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Exposure to Organo-Chlorinated Compound, PolyChlorinated Biphenyl (PCB), environmental and public health Implications: A Nigeria Case study

Michael P. Okoh

Abstract
Nigeria faces the challenge of organic waste, which is imported into the country. These wastes cause serious menace to human health, and environment, with reverberation, further afield. Baseline inventory of PCB contaminated oils and equipment had been conducted in Nigeria, albeit not exhaustive. However, the report from this study point to streams of contaminated oils and equipment, with possible variables in chemical composition of the dielectric fluid, bearing diversity in origin. The inventory report shows total amount of PCB-contaminated waste in Nigeria to be 3,400 tons; PCB-contaminated oil (421 tons), and the combined weight of PCB-contaminated equipment (1,061 tons) and all estimated, with possibility of higher value with a comprehensive inventory. Also, the main source and major users of this contamination has been identified. With such information, the main sources consisting formal and informal sector are presented with possible path, immediate route to the ordinary Nigerian citizens traced and schematically presented (see Fig.2). The hazard posed by PCB oils is further magnified, put in current Nigeria reality where such hazardous wastes could be use for cooking unknowingly. Major reasons for these import/exports are cheap pricing and lack of environmental and occupational standards. Thus, up until Basel, Stockholm combined with Rotterdam convention the toxic effluent from developed nations had flooded developing countries e.g. Nigeria. The concerted management of POPS in general and PCB in particular, is a public good. As such, it must be shaped by the broadest possible stakeholders from many of the various organizations with a role to play in shaping PCBs and POPs management cycle. In Nigeria for instance, such immediate stakeholders were identified in this study, with suggestion of ways to further strengthen individual roles in the onerous task of POPs management in general, and PCB in particular. Referencing earlier studies this paper discusses some indicators relating to PCB kinetics as well as its perceived role in delayed infertility, exposure limits based on findings was also suggested.
Aims of this review: Increase public awareness of the danger associated with PCB exposure with a view to generating significant social benefits that will reduce public health risks, locally and international, associated with the release of PCBs into the environment. Poisons, such as PCBs, cyanide and carbon monoxide produce life-threatening effects by means of enzyme inhibition. Increasing public awareness of the danger of these chemicals is beneficial, as it would enhance PCB and general POPs management, site clean-up and disposal of PCBs and contaminated materials. Achieving this would require the adoption of best available technology (BAT) that meets international best practices.

Keywords: PCBs, POPs, hazards

1. Introduction
The term polychlorinated biphenyls or PCBs, refers to a group of 209 chlorinated isomers (congeners) of biphenyls. In the United States for instance, PCBs were produced commercially for approximately 60 years with a wide of application in a variety of products, such as coolants, insulating materials, and lubricants in electrical equipment (such as transformers and capacitors). Other areas of PCB use and application include hydraulic fluids, plasticizers, surface coatings, adhesives, pesticides, carbonless copy, dyes, and waxes. The properties of PCBs that made them valuable for industrial applications included extreme stability, chemical inertness, resistance to heat, and high dielectric constant [16].
PCBs, classified among a group of persistent organic pollutants (POPs), are currently being categorized by the United Nations Environment Program [16]. This categorization is

necessitated by the fact that although PCBs are no longer produced in commercial quantity, however, they are found to be persistent in the environment for many years and can be found in air, water, soil, and food. Their peculiar properties such as low flammability and good insulating potential made PCBs valuable to manufacturers, and they were and, had been used extensively in a number of applications.

PCBs are insoluble in water but are soluble in organic or hydrocarbon solvents, oils, and fats. This characteristic, combined with their persistence, means that they do not degrade easily in the environment and may bio-accumulate up the food chain. As PCBs move through the environment, the absolute and relative concentrations of individual chloro-biphenyls change over time and from one environmental medium to another because of physical and chemical processes and selective bioaccumulation and metabolism by living organisms. These processes result in mixtures that are substantially different from the original mixtures that were released to the environment. These changes in the composition of the PCB mixtures complicate the identification, quantification, and risk assessments associated with PCBs. In recent years, substantial progress has been made in the scientific understanding of the dynamics of PCBs in the environment and the effects of PCBs on humans and the ecosystems.

