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PROFILING OF POLYCHLORINATED BIPHENYLS (PCBs) IN SOILS AROUND A SECTION OF PORT HARCOURT METROPOLIS, NIGERIA

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ABSTRACT
This research was conducted to ascertain the concentration of polychlorinated biphenyls in aroclor form present in soils around old transformer area sites of Rumuagholu, Port Harcourt Nigeria. This was in order to know if the soil were relatively polychlorinated biphenyl toxic and in need of remediation. In order to conduct the study, samples were collected from transformer sites of Rumuagholu. Samples were collected and analyzed for estimation of PCBs in aroclor concentrations using Gas-Chromatography-Electron capture detector. The total PCBs aroclor concentrations in the sites (A and B) were found to be 4×10^{-6} *ppm and* 1×10^{-6} *ppm respectively which were well below the regulatory standards of New Jersey Department of Environmental Protection, United States Environmental Protection Agency as well as the Ontario Ministry of Environment and Energy which have their PCBs regulatory standards set at 0.2ppm, 1ppm and 0.3ppm respectively for residential and agricultural uses. The research therefore shows that the soil samples are restively nontoxic with respect to PCBs and are not in need of remediation as stipulated under the United States Toxic Substances Control Act (TSCA). The research also shows little traces of some pesticides and that the transformers in this area have contributed little or no PCBs toxicity to the environment.*

Key Words PCBs, Toxicity, Soil, Transformer, Profile

INTRODUCTION
Polychlorinated biphenyls are a group of man-made organic chemicals consisting of carbon, hydrogen and chlorine atoms. This group consists of 209 different chemicals which share a common biphenyl structure but vary in the number and position of attached chlorine atoms. [1][2][3][4][5]

Each PCB molecule contains two phenyl rings linked together. A phenyl ring is a ring of six (6) carbon atoms to which hydrogen atoms are attached. In PCBs, chlorine atoms replace some of these hydrogen atoms. The number of chlorine atoms and their location in a PCB molecule determine many of its physical and chemical properties**.** Chlorine atoms may be present at some or all of the 10 possible positions which are numbered 2-6 on one ring and 2'-6' in the other ring. These different combinations are called congeners, each having a specific number of chlorine atoms located at specific positions. [2][3][4][6][7].

PCBs are produced by electrophilic chlorination of biphenyl with chlorine gas. PCBs were first synthesized in 1864 [6], but the commercial production of PCBs began between 1929 to 1980. PCBs were manufactured and sold as mixtures of several congeners, with a variety of trade names, including aroclor, pyranol, pyroclor (USA), phenochlor, puyralene (France), Clophen, Elaol (Germany), Santotherm (Japan), Fenchlor, Apieolil (talu), and Sovol (USSR). Polychlorinated biphenyls were commonly produced as complex mixtures for a variety of industrial uses. These compounds possessed high chemical and physical stability, as well as very good electrical insulating properties and these special characteristics led to the widespread commercial utility of PCBs. Ironically, one of the properties of PCBs which most contributed to their widespread industrial use, their chemical stability, is also one of the properties which causes the greatest amount of environmental concern. This unusual persistence coupled with its tendency to accumulate in living organisms, means that PCBs are stored and concentrated in the environment. This bio concentration raises concern because of the wide dispersal of PCBs in the global environment and the potential adverse effects they can have on organisms, including humans. [8][1]. Although no longer commercially produced in the United States, PCBs may be present in products and materials produced before the 1979 PCB ban. Products that may contain PCBs include: Transformers and capacitors, Electrical equipment including voltage regulators, switches, re-closers, bushings, and electromagnets, Oil used in motors and hydraulic systems, old electrical devices or appliances containing PCB capacitors, Cable insulation, Thermal insulation material including fiberglass, felt, foam and cork, Adhesives and tapes, Oil-based paint, Caulking, Plastics, Carbonless copy paper, Floor finish. [9]

Aroclor is a PCB mixture produced from approximately 1930 to 1979. It is one of the most commonly known trade names for PCB mixtures. There are many types of Aroclors and each has a distinguishing suffix number that indicates the degree of chlorination. The numbering standard for the different Aroclors is as follows: The first two digits usually refer to the number of carbon atoms in the phenyl rings (for PCBs this is 12). The second two numbers indicate the percentage of chlorine by mass in the mixture. For example, the name Aroclor 1254 means that the mixture contains approximately 54% chlorine by weight. The various Aroclors produced differed in the percentage of chlorine by weight. The degree of chlorination of any Aroclor may vary between 19 and 71% [10].

