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Determination of soil pollution derived from polychlorinated biphenyls (PCBs) in Bursa: spatial and temporal variations

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ABSTRACT

The soil is a natural reservoir and a transporter component of the terrestrial ecosystem for polychlorinated biphenyls (PCBs). The determination of PCBs is important to identify the necessary precautious steps to be taken. The objective of this study is to determine seasonal and regional PCB variations in the soil in Bursa-Turkey. In this context, soil samples were collected from 19 different points during summer and winter seasons and analyzed by gas chromatography-electron capture detector (GC-ECD) for Σ_{82} PCB. The regional variation of Σ_{82} PCB concentrations was 0.03-85 ng/g dry matter (DM). The highest Σ_{82} PCB concentration was measured sampling points near the iron-steel plant in both seasons. At all sampling points, Σ_{82} PCB concentrations were higher in winter than those in summer. In general, high-chlorinated homolog groups (>6-CBs) in summer and low-chlorinated homolog groups (<5-CBs) dominated in winter. Also, a significant correlation was found between the heavy species (>5-CBs) and TOC, while no significant correlation was observed between the light species (<5-CBs) and TOC. The Σ_7 PCB range of winter and summer seasons were 0.043-3.87 ng/g DM and 0.02-1.97 ng/g DM, respectively. The average Dutch Σ_7 PCB concentration in winter was 0.735 ± 1.05 ng/g DM, while in summer it was 0.462 ± 0.72 ng/g DM.

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1. Introduction

Polychlorinated biphenyls (PCBs) are anthropogenic persistent organic pollutants (POPs) that are widespread, toxic, and persistent in the environment and could be transported to large distances [1]. PCBs are aromatic compounds that come into play by bonding of different numbers (1 to 10) of chlorine ions on the biphenyl structure with different configurations (ortho, meta and para). PCBs were widely used for industrial and commercial applications before their production was gradually banned or restricted starting in 1970s [2]. PCBs are among the compounds that have been investigated carefully by researchers due to the threat of living organisms and carcinogenic property [3-7]. Therefore, these pollutants must be removed from any environmental media such as air, water, and soil.

The soil is a natural reservoir for PCBs and a carrier of the terrestrial ecosystem. PCBs are the compounds that accumulate in the soil and are absorbed by organic materials [8]. The concentration of PCBs in the soil varies depending on some factors such as the structure of the soil (organic matter content etc.), plant species, plant surface areas, environmental conditions (wind direction and intensity, temperature, humidity) [9]. It is known that concentrations of these compounds are generally higher in urban and industrial district soils [3],[5]. PCBs are usually arisen from burning of PCB-containing materials, contaminated water/air, mass transfer in soil/air interactions, waste storage areas, sludge drying beds, evaporation from the trash storage areas [1,10]. The PCB homolog group distribution in soil is affected by area properties, industrial characteristics, emission source and distance from this source. On the other hand, PCB distributions in soil might ensure information about pollution sources and the transport of PCBs at this distance. However, if there are various PCB sources in the sampling area, it is difficult to establish a clear relationship between homolog groups and sources.

Various restrictions were introduced to control the PCB levels around the world [11-14]. Several studies have been carried out to determine the PCB pollution level in soils in different countries. These countries include Norway [15], Spain [16], Sweden [9], France [17], Czech Republic [18], the United Kingdom [19] and Russia [20]. In our country, studies about PCB levels in soils are limited [3, 21, 22].

Bursa (40º 10’ N, 29º 4’ E), is an agricultural and industrial center which is one of Turkey's major metropolitan cities with a population of 2,901,396 in Turkey [23]. Intense industrial activities and population growth have led to increased environmental pollution. Bursa is the center of the Turkish automotive industry. Factories of motor vehicle producers, as well as automotive parts producers have been active in the city for decades. Textile and food industries are also strong, as well as fresh and canned food industries being present in the city’s organized industrial zones. In the present study, it was aimed to determine concentrations, profiles and homolog distributions of PCB in Bursa at 19 sites over two seasons.

Limited studies have been carried out to find out the effects of PCBs on soil and to determine the PCB pollution in the soil in Bursa-Turkey. Determining the PCB pollution in the industrial soil in Bursa is important because PCB has a mutagenic, carcinogenic effect by reaching to people through the food chain. The study is of scientific importance for evaluating an alternative application for the removal of PCB from soil.

