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Review Paper

POLICHLORINATED BIPHYNEYLS (PCBs) IN THE ENVIRONMENT: CURRENT INFORMATION ON PCBS EXTRACTION, PURIFICATION AND REMEDIATION TECHNOLOGIES

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ABSTRACT: Polychlorinated biphenyls (PCBs) are synthetic organic complexes having carbon, hydrogen and chlorine atoms. They have been used in several manufacturing and industrial applications due to their elevated boiling points, non-flammability, chemical durability, and insulating properties. In addition, PCBs are very stable and predominate in the atmosphere for a longer period. As a result, they may not only influence the specific organisms but eventually the whole environments. This review defines the sources, fate, and route of transmission of PCBs in the atmosphere followed by their accumulation in humans and animals. We deliver the explanation of recent understanding of extraction and purification techniques for PCBs separation from many polluted places along with suitable remedial approaches. Also, the diagnostic tasks and suggestions for upcoming research relating to PCBs evaluation in the atmosphere are reviewed. Generally, this review describes the widespread information on innovative techniques existing in the field of PCBs investigation.

Keywords: Environmental contamination, sediments, fishmeal contamination, extraction and purification methods, remediation methodologies, future recommendation.

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INTRODUCTION

Polychlorinated biphenyls (PCBs) are a class of chlorinated aromatic hydrocarbons synthesized by using biphenyl as a raw material. They are persistence organic pollutants (POPs). Germany's Schmidt and Schulz first synthesized PCBs in 1881 and began production in the United States in 1929. Until the mid-20th century, the US banned the production of PCBs after concluding that they deposit and preserve in the atmosphere and can cause harmful health effects in human beings and animals (Xiaoyan and Jianpei, 2008). The molecular formula of PCBs can be expressed as $C_{12}H(_{10-n})$ (n=1~10), and the structure is shown in fig1 (Xing *et al.,* 2006). There are many homologues in PCBs. Currently; there are 209 kinds of PCBs. These PCBs can be divided into three categories depending on the substitution number and position of chlorine atoms) (Miao, 1996) : (1) Dioxin-like polychlorinated PCBs (DL-PCBs), There are 12 kinds, which can be subdivided into highly toxic DL-PCBs and toxic DL-PCBs. The highly toxic DL-PCBs include PCB81, 77, 126, 169, except for PCB81; the other three are similar toxicity to 2, 3, 7, 8-tetrachlorodibenzo-p-dioxin (TCDD). Such PCBs have common structural features: para-positions (4 and 4') and at least two meta-positions (3, 3', 5 and 5') with substituted chlorine atoms and no ortho-positions (2, 2', 6 and 6') replace the chlorine atom, which has a planar molecular structure and is characterized by an aryl hydrocarbon receptor (AhR) antagonist, which is the most toxic PCBs component (Safe, 1996). The latter are congeners and isomers with only one substituted chlorine atom in the ortho position, including PCBs 105, 114, 118, 123, 156, 157, 167, and 189. Compared with highly toxic PCBs, they have similar coplanar structures, also have AhR antagonist activity, but their toxicity is weak; (2) resistive PCBs, there are 19 types of resistive PCBs (PCB45, 84, 91, 95, 88, 131, 132, 135, 136, 139, 144, 149, 171, 174, 175, 176, 183, 196, 197), a chlorine barrier at the ortho position at normal temperature forms a barrier to prevent covalent benzene ring. The rotation of the bond gives it a chiral isomer under ambient conditions (Harju, 1999). Compared to other PCBs, the resistance-type PCBs are more stable in nature, last longer in various environmental media, and are chiral in the process of environmental media and food chain flow. Studies have detected two types of PCBs from human milk and blue whales: PCB132 and PCB149, both of which have higher content and obvious chiral selection (Blanch, 1999); (3) the rest PCBs are ortho-substituted homologs with two chlorine atoms. The AhR antagonist activity of such PCBs is mostly weak, the competitive binding force to AhR is weaker than that of DL-PCBs, and the reactivity is better than that of the same number of chlorine substitutions. DL-PCBs are low, but such PCBs will remain in the environment for a long time.

The chemical structure, chemical properties and toxicity of DL-PCBs are very similar to those of 2, 3, 7, 8-TCDD, showing the characteristics of dioxins. DL-PCBs belongs to a class of PCBs, and their physical and chemical properties are similar to those of PCBs. The physical and chemical properties of PCBs are shown in Table 1. The pure substance of PCBs at normal temperature is in a crystalline state, and the mixture is mostly oily liquid. The PCBs with two, three or four chlorine atoms are liquid and have good fluidity. More the number of chlorine atoms, more the viscosity of PCBs, from honey to cream or waxy (high chloride biphenyl) (Song, 2010). PCBs are resistant to acids, alkalis, heat, corrosion, and oxidation, have good thermal insulation and high dielectric constant. Due to these special properties, the insulating oil of capacitor equipment and transformers is produced by PCBs. It can also be used as a pressure transmission medium for hydraulic systems, a heat carrier for heat conduction systems, and lubricating oils, coatings, adhesives, printing inks, resins, and rubber. , paraffin additives, etc. (Hu *et al.,* 2016).

