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PCB content in soil and plants along routes with high traffic intensity

Marta Gabryszewska*, Barbara Gworek, Barbara Garlej

Institute of Environmental Protection – National Research Institute, Krucza 5/11d st., 00-548 Warsaw, Poland, Tel. +48 (22) 37 50 543; email: marta.gabryszewska@ios.edu.pl (M. Gabryszewska), Tel. +48 (22) 37 50 503; email: barbara.gworek@ios.edu.pl (B. Gworek), Tel. +48 (22) 37 50 501; email: bi@ios.gov.pl (B. Garlej)

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ABSTRACT

The aim of the study was to evaluate the influence of road traffic intensity on the content of polychlorinated biphenyls (PCBs) in soil and plants. Relationships between the PCB content in soil and in plants to the distance from the route were determined. The study material was collected along three exit routes from Warsaw at the following distances from the route: 0, 5, 10, 20, 50, 100 and 200 m. The PCB content was analyzed using gas chromatography. In soil it varied within: 0.331–37.077 ng/g, and in plants within: 0.303–4.727 ng/g. Congeners 153 and 138 had the highest percentage content in the sum of the studied PCBs in soils, whereas congeners 28 and 52 in plants. Larger influence of the road traffic intensity on the PCB content was observed in the case of soil rather than plants.

Keywords: Polychlorinated biphenyls; Monocotyledons; Dicotyledons; Road traffic intensity; Soil

1. Introduction

Polychlorinated biphenyls (PCBs) are aromatic compounds that usually occur as mixtures of congeners. There are 209 congeners differing in the number of chlorine atoms attached to different parts of the biphenyl compound. They are characterized by poor electric conductivity, low flammability, high chemical stability, resistance to thermal decomposition, environmental degradation by biological, photolytic and chemical processes [1]. Due to these physical and chemical properties, PCBs have wide applications, for example, as the base products for isolation fluids used for filling capacitors and transformers, as hydraulic fluids, heat carriers in heating devices, conserving and impregnation media, as well as cooling oils [2–6]. Due to their toxicity and stability, production of PCBs was banned in the 1970s in most countries [7]. In Europe their production took place until 1985 (France and Spain) [8].

Cumulation of PCBs in soil may cause contamination of other elements of the environment for a long time, because the half-life of PCBs in the soil varies from 3 months to 47 years [9,7]. Near the Lake Michigan in Illinois and Wisconsin, the composition of air from six municipal landfills was analyzed. All PCB concentrations were below 0.5 μg/m^3 [10]. In the top layer of soils (0–15 cm) around Havana municipal landfills, the PCB content was below 0.05 mg/kg [11]. In the top layer of soils (0–15 cm) around Havana municipal landfills, the PCB content was below 0.05 mg/kg [11]. In the field study of *Cucurbita pepo* cultivation, it was shown that with the only source of contamination, in soil with an average PCB content of 21 ng/g, the PCB content in plant stems (11 μg/g) was higher than the leaf content (8.9 ng/g) [12]. Chen et al. [13] conducted research on the PCB content in *Cedrus deodara* needles harvested from the area of a large Dalian agglomeration in China, the PCB content was on average 4.4 ± 1.5 ng/g.

Beside the direct application of these compounds, the source of pollution in the environment is PCBs that originated from de novo synthesized by-products during thermal processes [14], for example: incomplete petrol combustion in motor engines. The reaction of de novo PCB synthesis is initiated by compounds that are present in petrol, such as dienes, and aromatic compounds, such as benzene, chlorobenzenes,

* Corresponding author.

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phenols and diphenyl esters [15]. Tetraethyl lead $(C_2H_5)_4Pb$ was added to petrol as an antiknock agent and 1,2-dichloroethane was added to prevent the deposition of lead compounds in the engine cylinders by transformation of tetraethyl lead into volatile lead (II) chloride. Due to its harmfulness, leaded petrol was banned in Poland in 2005. In an experiment on Škoda Favorit, Brož et al. [15] showed that combustion of leaded petrol leads to the emission of about 75–178 pmol of PCBs/m^3. Choi et al. [16] proved that road transport is the source of releases of PCBs into the air, and that the concentrations of PCBs depend on the ambient temperature.

Studies [17–19] have shown that emissions of PCB from modern diesel engines equipped with catalyzed exhaust after treatment systems for removal of particulate matter and NOx were low. These studies have also shown that the use of copper-zeolite and iron-zeolite urea selective catalytic reduction (SCR) for NOx control had no adverse effect on the emissions of PCBs from these engines when compared with non-catalytically treated engine out levels [19].