2. Material and methods

2.1. Soil Sampling

The selected 19 sampling points for determining soil pollution were shown in Fig. 1. PCB pollution levels were determined in 5 different land use areas (traffic, industrial, urban, rural, traffic+barbecue+urban). Surface soil samples were collected in winter and summer seasons in 2015. All experiments were made with two repetitions. The composite soil was obtained by mixing samples taken from 4 different points in the surface soil (0-5 cm) within an area of approximately 10 m^2. Stones and plants were removed from 100-150 g soil, which was then wrapped in aluminum foil and stored in air-tight plastic bags.

Figure 1. *Sampling points.*

The soil temperature was measured during the sampling. Also, pH, dry matter and total organic carbon (TOC) measurements were performed in the laboratory. The pH of the soil was measured with a Metler Toledo brand pH meter after mixing for 5 minutes and adding 30 mL of purified water to 15 g of soil. Samples were stored at 105 °C for 24 hours to determine dry matter (DM) values. SDM-5000 Shimadzu TOC Analyzer (TOC-V CPN) was used for TOC measurements. The soil was sieved through 2 mm. After a preliminary analysis, PCB concentrations were measured using gas chromatograph-electron capture detector (GC-ECD). Soil temperature (ST), pH, DM and TOC values of the soils were given in Table 1.

Table 1. *Seasonal characterization of soil samples.*

	ST (ºC)		pH		DM (%)		TOC (%)	
Sampling Points	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
1.Traffic	17	33	9.1	8.5	88	88	1.3	4.2
2.Industrial	15	32	8.9	8.4	83	91	2.9	3.9
3.Traffic	6	34	9.5	8.7	93	98	0.6	0.8
4.Urban	6	19	8.6	8.2	78	87	2.7	2.4
5.Urban	8	24	8.2	8.5	85	88	2.6	2.4
6.Urban	12	33	8.4	8.1	86	94	2.5	2.1
7.Urban	12	27	8.5	6.5	87	91	1.0	1.3
8.Traffic	12	34	9.3	8.5	92	90	6.0	1.8
9.T+B+U	16	32	9.4	6.4	94	98	4.8	5.8
10.Industrial	7	30	9.4	8.1	88	93	3.1	4.1
11.Industrial	15	24	8.9	8.6	87	91	2.1	2.8
12.Urban	17	25	8.7	9.0	91	93	1.1	0.8
13.Industrial	16	27	10.1	9.7	88	92	2.7	3.8
14.Industrial	14	29	8.6	9.1	87	93	2.4	1.7
15.Rural	14	35	8.5	8.2	84	97	1.1	0.8
16.Rural	9	28	8.9	9.0	89	92	0.1	0.9
17.Rural	2	21	8.9	8.0	81	93	1.2	1.9
18.Rural	16	23	8.8	7.5	81	95	1.6	1.9
19.Rural	18	27	8.5	8.3	75	93	6.0	5.5

2.2. Extraction and Other Pretreatments

A 30 mL solvent mixture consisting of dichloromethane / petroleum ether (DCM / PE) in volume (1/1: v / v) was added to 10 g soil sample. The samples were shaken at 200 rpm in an orbital shaker for 5 hours and afterward were extracted for 30 minutes in a 35 kHz Bandelin Sonorex brand ultrasonic bath. Then the sample was filtered with a glass fiber filter. Twenty-five mL of a DCM / PE (1/1: v / v) mixture was added to the soil remaining in the bottle and again subjected to extraction (30 minutes), the filtration process was repeated, and the filtrates were combined. Following this, the solvent exchange was performed with a rotary evaporator. The sample was concentrated to 5 mL (30 rpm, 25 ºC). Then, 15 mL of hexane (HEX) was added to the sample for solvent exchange, and the volume was again decreased to 5 mL. Then, the volume was reduced to 2 mL under a gentle nitrogen stream. Samples were cleaned and fractionated (PAH, PCB) by passing through a glass column with 3 g deactive silicic acid, 2 g deactive alumina, 1 g active sodium sulfate (Na_2SO_4). The fractionation column was first cleaned to remove possible pollutions by washing with 20 mL DCM and 20 mL PE. 2 mL of sample filtered through the cleaned column and PCBs were collected by adding 25 mL PE. Then, the volume was reduced to 1 mL with a slow stream of nitrogen gas. The samples were stored at -16 ºC until analyzed with GC-ECD.

