Content of PCB substances in carrot root and its relations to selected soil factors

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ABSTRACT

The influence of the content of polychlorinated biphenyls (PCB) in agricultural soil and its agrochemical properties on bioaccumulation of PCBs by edible part of carrot (*Daucus carota* L.) was monitored in 18 locations of the Eastern Slovakian lowland (ESL). The congeners Nos. 28, 52, 101, 138, 153 and 180 have been determined in almost all samples and in both soil and plant material. Soil PCB values varied between 0.16 µg/kg, detected in the congener 52, and 53.4 µg/kg for the congener 180. The average value of the sum of all the followed congeners was 17.9 µg/kg. The variation interval of investigated PCB congeners in carrot root ranged from the level below the detection limit of the analytical method until the maximum of 10.6 µg/kg, for the congener 153. Average amounts of PCBs significantly differed among individual congeners. The average value of the sum of all the followed congeners in carrot root was 5.39 µg/kg. Statistical evaluation of relationships between the concentrations of congeners in carrot root and in soil predominantly showed highly significant dependences. Interestingly, the contents of individual congeners in carrot root were more tightly correlated to the contents of the remaining congeners in the root than to the amount of the analogous congener in the soil. This suggested a possible synergistic effect of PCBs regarding their uptake by the plant. The increasing concentration of inorganic nitrogen in soil leads to an increase of the content of lightly chlorinated congeners in carrot root. Concentrations of lightly chlorinated congeners 28 and 52 were more significantly affected by followed chemical parameters than were concentrations of highly chlorinated congeners. Among the chemical parameters studied [available phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in the soil] only P and K gave statistically significant relationships. Changes in the potassium content were responsible for 7.8% variability in the amount of the congener 28. Similarly, Mg induced 7.6% of alterations in the quantity of the congener 180. Our results suggest that importance of both Ca and Mg concentrations in soil regarding the PCBs uptake were less as compared to the concentration of nitrogen. Statistically significant influence of the humus content in soil varying in range between 0.70 and 8.28% as well as the soil acidity (pH = 4.9–7.3) on the content of some of the investigated congeners in carrot root were not estimated.

Keywords: polychlorinated biphenyls; carrot; soil; soil properties; monitoring

Within the former Eastern-block countries of Europe, the Eastern Slovakian lowland (ESL) belongs to one of the most contaminated regions by polychlorinated biphenyls (PCBs). These highly persistent organic-chlorinated contaminants were produced for 25 years in this region. Despite the local ended production in 1984, PCBs have the tendency to accumulate in most of components of agricultural systems (Danielovič et al. 1999).

Taking into account a possibility of transmission of these contaminants from the soil into the plant production, we have undertaken the monitoring of these xenobiotics in agricultural soils of the soil of the Eastern Slovakian lowland. Simultaneously, the PCB concentrations in carrot root (representing a typical rooted plant) were determined. The principal aim of the study was to assess amounts of selected PCB congeners in the carrot root and to evaluate the effect of selected soil characteristics on PCB uptake by the plants. Additionally, interrelationships of concentrations of individual PCB congeners in carrot root were estimated.

MATERIAL AND METHODS

The current study was performed in the framework of the full-area monitoring of the PCB quantities in the Eastern Slovakian lowland during the period of 1998–2000. The total number of monitoring sites (18) and their identity was maintained in the course of 3-year study. The contamination by PCBs was evaluated in both plant and soil materials. The plant material was collected in the stage of technological maturity of carrots. The minimal weight of a plant sample was 300 g. The sampling site of the soil material was identical with the sampling site of the corresponding plant material. Soil samples were collected from the depth of 0–0.3 m using a soil sampler.

