Variations in environmental contamination by polychlorinated biphenyls (PCB) and chlorinated pesticides (Lindane, DDT) on pig farms in Hodonín district in 1994 to 1999

R. Ulrich, J. Raszyk

Veterinary Research Institute, Brno, Czech Republic

ABSTRACT: Environmental samples (*n* = 216) were collected at regular intervals from 1994 to 1999 on three pig farms (D., M., T.) in the area of the district town of Hodonín, Czech Republic. The samples of feed mixtures (*n* = 85), drinking water (*n* = 44), barn dust sediments (*n* = 45), and muscular tissue of feeder pigs (*n* = 42) were analysed for the concentrations of PCB (sum of 7 indicator congeners), DDT (sum of 6 isomers), and lindane (γ-hexachlorocyclohexane). The concentrations of lindane showed increasing tendencies in feed mixtures (1995–1999), drinking water (1997–1999), barn dust sediments (1996–1998), and pork (1997–1999). The limit of permissible concentrations (hereinafter limit) was exceeded in two samples of feed mixtures collected in 1994. The limit for DDT was exceeded in two samples of feed mixtures collected in 1994. Generally, the concentrations showed a decreasing tendency in feed mixtures and barn dust sediments (1997–1999) and regular fluctuations in pork. The limit for PCB was exceeded in two samples of feed mixtures collected in 1994 and in one sample of drinking water collected in 1995. The concentrations showed increasing tendencies in feed mixtures (1995–1998) and pork (1996–1998). Decreasing tendencies were observed in drinking water (1995–1999) and barn dust sediments (1994–1997). Compared with mean values for the Czech Republic, the concentrations of lindane were higher in feed samples collected in 1994, 1997, and 1998, in drinking water samples collected in 1994 and 1995, and in pork samples collected in 1994–1998, the concentrations of DDT were higher in feed samples collected in 1994, 1997, and 1998, drinking water samples collected in 1995, and pork samples collected in 1994 and 1996–1998, and the concentrations of PCB were higher in feed samples collected in 1997 and 1998, in drinking water samples collected in 1994 and 1995, and in pork samples collected in 1996–1998. The health risk of DDT, lindane, and PCB has been assessed as moderate, medium, and moderately increased, respectively.

Keywords: pig farms; polychlorinated biphenyls; lindane; DDT; feed mixtures; drinking water; dust sediments; pork; sources; health risk

The major pollution sources in the area under study, Hodonín district, Czech Republic, are lignite mines, oil and natural gas sources, a large power plant, and intensive road traffic. The agriculture in this area is characterised by intensive animal (pig) and plant production including viticulture and fruit production. Records provided by the District Veterinary Administration at Hodonín indicate that the power plant, combusting brown coal and lignite, was the most significant pollution source in the period of our monitoring (1994–1999). Therefore, impacts of this environmental burden on pigs, as reflected in the contamination by highly dangerous organic pollutants (polychlorinated bi-

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phenyls, chlorinated pesticides), were investigated on three farms located at distances of 6 km (farm D.), 10 km (farm M.), and 16 km (farm T.) from the district town.

Partial results of continuing investigations done on the three farms and focussed on environmental mutagenic factors (Raszyk *et al.*, 1995), occurrence of chlorinated pesticides and PCB in the farm environment (Raszyk *et al.*, 1996a) and porcine tissues (Raszyk *et al.*, 1996b), effects of the pollutants on the immune system (Raszyk *et al.*, 1997), and differences between cattle and pig farms (Raszyk *et al.*, 1998) were published previously.

Results of quantitative studies of the transfer of PCBs from feed into tissues of fattened pigs were published by Vemmer *et al.* (1989, 1991). The contents of chlorinated pesticides and PCB in feeds for pigs in the period 1991–1997 were monitored by Lovell *et al.* (1996). Glynn *et al.* (2000) studied possible regional differences in concentrations of PCBs and chlorinated pesticides in adipose tissues from pigs in the same period.