2.3. Quality Assurance / Quality Control

Ten percent of the soil samples were used as field blanks to test any contamination during sample handling and analysis. Then, 5 g Na_2SO_4 was weighed and placed in amber colored bottles to prepare field blanks. All the steps applied to the soil samples have been applied to the blank samples. A PAH surrogate standard was added to each sample (both soil samples and field blanks) to determine recovery efficiencies of the targeted PCB compounds. Average recovery values ranged between 30%-100%. All glass materials used in the laboratory were washed with HEX to prevent contamination after each operation. Limit of detection (LOD) for each PCB type was calculated. The LOD value was calculated as the mean blank mass plus three standard deviations [24]. PCB concentrations less than LOD were not reported in this study.

In this study, it was targeted to identify 82 PCB compounds, which can be listed as follows: PCB #4/10, #9/7, #6, #8/5, #19, #12/13, #18, #15/17, #16/32, #26, #31, #28, #21/53, #22, #45, #52, #47, #49/48, #44, #37/42, #41/64/71, #100, #74, #61/70, #66/95, #91, #56/60, #92, #84, #89/101, #99, #119, #83, #81/87, #86, #85, #135/144, #118, #114/149, #123, #131, #153, #132/105, #138/163, #126, #128, #167, #174, #156/171/202, #172, #180, #200, #170/190, #169, #199, #207, #194, #205, #206. Gas chromatograph analyzes for PCB measurements on the GC-ECD were performed with the HP 7890A GC-μECD (Micro-Electron Capture Detector) (Hewlett-Packard, USA). Temperature program used during the analysis: oven temperature is raised to 70ºC (2 min), ramp speed is 25ºC / min to 150ºC, 3ºC / min to 200ºC, 8ºC / min to 280ºC and kept at 280°C for 8 min. The ramp rate is increased from 10ºC / min to 300ºC and held for 2 min at 300ºC. The injector inlet temperature is 250ºC and the detector temperature is 320ºC. Helium gas as carrier gas and nitrogen gas in high purity were used as a basic gas together with helium. The flow rate of this gas was 1.9 mL / min. DB5-MS (30 m x 0.250 mm x 0.25 μm) was used as a column [25].

3. Results and discussion

3.1. Comparison of PCB Concentrations in Bursa Soils with Concentrations in Other Countries

Several studies around the world have been carried out to determine the PCB concentrations in soils and results were given below in Table 2. The highest PCB pollution was measured in Washington, USA [26] whereas the lowest one was obtained in Turkey-Hatay (Σ_{41} PCB: 0.18 ng/g) [27]. In the present study, it was determined that the regional Σ_{82} PCB concentrations in Bursa soil were ranged between 0.03-85 ng/g DM. So, the results in this study were comparable with the PCB concentrations obtained in other studies.

Table 2. *PCB concentrations in soils around the world.*

City, country	Sample number	PCB congener	Total PCB concent. (ng/g DM)	Ref.
Stockholm, Sweden	11	44	2.3-332	[9]
Izmir Turkey	48	41	0.2-805	[21]
Stockholm, Sweden	6	13	0.5-55	[28]
Washington, USA	34	65	260-23000	[26]
Trondheim, Norway	41	31	0.05-22	[29]
Shanghai, China	55	74	0.2-11	[30]
South England	4	30	10-670	[31]
Birmingham, UK	10	9	0.3-81	[32]
Britain	39	209	14-670	[8]
Catalonia, Spain	191	27	0.03-97	[33]
Gdansk, Poland	12	7	2.5-12	[7]
Hong Kong, China	66	7	0.1-9.87	[34]
Toronto, Canada	52	51	0.1-1	[35]
Nepal, South Asia	39	12	0.4-44	[36]
Taiyuan, China	15	144	0.1-4.7	[6]
France	22	7	0.1-150	[17]
Britain	46	37	1.1-1600	[15]
Norway	12	37	5.3-30	[15]
United Kingdom	200	33	0.3-80.6	[19]
Lithuanian	5	7	0.6-24	[37]
Hatay, Turkey	20	41	0.003-0.18	[27]
Izmir Turkey	6	36	4.9-66	[38]
Bursa, Turkey	43	83	0.8-3	[3]
Bursa, Turkey	19	82	0.03-85	This study