The toxicity of a PCB is dependent not only upon the number of chlorines present on the biphenyl structures, but also the positions of the chlorines. For instance congeners with chlorines in both para positions (4 and 4’) and at least 2 chlorines at the meta positions (3,5, 3’,5’) are considered to be “dioxin like” and are particularly toxic. When there is just one (1) or no substitution in the ortho position, the atoms of the congeners are able to line up in a single plane (sometimes referred to as coplanar). The planar or “flat configuration” is particularly toxic [11].

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According to Brunner *et al* in 1985[12] due to PCBs worldwide distribution, persistence in the environment, and their possible health effects, PCBs have attracted great concern over the past decades. Their ability to bioaccumulation in fatty tissues and their lipophilic behavior pose a serious threat to mammalian systems. PCBs are not particularly toxic in short term chronic testing. High dosages are necessary to induce a lethal response in most trophic levels. Chronic exposure to sub lethal concentrations combined with high lipid solubility and resistance to metabolism can result in PCB accumulation and a toxic response [13]. PCBs are known to elicit a spectrum of toxic and deadly responses in humans, laboratory animals and wildlife [8][10][3][14].

In a study carried out by Pestic *et al*., in 1988, soil, corn plants, and foliage from areas surrounding two electrical salvage companies involved in reconditioning old transformers had unusually high levels of polychlorinated biphenyls (PCBs) [15]. Levels decreased as distance from the factories increased. PCBs were dispersed into the air through incineration of waste oils; water and soil contamination was caused by runoff from the factories. PCBs found in the contaminated areas closely resembled Aroclor 1260 as did the PCBs in the waste oil, whereas PCBs in other areas were more similar to Aroclor 1254. PCBs on surface soils taken from an unplowed pasture near the factories also resembled Aroclor 1260, whereas samples taken from depths of 2-4 inches showed degradation of some PCB isomers. PCB concentrations in corn cobs and kernels were <0.05 ppm, whereas leaves contained PCB levels of up to 2.2 ppm.

The aim of this research is to determine the concentration levels of polychlorinated biphenyls in the soil around Rumuagholu transformer areas and to estimate if humans, plants and animals around this area are at risk of being exposed to PCB poisoning and to further make recommendations based on the values of this research work to appropriate authorities. To form baseline values from which other researchers can build on while carrying out further related research work.

MATERIALS AND METHODS

Sample of soil were collected from two transformer areas (site A and site B) of Rumuagholu in Port Harcourt by scooping the top soil area. The geographical coordinates of the area are latitude 4^0 88'N and longitude 6^0 96'E. The top soil samples were collected at depths of about 2cm each near the transformer vicinity. Ample amount of the soil was collected in amber glass bottles. The samples were stored in the refrigerator until they were analyzed. Apparatus and reagents used includes; 100ml conical flask, Vial bottles, Amber bottles, Weighing balance, Pipette filler, Beakers, Rotary evaporator, Spatula, Gas Chromatographer-Electron Capture Detector HP 6890 n-hexane, Dichloromethane, Anhydrous sodium sulphate, Distilled water, Chromic acid.

The soil sample was analyzed by the APHA 6630 B procedure.

The amber bottles to be used for the extraction of the soil samples were first chromatized with dilute chromic acid and then rinsed with distilled water in order to avoid any form of cross contamination. An extraction solvent mixture was then prepared using dichloromethane and n-hexane in the ratio of 3:1.

The weighing balance was zeroed using the weight of the amber bottles and then 5g each of soil samples from three sites of A and B respectively were weighed into separate amber glass bottles labeled A1, A2 and A3 for site A and B1, B2 and B3 for site B respectively. 50mL of Dichloromethane/hexane was added to the samples and the mixtures were then sonicated for 1hr. The extract was decanted and passed through a column packed with anhydrous Sodium Sulphate in order to dehydrate the sample.
The dried extract was concentrated and reduced using rotary evaporator to about 2ml at a temperature of about 35 degree centigrade and stored in a vial bottle for GC analysis.