The PCB compounds were extracted from soil samples by mixed extraction agent n-hexane and acetone (2:1) in a Soxhlet apparatus. The purification of extracts and qualitative-quantitative estimations were carried out following the protocol of Obligatory Methods of Soil Analyses (Kobza et al. 1999). High-Resolution Gas Chro-

Table 1. Minimum, maximum and average values of selected PCB congeners (µg/kg) in soil and carrot root

Congener		28	52	101	153	138	180	S*
Soil	min	0.167	0.159	0.184	0.175	0.165	0.168	1.018
	max	6.802	10.064	24.710	45.130	48.120	53.350	175.108
	average	0.775	1.324	2.578	4.175	3.848	5.220	17.920
Roots	min	0.063	0.059	0.069	0.066	0.062	0.000	0.319
	max	1.411	3.237	4.713	10.610	7.858	5.040	23.695
	average	0.301	0.503	0.890	1.460	1.485	0.753	5.391

* values obtained from the sums of congeners in individual samples

matography (HRGC) with the column HP-5 (5% diphenyl and 95% dimethyl polysiloxane) of the length of 50 m, internal diameter of 0.2 mm, and with the width of the stationary phase of 0.33 µm, was equipped by an electron capture detector, an automatic sample injector and a chromatographic station, and provided a sufficiently specific and selective identification and quantification of individual PCBs at trace levels (Němeček et al. 1994). For release of PCB congeners from carrot root the extraction of samples by diethyl ether was applied. The purification of samples and their quantification was identical with the determination of PCB congeners in soil samples. The concentrations of PCB congeners Nos. 28, 52, 101, 138, 153, 180 (according to the IUPAC classification) in both plant and soil material were estimated using the gas chromatograph HP 5890 SERIES II, in the Laboratory of Foreign Substances at the Regional Research Institute of Agroecology in Michalovce (Danielovič 1998).

The agrochemical characteristics of soil were determined according to the Obligatory Methods of Soil Analyses protocol (Kobza et al. 1999), and pH (KCl), humus content, available content of P, K, Ca, Mg, NH_4 and NO_3 were measured in the frame of this evaluation.

Soil and climatic conditions

The ESL region is spread in the territory of 200 000 ha and is characterized by an evident typological heterogeneity of soils. According to a complex soil survey, 15 representatives of principal soil units occur in this territory. Recent data from evaluations of the soil bonitation provided evidence that in the ESL region there are predominant soils with gley soilforming processes (i.e. gley fluvisols, pseudogleys, gley soils) that occupy 65% of agricultural soil. Regarding the soil type composition, soils of medium substantiality (54%) and heavy soils (43%) are prevalent, remaining soils are of the light type. The territory is peculiar by typological alterations of soils within small distances that led to the establishment of a diverse soil mosaic. The ESL territory represents the northeast salient of the large Potisk lowland. Most of this area creates a plane landscape with warm climate, ascending in the marginal zones where the nature of landscape changes into the erosive and accumulative upland. Due to the constraints of airflow from the north and northwest owing to the large mountain massifs, flowing from the south, northeast and/or the south prevails in this area (Fecenko and Šoltysová 1991).

Statistics

Obtained analytical data were statistically processed by the linear, multilplicative, exponential, and reciprocal correlative-regressive analysis. Only the results with a higher statistical significance are presented in the current study. As highly statistically significant was considered such a correlation coefficient significance value of which fell within the range of 0.00–0.01. Each of studied relations was completed by outputs from the quadratic correlative-regressive analysis.

RESULTS AND DISCUSSION

The results obtained from monitoring of selected PCB congeners in carrot root and in soil (in which carrot was cultivated) are presented in Tables 1 and 2, together with investigated chemical parameters of soil. Selected PCB

Table 2. Minimum, maximum and average values of selected chemical soil parameters

Soil	$N\text{-}NH_4^+$ (mg/kg)	$N\text{-}NO_3^-$ (mg/kg)	P (mg/kg)	K (mg/kg)	Ca (mg/kg)	Mg (mg/kg)	pH/KCl	Organic matter (%)
Min	6.200	0.700	13.800	129.090	457.500	81.000	4.900	0.696
Max	62.880	44.000	1 088.250	2 501.700	15 713.60	474.000	7.400	8.280
Average	20.065	8.568	268.022	836.702	2 732.057	235.333	6.429	3.074

Table 3. Minimum, maximum and average values of carrot root/soil ratios of concentrations of PCB congeners

Congener	28	52	101	153	138	180	S*
Min	0.007	0.010	0.012	0.013	0.014	0.000	0.015
Max	12.164	11.051	10.992	7.846	81.010	3.086	3.315
Average	1.197	1.124	1.258	0.871	3.074	0.581	0.574

* values obtained from the sums of congeners in individual samples

congeners were detected in almost all examined localities. PCB contamination was found out in both soil and plant materials.

