Screening of Wetland Plants Subjected to Stress From Polychlorinated Biphenyls Contaminated Soils

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Research Article

Keywords: Polychlorinated biphenyls, Phytoremediation, Wetland plant, Biodegradation, Electronic waste, Dechlorination

Posted Date: March 10th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-207623/v1

Abstract

Soil pollution due to electric and electronic waste (e-waste) has become a major problem that is degrading environment and drawing worldwide attention. PCBs are widespread and have potential health risk so their removal from the environment has become an international priority. Phytoremediation is considered as highly accepted and good method for treatment of contaminated soils. Current study was conducted to investigate the abilities of several promising wetland plants to degrade and dechlorinate PCBs and demonstrate their advantages in disappearance of polychlorinated biphenyls. The soils samples were collected from PCB-contaminated sites at Layyari, Karachi Pakistan. Under both floody and dry condition plants including *Alternanthera sessilis (L.), Bacopa moneiri (L.) Pennell, Centella asiatica (L.) Urban, Juncus articulatus L., Cyperus arenarius Retz* were grown. For dechlorination of PCBs three treatments were set up in a fully randomized layout of greenhouse pots. Soil from those pots was extracted and further analyzed by Gas chromatography equipped with a 63Ni electron capture detector. The detection limits of PCBs ranged from 0.009 to 0.082 μg/kg. In total PCBs degradation ratio was 22.44% while in high chlorinated PCBs almost 15.26% of the high polychlorinated biphenyls were removed from the soil after 2 month in the wetland planted soil, while only 4.64% was removed in the drowned control and 6.54% in the unplanted control. Present study concludes that this method only has high efficiency in removal of low chlorinated biphenyls, while low efficiency even nothing in removal of high components.

Introduction

Soil contamination due to disposal of electric and electronic waste and its informal recycling has paid significant attention in these years (Shen et al. 2009). Many toxic pollutants used in formation of electric appliances i.e. polybrominated diphenyl ethers used in used in circuit boards as flame retardants and polychlorinated biphenyls in transformers and capacitors, can be released during recycling process (Liu et al. 2008). In production of total municipal waste share of e-waste is about 5%. Global e-waste generation was 53.6 million tons in 2019 and expected to be 74 Million tons by 2030 while in 2050 it might reach 120 Million tons (Forti et al. 2020; World Economic Forum, 2019). Specifically, domestic appliances i.e. telecommunications, washing machines, TVs and computers are major portion of e-waste created worldwide (Akram et al. 2019). In developing countries, Pakistan has recognized as main importer of electronic waste that increases the domestic electrical waste generation. Now Karachi is considered as one of most populated, industrialized and urbanized coastal cities in world. Karachi city is surrounded by various industrial activities and having two main sea ports through which electrical waste is being imported from different countries then its valuable parts are separated and remaining is dispose off. While during recycling of e-waste main informal practice is burning of electrical waste in open air, its melting, acid baths and dismantling. Non recyclable waste is dispose off in water bodies or landfills. (Iqbal et al. 2017) In moderate to low income countries about 90% of electrical waste is handled by informal ways and un-proficient workers (Pathak et al. 2019).

The methods used in e-waste recycling process are often primitive, without appropriate amenities to save human health and environment (Wong et al. 2007). Contamination of soil, water, air and sediments occur due to extensive PCBs emission that is Contamination with PCBs still occurs and is considerable because of potential toxicity and bioaccumulation for wildlife and humans (Cogliano 1998; Zhao et al. 2006). For better control and recycling of e-waste in environmentally sound way a better long term management practice is required (Takahashi et al. 2017) A huge amount of POPS (Persistent organic pollutants) are entering in the environment due to human activities, maximum of them have ability to bioaccumulate in food chain, persistent and pose health risk to humans and wildlife (Scheringer et al. 2012)