Cheruiyot et al. [20] carried out experiment in which copper-zeolite SCR have been adopted in a heavy-duty diesel engine to reduce nitrogen oxide [20]. It turned out that concentrations of some PCB congeners in exhaust increased, for example: PCB 77 (4Cl) from not being detected to 14.7 pg/Nm^3; PCB 105 (5 Cl) from 20.2 to 27.6 pg/Nm^3; PCB 118 (5 Cl) from 38.1 to 61.2 pg/Nm^3; PCB 189 (7 Cl) from not being detected to 5.13 pg/Nm^3 [20]. Experiment with generator fueled with pure diesel and with fuel W20 (20 vol% waste cooking oil-based biodiesel + 80 vol% petrodiesel) indicated that W20 emitted less PCB than fueled with pure diesel [21,22].

Once entered the air compartment PCBs can reach soil and plants through absorption, rain dissolution, dry and wet deposition and be degraded by sunlight mediated reactions [23]. In soil, PCBs can be sequestered or immobilized as bound residues [24], transported via infiltration and runoff water, volatilize from surface, diffuse between adjacent layers and undergo bioturbation; if they are bioavailable. PCBs can be degraded in soil through abiotic processes (i.e., hydrolysis and photolysis), by aerobic bacteria (low-chlorinated congeners) and anaerobic bacteria (partial dechlorination of high chlorinated congeners) [25,26].

Plants can uptake PCBs from water, soil or atmosphere, during dry or wet deposition on the overground plant elements [5,27]. PCB homologues with low number of chlorine atoms in their particles, such as tri-chlorobiphenyls or tetra-chlorobiphenyls, may be accumulated by plants. Hepta- and octa-chlorobiphenyls are accumulated mainly during dry deposition [28]. At high octanol water partition coefficient, PCBs show a tendency to strong binding with the organic phase, therefore in soils rich in organic matter and in clayey soils, the uptake of PCBs by plants is restricted. When the number of chlorine atoms in the particle is lower, then the mobility of the compound is higher and uptake by plants becomes much easier.

This research is focused on evaluating the influence of road traffic on the PCB content in soil and plants in relation to the distance from the route. It was assumed that the road traffic intensity influences PCB content in soil and plants. In order to verify the working hypothesis, three main communication routes being exit roads from Warsaw, the capital of Poland, were selected for studies. Additionally, the relation between the number and type of PCB congeners was determined in mono- and dicotyledons, as well as their content in soil.

2. Materials and methods

2.1. Location and collection of samples

Soil samples were collected in 2009 and 2010 from three main exit routes from the largest city in Poland, the capital Warsaw. These roads lead to Gdańsk (TG), Lublin (TL) and Poznań (TP). In 2009, samples were collected along road TG and in 2010 along roads TP and TL. Samples were taken from waste lands located at the following distances from the route: 0 (where it was possible), 5, 10, 20, 50, 100 and 200 m having regard to the leeward (TG-2, TL-2 and TP-2) and windward directions (TG-1, TL-1 and TP-1). The soil samples were taken from the surface soil layer from the depth of 0–20 cm using the Egner's sampling stick. Each soil sample comprised a mixed sample from 6 to 8 points from four areas of 5 m^2 each. Overground parts of plants were collected from the same areas as the soil samples were analyzed. The area from which the samples were taken was varied in terms of vegetation that overgrows it. Hence it was not possible to take samples of the same plants in all research area. In order to evaluate PCB accumulation in the overground parts of plants, the material of dicotyledons (*Solidago canadensis* and *Solidago virgaurea*) for analysis was subdivided into leaves and stalks. Only leaves were analyzed in the case of *Betula pendula*.

Table 1 lists the particular plant species collected in particular sampling sites.

2.2. Chemical analyses

The plant and soil materials were frozen and then subject to lyophilization. Next the soils were grounded in a mortar, sieved through a sieve with 1-mm meshes and ground again in an agate mortar. The plant material was minced.

2.2.1. Methods of PCB analysis

About 15–20 g of dry soil or 5–10 g of dry plant material was extracted in n-hexane (95% pure) using a fast ASE 350

Table 1
Plant species collected in particular sampling sites

Sampling site (route number)	Plant (acronym)
TG-1 (E77)	*Poa annua*[a] (Pa), *Molinia caerulea*[a] (Mc), *Melampyrum nemorosum*[b] (Mn)
TL-1 (E372)	*Solidago canadensis*[b] (Sc)
TP-1 (E30)	*Betula pendula*[b] (Bp), *Solidago canadensis*[b] (Sc)
TL-2 (E372)	*Solidago virgaurea*[b] (Sv)
TG-2 (E77)	*Poa annua*[a] (Pa), *Poa nemoralis*[a] (Pn), *Molinia caerulea*[a] (Mc), *Impatiens parviflora*[b] (Ip)
TP-2 (E30)	*Solidago canadensis*[b] (Sc)

[a]Monocotyledons.
[b]Dicotyledons.