This paper shows trends of concentrations of chlorinated pesticides and polychlorinated biphenyls in feed mixtures, drinking water, barn dust sediments, and muscular tissue of pigs and presents a comparison of the data obtained in the area of Hodonín with available data from the remaining 80 districts of the Czech Republic.

MATERIAL AND METHODS

The analysed materials included samples of feed mixtures (n = 85), drinking water (n = 44), barn dust sediments (n = 45), and tissues of feeder pigs (n = 42) collected on three farms (D., M., T.) in Hodonín district in 1994 to 1999.

Farm characteristics

Farm D. housed 17 000 feeder pigs fed dry diets except for 2 barns where the liquid feeding system Funcki (Herning, Denmark) was installed. The pigs had unlimited access to drinkers supplied from a public water source. The materials collected on the farm consisted of 35 feed samples, 14 drinking water samples, 14 samples of barn dust sediments, and 14 samples of pork (77 samples in total).

Farm M. housed 10 000 feeder pigs fed liquid diets (system Schauer, Prambachkürchen, Austria). Water used for diet processing came from a private well. The premises were heated with natural gas. The materials collected on the farm included 25 feed samples, 18 samples of drinking water, 18 samples of barn dust, and 16 samples of pork (total 77 samples).

Farm T. housed 1 650 feeder pigs fed liquid diets (system Schauer, Prambachkürchen, Austria) and drinkers were at disposal. Water used for diet processing came from a public source. The materials collected on the farm included 25 feed samples, 12 water samples, 13 samples of barn dust sediments, and 12 samples of pork (total 62 samples).

Sampling

Dry feed samples (n = 85) were collected from feeding troughs (farm D.) or in the feed processing room (farms M. and T.). The minimum sample size was 2 000 g.

Drinking water samples (n = 44) were collected from drinkers or in the feed processing room (farm M.). The minimum sample volume was 2 000 ml.

Barn dust samples (n = 45) were collected from several sites in each barn using a vacuum cleaner. The mean sample weight was 1 500 g. The retained dust was sieved through a 0.7 mm mesh and only particles passing through it (approx. 85% of the total amount) were analysed.

Pork samples (n = 42) were collected from plantar muscles of the right thigh of slaughtered pigs (age 240 to 250 days, live weight 110 to 120 kg). The minimum sample size was 1 000 g.

Analytical methods

Chlorinated pesticides and PCB were determined, after extraction with organic solvents and removal of co-extracts by absorption chromatography in activated Florisil columns, by HRGC using the gas chromatograph Varian Star 3600 CX (Varian, USA) and the ^{63}Ni electron capture detector (Gajdůšková and Ulrich, 1992). The final results were derived from standard calibration curves using the software Star Chromatography Workstation Version 5.0. The results were expressed as the sum of seven indicator PCB congeners (IUPAC Nos. 28, 52, 101, 118, 138, 153, 180) and the sum of six DDT isomers (o,p'-DDE, p,p'-DDE, o,p-DDD, p,p'-DDD, o,p'-DDT, p,p'-DDT). Detection limit for

PCB was 50.0 ng/g and for lindane and DDT 10.0 ng/g; reproducibility for PCB, lindane and DDT was lower than 10.0%.

The contamination of the feed mixtures, drinking water and pork was assessed according to the current Czech Regulations.

No limits have been laid down for the content of pesticides and PCB in barn dust sediments so far. Therefore we used our own "internal" limits that were 0.10 mg/kg for lindane and sum of DDT, and 0.20 mg/kg for PCB.

Statistical data

The results were processed using the software Stat Plus, Version 1.01 (Matoušková *et al.*, 1992). To improve the meaningfulness, the data are presented in

a) figures showing mean values only and allowing the assessment of trends and comparisons with mean values for the Czech Republic (when available), and

b) tables showing the number of tested samples, arithmetic mean, ± S.D., and range (min.–max.).

In accordance with the binding methodology approved for the project GA/1650/93 by the Ministry of the Environment of the Czech Republic, the highest and the lowest numbers of samples were tested in 1994 and 1995, respectively.