It is top priority at global scale to eliminate PCBs from environment to reduce its potential health effects (Ding et al. 2009). Bioremediation using microbes considers the best alternative method to save environment at reduced cost and less environmental impacts. Several fungal species especially white rot basidiomycetes, degrade PCBs effectively than others (Perrigon et al. 2019) Prevailing chemical and physical procedures for soil remediation, oftenly generate secondary waste compared to that phytoremediation is cost effective process and cause minimum disturbance in environment (Doni et al. 2012). It is use of plant metabolism (phytodegradation, phytoextraction & phytovolatilization) and microbes directly linked with root surface area to rhizodegrade pollutants from the surroundings (Van et al. 2010). Plants belong to cucurbitaceae family uptake PCBs from soil and it has been successfully tested (Vergani et al. 2017) Plants reduce toxicity by absorbing PCBs through their roots and used them as energy source and transform them by various metabolic pathways. Plants belong to genera Medicago, Panicum, Festuca, Brassica and Nicotiana have been evaluated in different studies of phytoremediation. Although, Plants have enough capacity for the removal of PCBs but they also have been shown to prevent plant growth that severely effect phytoremediation (Pino et al. 2019). It can be tested in area that supports plant growth and it can easily be accepted both socially and aesthetically. Phytoremediation technology that focused on PCBs has been extensively reviewed in the literatures (Asai et al. 2002; Chekol et al. 2004; Chu et al. 2006a; Xu et al. 2010; Chen tu et al. 2011; Tu et al. 2011; Kurzawova et al. 2012; Meggo et al. 2013; Vergani et al. 2017; Pino et al. 2019). Phytoremediation is directly linked to rhizodegradation of PCBs by releasing different compounds through roots of various plant species (Musilova et al. 2016), comprising Festuca arundinacea, Medicago sativa and Brassica napus, enhance microbes responsible for PCB degradation and change the soil-microbes community structure (Teng et al. 2016). Microbial activity and biomass increases due to release of metabolites in rhizosphere thus in rhizosphere plant roots interact with several microbes i.e. plant growth promotors (PGP), fungi and endophytic bacteria (Di Lenola et al. 2018). Despite the persistency of high PCBs, their degradation and elimination continuous by microbes naturally (Emma et al. 2002) due to plant growth at e-waste contaminated areas microbial potential to degrade PCBs enhance as due to vegetation organic carbon increases in soil and plantation of deep rooted species helps microbes to degrade PCBs (Campanella et al. 2002). In several studies it was notices that plants contribute major in PCBs degradation but relevant models are rare. Many papers focus on tissues and cell of plants (Estime and Rier Jr 2001; Mackova et al. 1997). In order to improve absorption capacity of plant and extent application scope of phytoremediation, some researchers start to take transgenic method into consideration, which greatly promote removal of xenobiotic pollutants (Abhilash et al. 2009; Eapen et al. 2007; Van Aken et al. 2010). But the safety of this method must be paid attention in detail, we cannot't be at risk of it.

However, on one hand, the aerobic PCBs degradation by using plants usually degrade those PCB congeners which are slightly chlorinated such as five or few more congeners (Wiegel and Wu 2000). High-chlorinated congeners are quite recalcitrant to microbial metabolism for aerobic degradation. On the other hand, due to hydrophobic nature of PCBs they highly adsorb on soil organic matter but in case of soil-water situation where microbes are mostly available PCBs cannot be dissolved and degraded (Providenti et al. 1993). Plants usually have less catabolic enzymes important to attain metabolism for recalcitrant organic compounds result in slow elimination and inadequate degradation (Eapen et al. 2007). Soil pollution has become a major problem that is degrading environment and drawing worldwide attention. Phytoremediation is considered as highly accepted and good method for treatment of contaminated soils. Various approaches have been used worldwide to increase efficiency of phytoremediation (Song et al. 2019). Phytoremediation have some limitations that avoid large scale experimentation in field (JERALD et al. 1995; Salt et al. 1998).In view of an inconvenient disadvantage of phytoremediation, we must make clear it whether wetland plants can solve this question, which give us more widespread thought and focus. Wetland plants absorb water more efficiently than non-wetland plants but transpiring plant species negatively affect PCBs degradation (Smith et al. 2008). It's been understood from around 40 years that wetland plants and submerged aquatic macrophytes such as sea grasses are capable to oxygenate its roots to save themselves from negative effects of phytotoxins such as H_2S, Mn^{2+} and Fe^{2+} that produce in anaerobic situation (Huesemann et al. 2009). Meanwhile, wetland plants owed greater biomass and roots system created a great volume of active rhizosphere per surface area compared to other plants, which lead to frequent microbial activities, such as degradation of organic matters (Brix 1987; Cheng et al. 2009; Yang et al. 2007). What's more, it can provide different habitats for organism and better removal qualification to organics under the wetland conditions, on one hand, there was some anaerobic environment and on the other hand, contrary to that. As a result, high chlorinated PCBs were more soluble afterward few early reductive dechlorination stages, and hence more bioavailable then degraded soon afterwards (Imfeld et al. 2009). Consequently, the wetland plants can be selected with more degrading capacity at contaminated sites and in production of multi wetland plant species.

The aim of this research was to examine the abilities of several promising wetland plants to degrade and dechlorinate PCBs and demonstrate their advantages in disappearance of polychlorinated biphenyls as compared to phytoremediation only contained certain terrestrial plant. Make an attempt for screening high synthetically efficient wetland plant in PCBs degradation and dechlorination. Mostly, the present research can give an excellent trial for engineering application of PCBs polluted soils remediation.

