Research on the transport of PCBs with leachate water from contaminated soil

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Introduction

Phytoremediation is an in situ bioremediation strategy and its concept is based on the well-known fact that plants in association with rhizospheremicroflora are capable of degrading soil xenobiotics. The action of plants can include the degradation, accumulation, adsorption and volatilization of contaminant [1,2,3,4].

The objective of this study was to determine the effectiveness of some plants for phytoremediation of polychlorinated biphenyl (PCB) contaminated soils. Natural attenuation leads to the growth of plants and can cause changes in the physical and chemical properties of the contaminated soil. Therefore, the aim of this study is to examine dissipation of PCBs in the soil. Regular measurements of PCBs concentration in the soil and leachates over a longer period of time are required to evaluate whether this process achieves good results. A lysimeter experiment was conducted for 6 months under natural climatic conditions.

Materials and methods

Soil sampling and PCB extraction

Natural contaminated soil with PCBs was used in this study. That soil was excavated from an area around a damaged capacitor of an Electrical Transformer Station in Zadar (ETS 110/35 kV). Our research field is composed of four plots and located near ETS [5]. Three lysimeters have been set on each plot. Each lysimeter was filled with a 15cm homogenized soil layer. At the beginning of the experiment, soil samples were taken in three depths from each lysimeter (surface layer 0-5cm, middle layer 5-10cm and deeper layer 10-15cm) in order to have the distribution of PCB concentrations before planting. After the samplings, the soil was air-dried and sieved through a 2mm sieve. Samples were extracted three times by an ASE 200 extractor (Dionex, USA) with a mixture of hexane and acetone (1:1). PCB extraction was performed at 14 MPa and 100 $^{\circ}$C. A detailed description of the analytical method used can be found in different papers [6, 7, 8].

Lysimeter device

Each lysimeter was made of stainless steel with dimensions 70cm x 70cm x 20 cm. Lysimeters were placed at a mild incline, to direct the water flow into the bottles. At the bottom of each lysimeter, a hole has been created with a metal tube (10 cm in length) leading to the collection bottle (10 L). The hole was covered with mesh to prevent soil entering with the leachates. The glass bottle used to collect the leachates was placed in a wooden container to protect it from sunlight. Each container was placed at a depth of 70 cm from the surface of the soil and 15 cm below the experimental plot. Each glass bottle contained a mixture of hexane: acetone (3:1) and 1 L of tap water. Each lysimeter was filled with a 5 cm gravel layer to assist in water drainage and a 15 cm homogenized polluted soil layer. Plots were randomly selected and raked before planting. Plot No.1 was sowed with legume alfalfa (*Medicago sativa L*.) seeds, plot No.2 with a commercial grass seed mixture suitable for an arid Adriatic region, and plot No.3 was sowed with Arabidopsis thaliana (*Heynh L*.) seeds of. Plot No.4 was control plot which was left to grow wild. The experiment was under natural climatic conditions(Mediterraneanclimate,average air temperature during the year is over 15°C).

Leachate collection

The leachates were collected after each precipitation event. Upon collection, the leachates were filtered due to relatively large quantity of particular substances leached with the water. After filtration, the solid particles were extracted from the filter paper with in ultrasonic bath (twice per half an hour with an equal mixture of hexane: acetone). Only the hexane extracts were analyzed. Before extraction, in the filtrate phase of leached water NaCl was added to the satiation of solution, the volume of leachates was measured and the total quantity extracted. The PCBs were extracted from the filtrate phase by liquid/liquid partitioning with the addition of 100 ml hexane. Further, extracts were analyzed using the same methodology.

Results and Discussion

Before planting, we estimated the distribution of total PCBs within the various soil layers to contain Aroclor 1248 equivalents and seven types of PCBs, herein referred to as Σ PCB_7 (IUPAC No: PCB 28, PCB 52, PCB 101, PCB 118, PCB 138, PCB 153 and PCB 180). In the soil of plot No 1, the initial concentration of total PCBs (average of three lysimeters in each plot) was 61.1 μg g^{-1}, in the soil of plot No 2 it was 39.3 μg g^{-1} while in the plot No 3 it was 37.4 μg g^{-1}, and in plot No 4 it was 41.5 μg g^{-1}.