In Nigeria, work on hazardous waste management is comparatively few. However, a wide range of literatures, are available on the generation and management of organic waste, especially in the developed countries. Thus, to protect Nigeria's-environment from toxicants, knowledge of the pollution sources, pollutants, and toxic organic compounds, such as PCBs and POPs is important. Environmental pollution has increased in Nigeria, as a consequence of the expansion of urban, human, agricultural and industrial activities. The persistence of the organic compounds allows pollutants to accumulate in human, animals and plant tissues and pass on more to food supply and get into our bodies causing major problems. Actual or potential health effects that are associated with PCBs include cancer, reproductive and development toxicity, impaired immune function, effects on the central nervous system, and liver changes (US-EPA, http://www.epa.gov/solidwaste/hazard/tsd/pcbs/pubs/effects.htm., Connor et 1997 [12] , Carpenter 1998 [10]., Cogliano 1998) [11].

Therefore, for a pragmatic approach in mapping, managing and disposing PCBs, including inventory, transport and storage, treatment, and raising awareness on the issues of environment and health impacts from PCB contaminations is heightened.

2. PCB Inventory in Nigeria

Nigeria has never produced PCB and PCB-contaminated equipment, but it has imported PCBs in dielectric fluids from 58 different countries (*The World Bank Baseline Inventory of PCBs and PCB containing Equipment, Nigeria, 2009)*. During the project life cycle of the inventory, over 90 % of historical data were collected for electrical equipment, mostly transformers belonging to the defunct Power Holding Corporation of Nigeria (PHCN). Moreover, field surveys conducted were geared towards gathering information from selected Nigeria Electrical company (defunct-PHCN) substations in the country to get estimate of PCBs status. In the course of the field inventory, testing for PCB oil were conducted on selected transformers at different locations. A total of 281 transformer oil samples were analyzed using PCB screening test kits to establish chlorinated compound concentration greater than 50 ppm. PCBs would be among the chlorinated compounds whose presence in concentrations are greater than 50 ppm and, would result in a positive test (*Baseline National Inventory of PCBs and PCB containing equipment-Nigeria, 2009)*

The study found PCB in the equipment sampled. The total weight of dielectric fluid contained in such equipment sampled, were extrapolated nationally as presented in Table 1 below.

Table 1: Estimate of PCBs volume in Nigeria

Table 1 was adapted from the report of the Baseline National Inventory of PCBs and PCB containing equipment - Nigeria, 2009. However, because the study was not holistic there remains a significant data gap in the information available on PCB quantities in the country.

Table 1: Estimate of PCBs volume in Nigeria

Weight of Oil (Tonnes)	Inspected	Inventoried	Extrapolated
Total	2,840	14,290	32,500
Potentially	316	1,278	3,400
PCB-contaminated			
% contaminated	11	11	10

3. Major issues relating to PCB Waste in Nigeria

Considering the problems relating to persistent organic waste in Nigeria, five major components needs be focused upon. These are; Main Sources of PCB waste in Nigeria, Magnitude of the Problem, Health and Environmental Implications of PCB oil contamination, Current Management practices of PCB waste in Nigeria and Policy level initiatives in the country. However, the policy level initiative is off the scope of this review.

3.1 Main Sources of PCB Waste

There are formal and informal means of PCB supply and availability in Nigeria, as captured in Fig.1.