The lowest PCB content in soil samples was observed in the case of congener 28 (0.077 µg/kg) while the highest content was determined in the case of congener 180 (53.3 µg/kg). The average amount of all the PCB congeners in soil was 17.9 µg/kg. In previous studies, various concentrations of PCBs in soil were reported, ranging from non-detectable values to 500–600 µg/kg (Němeček et al. 1994, Podlešáková et al. 1994, 1997, Zavadil 1999). Greater concentrations of PCB congeners were usually associated with air-polluted areas in industrial regions and with inundative territories of water bodies. Zavadil

Table 4a. The results of regression analysis of the relationships among individual PCB congeners contents in soil and carrot root

	Parameter	P28	P52	P101	P153	P138	P180	SP
R28	*r*/*m*	0.127/mult.	0.980/exp.	–0.036/lin.	0.128/mult.	–0.081/mult.	0.415/mult.	0.113/mult.
	α	0.357	0.476	0.792	0.351	0.558	0.002	0.410
	r-sq	1.600	0.960	0.130	1.640	0.650	17.240	1.280
	*r-sq**	0.032	0.020	0.004	0.016	0.007	0.202	0.032
R52	*r*/*m*	0.413/mult.	0.121/mult.	0.120/mult.	0.194/mult.	–0.074/lin.	0.401/mult.	0.163/mult.
	α	0.002	0.380	0.383	0.156	0.589	0.002	0.235
	r-sq	17.060	1.460	1.440	3.770	0.550	16.120	2.660
	*r-sq**	0.103	0.030	0.000	0.031	0.005	0.076	0.028
R101	*r*/*m*	0.135/rec.	0.219/rec.	0.058/exp.	0.078/exp.	–0.120/mult.	0.124/mult.	0.031/exp.
	α	0.325	0.108	0.674	0.572	0.385	0.368	0.825
	r-sq	1.830	4.800	0.340	0.610	1.430	1.530	0.090
	*r-sq**	0.023	0.014	0.012	0.029	0.003	0.011	0.001
R138	*r*/*m*	0.232/rec.	0.665/rec.	0.095/rec.	0.182/mult.	–0.059/rec.	0.286/rec.	0.143/rec.
	α	0.089	0.000	0.492	0.184	0.667	0.035	0.298
	r-sq	5.370	44.240	0.900	3.320	0.350	8.160	2.040
	*r-sq**	0.020	0.023	0.011	0.063	0.010	0.026	0.006
R153	*r*/*m*	0.117/rec.	–0.045/rec.	0.173/mult.	0.192/mult.	–0.070/rec.	0.150/mult.	0.125/mult.
	α	0.395	0.746	0.206	0.161	0.611	0.276	0.365
	r-sq	1.370	0.200	3.000	3.678	0.490	2.240	1.550
	*r-sq**	0.009	0.003	0.025	0.042	0.004	0.057	0.016
R180	*r*/*m*	–0.166/exp.	0.061/rec.	–0.088/exp.	0.103/mult.	–0.105/mult.	0.242/mult.	–0.057/rec.
	α	0.226	0.658	0.525	0.454	0.447	0.076	0.679
	r-sq	2.760	0.370	0.770	1.060	1.100	5.840	0.330
	*r-sq**	0.017	0.005	0.008	0.040	0.005	0.032	0.008
SR	*r*/*m*	0.109/mult.	–0.050/rec.	0.182/mult.	0.255/mult.	–0.773/exp.	0.405/mult.	0.119/mult.
	α	0.427	0.713	0.184	0.061	0.575	0.002	0.386
	r-sq	1.200	0.260	3.310	6.480	0.600	16.440	1.420
	*r-sq**	0.007	0.005	0.019	0.070	0.006	0.069	0.002

R28 – PCB congener 28 (in the carrot root), etc., P28 – PCB congener 28 (in the soil), etc.,
SR – sum of PCB congeners in the carrot root, SP – sum of PCB congeners in the soil
r – correlation coefficient, *m* – regression model (linear, multiplicative, reciprocal or exponential), α – significance level,
r-sq – index of determinance, *r-sq** – index of determinance by quadratic regression

Table 4b. The results of regression analysis of the interrelationships among individual PCB congener contents in carrot root