extractor for 20 min in higher pressure and a temperature of 120°C. The extract was transferred to a flask and concentrated to 1 mL in a vacuum evaporator with a heated bath. The concentrated extract was purified using column chromatography. The columns were filled with florosil (5 cm) and aluminium oxide (5 cm). Gradient washing out was applied, using 20 mL n-hexane and 5 mL mixture of n-hexane:acetone (maximum 5% acetone in mixture). The eluate was concentrated to dry form in a vacuum evaporator with a heated bath. The remaining substance was dissolved in 1 mL n-hexane (GC 99% pure). Such prepared analyte was analyzed using gas chromatography with Varian electron capture detector (GC/ECD). The substances were separated using the VF-Xms column (30 m × 0.25 mm × 0.25 μm), helium was applied as the carrier gas (purity 5.0; flow 1 mL/min). The temperature sequence in the oven was as follows: 70°C for 3 min and 70°C–300°C at a rate of 5°C/min. Qualitative analysis of the studied compounds was based on signals (peak surface) using the calibration curve method. The limit of quantification (LOQ) was evaluated for all analyzed compounds.

Indicative congeners with expanded uncertainties (U) were determined in the studied samples; their values are presented in per cents.

The recoveries were calculated for each congener based on the testing of materials certified for soil and on the basis spike samples for plants. The final result for soils and plants was calculated taking into account the recovery for each congener. In Table 2 are presented validation parameters.

3. Results and discussion

3.1. Soil

Soil samples were collected from the surface layer of 0–20 cm taking into account the physical and chemical properties of PCBs. Poor solubility in water and high octanol water partition coefficient (K_{OW}) result in strong adsorption of polychlorobiphenyls by organic matter and clay minerals. Increase of the number of chlorine atoms in the particle causes increase of the octanol water partition coefficient [16], resulting in very slow translocation of PCBs to deeper soil horizons. Assuming the homogenous character of soil, it was calculated that 2,4-diCB requires 825 years to pass through 10 m of soil [29]. Most susceptible to washing out from soil are PCBs with a low number of chlorine atoms in the particle [5]. In the case of the remaining PCB homologues, the process may take place in the presence of organic solvents such as trichloroethylene or Freon 113 [30].

Table 3 shows the road traffic intensity values in 2010 [27], which indicate that the highest number of motor vehicles used route E77, and the lowest route E372.

Route E77, with sampling sites TG-1 and TG-2, was characterized by the highest intensity of motor-cars and trucks (Table 3) but with the lowest PCB concentration in soil. A considerable amount of pollution is emitted by large vehicles, which may influence the PCB content in particular components of the environment. The PCB contents in the examined soil samples are presented in Table 4. The PCB content in the soil does not depend on the number of vehicles but on the speed of the cars and the stopping distance.

Table 2
Validation parameters

PCB congener	PCB 28	PCB 52	PCB 101	PCB 118	PCB 138	PCB 153	PCB 180
Retention time (min)	30.3	31.6	34.8	37.2	39.5	38.1	42.5
Linearity: correlation coefficient (r)	0.994	0.993	0.993	0.995	0.997	0.997	0.997
LOQ soils (corresponding to lowest level of calibration curve) (ng/g)	0.007	0.012	0.008	0.006	0.012	0.006	0.004
LOQ plants (corresponding to lowest level of calibration curve) (ng/g)	0.028	0.013	0.011	0.018	0.012	0.011	0.016
Precision of certified material soils %RSD $n = 6$	7.04	9.35	3.29	4.49	5.48	5.18	7.70
% Recovery of certified material soils $n = 6$	67.2	67.8	75.5	74.8	76.0	68.5	66.1
Precision of spiked samples plant with 0.1 (ng/g) $n = 6$	7.62	10.53	8.42	6.60	12.16	10.84	13.8
% Recovery of spiked samples plant with 0.1 (ng/g) $n = 6$	102.1	72.2	74.5	75.2	66.9	71.5	63.9
Uncertainty $k = 2$, $p = 0.05$ (%)	30	23	35	33	27	36	30

Table 3
Average 24-h traffic intensity on particular routes with regard to different vehicle types [25]

Route number	Total number of vehicles	Motorcycles	Motor-car, microbus	Light trucks (delivery trucks)	Trucks		Buses	Tractors
					with trailer	without trailer		
E 77	55,602	319	48,217	3,035	1,156	2,334	536	5
E 30	32,555	109	25,096	4,186	1,330	1,574	247	13
E 372	19,101	80	14,670	1,541	1,259	1,283	259	9

Table 4
Content of PCB congeners in the surface layers of soil (0–20 cm) in sampling sites (ng/g) collected in different distance from three routes TG, TL and TP