In addition to the above properties, PCBs are also characterized by low vapor pressure, low water solubility, and high fat solubility. It is known from Table 1-1 that the more chlorine substitutions of PCBs, higher the melting point and floating-point, smaller the solubility and vapor pressure in water, larger the bioaccumulation factor, and larger the octanol-water partition coefficient (Kow). These properties cause PCBs to be easily volatilized into the atmosphere and migrate with the atmosphere. They migrate easily with atmospheric particulates and settle into water and soil (Cui *et al.,* 2015). PCBs are highly lipophilic (Kow>104). In general, the more chlorine atoms in PCBs, t larger the Kow (which can differ by 8 orders of magnitude) and longer the half-life, such as PCBs with 7 chlorine substituents. The half-life in soils and sediments can be as long as 33 years (Sinkkonen, 2000). PCBs can also be bioaccumulated and amplified through the food chain, and the more PCBs accumulate in the animal at the top of the food chain. For humans, the main exposure route for PCBs is through food contamination exposure. PCBs will be present in food for a long time and will be widely found in animal foods.

SOURCE AND DISTRIBUTION OF PCBS IN SEDIMENTS: In China, the production of PCBs began in 1965. Most of the factories were shut down in 1974 and did not stop production until the 1980s. During this period, China also imported a large number of power capacitor products containing PCBs from other countries. PCBs were included in the first batch of organic pollutants controlled by the Stockholm Convention on Persistent Organic Pollutants (Fan, 2008; Huang *et al.,*2011). PCBs will affect humans and the global environment through processes such as surface light flow, atmospheric dry and wet deposition, bioaccumulation and transmission (Sinkkonen, 2000; Carpenter, 2006; Ivanescu, 2015). According to the data analysis of the China Environmental Protection Agency, Asia has about 80% of the world's e-waste. What is more serious is that China has digested 90% of these pollutants, and about 50-80% of US e-waste has finally remained in China (Harju, 1999). Therefore, China's PCBs pollution problem will be widely concerned for a long time. PCBs in sediments are mainly from water bodies and are left in sediments through various processes such as adsorption, photolysis, chemical oxidation and microbial degradation *(*Lors *et al.,* 2012). PCBs have high absorptivity and are easily enriched in sediments, which is higher than water. Therefore, the main environment of PCBs is soil and sediment, so there are PCBs in farmland, watershed sediments, and offshore sediments (Nobuyoshi *et al.,* 2000; Herrick *et al.,*2016). In some areas, the concentration is high, and in some areas, the concentration is low. Studies have shown that PCBs are commonly found in estuaries, bays and offshore sediments in neighboring industrial areas, with content of ND~x*104ng/g. Studies have shown that the total content of the sediments in the Tiezhou Bay sediments is 9.83 ng/g. Compared with the content of sediments in other sea areas in china and abroad, it is at a moderately low level. At a moderately low level (Li, 2014); some people have studied the sediments in Gyeonggi-do Bay, South Korea, and the results show that the sediments contain PCBs, there are 101 kinds of PCBs homologues and their content is 10 ng / g ~ 580ng /g (Lee and Tanabe, 2001), some PCBs content has been obviously at the level of heavy pollution; some studies have collected sediments in the vicinity of Guangzhou and the inner harbor of Macao in the Pearl River Delta region, and found 128 kinds of PCBs homologues, with a total content of 485.45 ng/g and 338.53 ng/g respectively (Nie *et al.,* 2012).

PCBs CONTAMINATION OF FISHMEAL FEED: Fish and shrimp in the ocean are not only a part of the human diet but also an important raw material for fishmeal feed. Fishmeal is a high-protein feedstock that is cooked, dehydrated, dried, and pulverized with one or more fish as raw materials (Duan *et al.,* 2006). High protein content, balanced amino acid composition, good palatability and rich in unknown growth-promoting factors characterize the nutrient composition of fishmeal. It is an important feed ingredient in aquatic products, livestock and a small part of special animal breeding (Yin *et al.,* 2011). According to statistics, China is the country with the most demand for fishmeal, accounting for nearly one-third of the global total demand. From January to December 2016, the total amount of imported fishmeal in China exceeded 1 million tons, an increase of about 1.1% year-on-year; in 2016, China's fishmeal production was about 310,000 tons, an increase of 6% year-on-year; the total demand for fishmeal in China was about 1.4 million tons in 2016 (Yang, 2017). Research on fishmeal feed has focused on the development of alternative products, but for the time being, there are few real applications that can be applied to production. The development of the aquaculture industry will still occupy a unique position, and the dependence of animal production on fishmeal feed will continue to exist (Zhu, 2005).

