landfills[24].

However, majority of these methods tends to be disruptive, unsustainable and transfer polychlorinated biphenyls to different sections of the environment, instead of getting rid of them[25]. Therefore current research is been made to get a sustainable, alternative technologies of remediation for organic pollutants that are persistent. According to Ran et al., various mitigation and remediation methods would be listed to reduce the effects of Polychlorinated biphenyls in the environments[26]

Traditional Methods

- Phytoremediation of Polychlorinated biphenyls
- Microbial degradation of polychlorinated biphenyls
- De-halogenation of polychlorinated biphenyls by chemical reagents
- Removal of polychlorinated biphenyls by activated carbon

Advanced Technologies Method

- Supercritical water oxidation
- Ultrasonic radiation

- Catalytic hydro-dehalogenation of Polychlorinated biphenyls by bimetallic systems
- Nano scale zero-Valent iron (nZVI) base reductive dehalogenation

Multi-technology methods

- Biofilm covered activated carbon
- PCBs remediation Technologies coupled to electro kinetic remediation
- nZVI particles in combination with a second metal
- However, all of the above listed methods could be Biological, Chemical method, Physical method and Thermal methods or procedures.

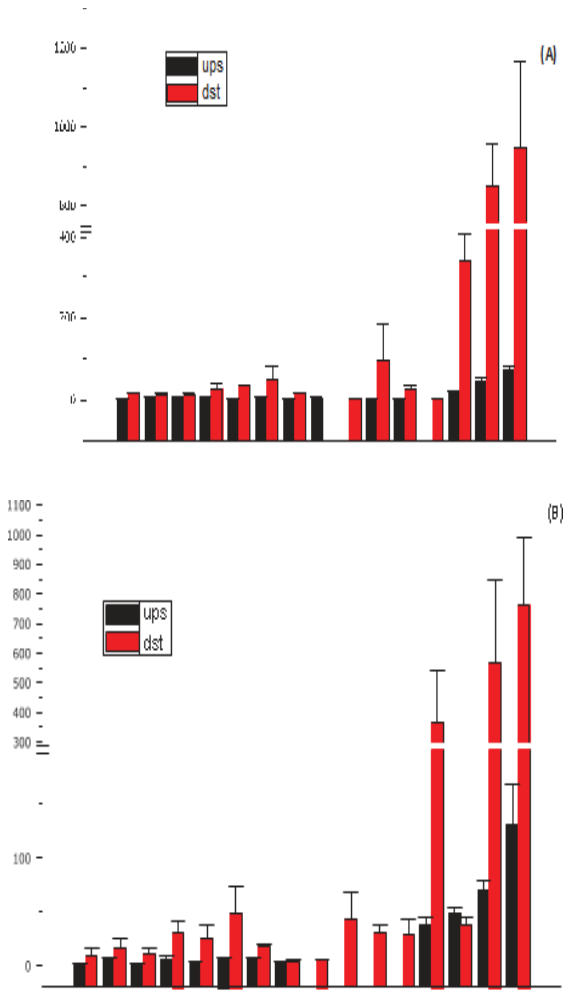

Figure4. *Concentrations of PCB congenersin Clariasgariepinus muscle tissue (A) and sediment samples(B) from upstream(ups)and downstream(dst)in the Ogun River.*

Source: *Adeogunet al*[17]