Sampling site	Distance from route (m)	Congeners							∑PCB
		28	52	101	118	138	153	180	
TG-1	0	0.329	0.116	0.056	0.066	2.016	0.181	0.167	2.931
	5	0.210	0.020	0.017	0.029	0.853	0.092	0.084	1.305
	10	0.179	0.020	0.032	0.021	1.724	0.112	0.089	2.177
	20	0.172	0.015	0.028	0.025	1.391	0.059	0.051	1.741
	50	0.192	0.016	0.011	0.167	0.045	0.132	0.024	0.587
	100	0.241	0.015	0.018	0.166	0.218	0.019	0.011	0.686
	200	0.513	0.016	0.024	0.041	0.294	0.047	0.017	0.951
TG-2	0	0.270	0.084	0.032	0.022	0.349	0.054	0.036	0.846
	5	0.176	0.069	0.010	0.022	1.055	0.055	0.035	1.421
	10	0.244	0.093	0.022	0.023	0.713	0.023	0.013	1.131
	20	0.140	0.031	0.011	0.015	0.895	0.035	0.037	1.163
	50	0.127	0.062	0.013	0.018	0.213	0.026	0.012	0.471
	100	0.473	0.153	0.023	0.026	3.144	0.073	0.050	3.942
	200	0.474	0.619	1.166	0.008	0.721	0.057	0.068	3.113
TL-1	5	0.390	0.032	0.038	0.014	7.259	0.134	0.093	7.960
	10	0.400	0.012	0.015	0.220	4.556	0.117	0.051	5.371
	20	0.314	0.106	0.032	0.006	3.962	0.077	0.050	4.547
	50	0.253	0.012	0.089	0.041	20.462	0.006	0.004	20.867
	100	0.367	0.069	0.021	0.017	10.536	0.016	0.021	11.047
	200	0.246	0.012	0.015	0.006	15.413	0.038	0.011	15.741
TL-2	5	0.009	0.128	0.011	0.018	0.899	0.050	0.017	1.133
	10	0.010	0.083	0.011	0.018	2.721	0.083	0.017	2.943
	20	0.011	0.147	0.011	0.022	3.829	0.053	0.025	4.097
	50	0.016	0.042	0.023	0.018	10.501	0.013	0.046	10.660
	100	0.018	0.040	0.011	0.018	3.520	0.011	0.036	3.654
	200	0.020	0.015	0.011	0.018	2.310	0.011	0.022	2.406
TP-1	5	0.797	0.020	0.068	0.234	4.880	0.148	0.313	6.460
	20	1.210	0.264	0.062	0.047	35.302	0.082	0.110	37.077
	50	0.542	0.106	0.306	0.021	28.679	0.021	0.053	29.728
	100	0.296	0.084	0.054	0.023	1.348	0.044	0.065	1.914
	200	0.466	0.129	0.072	0.032	1.860	0.062	0.095	2.716
TP-2	5	0.028	0.027	0.011	0.018	0.183	0.047	0.017	0.331
	10	0.034	0.028	0.017	0.018	0.424	0.011	0.020	0.552
	20	0.019	0.102	0.013	0.018	1.414	0.047	0.017	1.630
	50	0.013	0.064	0.058	0.018	1.548	0.019	0.017	1.737
	100	0.050	0.096	0.014	0.018	1.545	0.012	0.017	1.752
	200	0.010	0.073	0.011	0.018	0.264	0.011	0.017	0.404

The highest PCB content in the soil was determined in the samples collected along the TP road. This road is in poor technical condition, which causes that cars are driving slower and brakes more often, which is the cause of more flue gases and thus PCBs. A similar relationship was demonstrated in studies on the impact of road traffic on soil contamination with mercury [31]. Gworek et al. [31] showed that most of the mercury was found in soils around the TP road, where vehicles often brake and move so it generates more sands and indirectly mercury. The deposition time also affects the PCB content in the soil. The TP route is the oldest road among the routes studied and the youngest road is the TG. This is reflected in the results: the highest PCB content in the top soil layers was determined along the TP road and the lowest along the TG road.

The highest PCB content in soil was stated at 20 m from TP-1. In turn, maximal PCB contents in soils collected from TL-1 and TL-2 were located at 50 m from the routes. In the remaining sampling sites, the PCB content was lower and less variable with regard to distance from the routes. This observation may be linked with the fact that traffic intensity in Warsaw and its suburbs (TP-1, TL-1 and TL-2) was larger than in the remaining parts of the routes and the values presented in Table 3 are average values. Additionally, higher PCB contents in soils in Warsaw and its suburbs are influenced by the fact that in urbanized areas road transport is not the sole source of pollution. PCBs can be emitted due to low emission caused by burning of coal and sporadically also communal wastes. It was also spotted that there was second sphere of PCB deposition. After reaching maximum PCB content in soil about 20 or 50 m from the road (Table 4), depends on the route, PCB content start getting lower and then getting higher at about 100 or 200 m from the route. The first sphere of deposition was connected with falling of heavy dust and the second one with falling fine dust.