The vial bottles were placed on the injection chamber of the GC and 1µL was injected into GC- ECD HP 6890 and the result was calculated from the calibration using Mixed Pesticide Residue Accu Standard, USA. The mean result for each of the site was calculated and expressed in µg/kg as seen in table 1.

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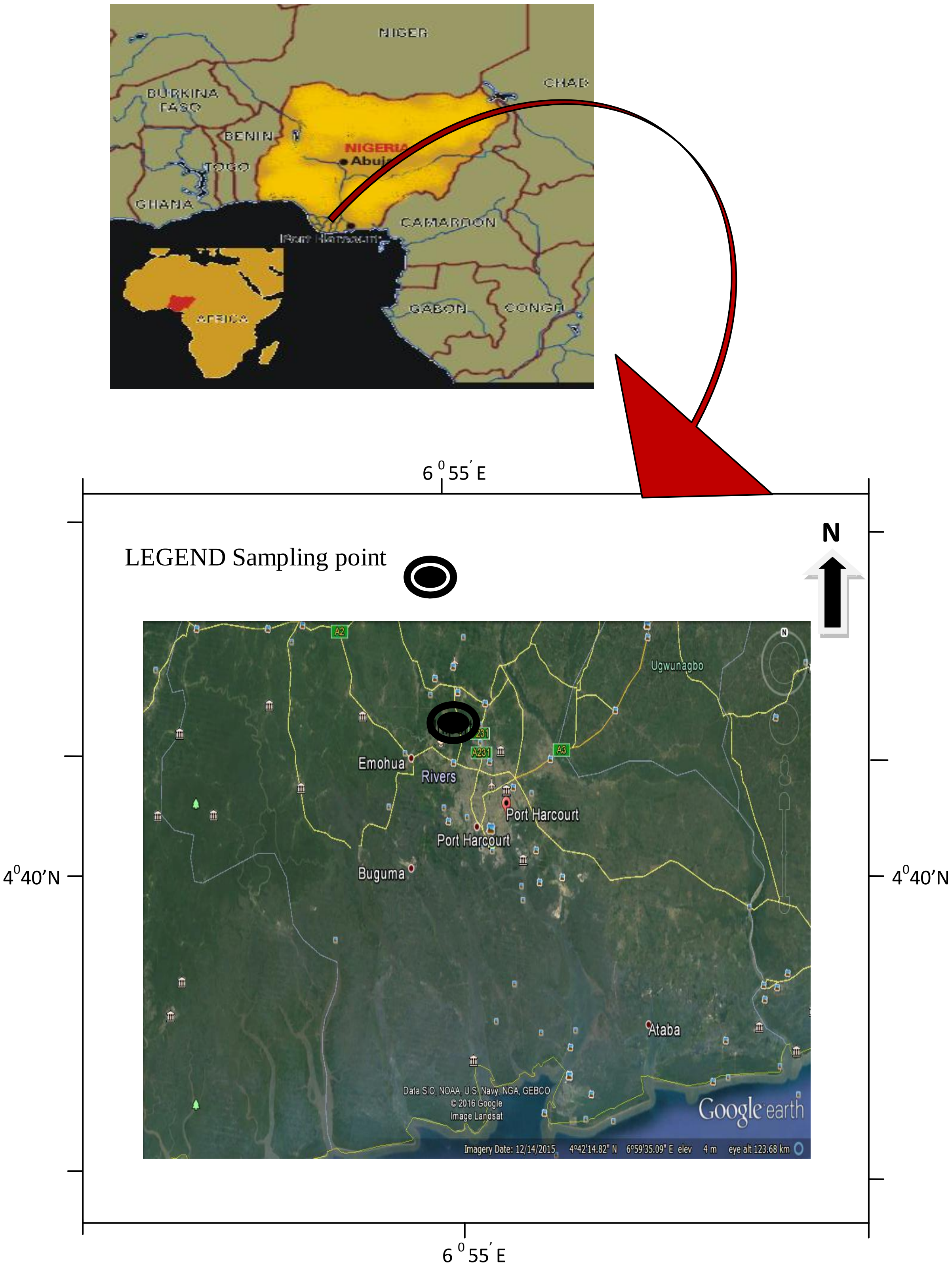