	Parameter	R28	R52	R101	R153	R138	R180	SR
R28	*r/m*		0.369/mult.	0.212/mult.	0.492/lin.	0.086/rec.	0.171/mult.	0.311/mult.
	α		0.006	0.120	0.000	0.532	0.212	0.020
	r-sq		13.620	4.500	24.400	0.740	2.920	9.690
	*r-sq**		0.114	0.148	0.303	0.067	0.038	0.269
R52	*r/m*	0.386/exp.		0.413/exp.	0.403/lin.	0.220/mult.	0.280/exp.	0.568/mult.
	α	0.004		0.002	0.002	0.107	0.038	0.000
	r-sq	14.930		17.060	16.230	4.840	7.840	32.260
	*r-sq**	0.100		0.284	0.196	0.094	0.138	0.325
R101	*r/m*	0.274/exp.	0.410/mult.		0.527/lin.	0.683/lin.	0.772/lin.	0.826/lin.
	α	0.043	0.002		0.000	0.000	0.000	0.000
	r-sq	7.500	16.810		27.750	46.690	59.660	68.240
	*r-sq**	0.014	0.157		0.401	0.527	0.621	0.691
R153	*r/m*	0.493/lin.	0.403/lin.	0.548/exp.		0.500/lin.	0.426/lin.	0.845/lin.
	α	0.000	0.002	0.000		0.000	0.001	0.000
	r-sq	24.24	16.230	29.990		25.050	18.110	71.420
	*r-sq**	0.007	0.187	0.278		0.255	0.197	0.720
R138	*r/m*	0.075/exp.	0.230/exp.	0.683/lin.	0.500/lin.		0.759/lin.	0.816/lin.
	α	0.585	0.092	0.000	0.000		0.000	0.000
	r-sq	0.570	5.270	46.690	25.050		57.590	66.590
	*r-sq**	0.007	0.040	0.592	0.353		0.641	0.677
R180	*r/m*	0.171/mult.	0.268/lin.	0.772/lin.	0.426/lin.	0.759/lin.		0.781/lin.
	α	0.212	0.048	0.000	0.001	0.000		0.000
	r-sq	2.920	7.190	59.660	18.110	57.590		60.920
	*r-sq**	0.012	0.073	0.694	0.320	0.665		0.663
SR	*r/m*	0.408/exp.	0.568/mult.	0.826/lin.	0.845/lin.	0.816/lin.	0.781/lin.	
	α	0.002	0.000	0.000	0.000	0.000	0.000	
	r-sq	16.620	32.260	68.240	71.420	66.590	60.920	
	*r-sq**	0.128	0.259	0.690	0.774	0.667	0.626	

R28 – PCB congener 28 (in the carrot root), etc., SR – sum of PCB congeners in the carrot root
r – correlation coefficient, *m* – regression model (linear, multiplicative, reciprocal or exponential), α – significance level,
r-sq – index of determinance, *r-sq** – index of determinance by quadratic regression

(1999) determined the sum of PCB congeners in inundation soil at the level of 114.9 mg/kg. Joneck and Prinz (1993) reported the maximal PCB quantity in agricultural soil as high as 36.0 μg/kg, and Jones (1989) observed a comparable value (50.0 μg/kg). Facek (1990) stated that a PCB content in agricultural soil does not usually exceed the value of 10 μg/kg.

Higher concentrations of PCBs detected in the present study could be attributed to the previous intensive production of PCB-based materials in the concerned region (Danielovič et al. 1999). Although this kind of production was terminated in 1984, PCB compounds are still present in all components of the environment within the area under consideration.

The variation interval of selected PCB congeners in carrot root ranged from the level below the detection limit of the analytical method to the maximum level of 10.6 μg/kg (in PCB congener 153). Average amounts of PCBs significantly differed among individual congeners. After an experimental contamination of soil, Hajšlová and Vávrová (1991) found the accumulation of PCBs in carrot root as being 7–16 μg/kg. The average value of the sum of all the followed congeners in carrot root was 5.39 μg/kg. Average concentrations of individual PCB congeners were determined as follows: congener 28–0.301 μg/kg, congener 52–0.503 μg/kg, congener 101–0.890 μg/kg, congener 138–1.49 μg/kg, congener 153–1.46 μg/kg, congener 180–0.753 μg/kg.