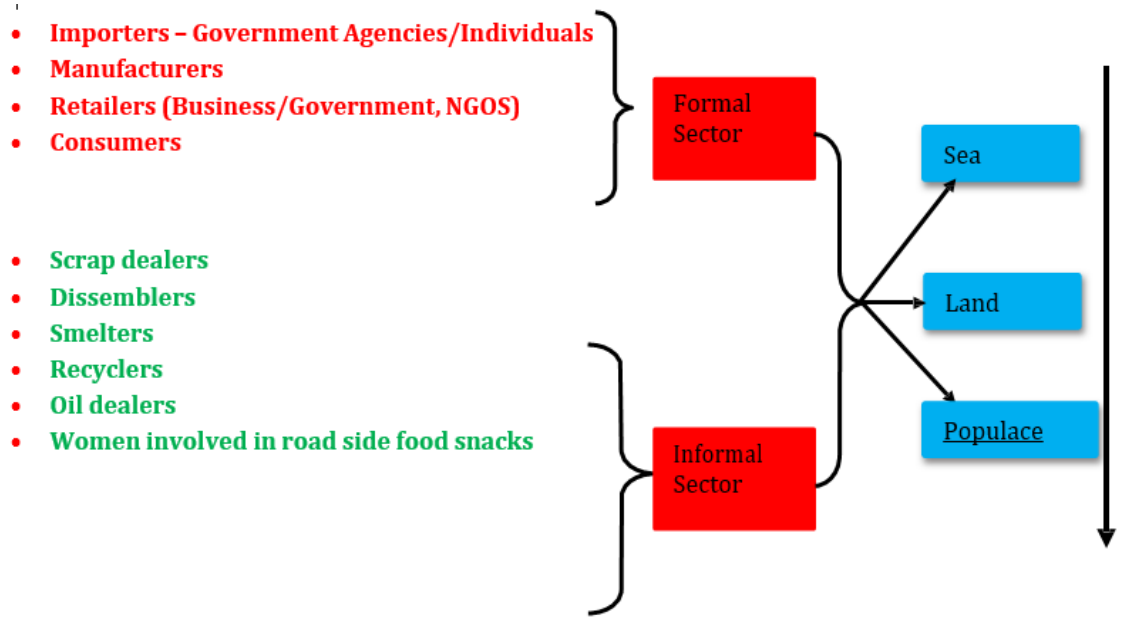

Fig 1: Formal/Informal PCB Supply Chain

Further elucidating these facts, an illustration of the various means by which, PCB get to the environment or to citizens, represented in the flow-chart below (Fig.2). As Fig 2 indicates, the involvement of various sectors further compounds the sources of generation.

Fig 2: Flow chart showing main source of PCBs in Nigeria.

During the inventory study, it was found that there are over 222 manufacturers from 58 countries who supplied transformers to Nigeria. This diversity of suppliers and equipment had contributed to the challenges of accurate data collection and interpretation. Moreover, below is a table adapted from the earlier inventory showing possible volume, after an inventory covering ten states of 36 excluding Federal Capital territory (FCT). However, a recent study was, commissioned by the World Bank for a comprehensive survey covering Nigeria.