Figure1. Map of Port Harcourt, Nigeria indicating sampling point (Rumuagholu)

RESULTS

Table 1: Concentration of PCB Detected in Aroclor Form

Parameters	Result (µg/kg) Sample A	Value in ppm	Result(µg/kg) Sample B	Value in ppm
Arochlor- 1016	BDL	0.000001ppm	0.001	0.000001ppm
Arochlor-1221	0.003	0.000003ppm	BDL	0.000001ppm
Arochlor-1232	0.001	0.000001ppm	BDL	0.000001ppm
Arochlor-1242	BDL	0.000001ppm	BDL	0.000001ppm
TOTAL	0.004	0.000004 ppm	0.001	0.000001ppm

Note: BDL-Below Detection Limit (0.001 µg/kg)

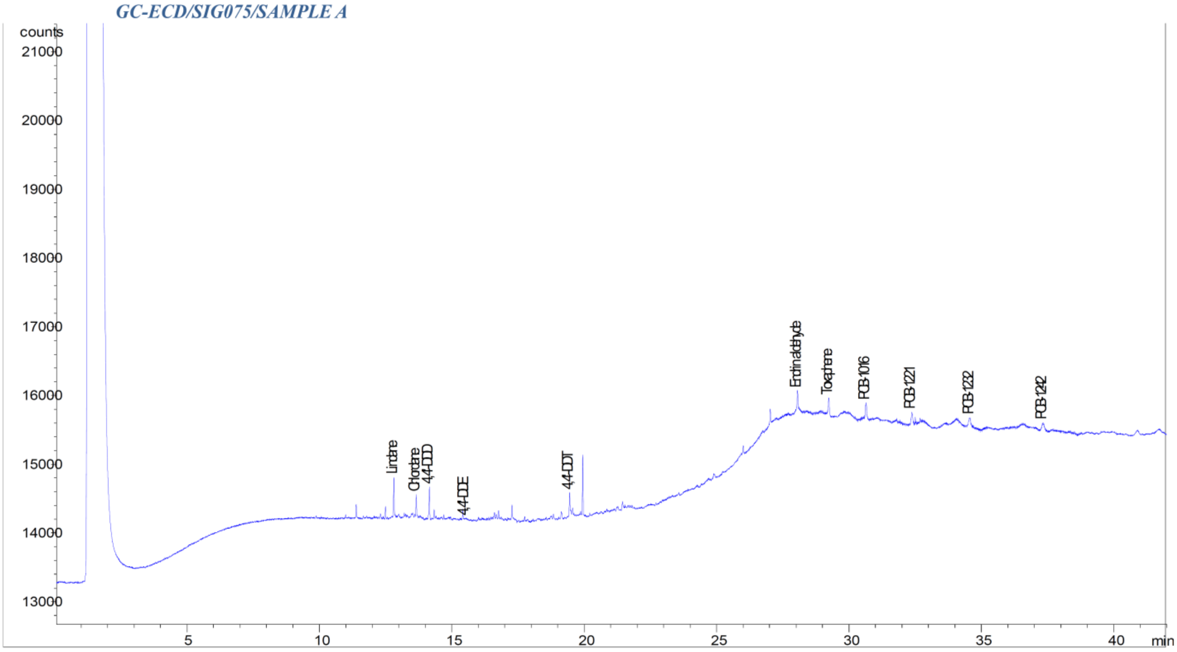

Figure 2. Chromatogram reflecting PCBs concentration at site A

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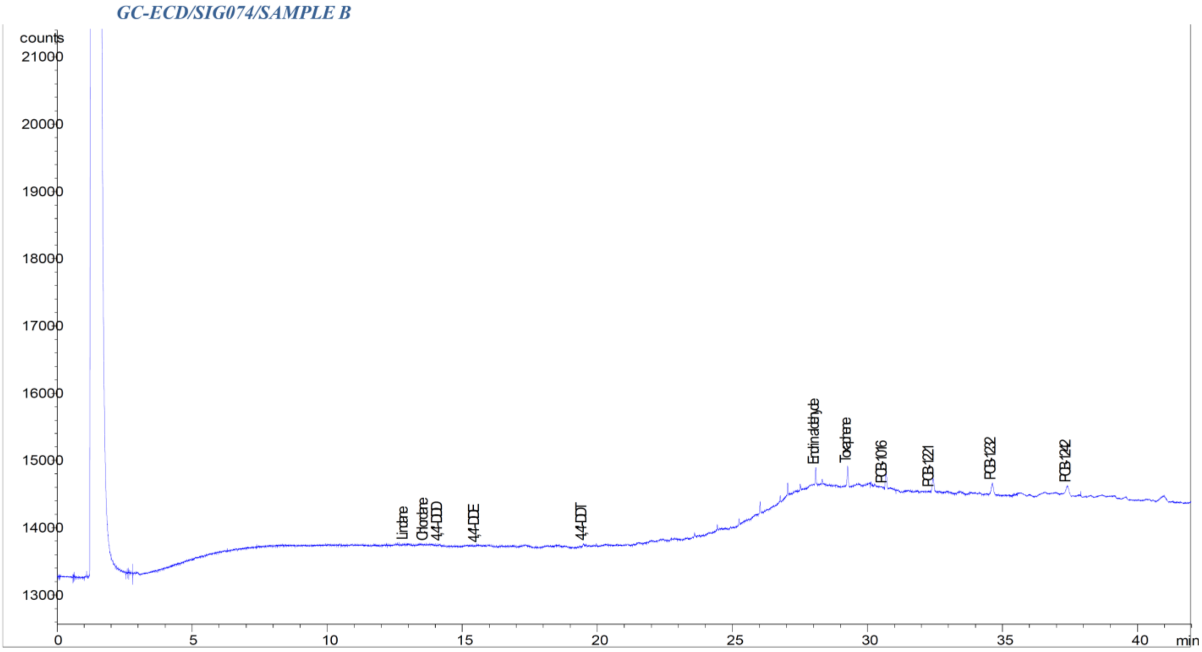

Figure 3. Chromatogram reflecting PCBs concentration at site B

DISCUSSION

The above table shows that arochlors 1016 and 1242 were below detection limit in sample A which represented site A however arochlors 1221 and 1232 were detected at 0.00003ppm and 0.00001ppm levels respectively. At site B only arochlor 1016 was detected while others were below the instruments detection limit.

PCB in the environment is regulated by Toxic Substances Control Act (TSCA).TSCA PCB regulations are implemented by EPA. The TSCA PCB regulations refer to approvals rather than permits, but the terms are essentially synonymous [16][17]

PCB-contaminated soil and sediments are regulated for cleanup and disposal under TSCA based on the date they were contaminated, the concentration of the source of PCBs, and the current PCB concentration. Under the TSCA, any soil or sediments containing PCBs ≥ 2ppm that were spilled after 1978 from a source ≥ 50 mg/ kg or a source unauthorized for use, are regulated as PCB remediation waste. Calculation of accurate toxicity is best done with use of the congener form. [16][17]