Materials And Methods

2.1 Site details and soil properties

The soils used in this study were collected from PCB-contaminated sites at Layyari, Karachi Pakistan. Around world, Karachi is main dumping ground of electronic waste. Mostly E-waste is being dumped with municipal waste, open burning of e-waste is common practice due to which many organic pollutants release and cause serious health effects. In Layyari, e-waste segregation is being done by the workers including children and women, not knowing the after effects due to informal handling and continuous exposure. Due to poverty in recessive areas of Karachi it's their main source of income and after segregation copper is being separated remaining material commonly burn without adopting proper health and safety measures. After collecting soils from e-waste contaminated sites it was dried and sieved through 2 mm sieve to remove roots and stones. Original PCBs concentration was 100 mg/kg that was further reduced after planting treatments in both floody and dry conditions. Soil texture was clay loam having pH 6.46 (H_2O 1:1), 4.19 g kg^{-1} total N, 63.8 g kg − 1 organic matter, 1.96 g kg^{-1} total P, 116 mg kg^{-1} exchangeable P, 370 mg kg^{-1} exchangeable K (dry weight basis) and 22.2 g kg^{-1} total K and (Soil properties: moisture content, organic matter, N, P, K, pH: 6.5, soil texture: clay loam and initial concentration).

2.2 Wetland plant selection

Following Pakistani plants were selected: *Alternanthera sessilis (L.), Bacopa moneiri (L.) Pennell, Centella asiatica (L.) Urban, Juncus articulatus L., Cyperus arenarius Retz.* Two conditions dry and floody were maintained.

2.3 Experimental layout

Immediately before bioremediation treatments, all polluted soil taken from 0–30 cm was mixed, putting forward residual branches and leaves, homogenized and passed through 2mm sieve, the soil sample attained (initial soil marked T0) was examined in triplicate to obtain an initial soil categorization (described in site details and soil properties).

There were three treatments set up in a randomized block design: flooding and dry soil without planting as controls, planted soil with wetland plant as test. The three treatments were set up in a fully randomized layout of greenhouse pots. Wetland plant grown in pots of height 26cm contained 5kg polluted soil. For flood and plant treatments, it was critical important to ensure the water level upon soil surface 5cm, which served as standard line in advance and replenishing water to the line daily. Contrary to flooding soil, dry treatment was so simple that you only spilled little water to make superficial soil moist. At last, to balance oxidation-reduction potential in soil and obtain stable and beneficial ecosystem for microbial community growth, placing the soil after pretreatment through getting rid of, grinding and sieve methods after flooding one week.

At the beginning of experiment, taking 0 moment samples served as initial concentration of polychlorinated biphenyls to estimate bioremediation efficiency of wetland plants. Afterwards, there was a job which took soil samples used five points method through self-made tools, four near corners and one in center, monthly. To guarantee good growth conditions for wetland plants, there were essential work monitoring greenhouse temperature and observing plant growth vigor daily.

2.4 Analytical methods

2.4.1 Chemicals

Pot cultural experiment

For it the purified water added into the polluted soil for maintain flooding depth and soil moist was purchased from certain pure water company.

Soil sample pretreatment

For pretreatment all solvents used (acetone, hexane, concentrated sulphuric acid) were of analytical grade (Sinopharm Chemical Reagent Co., Ltd, China). PCB209 were obtained from AccuStandard, China. Sodium sulfate (granular, anhydrous) and florisil were purified by heating at 450°C for 8h in a shallow metallic enamel tray.

Analysis

For analysis standard reference material arocher1254 was used that was also purchased from AccuStandard, China.

2.4.2 Analysis of PCBs in soil and wetland plant

Soil was weighed and five grams of sample was taken and extracted three times by the ultrasound extraction method in a centrifuge glass tube with 70ml combination of hexane–acetone (1:1, v/v). Gradient was 30ml, 20ml, and 20ml, respectively. Time was 5 minutes. The solution after extraction was concentrated by rotary evaporator by 1ml, diluted by 6 ml n-hexane and washed by concentrated sulfuric acid to 8ml. The mixture solution of shaking up and down repeatedly were centrifuged 5 minutes and the extracted solvent passed through anhydrous sodium sulfate and florisil column and wash with 100 ml mixture of hexane–acetone (9:1, v/v). The extracted solutions were concentrated to about 1ml in a rotary evaporator again, dissolved in 6 ml hexane in a nitrogen blowpipe and concentrated to 1ml using a Pressure Blowing Concentrator (Ding et al. 2009). The concentrations of PCB congeners were measured by a gas chromatograph equipped with a 63Ni electron capture detector (Agilent 6890, United States) (Shen et al. 2009). All procedures were performed under strict quality control to meet USEPA requirements. Decachlorobiphenyl (PCB209) was spiked to detect recoveries. The range of recoveries for PCB determination was 80–110%. In current study, the final values of the target compounds in soils were not corrected with recoveries. The detection limits ranged from 0.009 to 0.082 μg/kg.

2.5 Data analysis

Statistical analyses was done, including correlation among variables and mean values were calculated by using SPSS 13.0, The Microsoft excels 2007 and origin 75 was used to present the results in the form of bar graph. The percentage of removal efficiency of different wetland plants were calculated with the formula.