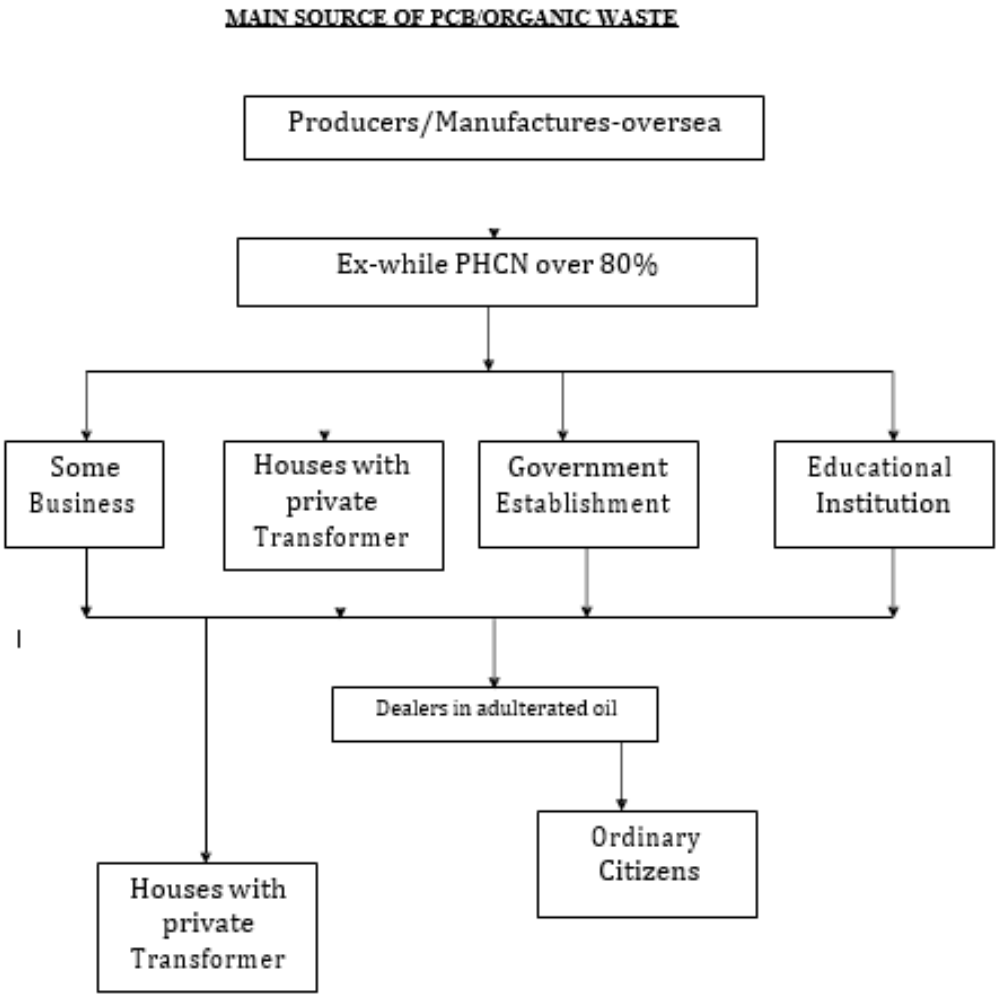

Fig 2: Flow chart showing main source of PCBs in Nigeria.

Table 2: Summary of Chlorinated oil with possible PCBs
Source: adapted from The World, 2009.

Table 2: Summary of Chlorinated oil with possible PCBs

Transformer Type	Weight of oil Chlorinated oil (kg)		
	Actual	Extrapolated	
		Inventoried	National
Generation	0	26,500	84,653
Transmission	234,069	1,060,642	1,078,878
Injection	78,718	87,064	657,638
Distribution	4,170	104,244	1,606,595
	316,957	**1,278,450**	**3,427,764**

3.2 Magnitude of Organic Pollutants with respect to Nigeria

The electrical and power generating industry has emerged as a growing segment of Nigeria industry both in terms of production and demands.

The management of PCBs is a major concern in Nigeria in recent times. Recycling, until recently has been dominated by the urban poor workers with very low literacy levels and with little awareness regarding the potential hazards of PCBs. Moreover, among the urban poor, there are a substantial number of women and children engaged in various recycling activities, which further compromise and exacerbate quality of health due to daily exposure to hazardous waste in general.

One of the major concerns related to PCB management, particularly in Nigeria, is the dumping of PCB contaminated products from developed countries. For instance large quantities of used transformers often find their ways into Nigeria due to activities of private businessmen. These transformers could be in the phasing out process in the parent countries but due to demands in Nigeria and elsewhere in developing countries, there is high accumulation of such products. Major reasons for these imports, are cheap pricing and lack of environmental and occupational standards. Thus, the Basel and Stockholm convention has helped to stop the toxic effluent of the developed nations flowing towards the world's poorest nations.