For sample A, the total PCB concentration as calculated in Aroclor form was found to be 0.000004ppm, this is far less than the regulatory limit of 2ppm and thus the sample site may be considered to be relatively toxic free with respect to PCBs and does not need to be remediated as given in the TSCA act. The fear of PCBs toxicity to plants, animals and humans from the transformers in this area is highly remote. A careful analysis of figure 1 below shows that some pesticide like Lindane, Chlordane and 4,4'-DDD (dichloro diphenyldichloroethane) were detected at 0.002 µg/kg, 0.001 µg/kg and 0.001 µg/kg respectively however 4,4'-DDE (dichloro diphenyldichloroethene), 4,4'-DDT (dichloro diphenyltrichloroethane), Endrin aldehyde and Toxaphene were not detected at site A.

For sample B, the total PCB concentration as calculated in Aroclor form was found to be 0.000001ppm, which is also a lot less than the regulatory limit of 2ppm. The sample site B may therefore also be considered relatively toxic free with respect to PCBs and may not require remediation as stipulated under the TSCA act. The fear of PCBs toxicity to plants, animals and humans from the transformers in this area is highly remote. Further careful analysis of figure 3 below shows that some pesticide like Lindane, Chlordane, 4,4'-DDD (dichloro diphenyldichloroethane), 4,4'-DDE (dichloro diphenyltrichloroethene) and 4,4'-DDT (dichloro diphenyltrichloroethane) were not detected at site B, however, Endrin aldehyde and Toxaphene were both detected at 0.001 µg/kg .