Mean concentrations of the pollutants in feed mixtures, drinking water, and pork were borrowed from the annual reports on contamination of food chains by xenobiotics in the Czech Republic (Valcl, 2000). Monitoring of chlorinated pesticides and PCB in drinking water by the State Veterinary Administration was discontinued in 1995.

RESULTS

The concentrations of lindane, DDT, and PCB in feed mixtures, drinking water, barn dust sediments, and pork are shown in Figures 1 through 12 and Tables 1 through 3.

Lindane (Figures 1–4, Table 1)

The statutory limit for lindane was exceeded in two samples of feed mixtures (0.177 and 0.523 mg/kg) collected in 1994. An increase in lindane concentrations was observed in feed mixtures (1995–1999), drinking water (1997–1999), barn dust sediments (1996–1998), and pork (1997–1999). Compared with the mean values for the Czech Republic (Figures 1–4), the concentrations of lindane were higher in feed mixtures (1994, 1997 to 1999), drinking water (1994, 1995), and muscular tissue (1994–1999).

Mean annual lindane concentrations ranged in feed samples from 1–54%, in drinking water samples from 0.1–0.8%, and in pork samples from 0.7–3% of the respective statutory limits (0.100 mg/kg, 3 000 ng/l and 2.0 mg/kg fat, respectively).

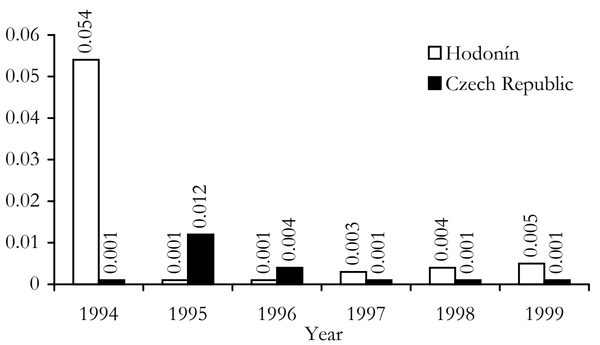

Figure 1. Lindane concentrations in commercial feeds for pigs (mg/kg) in Hodonín district (n = 85) and a comparison with mean values for the Czech Republic (1994–1999)

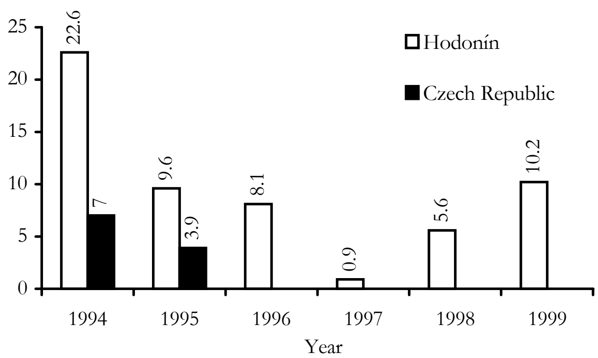

Figure 2. Lindane concentrations in drinking water for pigs (ng/l) in Hodonín district in 1994–1999 (n = 44) and a comparison with mean values for drinking water for farm animals in the Czech Republic in 1994–1995

Table 1. Lindane concentrations in commercial feeds, drinking water, barn dust sediments, and pork of pigs fattened in Hodonín district in 1994–1999

Year	*n*	Mean	SD	Min.	Max.
Commercial feeds – lindane (mg/kg)					
1994	15	0.0540	0.1370	0.0020	0.5230
1995	4	0.0004	0.0003	0.0001	0.0006
1996	11	0.0005	0.0004	0.0001	0.0010
1997	24	0.0030	0.0010	0.0010	0.0050
1998	12	0.0040	0.0020	0.0020	0.0080
1999	19	0.0050	0.0040	0.0020	0.0180
Drinking water – lindane (ng/l)					
1994	10	22.563	30.139	1.990	78.100
1995	9	9.558	8.004	0.060	20.930
1996	6	8.108	8.818	1.800	20.940
1997	7	0.879	0.983	0.100	2.940
1998	6	5.617	4.585	2.540	14.820
1999	6	10.160	3.160	5.130	13.690
Barn dust sediments – lindane (mg/kg)					
1994	11	0.046	0.056	0.011	0.203
1995	5	0.028	0.019	0.010	0.060
1996	6	0.008	0.007	0.001	0.020
1997	8	0.021	0.019	0.001	0.062
1998	6	0.051	0.064	0.021	0.182
1999	9	0.033	0.026	0.014	0.081
Pork – lindane (mg/kg of fat)					
1994	14	0.060	0.046	0.004	0.159
1995	3	0.038	0.014	0.024	0.052
1996	7	0.056	0.028	0.022	0.099
1997	6	0.015	0.015	0.005	0.037
1998	6	0.044	0.014	0.021	0.066
1999	6	0.060	0.005	0.051	0.067