The quality of fishmeal directly affects the health of farmed animals. There are many determinants of the quality of fishmeal, among which the quality of raw fish used in the production of fishmeal play an important role (Juanhua, 2013). The high protein content of fishmeal is an important component of energy feed. Therefore, the problem of PCBs contamination in fishmeal has attracted people's attention. The European Union (EU) Committee stipulates that the content of PCBs in fishmeal and fish oil should not exceed 1.25 ng TEQ/kg and 6 ng TEQ/kg at most (Baron and BØrresen, 2007). There have been reports on PCBs pollution in fishmeal, and there are few studies on PCBs pollution of fishmeal in China, while there are relatively many foreign countries. In the study, seven kinds of indicative PCBs residues in different samples of fishmeal feed were determined by gas chromatography. The results showed that PCBs were detected in some fishmeal feeds (Lan, 2008). On January 9, 2004, Science magazine confirmed that farmed salmon is more susceptible to contamination by PCBs and other toxins than wild salmon, which is considered a potential source of these pollutants (Longstaff, 2005). For the pollution of PCBs in fishmeal feed, people have begun to look for degradation methods, such as (Baron and BØrresen, 2007) used UV light to degrade the PCBs in fish meal. The results showed that after 5 days of irradiation, the content of PCBs in the fishmeal was reduced by 70%. It was also shown that combined with the separation of waste fish juice and concentrated fat, chloroform/methanol extraction can effectively remove PCBs from fishmeal feed (Oterhals, 2008). In general, the problem of PCBs contamination of fishmeal feed has always existed, and it will continue to be concentrated in the animal body that ingests the contaminated feed because of the food chain transmission of PCBs, which is not only bad for the health of farmed animals, but also bad for humans.

OVERVIEW OF PCBs EXTRACTION AND PURIFICATION METHODS IN SEDIMENTS

Extraction method of PCBs in sediment: PCBs are widely used in the environment and are difficult to degrade. After long-term exploration, many pre-processing technologies have been established and are well used for the detection and analysis of PCBs. Soxhlet extraction, accelerated solvent extraction, ultrasonic-assisted extraction, solid-phase extraction, and supercritical extraction are the main extraction techniques for PCBs in marine sediments (Viguri, 2002; Carro *et al.*,2017). The purpose of this step is to enrich the components to be tested, eliminate matrix interference, improve detection sensitivity, and reduce detection limits.

Soxhlet is a solid sample processing method that uses solvent reflux and siphon principle to infiltrate a solid for a long time to leach the desired organic matter. It is one of the ISO standard methods (Song, 2015). This method is commonly used for the extraction of non-polar and semi-volatile trace organic pollutants in solid samples such as soil, sediment, and biological tissues. (Viguri, 2002) used a Soxhlet extraction method to extract polycyclic aromatic hydrocarbons (PAHs) from sediments in a 1:1 dichloromethane-acetone mixture (75 °C). After 24 h, PAHs recovery was obtained. The recovery rate is between 90%-110%; (Aydin and Tor, 2006) extracts PCBs from coastal sediments and organochlorine pesticides in a 1:1 n-hexane-acetone solvent, 5-7 times per hour. After 24h, the recovery rate was between 87.9%-104%. Soxhlet extraction is widely used because of its simple equipment, low cost, wide range of sample extraction, easy operation and stable extraction. However, this method consumes a lot of solvents and may cause new pollution to the environment (Banjoo, 2005; Zhang *et al.*,2011).

Accelerated solvent extraction (ASE) is based on the principle that the solubility of a solute in different solvents is different, providing high temperature and high pressure, selecting a suitable solvent to achieve efficient and rapid extraction of organic matter in solid or semi-solid samples (Niu *et al.*, 2014). Li *et al.* (2006) used ASE to extract PAHs from marine sediments and used dichloromethane as the extraction solvent. Under the system pressure of 11724 kPa and temperature of 100°C, static extraction for 7 min allowed 16 samples of PAHs to be extracted. The standard recovery rate is between 74%-138%, which can meet the requirements of PAHs analysis in sediments. He *et al.* (2012) compared the extraction effects of C_6H_{14} and C_3H_6O solvents on the extraction of PCBs in sediments. Compared with Soxhlet extraction, mechanical shock extraction, ultrasonic extraction, ASE shortens the extraction time and is obvious. Reducing the amount of extraction solvent, it is easy to operate, high degree of automation (Niu *et al.*, 2014).