3.3 Health and Environmental Implications of PCBs and POP

Humans and animals do get exposed to PCBs through their diet. PCBs are soluble in fat, thus, are readily absorbed in the fat of animals hence, they bio-accumulate in aquatic and terrestrial species. This accumulation is biomagnified in higher species (such as humans), up the food chain.

Disposal of Organic wastes are a problem faced by many regions across the globe. It is even more compounded in Nigeria, because until now, the efforts to combat waste pollution and its health consequences were not given the enabling laws and where available, it lacks enforcement. Organic wastes that are landfilled produces contaminated leachates, which eventually pollute the groundwater [29]. For example, Guiyu, Hong Kong a flourishing area of illegal E/organic-waste recycling area, face acute water shortages due to the contamination of water resources [8]. This is occasioned by disposal of recycling wastes such as acids, sludges etc. in rivers. Mercury leaches when certain electronic devices, such as circuit breakers are destroyed [8]. The same is true for polychlorinated biphenyls (PCBs) from condensers. Further, when brominated flame retardant plastic or cadmium containing plastics are landfilled, both poly-brominated diphenyl ethers (PBDE) and cadmium may leach into the soil and groundwater. It has been found that significant amounts of lead ion are dissolved from broken lead containing glass, such as the cone glass of cathode ray tubes, gets mixed with acid waters and these are a common occurrence in landfills (Borthaku and Singh, 2012 [8]., http://www.step-initiative.org).

Additionally, uncontrolled fires could arise at dumpsite and this are a frequent occurrence in Nigeria. When exposed to fire, metals and other organic chemical substances, such as toxic dioxins and furans tetrachloro dibenzo-dioxin (TCDD) - polychlorinated dibenzodioxins (PCDDs), Polybrominated dibenzo-dioxin (PBDDs) and Poly chlorinated dibenzo furans (PCDFs) from halogenated flame retardant products can be emitted (http://www.step-initiative.org; Borthaku and Singh, 2012) [8]. The most dangerous form of on controlled burning of hazardous waste is the open-air burning of plastics in order to recover copper and other metals (http://www.step-initiative.org). The toxic fall-out from open air burning affects the local environment and broader global air currents, depositing highly toxic by-products in many places throughout the world (http://www.step-initiative.org). A Most recent study by the World Health Organization (WHO) [30] indicated that 4.9 million deaths were attributable to environmental exposure to POPs including PCBs and other chemicals in 2004. Such study, are revealing and relevant to Nigeria, where life expectancy is placed at 53 years (World Health Organization), for the general population. In Nigeria and, some other countries, hazardous waste streams are mixed with municipal or solid wastes and then either dumped or burned in the open air. Such habits, requires a concerted governmental efforts if, to be abated. Moving forward this direction, is so far gloomy hence, a concern for many health and environmental experts. Bearing, earlier studies of cancer in humans in occupational settings implicated PCBs as a carcinogenic compound [4].

Studying PCB kinetics, [21], investigated live fish, using as food live sandworms to look at dietary uptake and depuration kinetics of PCBs. Following, the assimilation efficiency (AE), of 84 congeners PCB, via the gastrointestinal tract (GIT) to the muscle of the fish were measured. Indication from the experiment suggested high co-transport of hydrophobic PCB and fatty acids into gastrointestinal tract epithelium cell. These experiments indicated, and bring to the fore, area with high potency of accumulation in aquatic lives.