PCB concentration in Bursa-Turkey (this study) was found to be similar to those measured in Birmingham-England [32], United Kingdom [19] and Catalonia-Spain [33]. However, these levels were lower than the results in the United Kingdom, USA, France, South England, and Sweden [9,15,17,26,31]. The Σ_{82} PCB concentration in Bursa reached 85 ng/g DM. However, it was the case only at the sampling point 11 (industrial area), and concentrations at the other sampling points were found to be below 20 ng/g DM. Taşdemir et al. [3] investigated 82 PCB compounds in Bursa soil in 2008, and the maximum Σ_{82} PCB amount was five ng/g DM. In the present study and the study by Taşdemir et al. [3] PCB number and some sampling points were similar (17 points) whereas two sampling points were different. Comparing the results of the two studies, PCB concentrations in Bursa soil have increased in the last seven years. Rapid growth in industrial activities and increasing population in the city might have caused to obtain high PCB concentration in the present study.

There are two limit values for PCBs on the list of pollutant limit values in the Soil Pollution Control and Regulation on Point Source Polluted Land in Turkey [12]. The present results did not exceed the limit values of 0.2 and 6 mg/kg, which are the limits for the "ingestion of soil-skin-based transport route" in the regulation. However, the limit value of 0.003 mg/kg given in "transport route to groundwater" (for dilution factor = 1 and mixtures outside Arochlor 1016) was exceeded. Therefore, there was a risk for sites where the dilution was expected to be low, and the groundwater was close to the earth.

3.2. *Spatial and Temporal Variation of PCB Concentrations*

The spatial and temporal variation of Σ_{82} PCB concentrations measured during summer and winter seasons were given in Fig. 2. As expected, PCB concentrations at different sampling points varied temporally. Concentration values for Σ_{82} PCB ranged between 0.03-17 ng/g DM (min.-max.) and 1.13-85 ng/g DM (min.-max.) for the summer and winter seasons, respectively. The highest Σ_{82} PCB concentration was measured at the sampling point 11 in both seasons. It was thought that combustion activities in the iron-steel plant were effective in increasing the PCB pollution and the emissions generated during the recycling stages of the dielectric fluids, part metals, condensers, softeners in the casting plant might have transferred to the soil by atmospheric deposition. During winter the number 13 (Kestel) region and during summer the number 14 (Çemtaş) region were the other regions where PCB concentrations were high. It was thought that the industrial activities carried out at these sampling points were effective in increasing PCB concentrations. Previous researchers showed that the risk of PCB pollution and exposure to PCBs in soils close to industrial areas were high especially near iron-steel plants [17,21,22]. Likewise, high PCB concentrations were also measured in the studies conducted around thermal power plants [39, 40].

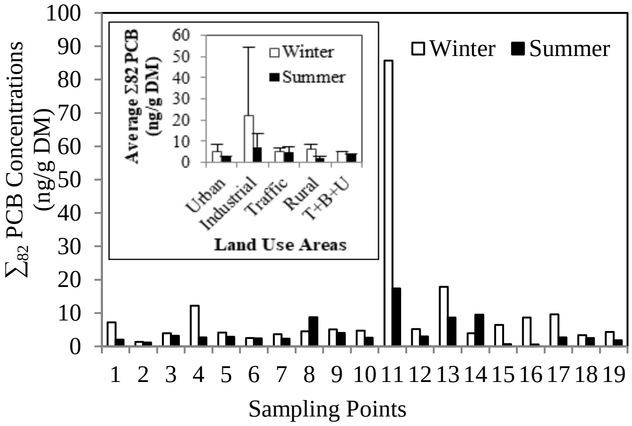

Figure 2. *Spatial and temporal variations of PCB concentrations.*

The sampling points were divided into five different categories regarding land use areas. Average Σ_{82} PCB concentrations and standard deviation values were provided in the small chart in Fig. 2. PCB concentrations in summer were lower than in winter in all land use areas. Semi-volatile PCB compounds with high vapor pressure were expected to evaporate with increasing temperature. Also, PCB compounds in surface might have photodegradated with sunlight [41]. Similarly, Kurokawa et al. [42] found that PCB concentrations in winter were higher than in the summer. However, in the study conducted by Tasdemir et al. [3] seasonal PCB concentrations in soils did not differ very clearly.