Ultrasonic extraction (UE) is a multi-stage effect such as strong cavitation effect, disturbance effect, high acceleration, crushing and stirring effect, which enables macromolecular substances to move at high speed, therefore, the PCBs are better dissolved in the solvent (Liu, 2014). Aydin *et al.* (2006b) showed that the PCBs in the soil samples were extracted by micro-ultrasonic extraction technology, the recovery rate of PCBs exceeded 90%, and the relative standard deviation was less than 7%. Banjoo *et al.* (2005) extracted PAHs from marine sediments with a 1:1 mixture of n-hexane-acetone for 15 min. After 4 cycles, the results showed that the recovery of ultrasonic extraction exceeded 90%. Compared with conventional extraction technology, ultrasonic extraction technology has obvious advantages such as fast, low cost and high efficiency (Yang, 2010).

Solid-phase extraction (SPF) is a solid adsorbent that adsorbs a target analyte from a liquid sample to separate it from the interferent, elutes the analyte, and separates and enriches the target analyte. It consists of four steps: activation, loading, rinsing, and collection (Liu *et al.,* 2014). Chen *et al.* (2017) extracted with 1:1 (v/v) acetone and n-hexane, concentrated by rotary evaporation in a water bath at 40°C and transferred to 5 mL of n-hexane, and then purified by automatic solid-phase extraction system. Finally, better recovery was obtained. The SPF is widely used in environmental and pharmaceutical analysis fields. It is a standard method that can be used for the detection of various pollutants such as air, water, sediment, etc. It has the advantages of reliability, high efficiency, and small solvent usage (Song *et al.*,2012).

Supercritical fluid extraction (SFE) is the relationship between the solubility of a supercritical fluid (such as water or CO_2) and its density. In the supercritical state, the supercritical fluid is contacted with the substance to be separated, and the polarity is selectively selected (Chikushi *et al.*, 2012). The components with different boiling points and molecular weights are extracted in order to achieve the purpose of separating organic matter (Patela *et al.*, 2011). Miyawaki *et al.* (2008) used supercritical CO_2 technology to extract DL-PCBs from soils and sediments. The results show that the method has good reproducibility and the relative standard deviation is less than 21%. Reimer (1995) used SFE and Soxhlet extraction techniques to extract PAHs from the soil, and then compared the two methods. The results showed that the extraction efficiency of SFE on soil PAHs was higher than that of Soxhlet extraction. Supercritical fluid extraction technology not only has the characteristics of traditional extraction methods but also supplements many shortcomings. However, in addition to the small sample requirements, convenient operation and rapid detection, there are also insufficient monitoring standards (Zhu,2016).

METHOD FOR PURIFYING PCBs IN SEDIMENT: The main purpose of the extraction is to replace the PCBs in the sample with organic solvents, and the two organic solvents, acetone and n-hexane, can dissolve many other organic substances, so purification is an indispensable part. At present, the purification methods of PCBs mainly include acidification, gel permeation chromatography, and adsorption chromatography.

The main action solvent of the acidification method is sulfuric acid. Sulfuric acid is subjected to an addition reaction with a double bond of an impurity in the substance to be purified, and the resulting sulfonated product is dissolved in sulfuric acid, thereby separating the impurity and the target substance (Liu *et al.*, 2017). In another method of purifying, sulfuric acid is combined with potassium permanganate on the basis of pure sulfuric acid purification: first adding sulfuric acid in the sample, then adding potassium permanganate, and removing the single oxidation by strong oxidation of sulfuric acid and potassium permanganate (Zunying, 2008). However, this method also has limitations. The operation is complicated, the target product is easily lost, and the waste liquid after purification is more, thereby increasing the environmental burden.

Column chromatography has been used to purify the substance through the column filled with various adsorbents (Yan *et al.*, 2011). It can be seen that the key to this purification method is the adsorbent in the column. In general, adsorbents are graphite, silica gel, Florisil, and similar compounds. Graphite has a good adsorption effect on weakly polar substances, proteins, polyphenols, and other substances in the sample (Zhang *et al.,* 2008), but the graphite used in this method is more expensive than other adsorbents, so limit its application in purification. Silica gel can be prepared by sodium silicate and sulfuric acid. It is a weakly acidic regenerable adsorbent. Concentrated sulfuric acid, silver nitrate, and sodium hydroxide can be combined with silica gel to form acidic silica gel, silver nitrate silica gel and alkaline silica gel. Silver nitrate and sodium hydroxide can be combined with silica gel to form acidic silica gel, silver nitrate silica gel, and alkaline silica gel. These three compounds have different effects on specific impurities (Fenqiang *et al.*, 2016). Florisite, also known as magnesium silicate adsorbent, is a polar adsorbent that is capable of adsorbing polar compounds. Flori Silica column has lower purification costs, which is widely used in many organic pollutant detection fields and has become the most commonly used means for purifying PCBs. This method also removes interfering polar organic compounds: pesticides and polychlorinated hydrocarbons (Shen *et al.,* 2017). Column chromatography in addition to the three fillers described above, there are many other filling options, such as alumina. This method is safer than other methods, simple to operate, and higher in recovery rate, but it also has its disadvantages like the efficiency of separation is lower than other methods (Manolis *et al.*,2014).