At the subcellular level the lysosomal system has been identified as a particular target for the toxic effects of contaminants such as PCBs [25]. The lysosomal compartment is sensitive, thus any pathological alterations in lysosomes can be used to identify adverse environmental impacts on organisms [25, 25]. One of the characteristic changes is the increased fragility of the lysosomal membrane [25]. Many experimental

studies with marine invertebrates have shown that lysosomal alterations can be induced by single toxicants such as Cu/organochlorine e.g. PCBs [25]. Such studies have also proved that lysosomes are sensitive to field exposures of mixtures principally containing DDT, hexachlorocyclohexane and PCBs [24]. It is probable, PCBs pollutant may be poison/inhibitor that (share similar characteristics) target, the ABC (family of ATP-dependent transporters that pump amino acids, proteins e.t.c. out of cells against a concentration gradient) transporters. It is thought the human genome contains many genes ~48 coding ABC transporters, and many of which are involve in maintaining, the lipid bilayers, such as the lysosomes.

Most enzyme inhibitors largely fall into two broad classes: those that cause irreversible inactivation of enzymes and those whose inhibitory effects can be reversed. Inhibitors of the first class usually cause an inactivating, covalent modification of enzyme structure. For example, cyanide is a classic example of an irreversible enzyme inhibitor, by covalently binding mitochondrial cytochrome oxidase it inhibits the reactions associated with electron transport. Similarly, For example, induction of the hepatic biotransformation enzyme cytochrome P4501A by, PCBs and dioxins has been successfully measured for enzyme activity, enzyme amount, or mRNA, in 27 different fish species [23]. Indicatively, of the results gathered, marine invertebrate was more profound. Thus, one such successful example was of crayfish treated with 2,3,7,8-tetrachloro-dibenzo-p- dioxin (TCDD) and, cytochrome P450 was significantly induced at 3 µg of TCDD kg body weight, compared to an LD50 of 30-100 µg kg of body weight [23].

Although, the mechanism of PCB toxicity is yet be fully understood, its inherent danger can and could, be viewed from the foregone perspective. Bearing, cellular reactions in most animals exposed to pollutants, often do not show marked differences qualitatively, but only quantitatively, from those of normal metabolic state [22].

Most, recent studies [26] suggested exposure to PCBs and other organo-chloride play a role in the pregnancy delay in women. With increasing exposure, it was observed, the odds for pregnancy declined by 17 to 29 percent for couples in which males were exposed to PCB congeners 138, 156, 157, 167, 170, 172, and 209 and to DDE, produced when the pesticide DDT degrades in the environment (NIH/National Institute of Child Health and Human Development, 2012). Validating earlier results, suggesting some PCBs congeners have ability to alter reproductive processes in mammals, even in doses that do not cause other signs of toxicity [5]. Other, short-term effects of PCBs in humans include body weight loss, impaired immune function, and effects on the central nervous system, causing headaches, dizziness, depression, nervousness, and fatigue. Chronic exposure may also result in changes to the liver and related enzyme activity [9, 2, 10, 11].

Increasingly, it is recognized that the poor management of chemicals adversely affects human health and the environment, disproportionately affecting the urban and rural poor, particularly women and children. PCBs are a dangerous neuro-toxicants as they share similar kinetics with e.g. cyanide, as both are irreversible inhibitors. The kinetic effects of irreversible inhibitors primarily, are to decrease the concentration of active enzyme. The hazard associated with PCB is profound, with such recognition, coupled with the inherent environmental risks associated with handling PCBs, due diligence must therefore be enforced with the intents of minimizing risk to the environment, human health and surrounding communities. Thus, using data available from various scientific and toxicological studies on these materials along with information from actual levels found in most work place, occupational safety exposure of these toxicants should be strictly enforce in Nigeria. Here, safe exposure refers, exposure limits based on studies that defined safe levels to workers, working in a contaminated environment [19, 26].