The soil in the middle layer had higher levels of Σ PCB_7 in plots No 2 and No 3 (about 11.4 μg g^{-1}) as compared with about 10.6 μg g^{-1} in the surface layer, and about 10.9 μg g^{-1} in the deepest layer. The concentrations of Σ PCB_7 in plot No 1 decreased according to depth, with the surface layer containing (15.7 ± 0.9 μg g^{-1}), the middle layer (14.9 ± 1.1 μg g^{-1}) and the deeper soil layer (13.5 ± 0.3 μg g^{-1}).

As seen, the levels of the total PCBs and Σ PCB_7 were significantly higher in plot No 1. Dissipation of the Σ PCB_7 in plot No 4 ranged from 11.3 μg g^{-1} to 11.9 μg g^{-1} (fig. 1). The concentration of PCBs in the leachates was expressed as the arithmetic means of 3 the lysimeters of each plot. Results of the analysis of the Σ PCB_7 in the leachates are illustrated in Fig. 2.

Two treatments could be distinguished in the dissipation of the Σ PCB_7: an irrigation event (only on plots No 2 and No 4) as well as four rainfall events. After the first irrigation of plots No 2 and No 4 with tap water, the measurement of Σ PCB_7 in the leachates was about 2300 ng l^{-1}. A second irrigation was performed only on plot No 4 (before planting) and the content of the Σ PCB_7 decreased by a further 1549 ± 1179 ng l^{-1} in the soil.

During the second rainfall event (after planting, in September) the dissipation of the Σ PCB_7 was very uneven, possibly due to the soil not being stabilized. The concentration of Σ PCB_7 in the leachate of plot No 3 was the highest (an average of 7644 ± 1190 ng l^{-1}), while plot No 2 was the lowest (3780 ± 1320 ng l^{-1}). After the third rainfall event, the concentration of Σ PCB_7 in the leachates of plot No 1 and No 2 were similar (around 2269 ng l^{-1}) while the concentration s in the plots No 3 and No 4 were the same, at 1323 ng l^{-1}.

The fourth rainfall event has rinsed similar quantities of PCBs (about 2267 ng l^{-1}) from plots No 1, No 2 and No 3. The level of the Σ PCB_7 in plot No 2 was significantly lower at 1113 ± 281 ng l^{-1}. The rate of dissipation is highly depended on environmental factors as well as the age and level of contamination [9, 10].

During a period of 6 months, nine rainfall events occurred, but we analyzed only the first four leachates of rainwater, while the concentrations of PCBs in the following 5 leachates (a short rainfall period of 10 weeks) were calculated according to the concentrations of the PCBs from the fourth rainwater leachate.