Gel permeation chromatography was developed in the 1950s. The principle of purification is to separate and elute molecules of different sizes by means of a porous gel stationary phase. Generally, macromolecules are eluted first with respect to small molecules (Li *et al.*,2017). This method is especially suitable for sample materials with high return content. It has the advantage of being able to separate contaminants of unknown polarity, which is convenient and quick and can remove the grease, but its disadvantage is that it is difficult to completely purify the oil and fat in the sample, resulting in purification. The result is not ideal.

Many of the current methods are formed by combining different analytical methods based on many classical extraction methods. For example, Wang *et al.* (2013) combined pre-treatment with accelerated solvent extraction and solid-phase extraction purification, and then used gas chromatography/triple quadrupole tandem mass spectrometry to detect PCBs. Hexane (1:19, v/v) mixed solution, elution rate of 0.6mL / min, ASE extraction temperature of 90°C, extraction time of 6min, the actual standard sample recovery was 95.6% ~ 125.7% and 70.4% ~ 124.7%, the extraction, and purification effect of this method is better. Liu *et al.* (2008) used the weakly polar and medium polarity double capillary column complementary separation technology to perform qualitative and quantitative analysis of DL-PCBs in the sample based on Soxhlet extraction technology. Ren *et al.* (2008) used the Soxhlet extraction and gas chromatography high-resolution mass spectrometry for the determination of dioxins and DL-PCBs in environmental samples. Although there are many methods for detecting and analyzing PCBs, each has its own advantages and disadvantages. Therefore, finding better detection and analysis methods will improve the accuracy of detection, and facilitate accurate understanding of the content of PCBs in environmental media, combined with previous research results. This study will improve the extraction and purification steps of PCBs in order to obtain better results.

ANALYTICAL PROBLEMS AND ADVANCEMENTS: Analytical methods for the estimation of PCBs have been under examination for over the previous four decades. While the analysis of PCBs in different sample mediums is an established field of environmental analytical chemistry, the main methods remain the same for the previous two decades excluding the application of mass spectrometry (MS) detectors in place of traditional detectors. But, the present options mainly, the usage of high-resolution mass spectrometry and isotope labeled protocols in the investigation of PCBs are expensive, which has limited the scientists from emerging countries as demonstrated by the less number of publications on PCBs from Africa, South Asia and South America (David, 1998). Consequently, it is important to develop cost-effective methods employing new approaches consuming low solvent use, Solid-phase microextraction, and microscale glassware to support researchers from the emerging countries where they have narrow analytical funds. The investigation of PCBs in surface waters having wastewater sewages is very difficult job. In such samples, due to the existence of waste compounds, medium effects like ion-suppression and variation in retaining times may limit the examination of PCBs even with the extremely advanced MS detectors. While many modern sample cleaning and extraction techniques have been developed recently, only a few extraction/cleaning methods are appropriate for extraction of PCBs from the compound (Govindan, 2015). Sometimes some hindering compounds caused problems in the detection of PCBs. So, it compulsory to confirm the elimination of all hindering compounds by means of the best existing cleaning techniques. Besides the sample complication, hindrances may also occur from the laboratory and area pollution counting from chemicals, solvents, glassware, washing solutions, plasticizers and other PCB holding substances in sample handling process.

REMEDIATION METHODOLOGIES FOR PCBs: In the last few years, many chemical, physical and biological remediation techniques have been developed for the PCBs polluted water, soils and sediments. Traditional remediation methods involving thermal incineration, phytoremediation, microbial degradation along with the new visions such as supercritical water oxidation (SCWO), ultrasonic radiation, activated carbon, nanoscale zerovalent iron (nZVI) based reductive dehalogenation and combined nZVI techniques are used for PCBs remediation. A few of these approaches are still in the early developing stage, thus imposing advance research attention (Lisa *et al.,* 2010).