3.4 Management of PCBs waste in Nigeria

In a recent inventory of PCB contaminated equipment carried out in Nigeria (The World, 2009), and a feasibility study for PCB disposal completed (feasibility studies of disposal options of PCB, 2014), it became apparent that the defunct Power Holding Company of Nigeria (PHCN) PHCN is the greatest user of dielectric fluid in the country. In many cases it was observed that, electrical items (transformers) are stored unattended mostly, because of lack of knowledge about their management. Such transformers and other electrical hazards lie in warehouses and substations across the federation. These waste particularly the PCBs oil find, their ways to the market via dealers and, could be use for cooking unknowingly. Thus, implementation of appropriate management measures including stringent regulations of sales of such organic waste is very necessary. The management practices currently operational in the country, has inherent dangers with severe health and environmental implications.

Historical information that was obtained during the course of earlier study suggests the existence of PCBs in the Nigerian environment. Moreover, the composition of PCB waste, were of diverse nature. Therefore, in such circumstance major approach would be via treatment with known, established methods and dispose thereof, dangerous materials and waste in a globally acceptable manner.

Nigeria has national regulations on hazardous/toxic chemicals for which PCBs fall under, and is also involved in the implementation of the International Convention, Procedures and Protocols on Hazardous/Toxic Wastes and Chemicals and Radioactive Waste Management. Since 1998, Nigeria develop national regulations on the Basel Convention on Trans-boundary Movement of Toxic Wastes; Procedures/Protocols on "Prior Informed Consents" (PIC) under the Rotterdam convention, on Hazardous Chemicals in International Trade. Along this line a strategy plan was develop to amongst other things, (see table 3), meet international standard.

Table 3: Management of hazardous wastes/toxic chemicals/radioactive waste

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Hazardous waste	Toxic chemicals	Radioactive waste
1. Require and assist industries to change to cleaner production methods and adopt preventive and recycling technologies.	1. Control chemical hazards through pollution prevention, emission inventories, product labelling, use limitation procedures for safe handling and exposure regulations.	1. Promote ways to minimise and limit the generation of radioactive wastes.
2. Encourage the phasing out of processes that produce high risks because of hazardous waste generation.	2. Phase out/ban high risk chemicals that are toxic persistent and bioaccumulative and whose use cannot be adequately controlled or monitored.	2. Develop/acquire technology for safe handling of radioactive waste.
3. Carry out environmental audits of existing industries to improve hazardous waste management.	3. Develop policies which will be based on principles of producer/ polluter liability.	3. Develop policy which will make mandatory for used radioactive materials to be returned to suppliers.
4. Producers to be responsible for the environmentally sound disposal of the hazardous wastes they generate.	4. Emphasize the use of biological control methods for pest-control.	4. Prohibit unauthorized storage or disposal of radioactive wastes.
5. Establish public awareness and training programmes for industries and government workers on hazardous waste issues, especially waste minimization.	5. Provide information on chemical hazard in local languages.	
6. Build treatment centres for hazardous waste either at national or state level. Industries should treat, recycle, re-use and dispose of wastes at or close to the site where they are created.	6. Establish emergency-response centres including poison-control centres.	
7. Create alert systems to detect illegal traffic in hazardous wastes	7. Control the importation of banned or restricted chemicals/pesticides.	
	8. Adopt community right-to-know programmes that provide information on accidental releases and annual routine emissions of toxic chemicals	

To achieve these objectives requires inter-agency cooperation (Fig 3: Scheme of governance model for PCB to enhance delivery). From various studies it is apparent, their remain a gap in the management efforts in Nigeria. Some of these gaps include;