The lowest concentrations were measured in rural areas (1.8 ng/g DM) in summer and traffic + barbecue + urban (T+B+U) area (5.1 ng/g DM) in winter while the maximum PCB pollution was observed in industrial areas in both seasons. In the industrial area, average Σ_{82} PCB concentrations were calculated as 22 ng/g DM in winter and 7.3 ng/g DM in summer. As discussed previously, it was seen that the facilities in the industrial regions were significant PCB sources. In rural areas, the source of PCB pollution was considered to be the transportation an atmospheric deposition from industrial and urban areas located near rural regions [3, 42]. Additionally, in winter possible PCB sources in the direction of the dominant wind may have resulted in higher concentrations than expected in rural areas. In these regions, decreased PCB levels was obtained probably due to evaporation and photolysis in summer [43, 44]. Similar to our study, several researchers found that PCB concentrations in urban areas were higher than those in rural areas [34, 45, 46]. Another source of PCB was found to be exhaust emissions by several researchers [47-51].

3.3. *Relationship between PCB Concentrations and TOC*

Seasonal TOC values of soil samples were given in Table 1. In the winter season, TOC values ranged from 0.1% (sampling point 16) to 6% (sampling points 8 and 19) with an average value of 2.41%. These values ranged between 0.8% (sampling points 3, 12 and 15) and 5.8% (sampling point 9) during the summer. It was commonly observed that PCB concentrations in environmental media are effected by TOC content, with higher concentrations accompanied by high TOC [33]. In the present study, a relationship between PCB concentrations and TOC was examined by correlation analysis and no significant correlation was found ($r = 0.04$, $p > 0.05$) whereas there was a significant correlation in summer ($r = 0.20$, $p < 0.05$). In addition, the correlation between the Dutch 7 and the TOC content was found to be significant for both seasons (winter: $r = 0.23$, $p < 0.05$, summer: $r = 0.25$, $p < 0.05$). There was no significant correlation between light species (<penta-CB) in winter and summer. However, significant correlations between heavy species (> penta-CB) and TOC were found in summer ($r = 0.26$, $p < 0.05$) and winter ($r = 0.12$, $p < 0.05$). This result showed that TOC content might have affected the accumulation of the heavy PCB congeners in the soils of Bursa. This indicates that the PCB concentrations in the soils can partly be explained by the adsorption of the PCB burden by soil organic fractions as it was observed by [3]. Similar to our results in a previous study [19] a significant relationship was found between soil organic content and 5-, 6-, 7-, 8- and 9-CB except for light PCB groups. Heywood et al. [19] attributed this to the potential for high-chlorinated PCBs to have more relevance to organic carbon than to less chlorinated PCBs. Likewise, [35] found a statistically significant correlation between total PCB and soil organic content. On the other hand, [20] and [52] found no relationship between organic carbon and PCB levels. They partially explained this by the extremely low levels of organic carbon in the soil samples, varying between 0.09 and 0.34% [52].

3.4. *Homolog Distributions of PCBs in Soil*

PCB compounds with medium molecular weight were detected at high ratios among the PCB types obtained in the soil samples, and these data were comparable with the results of the previous study in the Bursa soil [3]. Fig. 3 showed the temporal variation of the homogeneous distributions of PCBs concentrations measured in soil samples from 19 different points. According to Fig. 3, 5-CB species in winter and 6-CB species in summer were predominant with the concentrations as 22 ± 20 ng/g DM and 17 ± 16 ng/g DM, respectively.