FUTURE RECOMMENDATIONS: The fundamental scientific study on PCBs in the last few years has exposed many unpredicted findings. Predominantly, the intensities of PCBs in the atmosphere are no longer reducing, but actually, they are increasing in some geographic areas (McLachlan *et al.,*2018). PCBs can cause life-threatening health effects via some unfamiliar means instead of conventional regulatory patterns. Up till now, most of investigation efforts regarding harmful effects related with PCBs was focused on DL PCBs. Contact to elevated levels of DL-PCBs may injure the liver and can cause chloracne, while prolonged contacts to lower levels correlate with immune system abnormalities and tumor. For over years of study on PCBs toxicity proves that environmental health hazards related with PCBs need to be improved. The hypothesis of nutrition as the main path of contact to PCBs may require to reconfigure reflecting inhalation as the another important path of contact (Ampleman *et al.,*2015). PCBs may also cause the neurotoxicity; therefore a new research is essential to detect particular PCB molecules that can act as neurotoxins and to demonstrate the procedure (s) by which they restrict with neurodevelopment. More recently, the use of several technologies is providing favorable results in the remediation of PCBs. Consequently, the successful treatment of PCBs not only recognized by the selection of effective remediation technology, it also require to consider the public acceptance modifying environmental and human health influences of the respective remediation technology, neither of which have been achieved so far (Stoin *et al.*,2015). Thus, it is another important issue to discover promising remediation methods for efficient PCBs destruction *in-situ* and *ex-situ* to evaluate their environmental burdens and risks associated with the implementation of the respective technology. Moreover, many analytical procedures are presently accessible for the investigation of PCBs present in soil, sediments, fish, food, birds, mammals, human milk and blood samples, and these approaches could be performed comparatively at reduced costs in emerging countries. However, the convenience to latest capillary gas chromatography combined with MS detection for the extraction of PCBs is essential to take part in local and worldwide resemblance. Generally, these approaches must be advanced to increase the performance of techniques to be adopted in emerging countries due to the financial limitations. Therefore, an appropriate optimization of gas chromatography is important for the investigation of PCB molecules regardless of the particular detectors (Eguchi1 *et al.*,2017).