The total PCB content in soil near traffic routes varied within 0.331–37.077 ng/g. On Taiwan, the PCB content was 2,960–42,400 ng/g in soil surrounding an oil refinery and 2.62–23.8 μg/g in urbanized areas [32]. In the industrial areas of Aliaga in Turkey, the PCB content in soil was much higher than in Warsaw and reached 0.23–805 ng/g [33]; higher values were also noted in large cities such as Ljubljana (Slovenia) at 2.8–48 ng/g or Glasgow (Scotland) at 4.5–78 ng/g [7]. Zhang et al. [34] reported the content of indicative congeners in rural soils of Hong Kong 0.16 ng/g. The contents of PCB in industrial soils from Central and Southern Europe were lower than in Poland and amounted, respectively, 0.11 and 0.29 ng/g [35].

In soils collected from sites along routes TP and TL, the highest per cent content of the studied PCBs in their sum was noted for congener 138 (over 80%) (Fig. 1). Along route E77 (TG-1 and TG-2), a significant per cent content in the sum of the studied PCBs was noted for congener 138 (60%) and congener 28 (about 20%).

The dominating congener 138 belong to homologue hexachlorobiphenyls, has a long half-time, high K_{OW} coefficients and low vapour pressure. This means that this congener is retained in soil and is not transported on larger distances due to their evaporation from soil. Only the value of congener 138 was distinctly different from the others; its highest values were noted at about 50 to 100 m from the routes. This means that at such distances from the source of pollution (transportation) it underwent deposition from the atmosphere, because in more distant objects its content is much lower. Salihoglu and Tasdemir [36] found that the dominant congeners, in traffic/urban soils in Bursa, were 153 and 138 belonging to the homologue hexaCB and 180 (heptaCB). Values of the remaining congeners were rather low. Similar results were observed for PCB concentrations in the fumes of Škoda Favorit. The highest concentrations were noted for two homologues: tetrachlorine-biphenyls and hexachlorine-biphenyls [15].

The correlation coefficients between the basic properties of the soil as: organic carbon content, parts <0.02 mm, sorption capacity and the content of specific PCB congeners and their sum in the soil were calculated. The results did not indicate statistically significant relationships.

3.2. Plants

Congener 180 (PCB with seven chlorine atoms in the particle) has a high partition coefficient and uptake by plants is more difficult, therefore its contents in plants are low in comparison with the other congeners. Table 5 shows the content of PCB congeners for particular plants.

Congener 28 prevailed in mono and dicotyledons, as it reached averagely about 70% of the sum of the studied PCB congeners in the plants (Fig. 2). A significant content, about 10%, was noted for congener 52. Among the analyzed congeners, the low number of chlorine atoms in the PCB particle (three chlorine atoms in the case of congener 28 and four chlorine atoms in the case of congener 52) favours their uptake by plants. Li et al. [37] shown in tests of uptaking PCB-5 by corn, pumpkin and soybean that PCB content in roots were much larger than in stems and leaves.

In an experiment conducted by Liu and Schnoor [38], the uptake of PCB compounds by plants and their translocation was analyzed during hydroponic growth of poplar. The roots contained the following congeners: 3 (one chlorine atom), 15 (two chlorine atoms), 28 (three chlorine atoms), 52 (four chlorine atoms) and 77 (four chlorine atoms). Translocation of congeners 3 and 15 to the stalk and of congener 28 to the wood was noted. In turn, PCB compounds 52 and 77 were not translocated. No PCBs were noted in the leaves [38]. Results obtained for *Solidago canadensis* and *Solidago virgaurea* indicate that a considerable share in the sum of the studied PCBs in leaves had congeners 138 (hexachlorobiphenyl) and 180 (heptachlorobiphenyl); in stalks this content was lower, which may suggest that the compounds were accumulated from the atmosphere.

The content of particular compounds in plants increased to about 50 m distance from the routes, then subsequently decreased. This observation confirms the hypothesis that the analyzed compounds underwent deposition from the atmosphere at a distance of about 50 m from the analyzed source of pollution (traffic intensity). The sum of PCB contents in plants varied within 0.303–4.73 ng/g. The highest PCB contents were observed for TP-1 in the case of *Betula* – 4.73 ng/g, TL-2 for *Solidago virgaurea* – 3.91 ng/g and TG-1 for *Poa annua* – 3.30 ng/g. Lack of distinct influence of traffic intensity on the content of pollution in plants may result from the fact that the plants are 1- to 2-year old and this