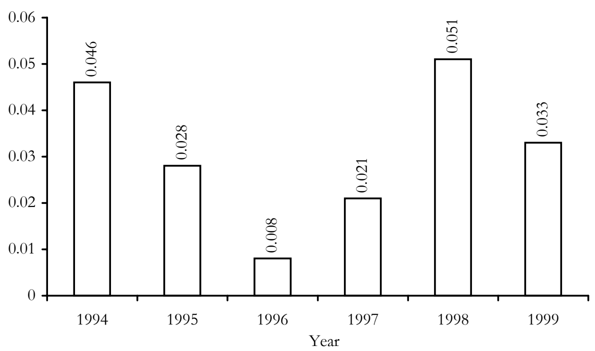

Figure 3. Lindane concentrations in barn dust sediments (mg/kg) collected on pig farms in Hodonín district in 1994–1999 (*n* = 45)

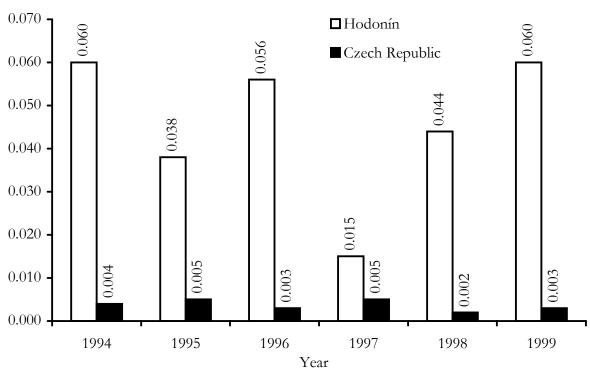

Figure 4. Lindane concentrations in pork of pigs (mg/kg of fat) fattened in Hodonín district (*n* = 42) and a comparison with mean values for the Czech Republic (1994–1999)

DDT (Figures 5–8, Table 2)

The limit for DDT was exceeded in three samples of feed mixtures collected in 1994 (0.054 and 0.071 mg/kg) and in 1997 (0.064 mg/kg). Decreases in DDT concentrations were observed in feed mixtures and barn dust sediments (1997 to 1999). The concentration of DDT in muscular tissue fluctuated regularly. Compared with the mean for the Czech Republic (Figures 5–8), the concentrations of DDT were higher in feed mixtures (1994, 1997, 1998), drinking water (1995), and muscular tissue (1994, 1996–1998).

Mean annual DDT concentrations ranged in feed samples from 2–38%, in drinking water samples from 0.1–0.8% and in pork samples from 1.6 to 8.3% of the respective statutory limits (0.050 mg/kg, 1 000 ng/l and 1.0 mg/kg fat, respectively).

PCB (Figures 9–12, Table 3)

The limit for PCB was exceeded in two samples of feed mixtures (0.067 and 1.451 mg/kg) in 1994 and in one sample of drinking water (63.3 ng/l) in 1995. Increases in PCB concentrations were observed in feed mixtures (1995–1998), barn dust sediments (1994–1997), and pork (1996-1998). Decreasing tendencies of PCB concentrations were observed in drinking water (1995–1999) and barn dust sediments (1997–1999). Compared with the mean values for the Czech Republic (Figures 9–12), the concentrations of PCB were higher in feed mixtures (1997, 1998), drinking water (1994, 1995), and pork (1996–1999).