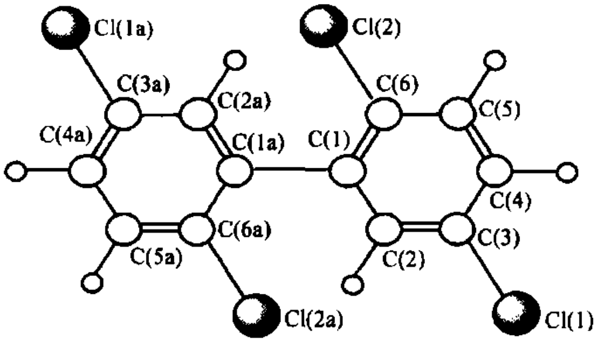

Figure-1: Chemical structure of PCBs

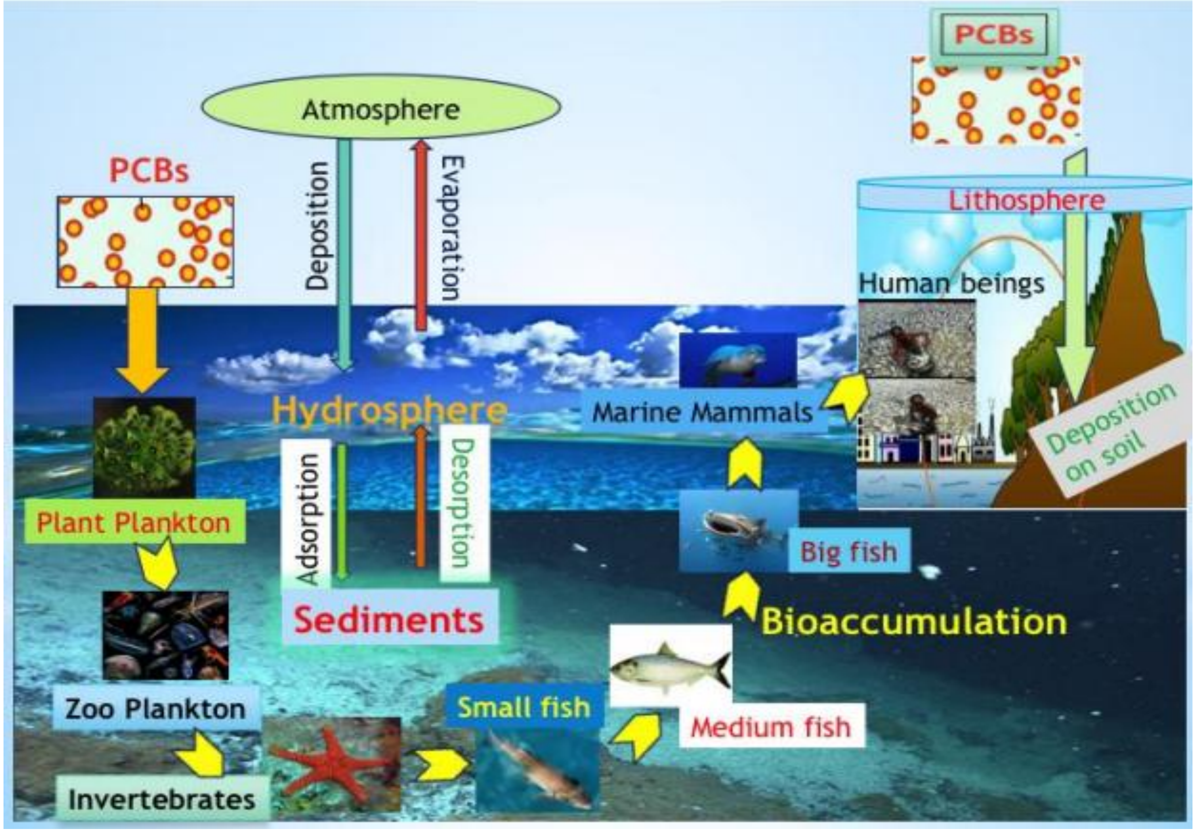

Figure-2: Possible route of transmission of PCBs in the environment (Reddy *et al.*,2018)**.**

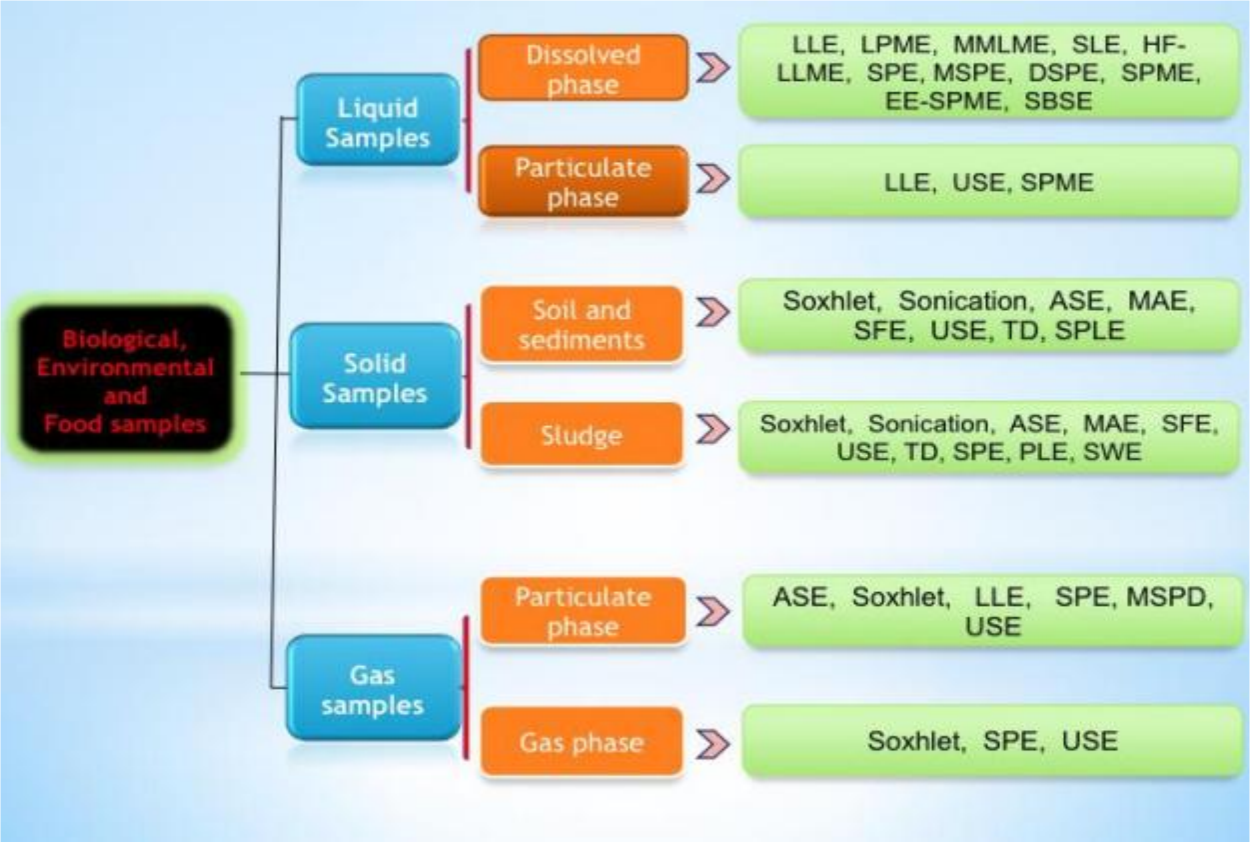

Figure-3: Sample pretreatment methods for extraction of PCBs (Reddy *et al.*,2018)**.**