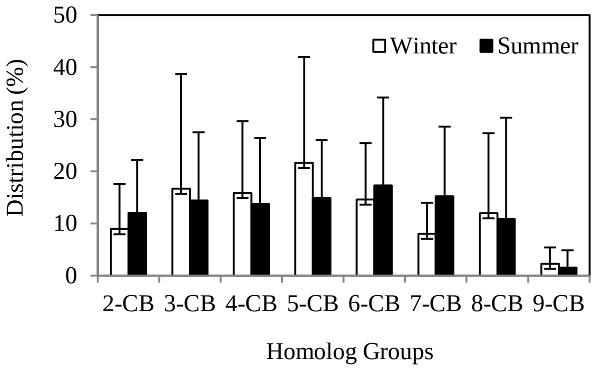

Figure 3. *Seasonal variation of PCB homolog groups in Bursa soils.*

3-,4-,5-CB species were predominant in winter, while 6-, 7-CB species predominated in summer as seen in Fig. 3. The least homolog group in both seasons was 9-CBs. At 19 sampling points, there were found only four species of the 9-CB in winter and three species of 9-CB in summer. Similar results were obtained in 2008 and 9-CBs were observed in 8 of 43 sampling points [3]. Several researchers found that the homolog distributions of PCBs in the soil can vary. For example, Breivik et al. [2] showed that the 3-,4- and 5-CB species formed 70% of the Σ_{22} PCB concentrations. 3-,4-CB in Harbin-China [53] and 5-, 6-CB were predominant in England soil [15]. Similarly, examinations in Izmir-Turkey [38] and Spain [33] resulted that the 5-, 6-CB PCBs were predominant in the soil. In another study conducted in Taiyuan-China [6], the concentrations of 2-,3-,4-CB were found to be higher.

The percentage of 3-,4-,5-CB light PCB species in summer were lower than in winter. It was estimated that these species were removed from the soil by evaporation and photolysis with increasing temperature [43, 44]. It was emphasized by several researchers that the concentrations of PAHs in the group of semi-volatile organic compounds (SVOCs) such as PCBs were partially removed by photodegradation in the presence of sunlight [54, 55]. It was thought that some of the organic compounds and the PCBs other than targeted PCB species in the soil structure might have been converted to targeted 2-CBs species by photodegradation.

When the homolog distributions according to land use areas were examined 3-,4-,5-,6-,8-,9-CB species predominated in industrial regions in winter while 2-, 7-CB species predominated in the traffic area. Broz et al. [49] showed that there might be more contributions to the level 3- and 4-CB of traffic than other groups. In summer, 3-,4-,6-,8-,9-CB species were dominant in industrial areas, 2-,5-,7-CB species were dominant in the traffic area. In industrial areas, it was seen that the heavier species PCBs deposited to the soil. Similarly, Ren et al. [35] found that heavy chlorinated PCBs were deposited near sources, while light PCBs were transported over long distances.

3.5. Total Dutch 7 Concentrations in Land Use Areas

Dutch Σ_7 PCBs concentrations in winter and summer seasons in different land use areas were given in Table 3. The molecular weights of the Dutch 7 PCBs (PCB-28, 52, 101, 118, 138, 153 and 180) are 257.54, 291.99, 326.43, 326.43, 360.88, 360.88, 395.32 g/mol (Analytical standard-Sigma Aldrich). The average Dutch Σ_7 PCB concentration in winter was 0.735±1.05 ng/g DM, while it was calculated as 0.462±0.72 ng/g DM in summer. Dutch 7 amounts accounted for 7% of Σ_{82} PCBs in winter and 11% in summer. As mentioned above, the amount of Σ_{82} PCB in winter was higher than those in the summer. However, it was noticed that the percentage of 7 Dutch in winter (%) was less than the amount in summer. This data showed that the evaporation of Dutch 7 group was relatively low in summer.