Results

3.1 Degradation efficiency of total polychlorinated biphenyls

Figure 1 demonstrates the removal rate of wetland plants includes Alternanthera sessilis (L.) (AS), Bacopa moneiri (L.) Pennell (BMP), Centella asiatica (L.) Urban (CAU), Juncus articulatus L. (JA), Cyperus arenarius Retz (CAR), and controls to all PCBs using pot culture after a standard 2 month incubation period in both dry and floody conditions.

After screening experiment of 2-months, PCBs concentration was less in wetland planted pots as compared to unplanted controlled treatment. The amount of PCBs reduced slightly in wetland plants and unplanted treatments, drowned and dry treatments. In terms of controls effecting on removal of PCBs, control dry have more efficiency in removal as compared to the flood control. Bioavailability of PCBs is strongly affected by physicochemical properties of soil so soil properties have been evaluated before initiating experimental work (Vergani et al. 2017).

3.2 Dechlorination of high chlorinated biphenyls

As shown in Fig. 2 for the degradation or dechlorination efficiency value of PCBs which contained 5–7 chloride atoms in biphenyls molecular, in general, the concentrations of high chlorinated PCBs reduced speedily and more degradation was observed in the wetland plants than in unplanted treatments. The results showed that far from total removal rates of high chlorinated in planted soils were much higher than in unplanted soils.

3.3 Degradation of low chlorinated biphenyls

The mean values of PCB homologues under various treatments in the soils are shown in Fig. 1.

For the low chlorinated congeners of PCBs, wetland plants contained 27.31% have good removal efficiency in degradation of PCBs as compared to 9.27% and 6.54% in the unplanted control.

In terms of dry and flood controls, dry has a better efficiency than flood treatment for degradation of low chlorinated PCBs. The 9.27% and 6.54% of the initial PCBs were removed from unplanted treatments, respectively.

Discussions

As for removal of persistent organic pollutants, most economic and widely used technology is phytoremediation, which brought up a great deal of focus from domestic and overseas. The mechanism researcher based mostly contained plant root absorption, transformation, and volatilization or metabolized by plant cells and microbial degradation. PCBs phytoremediation directly linked with process of rhizodegradation and associated with many compounds that released by roots of various plant species (Musilova et al. 2016), including *Festuca arundinacea, Brassica napus* and *Medicago sativa*. These species increases population of microorganisms responsible for PCB degradation and can which can change community structure of soil microbes (Teng et al. 2016). Although the removal efficiency is good, it is insufficient to dislodge high chlorinated pollutants, such as PCBs. We think the wetland plants can solve this problem. To our astonishment, Most of the pioneers focused their research center on removal of nutrition, such as TN, TP and others through various wetland plants which contained the fibrous-root plants and rhizomatic-root plants (Cheng et al. 2009; Stottmeister et al. 2003). There are some proves about removal of nutrition and heavy metals using the wetland plants to treat waste water (Wang et al. 2002). In recent study conducted by Salimizadeh et al. 2020 phytoremediation was done by *Alternanthera sessilis L.* and 17 PCB congeners were selected combination of low and high chlorinated congeners. Degradation efficiency of PCBs was 21.4 %.

Research relevant to degradation of organic compounds in wetland species is still in beginning. (Imfeld et al. 2009). In a previous study conducted by Chu et al. revealed that solution of two wetland plants, rice and common reed, gathered and converted PCBs and DDT mixed with culture solution (Chu et al. 2006b). Meanwhile, they also paid close attention to the enzyme systems of the wetland plants, *P. australis* and *O. sativa*, to make it clear that which was much more effective to transform and degrade organic pollutants (Chu et al., 2006a). In the present study the wetland plants (*Alternanthera sessilis (L.) (AS), Bacopa moneiri (L.) Pennell (BMP), Centella asiatica (L.) Urban (CAU), Juncus articulatus L. (JA), Cyperus arenarius Retz (CAR)*) were selected to sort out the removal efficiency of the PCBs contaminated soil starting from the lower chlorinated to higher chlorinate and PCBs in combined form in soil. Soils having maximum concentration of clay and organic matter absorb PCBs molecules strongly by complicating plant uptake and microbial degradation (Vitale et al. 2018). In a study by Mbemba et al. *Cyperus papyrus L.* can be used for removal for organic pollutants (Mbemba et al. 2019)

In rhizosphere microbial activity and biomass increased by releasing metabolites by plant roots because rhizosphere is that thickly populated zone where plant roots directly interact with the microorganisms, such as fungi, plant growth promoters (PGP), and endophytic bacteria (Lenola et al. 2018). Previous research has described that the type of plant has also impact on population of soil microbes (Terzaghi et al. 2018). This is strongly related to root exudates composition that changes with change in plant species and also with ability of plant to develop links with microorganisms i.e. Mycorrhizas (Ionescu et al. 2009).