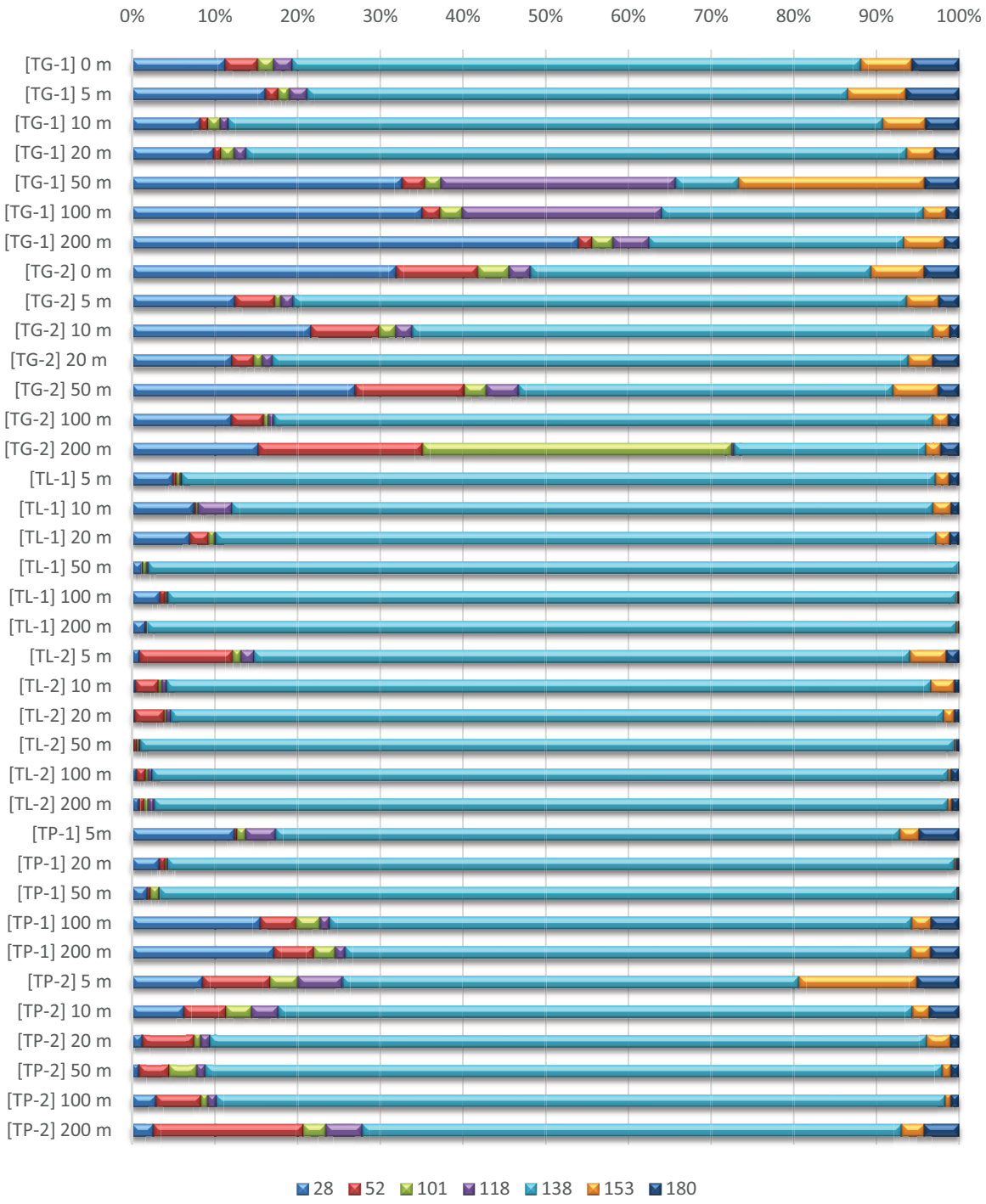

Fig. 1. Percentage content of PCB congeners according to their total content in soil samples (windward direction).

period of time is too short for the accumulation of such pollutants. In turn, soil is vulnerable to exposure for many years. This fact explains the much higher PCB contents in soils in comparison with the content in plants. The highest PCB content in *Betula* leaves results from their covering by a specific sticky substance favouring the retaining of pollutants. In most cases the PCB values in monocotyledons were lower than in the dicotyledons, most probably due to the large surface of the leaves of the latter group. PCB content in *Solidago* leaves was higher than in stalks, which indicates deposition from the atmosphere as the main source of pollution. Studies on *Cucurbita pepo* in field conditions, where the main source of pollution was soil polluted by a PCB mixture (Arcolors 1254 and 1260), gave opposite results, that is, higher contents in stalks (11 ng/g) than in leaves (8.9 ng/g) [39].