Table 3. *Dutch Σ_7 PCB concentrations in different land use areas.*

7 Dutch Species	**PCB Concentration (ng/g DM) (Winter)**				
	Industrial	Rural	Urban	Traffic	T+U+B
PCB 28	<LOD	<LOD	<LOD	<LOD	<LOD
PCB 52	0.02 ± 0.04	0.4 ± 0.6	0.12 ± 0.21	0.2 ± 0.21	< LOD
PCB 101	< LOD	0.1 ± 0.25	< LOD	< LOD	< LOD
PCB 118	< LOD	< LOD	< LOD	< LOD	< LOD
PCB 138	0.4 ± 0.8	0.09 ± 0.16	0.15 ± 0.33	0.26 ± 0.29	< LOD
PCB 153	< LOD	0.27 ± 0.45	0.07 ± 0.16	0.61 ± 0.55	< LOD
PCB 180	0.6 ± 1.06	0.07 ± 0.14	0.11 ± 0.06	0.24 ± 0.22	0.04 ± 0
7 Dutch Species	**PCB Concentration (ng/g DM) (Summer)**				
	Industrial	Rural	Urban	Traffic	T+U+B
PCB 28	0.01 ± 0.02	< LOD	< LOD	< LOD	< LOD
PCB 52	0.19 ± 0.34	0.004 ± 0.006	< LOD	0.02 ± 0.016	< LOD
PCB 101	< LOD	< LOD	< LOD	< LOD	< LOD
PCB 118	< LOD	< LOD	< LOD	< LOD	< LOD
PCB 138	0.20 ± 0.24	< LOD	0.06 ± 0.13	0.34 ± 0.41	< LOD
PCB 153	0.16 ± 0.19	0.02 ± 0.05	0.16 ± 0.26	0.12 ± 0.11	< LOD
PCB 180	0.63 ± 0.54	0.02 ± 0.04	0.14 ± 0.27	0.50 ± 0.49	< LOD

Σ_7 PCB range in winter and summer seasons were 0.043-3.87 ng/g DM and 0.02-1.97 ng/g DM, respectively. In previous years, the amount of Σ_7 PCB (0.2-1 ng/g DM) in Bursa soil was at similar levels [3]. Bozlaker et al. [21] measured Σ_7 PCB in an industrial area in İzmir as 0.23-805 ng/g DM. Wang et al. [46] reported that the Σ_7 PCB ranged between 0.14 and 1.00 ng/g DM and the average concentration was 0.57 ng/g DM in Chinese soil. For a total of 6 PCBs (28, 52, 101, 138, 153, 10) measured in Central Germany, the concentration ranged between 0.9-3 ng/g DM and was higher than in Bursa for both seasons [56]. The total average concentration value of 5 PCBs in Glasgow and Torino in European cities was measured between 43-86 ng/g DM [57] and PCB pollution was found to be much higher than in Bursa soil.

4. Conclusions

The present study was conducted to examine seasonal and regional concentrations and homolog of PCBs in Bursa where population and industrial activities are intense. The major results can be listed as follows:

- PCB concentrations in soil ranged between 0.03 and 85 ng/g DM. The highest Σ_{82} PCB concentration in summer and winter season was measured near the iron-steel plant. PCB concentrations in other industrial areas were also high.
- At all sampling points, Σ_{82} PCB concentrations in summer were lower than those in winter.
- In summer, 6-,7-,8- CB species were dominant, while 3-,4-,5- chlorinated species dominated in winter. It was observed that the less chlorinated species evaporated in summer and the lower concentrations measured in the soil.
- At the sampling point 11, Dutch Σ_7 PCB compounds accounted for constituted approximately 20% of the PCBs. In winter, max. Dutch Σ_7 PCBs was 24% at the sampling point 13. In summer, max. Dutch Σ_7 PCB was measured (19%) at sampling point 11.
- There was no significant correlation between TOC and lighter PCB species (<5-CBs) for both seasons. Furthermore, it was found that there was a correlation between heavy PCB species (> 5-CBs) and TOC.
- The results showed that PCB levels did not exceed the legal limit values of 0.2 and 6.0 mg/kg, which are the specified figures for the "ingestion of soil-skin-based transport route" but the limit value of 0.003 mg/kg given for "transport route to groundwater" was exceeded. Therefore, there was a risk for sites where the dilution is expected to be low, and the groundwater is close to the earth considering the highest measured value.

Hazardous/toxic pollutants in the solid and liquid phase as a result of increasing industrial activities cause environmental pollution. The time and amount of soil exposure to these contaminants should be investigated. Suggestions about control of PCB pollution in the environment can be written as follow:

- If wastes from industries are discharged to the soil, they should be identified and checked at regular intervals. Inappropriate discharges should be monitored and prohibited.
- Due to the fact that PCBs are found in the environment for a long time, PCB levels should be measured in equipment such as transformers, capacitors, computers, etc., and these and these devices which are contaminated with PCBs should be stored or disposed of in proper conditions.
- The materials used in the market such as paint and waste oil should be checked regularly and their PCB levels should be minimized.
- Studies should be made to reduce PCB pollution at the source (at home, at work, etc.).

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