All PCBs attenuation is results of interaction among high-chlorinated PCBs in Dechlorination, low PCBs in degradation and plant absorbing PCBs self-attenuation and PCBs volatilization, which is also important target in our project that will be screening of best wetland plant that exhibited good removal efficiency in total PCBs. The present study is novel and first time describes the PCBs removal efficiency from the wetland plant, which combine plant remediation with anaerobic degradation using microbial function.

Each congener's degradation directly depends on its substitution pattern and number of chlorines present. Few researches has described the degradation of single congener existed in Aroclor mix., some others have calculated PCBs degradation according to fall in total Aroclor concentration which does not permit estimation of each congener removal. Moreover, the rate of degradation is different for each congener and depends mainly on the pattern of chlorination and amount of chlorine in molecule (Paasivirta and Sinkkonen 2009). We found that the amount of total PCBs, not depending on degree of chlorination, was decreased to maximum extent in wetland than in unplanted treatment. According to the research of Stottmeister about effects of plants and microorganisms in wetland on organic chemicals, in wetlands, the main role in the transformation and mineralization of organic pollutants is played not by plants but by microorganisms (Stottmeister et al. 2003). The measurement result of plant samples shows that in this research, PCBs concentration in shoots and roots of wetland plant are few. The experiment whose result showed only 0.43% of extractable total soil PCBs was detected in the whole plant Ding et al., 2011 supports it (Ding et al. 2011). Consequently, we mainly explain reason why the wetland plants are better than others from the point of view of microorganism.

Rice and reed plants have been considered to takeup maximum concentration of PCBs (Chu et al. 2006b). Uptake of contaminants done by various processes i.e. phytoaccumulation, phytodegradation and phytovolatalization whereas, metabolic conversion of organic pollutants is significantly more appropriate for PCBs removal.

This would show the processes except microbial degradation in aerobic condition as a result of aeration in root zone accountable to reduce PCBs in the planted soils. Microbial degradation of PCBs in plant roots can be increased by organic carbon supply, inducing PCBs catabolic pathway, discharge of bio surfactants in soil and diffusion of oxygen in soil (Meggo et al. 2013). So, the contaminants that release in rhizosphere by plant roots have considerable effect on degradation of organic contaminants by microbes (Jha et al. 2015)

Data from this potted trial did show significantly that there was not all lesser amount of PCBs from wetland-planted treatments as compared to unplanted soils in 60 days of experiment for remediation purpose (see Fig. 3). The removal of PCBs in controlled treatments may be due to self-degradation and volatilization of compounds in soil media (Mackova et al. 2009), which point out considerable decline in PCB concentration i.e. 470 μg/g concentration in 1999, decreased and average amount was 330 μg/g in 2003 and 200 μg/g was calculated in 2005. Meanwhile, it is demonstrated that current study plays a more important role in the degradation of PCBs from soil. These results finalized the observations of Chu et al. (2006) and Kei (2004) in hydroponic culture experiment that wetland plant does facilitate the depletion of soil PCBs (Chu et al. 2006b; Kei 2004). Lower PCBs congeners may transfer through plants, deposited in lignin or plant cell wall, and then might be degraded inside plant tissues or transpiration loss (Van Aken et al. 2010). Furthermore, native soil microbes have vital role in bioremediation of PCBs aerobically with few chlorines (Mackova et al. 2010). Considered what we know about accumulation of PCBs by using plant methods, they mainly utilized plant roots to absorb PCBs from contaminated soils, transported to stem and leaves, which complete the complex processes(Liu and Schnoor 2008; Pavlikova et al. 2007; Zeeb et al. 2006). However, in present work, there were minimal PCBs existed in plant, which make the decrease processes more clear. Except volatilization, microorganism degradation played critical role. The wetland plant roots possessed the function of tight oxygen to create aerobic situation and low PCBs concentration, thus increase the aerobic degradation of low PCBs congeners (Armstrong et al. 1990; Pezeshki 2001; Wiebner et al. 2005). In aerobic degradation, oxygen released around root area or rhizosphere, specifically root tips surroundings and upon young laterals (Armstrong et al. 1990). Furthermore, plants release a vast range of organic matter via roots in rhizosphere (Rovira 1959). Bioavailability of contaminants could be enhanced through root exudates that provide extra substrates for co-metabolic degradation and modification in soil to get it more feasible for microbial conversion (Molnar et al. 2005; Singer et al. 2003). Additionally, this type of variety added in removal of contaminants from polluted soils as organic pollutants degradation may involve different organisms having unique enzymes system (Meharg and Cairney 2000).

The accurate opportunity for biodegradation of perchloroethylene, maximum chlorinated congeners and hexachlorobenzene is only reductive dechlorination (Wischnak and Müller 2008). Due to diverse redox conditions, prevailing because of halophyte roots that donate oxygen, a wetland is basically a metabolically strong technical ecosystem (Stottmeister et al. 2003). In present work, there was a long-term drowned environment under different wetland plants, which arose up anaerobic conditions; although there were many plant roots that could oxygen to peripheral soil. Consequently, the difference in different wetland plant was so obvious that efficiency in dechlorination of high-chlorinated biphenyls is not related to the length and width of roots.