Relations between the content of PCB congeners in plants and their content in soil and distance from the route were also analyzed. The results did not indicate statistically significant

Table 5
Content of PCB congeners in plants samples (ng/g) collected in different distance from three routes TG, TL and TP (windward and leeward direction)

Sampling site	Distance from route (m)	Plant symbol	Congeners							∑PCB
			28	52	101	118	138	153	180	
TG-1	0	Pa	1.247	0.144	0.034	0.025	0.044	0.026	0.016	1.536
	5	Pa	3.088	0.049	0.034	0.025	0.059	0.026	0.016	3.297
	10	Mc	0.969	0.049	0.034	0.025	0.021	0.026	0.016	1.140
	10	Mn	0.733	0.143	0.034	0.025	0.021	0.026	0.016	0.998
	20	Mc	1.056	0.337	0.034	0.093	0.021	0.026	0.016	1.583
	50	Mn	0.59	0.118	0.034	0.025	0.021	0.026	0.016	0.830
	50	Mc	0.486	0.079	0.034	0.025	0.021	0.026	0.016	0.687
	100	Mc	0.827	0.049	0.034	0.025	0.053	0.026	0.016	1.030
	200	Mn	0.831	0.223	0.034	0.025	0.021	0.026	0.04	1.200
	200	Mc	0.798	0.14	0.034	0.025	0.088	0.026	0.016	1.127
TG-2	5	Pa	1.774	0.517	0.034	0.025	0.021	0.026	0.103	2.500
	20	Mc	0.655	0.32	0.034	0.029	0.021	0.026	0.067	1.152
	50	Mc	2.213	0.121	0.034	0.025	0.021	0.026	0.016	2.456
	100	Ip	1.397	0.26	0.034	0.025	0.021	0.026	0.034	1.797
	100	Pn	1.414	0.049	0.034	0.025	0.021	0.026	0.083	1.652
	200	Pn	0.913	0.049	0.034	0.025	0.021	0.026	0.077	1.145
TL-1	5	Sc	1.353	0.223	0.036	0.025	0.042	0.045	0.016	1.740
	10	Sc	1.253	0.344	0.034	0.025	0.021	0.026	0.016	1.719
	20	Sc	2.385	0.357	0.034	0.025	0.12	0.085	0.016	3.022
	50	Sc	1.041	0.238	0.034	0.025	0.021	0.026	0.016	1.401
	100	Sc	0.823	0.237	0.034	0.025	0.021	0.026	0.016	1.182
	200	Sc	1.065	0.049	0.034	0.025	0.021	0.026	0.016	1.236
TL-2	5	Sv l	1.016	0.860	0.011	0.018	0.090	0.011	0.305	2.310
		Sv s	0.420	0.329	0.011	0.018	0.093	0.011	0.693	1.574
	10	Sv l	0.621	0.535	0.479	0.018	0.303	0.011	0.475	2.442
		Sv s	0.301	0.013	0.075	0.105	0.124	0.011	0.239	0.867
	20	Sv l	0.558	0.554	0.011	0.018	0.081	0.011	0.044	1.277
		Sv s	0.166	0.013	0.011	0.018	0.124	0.011	0.117	0.461
	50	Sv l	0.277	0.337	0.011	0.018	0.096	0.011	0.017	0.767
		Sv s	0.067	0.078	0.011	0.018	0.012	0.091	0.179	0.457
	100	Sv l	0.034	0.013	0.011	0.018	0.109	0.055	0.064	0.303
		Sv s	0.107	0.013	0.011	0.018	0.111	0.205	0.052	0.517
	200	Sv l	3.214	0.424	0.011	0.018	0.092	0.085	0.069	3.913
		Sv s	0.043	0.262	0.011	0.018	0.012	0.011	0.087	0.444
TP-1	20	Bp	1.021	0.049	0.034	0.025	0.021	0.026	0.016	1.192
	20	Sc	0.983	0.049	0.174	0.025	0.111	0.026	0.111	1.479
	50	Bp	1.28	0.2	0.133	0.025	0.146	0.026	0.016	1.826

(*Continued*)

Table 5 (*Continued*)

Sampling site	Distance from route (m)	Plant symbol	Congeners							∑PCB
			28	52	101	118	138	153	180	
	50	Sc	1.101	0.167	0.034	0.025	0.021	0.026	0.016	1.390
	100	Bp	3.372	0.523	0.089	0.05	0.021	0.656	0.016	4.727
	100	Sc	1.407	0.198	0.034	0.025	0.021	0.064	0.016	1.765
	200	Sc	1.279	0.253	0.101	0.025	0.156	0.129	0.105	2.048
TP-2	5	Sc l	0.055	0.098	0.221	0.072	0.779	0.044	0.456	1.725
		Sc s	0.028	0.195	0.161	0.072	0.048	0.044	0.108	0.656
	10	Sc l	0.08	0.154	0.043	0.072	0.24	0.055	0.185	0.830
		Sc s	0.044	0.104	0.073	0.072	0.048	0.044	0.066	0.451
	20	Sc l	0.085	0.16	0.043	0.072	2.571	0.189	0.593	11.713
		Sc s	0.072	0.052	0.043	0.072	0.316	0.044	0.188	0.787
	50	Sc l	0.028	0.052	0.043	0.076	0.364	0.044	0.276	0.883
		Sc s	0.028	0.052	0.043	0.072	0.062	0.044	0.089	0.390
	100	Sc l	0.028	0.174	0.043	0.072	0.422	0.044	0.205	0.988
		Sc s	0.044	0.052	0.043	0.072	0.081	0.044	0.223	0.560
	200	Sc l	0.028	0.22	0.043	0.072	0.262	0.044	0.114	0.783
		Sc s	0.028	0.149	0.043	0.072	0.052	0.044	0.078	0.465