Mean annual PCB concentrations in feed samples ranged from 4–222%, in drinking water samples from 5–24%, and in pork samples from 13.6–29.6%

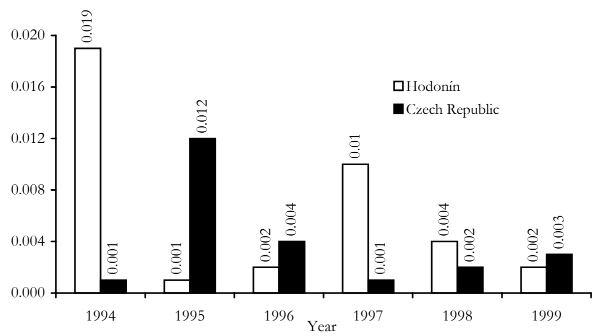

Figure 5. DDT concentrations in commercial feeds for pigs (mg/kg) in Hodonín district (n = 85) and a comparison with mean values for the Czech Republic (1994–1999)

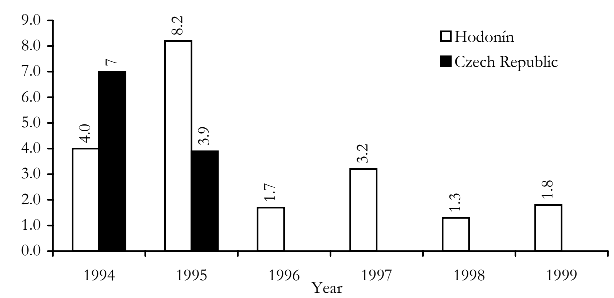

Figure 6. DDT concentrations in drinking water for pigs (ng/l) in Hodonín district in 1994–1999 (n = 44) and a comparison with mean values for drinking water for farm animals in the Czech Republic in 1994 –1995

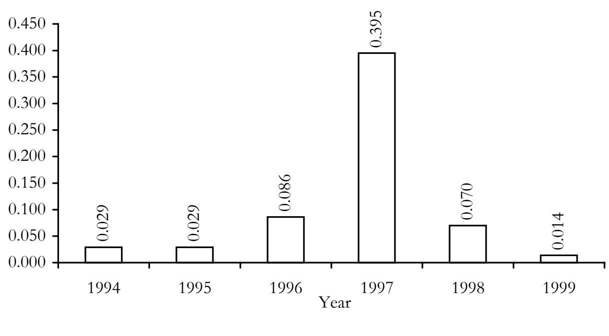

Figure 7. Concentrations of DDT in barn dust sediments (mg/kg) collected on swine farms in Hodonín district in 1994–1999 (n = 45)

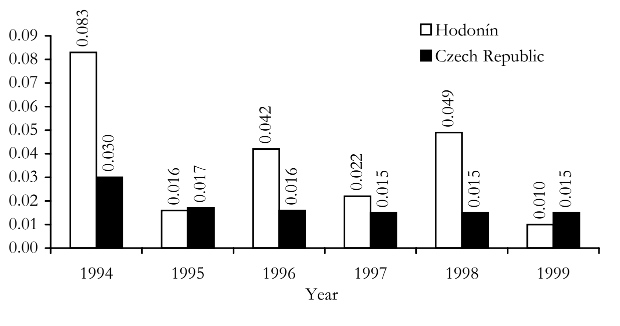

Figure 8. DDT concentrations in pork of pigs (mg/kg of fat) fattened in Hodonín district (n = 42) and a comparison with mean values for the Czech Republic (1994–1999)

Table 2. Sum of DDT concentrations in commercial feeds, drinking water, barn dust sediments, and pork of pigs fattened in Hodonín district in 1994–1999