Results of current study indicated the increase in PCB dechlorination through wetland plants, whereas maximum percentage of PCBs removal (approach 16%) was closed with the tall fescue of Shen et al that percentage removal for highly chlorinated congeners added to 18% of all PCBs degradation under no-amendment treatment (Shen et al. 2009).

These consequences may be attributed to support and stimulation of native bacterial species responsible for PCBs degradation in root zones also the capability of plants to degrade PCBs (Mackova et al. 2009). The actual amount biodiversity in root zone or soils may vary, associated with inadequate aqueous diffusion, change in organic matter amount and dissimilar soil texture (Chaudhry et al. 2005). According to the review about potential for phytoremediation of PCBs, another possibility is that plant-produced enzymes may be degrading the high chlorinated biphenyls to lower-chlorinated congeners (Zeeb et al. 2006).

There existed a certain extent of degradation, ignorant of total polychlorinated, high and low chlorinated biphenyls, under aerobic or anaerobic conditions. Various environmental factors affect the organic matter degradation i.e. aeration, temperature, nutrient availability, soil pH and temperature. Rise in temperature may cause decline in POPs concentration in soils and increase their degradation (DiVincenzo and Sparks 2001). Some other mechanisms for degradation of PCBs, do not involve microbes i.e. evaporation, chemical destruction and hydrophobic adsorption through organic matter (Ding et al. 2009).

Conclusions

Plant is an important remediation material in improving PCBs contaminated soils. However, this method only has high efficiency in removal of low chlorinated biphenyls, while low efficiency even nothing in removal of high components. In this study, we utilize wetland plants to dispose PCBs and screen most efficient plant. We first combine aerobic with anaerobic degradation procedure, which mainly devote to microbes and wetland plants. There into, plant providing excludes and anaerobic environment play critical role in all PCBs removal, which is objective of our study. There are numerous bio-chemical, morphological and physiological factors that play vital role in involvement of plant for PCBs degradation efficiency in all conditions.

Study also demonstrates that otherness in different wetland plant leads to different removal ability to all PCBs, high and low chlorinated biphenyls. In terms of gross PCBs loss, soils with wetland plants have more degradation ability, compared to two controls. The high chlorinated has same circumstance, while the low has a little difference. We get what we want to obtain by present experiment about wetland plant screening, which has meaningful effect on future research.

This study may not exactly explain the results under floody conditions. Moreover, reported variations could be due to certain experimental conditions i.e. immature wetland plants, contaminated soils and small unit size etc. Meanwhile, due to empirical nature of research studies the mechanisms elucidating alterations in removal among species generally remain unidentified. Inspite of all these limitations, we firmly believe that experimental species comparisons such as those studied here are important in screening for novel species or guiding species selection for a specific application.

Declarations

Acknowledgments

Special thanks are due to the Higher Education 664 Commission of Pakistan NRPU projects 7958 and 7964. Further thanks 665 are due to Pakistan Science Foundation project PSF/Res/CP/C-CUI/Envr 666 (151). Furthermore, thanks are due to Pakistan Academy of Sciences for 667 funding.

Authors’ contributions

Foqia Khalid wrote paper, Muhammad Zaffar Hashmi review and supervised, Nadia Jamil wrote some parts of paper, Abdul Qadir wrote some parts of paper

Funding

Higher Education Commission of Pakistan NRPU projects 675 7958 and 7964. Thanks are due to Pakistan Science Foundation project 676 PSF/Res/CP/C-CUI/Envr (151) for providing the funding. Furthermore, 677 thanks are due to Pakistan Academy of Sciences for funding.

Data availability

Data is based on Lab and experimental work. Samples were collected and proper analysis and experiment was conducted and added results were obtained.

Compliance with ethical standards

Competing of interests

The authors declare that they have no competing interests.