Sv s – *Solidago virgaurea* stalk, Sv l – *Solidago virgaurea* leaves, Sc s – *Solidago canadensis* stalk, Sc l – *Solidago canadensis* leaves.

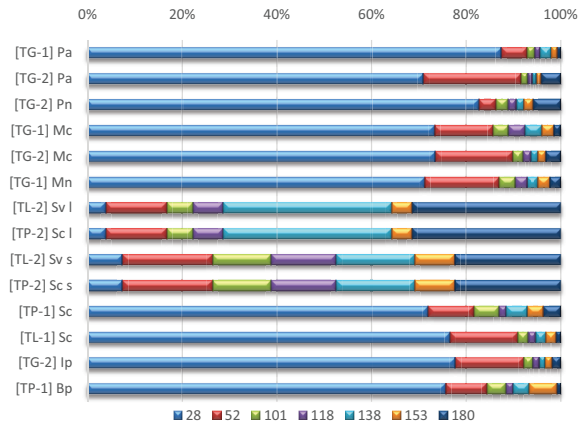

Fig. 2. Percentage content of PCB congeners according to their total content in plants samples.

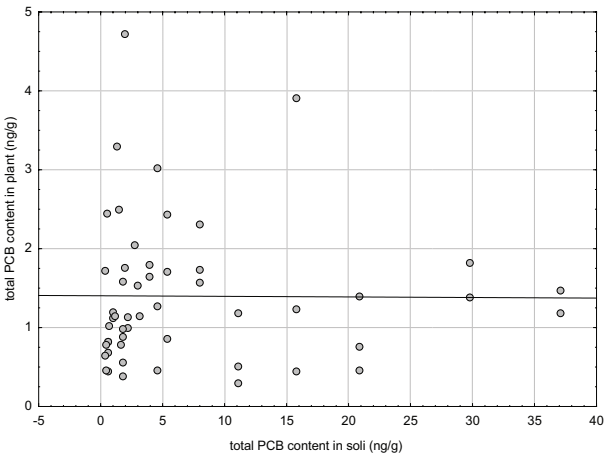

Fig. 3. Relation between the content of PCB congeners in soil and plants.

relationships. Fig. 3 shows a chart for the regression equation: $y = 1.4035 – 0.000774 \times x$, where x is the sum of the studied PCB congeners in soil, and y is the sum of the studied congeners in plants. The correlation coefficient (r) was –0.0078 and the confidence level (p) was 0.9564.

There is no direct relationship between the PCB content in the analyzed soil and plants what is shown in Fig. 3.

4. Conclusions

The PCB content in the soil depends on the speed of the cars and the braking distance which is related to amount of flue gases. The TP road is the oldest one and the youngest is the TG road. The age of road relate to longer time of deposition and bigger PCB content in soil. The highest PCB content in the soil was determined in the samples collected along the TP road and the lowest along road TG. There were two zones of increased accumulation: one was up to a distance of 20 or 50 m from the route and it was connected with falling of heavy dust, the second zone was located 100 or 200 m from the route and was connected with falling of fine dust. The total content of PCBs in soil adjacent to the communication routes was within: 0.331–37.077 ng/g. Among the analyzed PCB congeners in soil

dominated congener 138, whose percentage content in the total PCB content varied within 50%–80%.

The mean content of PCBs in the studied soil was according to the following order: *Betula* leaves (4.73 ng/g) > *Solidago virgaurea* (3.91 ng/g) > *Poa annua* (3.30 ng/g). In plants growing along the communications routes, the PCB content was lower than in soil; congeners 28 and 52 dominated among the analyzed congeners, and their percent content with regard to the PCB total was 70% and 10%, respectively.

Statistic analysis did not show significant relationships between the PCB content in plants and soil. Higher PCB values were noted in plants growing at distances up to 50 m from the route, similarly as in the case of soil. Along the route with the highest traffic intensity and low velocity of the vehicles due to traffic jams, a PCB accumulation zone up to 100 m was noted both on the windward and leeward sides.

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Symbols

r — Correlation coefficient
p — Confidence level

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