Interestingly, the higher average amount of PCB congeners in carrot root than in soil was observed in the current study (see Table 3). According to this table, carrot root:soil ratios were as follows: congener 28–1.19, congener 52–1.12, congener 101–1.26, congener 138–3.07, congener 153–0.87, and congener 180–0.58. Based on the sum of congeners, this ratio was 0.57.

When the PCB concentrations in individual carrot samples were considered, 98 samples from the total number of 324 ones displayed a higher concentration of the giv-

Table 4c. The results of regression analysis of the relationships among individual PCB congeners contents in carrot root and the followed soil chemical characteristics

	Parameter	NH_4	NO_3	P	K	Ca	Mg	pH/KCl	Organic matter
R28	*r*/*m*	0.318/lin.	0.378/lin.	0.217/lin.	–0.279/mult.	0.187/lin.	–0.153/lin.	–0.074/rec.	0.241/mult.
	α	0.018	0.004	0.113	0.039	0.171	0.263	0.591	0.077
	r-sq	10.110	14.290	4.670	7.800	3.510	2.350	0.550	5.770
	*r-sq**	0.110	0.143	0.048	0.138	0.039	0.024	0,009	0.075
R52	*r*/*m*	0.364/lin.	0.407/lin.	0.140 lin.	–0.257/mult.	–0.087/rec.	–0.147/lin.	–0.050/mult.	0.157/mult.
	α	0.006	0.002	0.306	0.058	0.527	0.283	0.715	0.251
	r-sq	13.280	16.550	1.970	6.600	0.760	2.170	0.250	2.470
	*r-sq**	0.135	0.167	0.035	0.035	0.004	0.022	0.002	0.056
R101	*r*/*m*	–0.142/rec.	0.118/exp.	–0.134/rec.	–0.181/mult.	–0.078/mult.	–0.061/exp.	–0.222/lin.	–0.089/lin.
	α	0.299	0.391	0.331	0.187	0.571	0.657	0.104	0.519
	r-sq	2.030	1.390	1.780	3.260	0.610	0.370	4.920	0.790
	*r-sq**	0.002	0.015	0.000	0.000	0.025	0.006	0.049	0.008
R138	*r*/*m*	–0.104/lin.	0.063/exp.	–0.166/mult.	–0.250/mult.	–0.070/lin.	0.115/lin.	–0.161/lin.	–0.147/mult.
	α	0.451	0.648	0.226	0.065	0.612	0.402	0.239	0.283
	r-sq	1.080	0.400	2.760	6.270	0.490	1.330	2.610	2.170
	*r-sq**	0.015	0.025	0.026	0.035	0.022	0.016	0.038	0.021
R153	*r*/*m*	0.185/exp.	0.351/lin.	0.228/exp.	0.189/lin.	0.168/lin.	–0.087/rec.	–0.149/exp.	0.200/lin.
	α	0.177	0.009	0.095	0.168	0.221	0.528	0.276	0.143
	r-sq	3.420	12.320	5.180	3.560	2.820	0.750	2.230	4.010
	*r-sq**	0.048	0.127	0.116	0.086	0.035	0.007	0.013	0.040
R180	*r*/*m*	–0.717/lin.	–0.022/mult.	–0.057/lin.	–0.172/exp.	–0.082/mult.	0.275/rec.	–0.175/lin.	–0.101/mult.
	α	0.603	0.874	0.681	0.208	0.553	0.042	0.202	0.463
	r-sq	0.510	0.050	0.320	2.970	0.670	7.580	3.050	1.020
	*r-sq**	0.008	0.023	0.010	0.026	0.013	0.015	0.033	0.007
SR	*r*/*m*	0.159/mult.	0.234/lin.	0.105/lin.	0.243/rec.	0.047/lin.	0.075/rec.	–0.185/exp.	0.066/mult.
	α	0.247	0.085	0.461	0.074	0.734	0.585	0.176	0.631
	r-sq	2.520	5.480	1.030	5.880	0.220	0.570	3.420	0.440
	*r-sq**	0.022	0.069	0.014	0.015	0.004	0.003	0.027	0.002

R28 – PCB congener 28 (in the carrot root), etc., SR – sum of PCB congeners in the carrot root
r – correlation coefficient, *m* – regression model (linear, multiplicative, reciprocal or exponential), α – significance level,
r-sq – index of determinance, *r-sq** – index of determinance by quadratic regression

en PCB congener in carrot root than in soil. The greatest difference was found in congener 138 in which the concentration in carrot was found to be 81 times higher than in soil in a sample, which was collected in the year 1998.