Ethical approval

Not applicable

Consent to participate

Not applicable

Consent to publish

Not applicable

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Figures

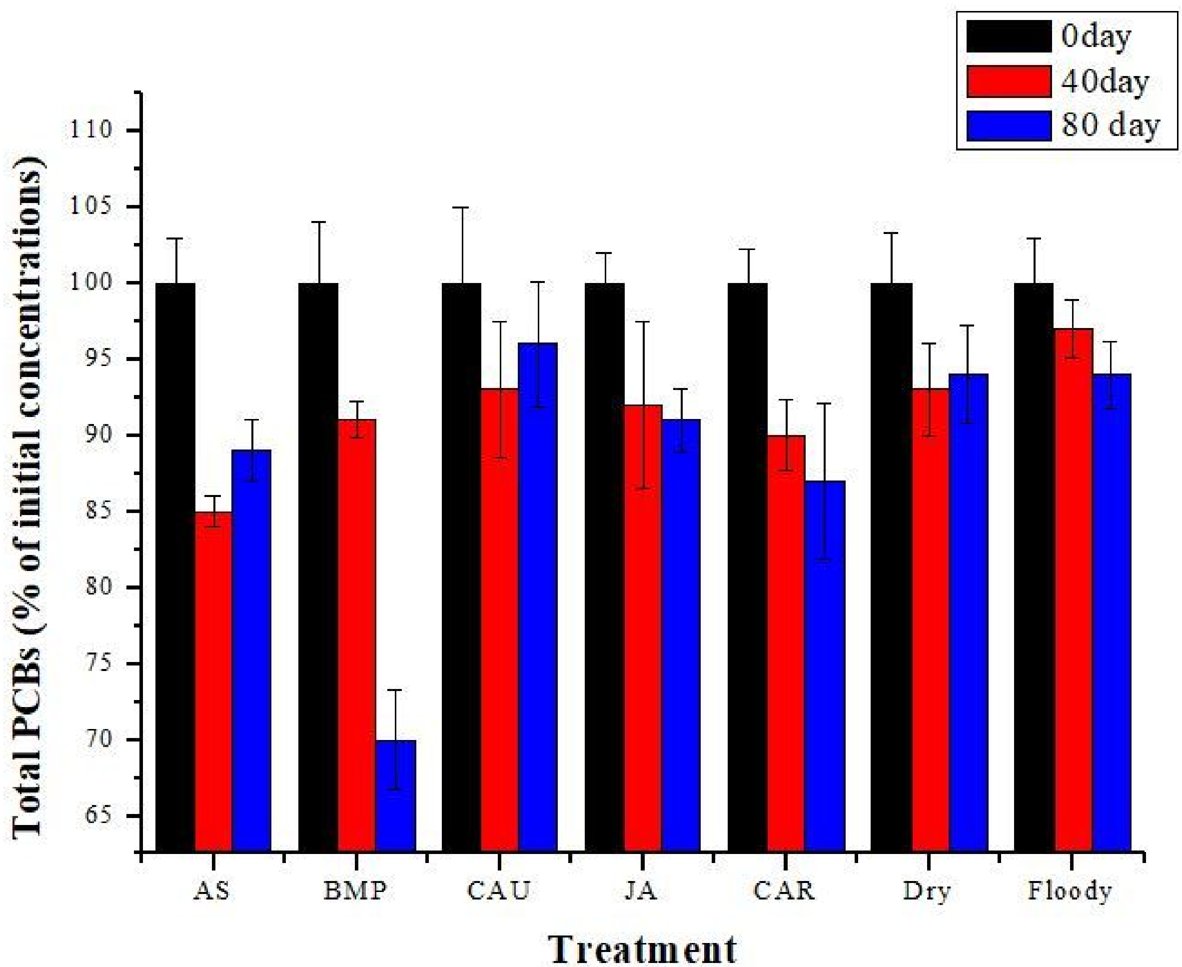

Figure 1

Removal efficiency of total PCBs in different treatments