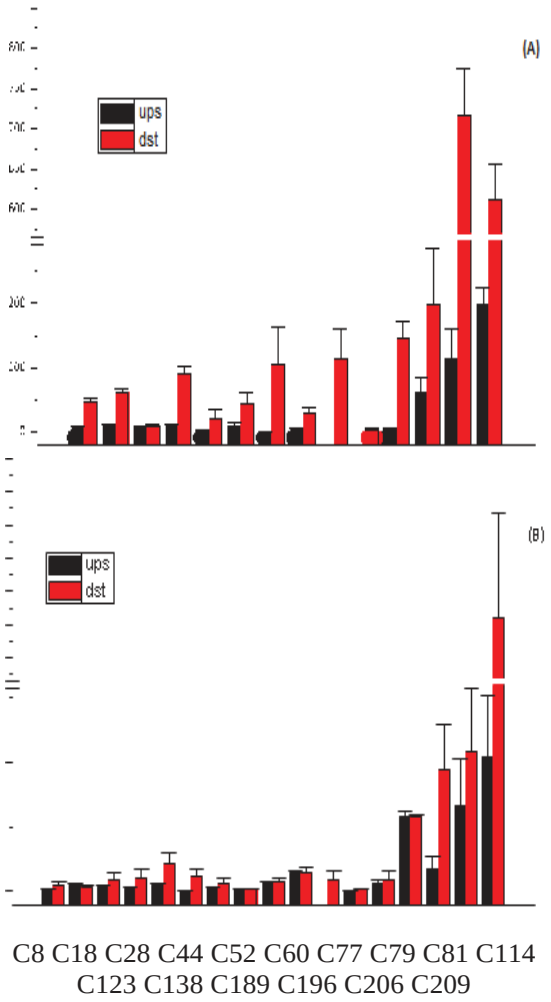

Figure5. *Concentrations of PCB congenersin Clariasgariepinus muscle tissue (A) and sediment samples (B)from upstream(ups) and downstream(dst) in the Ona River.*

Source: *Adeogunet al*[17].

Traditional Methods

Phytoremediation of Polychlorinated Biphenyls:

It is the process by which organic pollutants in soilor ground water are biodegraded and uptake into plants tissues via their roots and then transformation by enzymes of plants or direct vitalization into the atmosphere. Some plant species been used for this are Medicago sativa (alfalfa), Lespedeza cuneate (Chinese bush clover), Lathyrussylvestri (everlasting pea), etc[26].

Microbial Degradation of Polychlorinated Biphenyls

It is the natural biological process which deals with the use of microorganisms (e.g. fungi, bacteria) to degrade, breakdown, change and removal of contaminants or hazardous materials.

Microbial degradation of polychlorinated biphenyls includes the two possible pathways; anaerobic dehalogenation and aerobic dehalogenation[27].

By Chemical Reagents

These method coverts polychlorinated biphenyls to compounds with low level of toxicity by the use of progressive replacements of chlorines[28].

By Activated Carbons

Activated carbon is used widely to remove hazardous organic and inorganic compounds due to the highly structure of carbonaceous materials that increases the surface area (500-2500m^2/g) for adsorption or chemical reactions [26].

Advanced Remediation Technologies Method

Supercritical Water Oxidation

It is a clean technology which occurs at water temperatures and pressures above the critical point of water (647K and 22.064MPa) [29].

Ultrasonic Radiation

Ultrasonic radiation is acoustic cavitation[30]. Cavitation is the destruction of active forces of molecules in the liquid phase by mechanical activation thereby allowing bubble growth through the diffusion of solute vapour[36].

Catalytic Hydrodehalogenation by Bimetallic Systems

It involves the use of two different metals; one zero-valent form with a negative reduction potential and the other transition metals with a high reduction potential as the reducing catalyst[32; 24].

Nano Scale Zero-Valent Iron (Nzvi) Base Reductive Dehalogenation

It uses Nano scale zero-Valent iron (nZVI) particles of which diameter <100nm which usually have core shell structure. The outside ion of n ZVI particles can react with water and oxygen to form an outer (hydr) oxide layer in aqueous environments[26].

Multi Technology Methods

Removal by Biofilm Covered Activated Carbon

It is the use of biofilm covered activated carbon particles for the treatment of waste water, post-treatment, portable water purification and organic contaminants removal [38;31].

Pcbs Emediation Technologies Coupled to Electro Kinetic Remediation

It uses low-level direct current as a “cleaning agent” to remove organic pollutants from soil or other environments (e.g. aquatic environment) [34].

Nzvi Particles in Combination with a Second Metal

One major concern of this method is the reduction of surface reactivity due to iron oxide formation on the surface of nano-particles[26].

Conclusion

Polychlorinated biphenyls (PCBs) are mixtures of up to 209 individual chlorinated compounds called congeners. These compounds are anthropogenic having no natural sources and they appear as colorless to light yellow oily liquids or waxy solids. Anthropogenic polychlorinated biphenyl (PCBs) in aquatic lives poses threat to human and ecological health Nigeria. Ogun River and Ona River in Nigeria have been sampled to show that C. gariepinus actually contained Polychlorinated biphenyls.

Recommendation

There should be more research on how to recycle and utilize these wastes instead of allowing them to constitute nuisances. Industries should also keep clean and hygienic environment and also adhere to proper waste treatment before disposal into the aquatic environment not minding the cost of the treatment. There is need for Governments agencies to mitigate or stop the use of Polychlorinated biphenyl compounds in the manufacture of various substances due to its harmful effects.

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