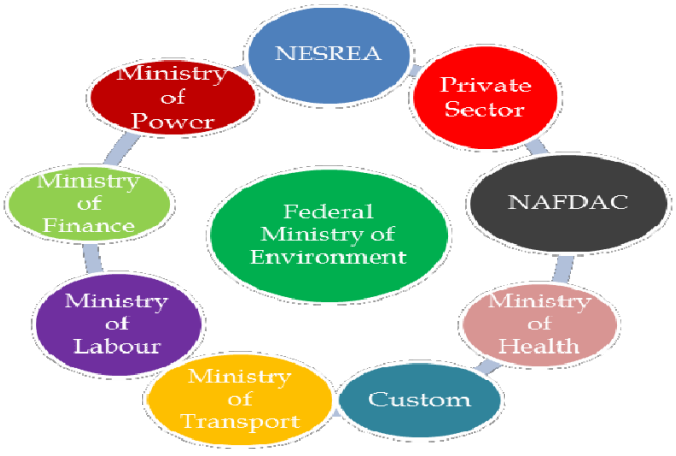

Fig 3: Scheme of governance model for PCB to enhance delivery (source: PCB policy, PMU, World Bank, 2014).

- ***Weak Database***

Inadequate/inaccurate data is a major constraint to policy formulation and project implementation in Nigeria. The inadequate inventory of Nigeria's natural resources is responsible for the dearth of detailed technical data that could be used to plan the management and national utilization of the resources.

- ***Inadequate Enforcement***

The inadequacy of both the policy and legal instruments notwithstanding, the enforcement of the existing environmental rules and regulations remains problematic. This especially so, as there are no clear demarcation of responsibilities between the Agency, Federal and State Ministries, further compounds inadequacy of the monitoring and enforcement mechanisms.

- ***Institutional Problems***

There is inadequate institutional capacity. The inter-sectoral communication are not well co-ordinated to manage the environmental and resource management network throughout the country.

4. Conclusions/Suggestions

Chlorinated compounds are produced in large quantities and have properties that explain their accumulation in various ecosystems (namely, lipophilicity and low or negligible metabolism rate in the organism). Due to their lipophilicity, chlorinated compounds from food and from the aqueous environment, accumulate in the fatty tissues of fish and shellfish.

With a partial study (feasibility studies of disposal options of PCB in Nigeria, World Bank, 2014), sound management procedures were recommended for disposal and treatment of PCB in Nigeria (details as published in the World Bank report, 2014). Above all, during the study, oil spills and leaks were observed in the immediate surroundings of transformers and its contamination with other solids and its possible leaks into the Lagos-lagoon (see Fig 4 A & B).

Fig 4 A: Pool of possible PCB oil with contaminated solid debris

Fig 4 B: Man-whole of contaminated PCB oil with direct leachate into the Lagoon

Due to dearth of statistical data, there are no empirical number or percentage to quote however, the incurable damage to the environment particularly aquatic lives and the populace is unarguable hence, need for containment therefore, is long overdue.

The need for a robust management of these organo-pollutants in Nigeria should not be handle with levity it should be treated as a priori. Moving forward, I suggest:

- Oil and allied companies should be encouraged by Nigerian government to organize annual Safety, Health and Environment Week in their operational areas to sensitize their work force on the sound management of general organic pollutants including PCBs and other chemicals.
- The Federal Ministry of Environment with the statutory responsibility to oversea environmental safety should be encouraged to frequently carry out environmental baseline studies and establishing oil/pollution, monitoring stations in high, risk area.
- Encouraged to frequently carry out Environmental Impact Assessments (EIA) and Environmental Evaluation Reports (EER) on new projects,
- Control the use of chemicals such as dispersant, drilling fluids and refilling oils through mandatory testing for toxicity effects on both aquatic organisms and measurement of biodegradability.
- Encourage the provision, and maintenance of necessary infrastructure for environmentally sound maintenance that includes, good sorting/transportation of and disposal of municipal solid waste.
- Provides reasonable budgeting to addressing organic/municipal solid waste so, ensure safe and healthy environment
- Encourage and oversea prompt remediation of polluted or contaminated sites though the use of safe and environmentally sound technologies.

When these are achieved it form an important aspect geared towards poverty reduction with concomitant human health promotion. Suffice is to say therefore, that global best practices needs be encouraged in Nigeria at all times to enhance for good PCBs or POPs management.

5. Acknowledgements

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6. Conflicts of Interests

I declare that there are no conflicts of interests.

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