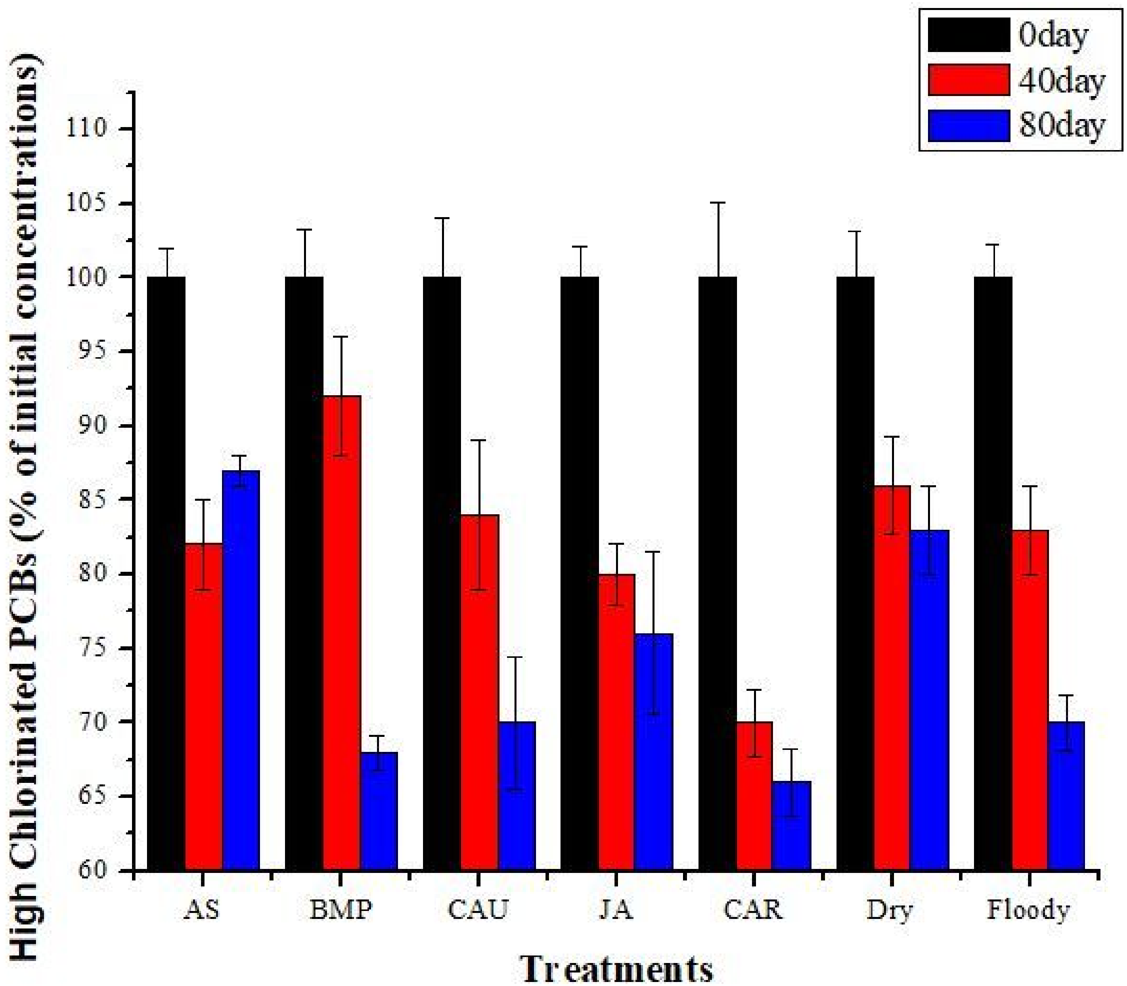

Figure 2

Removal efficiency of high chlorinated biphenyls in different treatments

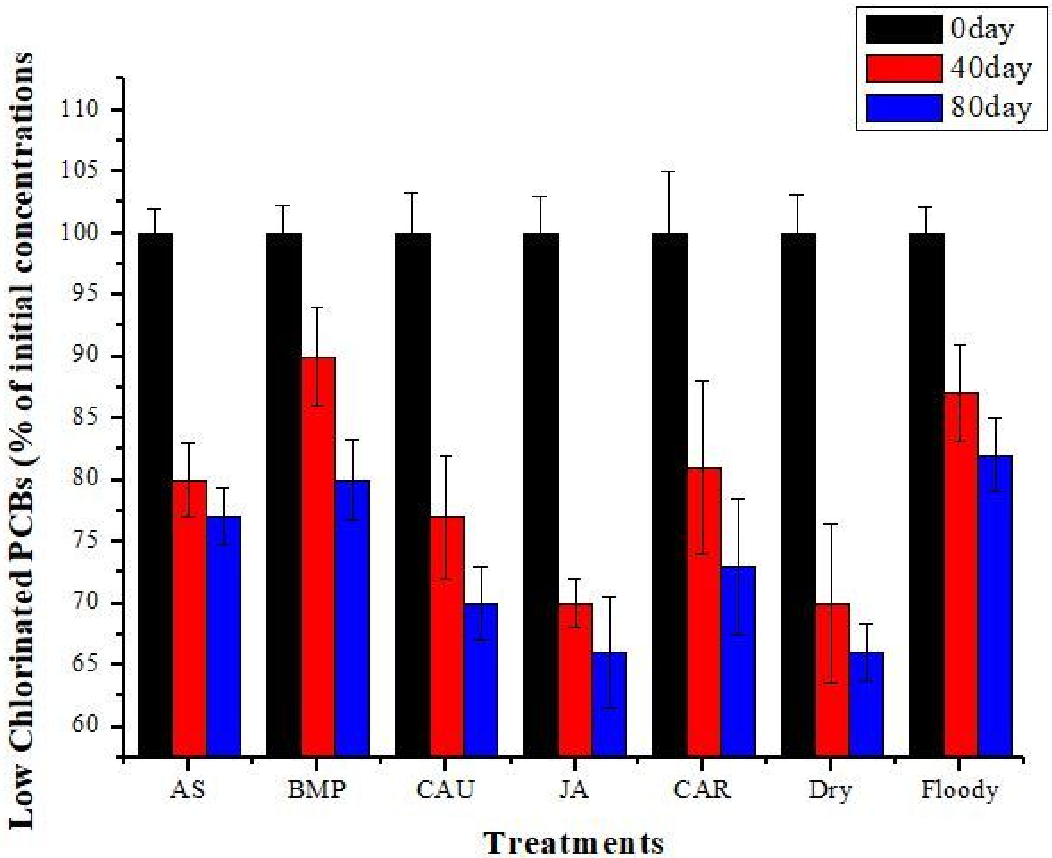

Figure 3

Removal efficiency of low chlorinated PCBs in different treatments