A similar distribution of PCB congeners in soil and carrot root was reported by Hajšlová and Vávrová (1991) with conclusion that carrot root can accumulate 3–4% of PCBs from soil. In addition, Zavadil (1994, 1995) found the cumulative effect of PCBs in carrot root, which had been contaminated by irrigative water. Webber et al. (1994) followed the plant uptake of PCBs from a sludge-treated coal refuse. Mean PCB concentrations in the soils were ≤ 4 mg/kg dry weight and there was no consistent effect on them of sludge application rate. Mean PCB concentrations in the plant materials were < 300 µg/kg dry weight, however, there were differences among and within the crops. The concentrations decreased in the order: carrot peels > carrot tops > cabbage wrapper and inner leaves > carrot core > corn ear leaf and stover > corn grain. Except for cabbage wrapper leaves, the PCB concentrations in plant materials were not related to those in soil.

Paterson et al. (1990) and Offenbacher (1992) stated that the increased PCB concentration in carrot root has been predominantly associated with the upper epidermal layer of roots (and not with the inner part). Hajšlová and Vávrová (1991) quantified the 97% residual rate in the epidermal layer, with epidermis representing only 14% of a total determined weight of the plant. In terms of considerations about possible resources of carrot contamination, and consequently of possible intoxication of men, the ability of plants to accumulate 81-fold higher concentration of PCB in their edible parts than in soil is especially important in this context.

The statistical evaluation of relationships between the contents of corresponding PCB congeners in carrot root and soil as well as among the individual PCB congeners within carrot root revealed 35 highly significant and 6 significant dependencies (total number of analyzed dependencies was 91) (see Table 4a, b). Notably, the concentration of individual PCB congeners in carrot root was more corresponding with the concentrations of remaining congeners in carrot root than with the PCB content of respective congener in soil. It suggested a possible synergistic effect of PCBs regarding their uptake by the plant.

Unlike the PCB concentration of individual congeners in carrot root, which in most cases positively induced the concentrations of remaining congeners in carrot root, the concentration of congeners in soil has positively implied the PCB quantity in carrot root only in 34 of all the 49 analyzed cases. However, the amount of a given congener in soil was always positively correlated with the amount of the same congener in carrot root. Comparing different congeners, an inverse correlation and/or non-linear positive correlation were found in all cases. The highest number of inverse correlations (5) was observed with the PCB congener 138.

The statistical evaluation of the relationships between PCB congeners in carrot root and investigated chemical parameters of soil pointed out for 4 highly significant and 2 significant dependencies (the total number of analyzed dependencies was 42) (Table 4c). Statistically significant influence of humus content in soil varying in range between 0.70 and 8.28% as well as the soil acidity (pH = 4.9–7.3) on the content of some of the investigated congeners in carrot root were not estimated.

According to Barančíková et al. (1995), the PCB concentration in soil is influenced mainly by the quality of the humus rather than by its quantity. The results gained in this study were in line with this statement. In the case of the soil pH, PCB congeners are almost non-soluble in water that might play the key role in no substantial influence of the soil pH on their amount. The finding that, unlike the mobility and fixation of heavy metals in soil, the pH values do not analogously affect PCB compounds, is of importance for practical purposes. Barančíková et al. (1995) found that pH had a lower effect on the accumulation of PCBs in carrot root compared to a humus content.

Among the evaluated dependencies the highest number of significant correlations (3) in evaluating the PCBs quantity was found with the amount of nitrates (i.e. NO_3-parameter). The changes in the NO_3 concentrations accounted for 14.3% of variability in the concentration of congener 28 in carrot root, for 16.6% of variability in congener 52 and for 12.3% of variability in highly chlorinated congener 153. These positive correlations could be explained by a more intensive growth of root resulting in the greater uptake of PCBs from soil. The major question now arised concerning reasonability of extensive cultivation of carrot in soils contaminated by PCBs (also in cases when the below-limit value of PCBs contamination was determined). As to remaining congeners (101, 138, 180), their concentration has not been significantly affected by the quantity of nitrates.