Year	*n*	Mean	SD	Min.	Max.
Commercial feeds – sum of DDT (mg/kg)					
1994	15	0.0190	0.0220	0.0010	0.0710
1995	4	0.0004	0.0002	0.0002	0.0006
1996	11	0.0020	0.0030	0.0010	0.0120
1997	24	0.0100	0.0150	0.0010	0.0640
1998	12	0.0040	0.0020	0.0010	0.0080
1999	19	0.0020	0.0020	0.0010	0.0100
Drinking water – sum of DDT (ng/l)					
1994	10	4.018	3.185	1.600	10.300
1995	9	8.226	14.531	0.330	45.750
1996	6	1.748	1.191	0.780	3.920
1997	7	3.187	1.811	0.870	5.580
1998	6	1.308	0.613	0.620	2.420
1999	6	1.802	0.491	1.190	2.590
Barn dust sediments – sum of DDT (mg/kg)					
1994	11	0.029	0.041	0.007	0.151
1995	5	0.029	0.036	0.007	0.092
1996	6	0.086	0.133	0.001	0.304
1997	8	0.395	0.856	0.001	2.451
1998	6	0.070	0.095	0.004	0.215
1999	9	0.014	0.022	0.002	0.071
Pork – sum of DDT (mg/kg of fat)					
1994	14	0.083	0.051	0.026	0.214
1995	3	0.016	0.002	0.015	0.018
1996	7	0.042	0.031	0.012	0.091
1997	6	0.022	0.012	0.014	0.045
1998	6	0.049	0.017	0.019	0.066
1999	6	0.010	0.003	0.007	0.015

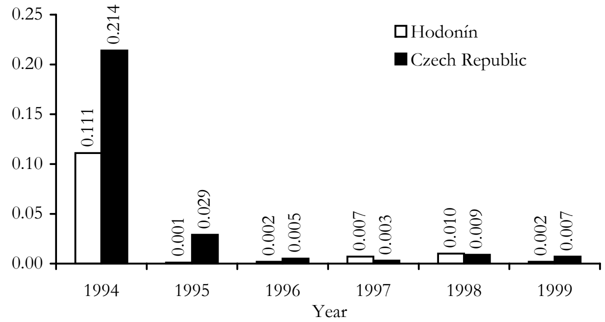

Figure 9. PCB concentrations in commercial feeds for pigs (mg/kg) in Hodonín district (n = 85) and a comparison with mean values for the Czech Republic (1994–1999)

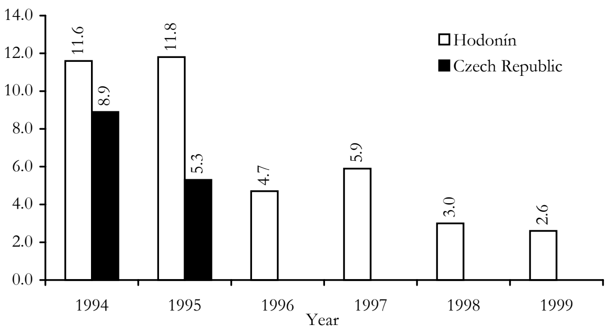

Figure 10. PCB concentrations in drinking water for pigs (ng/l) in Hodonín district in 1994–1999 (n = 44) and a comparison with mean values for drinking water for farm animals in the Czech Republic in 1994–1995

Table 3. Sum of PCB concentrations in commercial feeds, drinking water, barn dust sediments, and pork of pigs fattened in Hodonín district in 1994–1999

Year	*n*	Mean	SD	Min.	Max.
Commercial feeds – sum of PCB (mg/kg)					
1994	15	0.1110	0.3710	0.0010	1.4510
1995	4	0.0009	0.0007	0.0002	0.0018
1996	11	0.0020	0.0020	0.0010	0.0060
1997	24	0.0070	0.0040	0.0010	0.0200
1998	12	0.0100	0.0070	0.0030	0.0250
1999	19	0.0020	0.0030	0.0010	0.0120
Drinking water – sum of PCB (ng/l)					
1994	10	11.619	5.293	4.400	19.720
1995	9	11.806	19.705	1.450	63.580
1996	6	4.755	2.173	2.490	8.840
1997	7	5.907	2.511	2.740	10.220
1998	6	3.022	0.786	2.220	4.480
1999	6	2.650	0.806	1.740	3.810
Barn dust sediments – sum of PCB (mg/kg)					
1994	11	0.088	0.066	0.008	0.210
1995	5	0.330	0.679	0.018	1.544
1996	6	0.486	0.794	0.002	1.889
1997	8	2.041	3.812	0.005	9.926
1998	6	0.894	1.314	0.010	2.739
1999	9	0.182	0.456	0.005	1.387
Pork – sum of PCB (mg/kg of fat)					
1994	14	0.079	0.040	0.024	0.151
1995	3	0.085	0.009	0.075	0.093
1996	7	0.068	0.070	0.006	0.192
1997	6	0.104	0.038	0.064	0.171
1998	6	0.148	0.053	0.081	0.208
1999	6	0.031	0.005	0.025	0.036