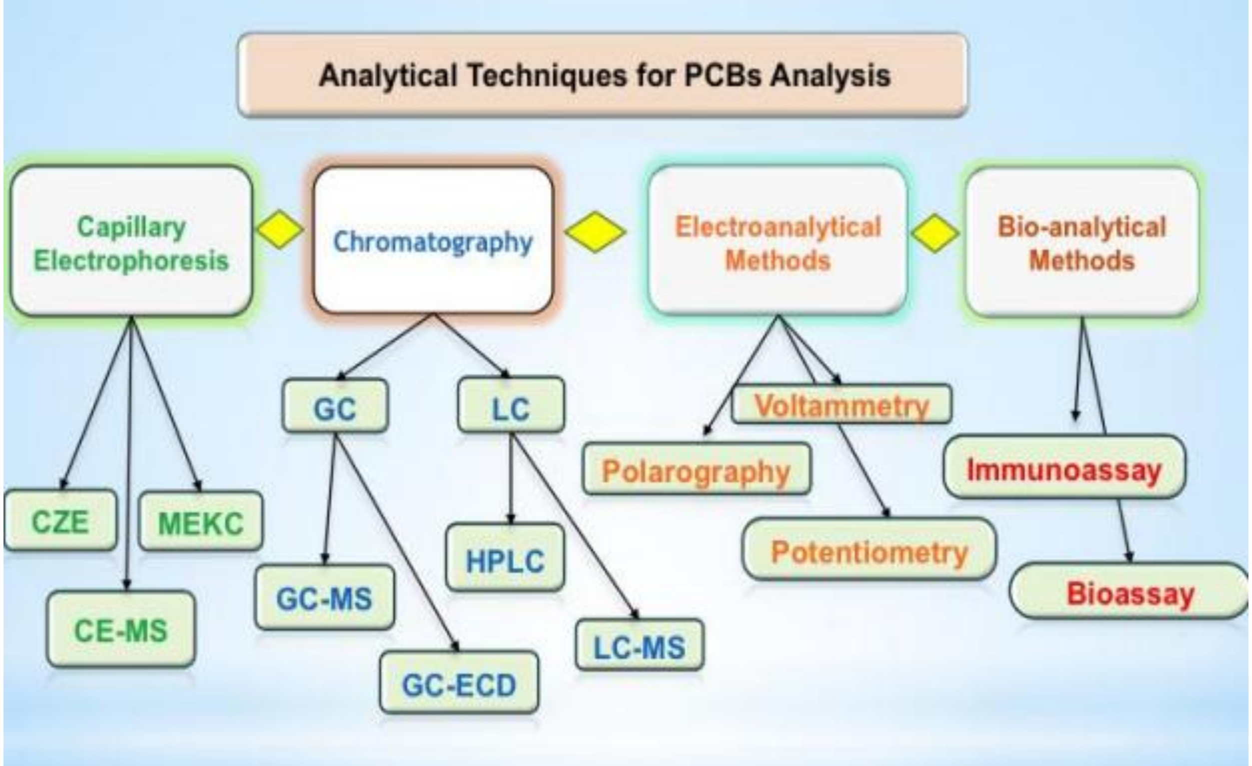

Figure-4: Techniques for PCBs analysis (Reddy *et al.*,2018)**.**

Table-1: Physical and chemical properties of PCBs homologs.

Homologous	monomer Quantity	Melting point / °C	Boiling point / °C	Vapor Pressure (25℃) /Pa	Evaporation rate25℃ $g/m^2\cdot h$	Log Kow	Solubility g/cm^3
Biphenyl	1	71	256	4.9	0.92	4.3	9.3
Monochlorobiphenyl	3	25~77.9	285	1.1	0.25	4.7	4
Dichlorobiphenyl	12	24.4~149	312	0.24	0.065	5.1	1.6
Trichlorobiphenyl	24	28~87	337	0.054	0.017	5.5	0.65
Tetrachlorobiphenyl	42	47~180	360	0.012	4.2×10^{-3}	5.9	0.26
Pentachlorobiphenyl	46	76.5~124	381	2.6×10^{-3}	1.0×10^{-3}	6.3	0.099
Hexachlorobiphenyl	42	77~150	400	5.8×10^{-3}	2.5×10^{-4}	6.7	0.038
Heptachloride	24	122.4~149	417	1.3×10^{-4}	6.2×10^{-5}	7.1	0.014
Octachlorobiphenyl	12	159~162	432	2.8×10^{-5}	1.5×10^{-5}	7.5	5.5×10^{-3}
Nonachlorinated biphenyl	3	182.8~206	445	6.3×10^{-6}	3.5×10^{-6}	7.9	2.0×10^{-3}

Conclusion: PCBS are the most important toxic pollutants present in the environment. PCBs has been detected almost everywhere such as soil, water, sediments, food, air, living organism, blood, human milk and blood. This review describes the extraction, purification and remedial approaches for PCBs. However, the complete removal of PCBs from environment has not been yet possible. More research that is new is still required to solve this problem of modern society.

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