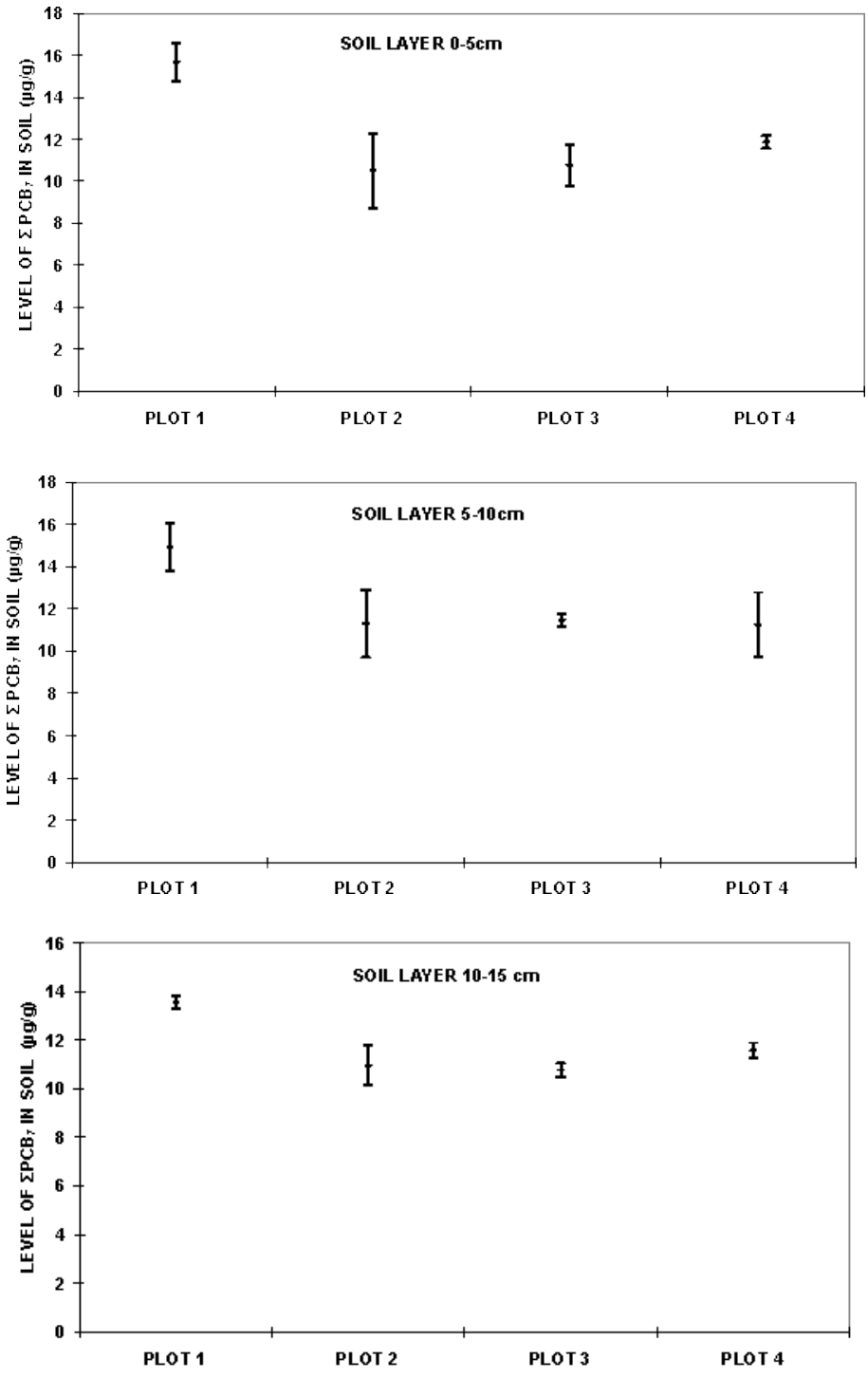

Figure 1. PCBs concentration as Σ PCB_7 (average followed by the standard deviations) in presented soil layers of researched plots before planting

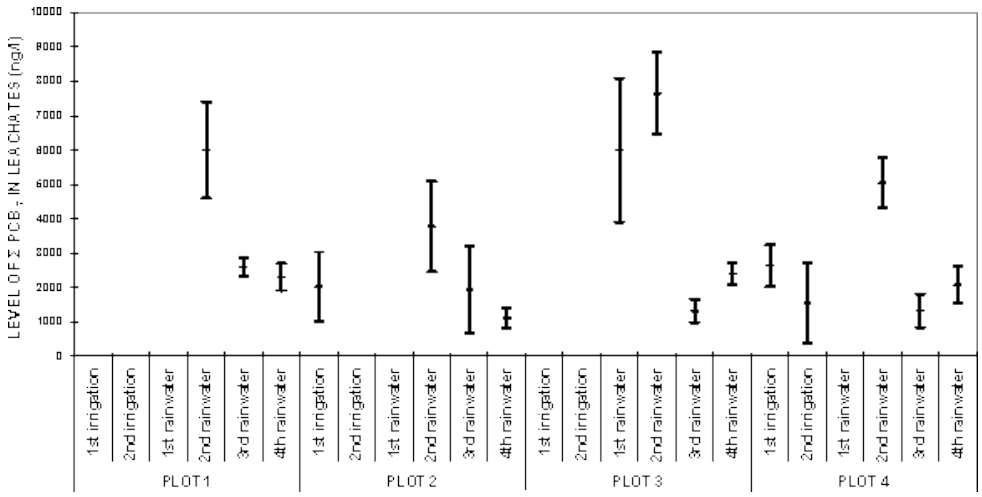

Figure 2. Concentration of Σ PCB_7 in the leachates after irrigation and rainfall events

Conclusion

The soil from plot No 1 had a significantly higher total PCB quantity (about 4.63 g PCBs) than the soil from other three plots (an average of 2.99 g PCBs). That difference was probably connected with insufficientmixing of the real contaminated soil which was used in the lysimeters. After 6 months (including nine rainfall events) the results indicate that very low quantities of PCBs were leached from the soil. During these first 6 months, 0.79 mg of PCBs were transferred from the plot No 1, 0.60 mg from the plot No 2, 0.67 mg from the plot No 3 and 0.70 mg from the control plot. The cumulative amount of PCBs leached in that initial period represents about 0.2 ‰ of the quantity of PCBs present in the soil.

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