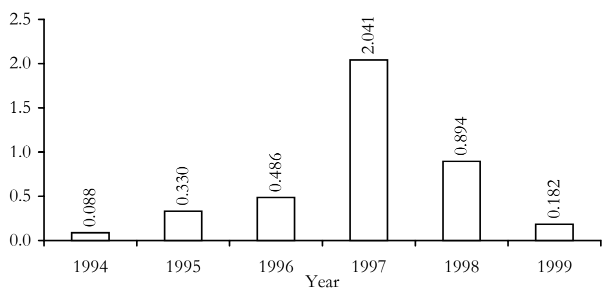

Fig. 11. PCB concentrations in barn dust sediments (mg/kg) collected on pig farms in Hodonín district in 1994–1999 (n = 45)

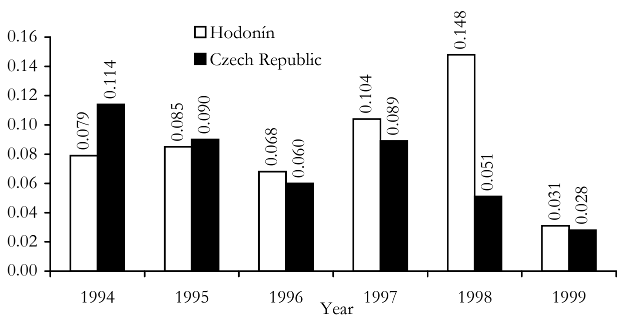

Figure 12. PCB concentrations in pork of pigs (mg/kg of fat) fattened in Hodonín district (n = 42) and a comparison with mean values for the Czech Republic (1994–1999)

of the respective statutory limits (0.050 mg/kg, 50 ng/l and 0.2 mg/kg fat, respectively).

DISCUSSION

Limits of permissible concentrations can be established in respect of 1) pollutant types; 2) sample types; 3) locations of farms.

Analyses of 171 samples of feed mixtures, drinking water, and pork showed that the limits for PCB, DDT and lindane were exceeded in 3 (1.75%), 3 (1.75%) and 2 (1.17%) samples, respectively.

In terms of sample types, the limits were exceeded in feed mixtures (7 of 85 samples; 8.2%) and in drinking water (1 of 44 samples; 2.3%). No exceeding was found in pork samples (n = 42).

In terms of farms, the limits were exceeded on farm M. in 4 of the 59 tested samples (6.8%; 1 water and 3 feed samples), on farm D. in 3 of the 63 tested samples (4.8%; 3 feed samples) and on farm T. in 1 of the 49 tested samples (2.0%; 1 feed sample)

Most of the excessive values were found in 1994 (n = 6) followed by 1995 and 1997 (n = 1). All samples collected in 1996 through 1999 were free of excessive concentrations of lindane and PCB. The lowest values relative to the limits were found for lindane and DDT in drinking water. The highest values relative to the limits were found for lindane, DDT, and PCB in feed samples. The lowest and the highest values relative to the limits for pork were found for lindane and PCB, respectively. The mean PCB concentration in pork (0.031 mg/kg) for 1999 is comparable with the mean (0.035 mg/kg) found within a monitoring in Belgium (Esposito *et al.*, 2001). Data on the contamination of pork provide information on health risks associated with the consumption of this meat kind.