This shows that the transformers in these areas have contributed little or no PCB toxicity in these environments despite more than a decade of their installation. The transformers may or may not be PCB transformers. However the presence of some concentration of the PCB Aroclor in the soil environment shows that there must be a source. This source may be as a result of transport from one site to another or may also be as a result of little leakages that occur from the transformers when they are overheated. The detection of traces of pesticides in both sites could possibly be their transport from farmlands or other related areas.

It is therefore recommended that periodic checks are done within these sites that are so close to residential areas to forestall potential health catastrophe. Further analysis should also be carried out on the transformers by environmental safety agencies to ascertain the source of the PCB contamination and to ensure that the transformers present on these sites are not PCB transformers.

REFERENCES

WHO (2003). Polychlorinated biphenyls (PCBs). Human health aspects. Concise international chemical assessment document 55 ISSN 1020-6167

Bedard, D. L., R. E. Wagner, M. J. Brennan, M. L. Haberl, and J. F. Brown, Jr. (1987b). Extensivedegradation of Aroclors and environmentally transformed polychlorinated biphenyls by *Alcaligenes eutrophus H850*. Appl. Environ. Microbiol. 53:1094-1102.

Mousa, M. A., Quensen, J.F.III, Chou, K. and Boyd,S, A.(1996). Microbial dechlorination alleviates inhibitory effects of PCBs on mouse gamete fertilization in vitro. Environ. Sci. Technol. 30:2087-2092.

Quensen, III, J. F., Boyd, S. A. and Tiedje, J. M. (1990). Dechlorination of four commercial polychlorinated biphenyl mixtures (Aroclors) by anaerobic microorganisms from sediments. Appl. Environ. Microbiol. 56:2360-2369.

Waid, J. S. 1986a. PCBs and the environment. Vol. I. CRC Press, Inc., Boca Raton, Fla.

WHO. (1993). Environmental Health Criteria 140: Polychlorinated biphenyls and terphenyls. Second Edition. WHO, Geneva.

USEPA(2016). About Polychlorinated biphenyls PCBs.

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http://www.gascape.org/index-02/PCBs- (Polychlorinated Bip.)

ATSDR (2000). Toxicological profile for polychlorinated biphenyls (PCBs). Atlanta, GA, US Department of Health and Human services, Agency for toxic substances and disease registry. 765pp

https://www.epa.gov/pcbs/fluorescent-light-ballasts-flb-disposal

Crine, J. (1988). Hazards, decontamination, and replacement of PCB. A comprehensive guide. Environmental Science Research. Vol. 37. Plenum Press, New York.

Roberta, C.B. (2003). The Chemistry of Polychlorinated Biphenyls. http://Environmental Chemistry. Com/yogi/chemistry/PCB.html

Brunner, W., Sutherland, F. H. and Focht, D. D. (1985). Enhanced biodegradation of polychlorinated biphenyls in soil by analog enrichment and bacterial inoculation. J.Environ. Qual. 14:324-328.

Exner, J. H. (1982). Detoxification of hazardous waste. Ann Arbor Science Publishes, Ann Arbor,Michigan.

Safe, S. and Hutzinger, O. (1987). Polychlorinated biphenyls (PCBs): mammalian and environmental toxicology. Environment programme (pdf) pp40.

Pestic, M.J., Greichus, Y.A. and Dohman, B.A. (1980). Polychlorinated biphenyls (PCBs) of areas surrounding two transformer salvage companies, colman, south Dakota. US National library of Med, National institute of health. Vol.14 (1): 26-30

Cook, K and USEPA, (2012). Engineering issue: Technology alternatives for the remediation of PCB-contaminated soil and sediments. EPA 600-S-13-079.40pp.

Davila, B., Whitford, K.W. and Saylor, E.S. (1993). Technology alternatives for the remediation of PCB-contaminated soil and sediment. EPA Engineering issue. EPA/54o/S-93/506:pp1-4