The NH_4-parameter had a significant (or highly significant) effect on the concentration of lightly chlorinated congeners (in congener 28 it influenced 10.11% of variability, in congener 52–13.28%). In contrast to this, the concentration of highly chlorinated congeners was not affected by the above-mentioned parameter in greater extent. Similar conclusions were also derived in studies on the transport of chemical pollutants and microrganisms from the livestock slurry via the soil horizon (Papajová et al. 2002, Vasilková et al. 2002).

Concerning available phosphorus (P), potassium (K), calcium (Ca), and magnesium (Mg) in soil, only K and Mg exhibited a statistically significant influence on the PCBs content. Variability in the potassium content affected 7.8% variability in the content of congener 28, whereas magnesium induced 7.6% of variability in the concentration of congener 180. In our study, potassium and magnesium were less associated with the PCBs uptake than nitrogen.

With respect to the overall statistical outputs it can be concluded that the concentrations of highly chlorinated PCB congeners were more dependent on selected chemical parameters than the concentrations of highly chlorinated congeners.

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ABSTRAKT

Obsah PCB látek v kořeni mrkve a jejich vztah k vybraným půdním faktorům

Vliv obsahu polychlorovaných bifenylů (PCB) v zemědělské půdě a jejích agrochemických vlastností na bioakumulaci PCB látek v konzumní části mrkve obecné (*Daucus carota* L.) byl sledován na 18 lokalitách Východoslovenské nížiny v letech 1998–2000. Kongenery PCB č. 28, 52, 101, 138, 153 a 180 byly kvantifikovány téměř ve všech vzorcích, a to jak v půdě, tak v rostlinném materiálu. V půdních vzorcích byl naměřen minimální obsah PCB 0,16 µg/kg u kongeneru 52 a maximální obsah PCB 53,4 µg/kg u kongeneru 180. Průměrná hodnota součtu kongenerů dosáhla 17,9 µg/kg. Variační rozpětí obsahu sledovaných kongenerů PCB v kořeni mrkve se pohybovalo od hodnot pod mezí detekce stanovení analytické metody až po maximální hodnotu 10,6 µg/kg pro kongener 153. Průměrné obsahy PCB se podle jednotlivých kongenerů významně lišily. Průměrná hodnota součtu kongenerů byla 5,39 µg/kg. Při statistickém hodnocení závislosti obsahu kongenerů PCB v kořeni mrkve na obsahu kongenerů v půdě i vzájemného vztahu obsahu jednotlivých kongenerů ve vzorcích mrkve jsme zjistili značný počet statisticky vysoce průkazných hodnot. Obsah jednotlivých kongenerů v kořeni mrkve byl ovlivněn jak obsahem ostatních kongenerů v kořeni mrkve, tak i obsahem těchto kongenerů v půdě. Z toho lze odvodit předpoklad synergického působení těchto látek při jejich příjmu rostlinou. Zvyšování obsahu anorganického dusíku v půdě způsobilo průkazné zvýšení obsahu nízkochlorovaných kongenerů v kořeni mrkve. Obsah kongenerů PCB 28 a 52 je celkově více závislý na sledovaných chemických parametrech půdy, než je tomu u vysokochlorovaných kongenerů. U ostatních chemických vlastností půdy, tj. obsahu fosforu (P), draslíku (K), vápníku (Ca), hořčíku (Mg), jsme zjistili statisticky průkaznou závislost pouze v případe K a Mg. Variabilita obsahu draslíku způsobila 7,8 % změn obsahu kongeneru 28 a podobně hořčík způsobil 7,6 % změn obsahu kongeneru 180. Draslík a hořčík mají menší význam v příjmu PCB látek, než je tomu v případě dusíku. Nebyl prokázán statisticky významný vliv obsahu humusu v půdě, který se pohyboval v rozmezí 0,70–8,28 %, ani půdní reakce (pH = 4,9–7,3) na obsah kteréhokoli sledovaného kongeneru v kořeni mrkve.

Klíčová slova: polychlorované bifenyly (PCB); mrkev; půda; půdní vlastnosti; monitoring

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