Monitoring of organic pollutant concentrations in barn dust sediments provides the basic information for the assessment of indoor contamination rate in animal houses. Considering our internal limits for PCB (0.200 mg/kg), DDT (0.100 mg/kg), and lindane (0.100 mg/kg) in barn dust sediments, excessive concentrations were found in 11 (24.4%), 7 (15.5%), and 2 (4.4%) of the 45 tested samples, respectively. All the 20 samples showing excessive concentrations were collected on farm M. Nevertheless, the limits for none of the three pollutants were exceeded in any pork sample collected from pigs fattened on this farm.

Analyses of barn dust sediments proved to be a useful tool for the identification of pollution sources in our previous studies (Raszyk *et al.*, 1998). Thus we were able to identify paint coats and capacitors as sources of PCB, imported fish meal and soy as sources of DDT, and the drug Fenoform forte used in the treatment of ectoparasitic infections as a source of lindane. It must be pointed out, however, that increased concentrations of pollutants in dust sediments need not be necessarily associated with increased concentrations in airborne particles (aerosol).

The concentration of DDT in barn dust sediments paralleled its concentration in feed mixtures. Therefore we can assume that the major source of DDT found in dust sediments was feed mixtures. No similar relation was found for lindane and PCB and these pollutants probably came from other major sources.

DDT was used in the Czech Republic since 1945, and its use as an agricultural insecticide has been prohibited since 1974. DDT is still used in some African, Asian, and South American countries within the control of some insect-transmitted diseases (malaria, sleeping sickness) (Anonymous, 1995). Some feed components imported from such countries can be contaminated by DDT. Another source of DDT can be the contaminated soil around pig farms. DDT is known to persist in soil for more than 30 years (Aislabie *et al.*, 1997). A part of it is degraded by biological processes and another part volatilises (Hawthorne *et al.*, 1996).

Fenoform forte (an antiectoparasitic drug containing 10% of lindane) at 1.5% concentration was used in Hodonín district for the treatment of mange in pigs until 1990. Lindane-containing plant protection products (Lindan WP 80, Lindram 50/35) were used in Hodonín district for the treatment of rape against *Ceutorhynchids* until 1993. Like DDT, contaminated feed can become a source of lindane for pigs.

PCB produced by Chemko (Strážske, Slovakia) were used in the Czech Republic in the past. The manufacture was discontinued in 1984 and the use of PCB-containing paints was banned in the Czech Republic in 1986. The major sources of PCB identified on the pig farms included:

1. Old PCB-containing paint coats; if the paints contain more than 10 g of PCBs per 1 kg and animals have access to the painted construction parts, the concentration of PCB can exceed 10 mg/kg of fat.

2. Old capacitors (as components of ventilators and fluorescent lamps) and transformer fillings; most of them have already been removed from the pig farms.
3. Occasional contamination of feed mixtures; the highest mean concentration of PCB in feed mixtures was found in the Czech Republic in 1994 (Delor 106, 0.214 mg/kg). Hazardous components of feed mixtures include rendered fats and fish and meat-and-bone meals.

Other possible sources of PCB include grit-coating plants, dumps of discarded capacitors and transformers, and PCB-contaminated mineral insulation oils.

CONCLUSIONS

The statutory limits of PCB, lindane and DDT were sporadically exceeded in feed samples collected in 1994.

Moderately increasing tendencies were observed for lindane and PCB in feeds (1995-1998), barn dust sediments (1996–1998), and pork (lindane 1997–1998; PCB 1996-1998).

Compared with mean values for the Czech Republic, pork produced in Hodonín district contained more lindane (1994–1999), DDT (1994, 1996–1998), and PCB (1996–1999).

Probable major sources of PCB, lindane and DDT on pig farms in Hodonín district were identified.

DDT insecticides, PCB-containing paints, and lindane as a plant protection product are no more used in Hodonín district since 1974, 1986, and 1994, respectively.

The results of the study are relevant to human preventive and occupational medicine.

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Corresponding Author

Ing. Robert Ulrich, Veterinary Research Institute, Hudcova 70, 621 32 Brno, Czech Republic
Tel. +420 5 41 32 12 41, fax +420 5 41 21 12 29, e-mail: ulrich@vri.cz