Variations in contamination by mercury, cadmium and lead on swine farms in the district of Hodonín in 1994 to 1999

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ABSTRACT: Environmental samples (n = 254) were collected at regular intervals from 1994 to 1999 on three swine farms in the area of the district town Hodonín, Czech Republic. The samples of feed mixtures (n = 85), barn dust sediments (n = 44), and muscular (n = 42), hepatic (n = 41), and renal (n = 42) tissues of feeder pigs were analysed for the concentrations of mercury, cadmium and lead. The concentrations of mercury showed decreasing tendencies in animal tissue samples (1994–1996). Compared with the mean for the Czech Republic, the concentration of mercury was markedly higher in liver and kidney samples (0.064 mg/kg and 0.114 mg/kg, respectively) collected in 1998, the concentration of cadmium was moderately higher in feed, muscle, liver, and kidney samples collected in 1996–1998. Statutory limits were exceeded in two liver and two kidney samples and one feed sample only. The concentration of lead in muscle, kidney, and feed samples (1994–1996) and barn dust samples (1996–1998) showed also a decreasing tendency. However, the limit was exceeded in 16 muscle samples (0.11 to 0.23 mg/kg) collected in 1994–1999 and two kidney samples collected in 1996 (0.74 mg/kg) and 1999 (0.77 mg/kg). Heavy metals present in dust sediments apparently did not contribute significantly to their content in animal tissue. While the health risk resulting from the contents of mercury and cadmium can be classified as moderate, the contents of lead must be regarded as markedly more dangerous. ***For free full paper in pdf format see http://www.vri.cz/vetmed.asp***

Keywords: swine farms; heavy metals; mercury; cadmium; lead; feed mixtures; dust sediments; pork; liver; kidney; health risk

INTRODUCTION

The major pollution sources in the area under study, the district of Hodonín, Czech Republic, are lignite mines, oil and earth 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-growing. The power plant combusting brown coal and lignite and producing 1 390 tons of solid emissions a year is recognized as the most significant pollution source in the period of our monitoring (1994–1999). Our preliminary analyses done in 1980s' demonstrated that the concentrations of lead, cadmium and mercury in fly ash from this power plant reached 32, 0.26, and 0.11 mg/kg, respectively (Raszyk *et al*., 1992).

Partial results of long-term investigations done on three swine farms and focussed on environmental mutagenic factors (Raszyk *et al*., 1995), occurrence of heavy metals 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 swine farms (Raszyk *et al*., 1998) were published currently. The concentrations of mercury, cadmium, and lead in edible tissues of animals were investigated in Sweden (Jorhem *et al*., 1991) and Finland (Niemi *et al*., 1991). Data on the occurrence of mercury, cadmium, and lead in the biosphere were summarised by Cibulka *et al*. (1991). Nicholson *et al*. (1999) tested livestock feed samples for the contents of heavy metals. No statutory limits have so far been laid down for the content of heavy metals in barn dust sediments; therefore we have been using the following internal non-statutory values for the assessment of the contamination rate: 0.05 mg/kg for mercury, 1.00 mg/kg for cadmium, and 15.00 mg/kg for lead.

This study was focused on 1) assessing of long-term trends of heavy metal concentrations in feed mixtures, barn dust sediments and muscular, hepatic and renal tissues of feeder pig; 2) comparison of the values obtained in the district of Hodonín with available mean values reported from the remaining 80 districts of the Czech Republic (Valcl, 2000).

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MATERIAL AND METHODS

Farm characteristics

The farm D. housed 17 000 feeder pigs fed dry diets except for 2 barns where the liquid feeding system Funcki (Herning, Denmark) was installed. Drinking water came from a public source and the pigs had access to drinkers.

The 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 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.

Sampling

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

Barn dust samples (*n* = 44) were collected using a vacuum cleaner from several sites in each barn. 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.

Muscle samples (*n* = 42; min. size 1 000 g) were collected from plantar muscles of the right thigh, hepatic samples (*n* = 41; min. size 100 g) from right lobe, and renal samples (*n* = 42; min. size 100 g) from the right kidney of pigs slaughtered at the age of 240 to 250 days and live weight of 110 to 120 kg.

Analytical methods

Ten grams (animal tissues), or five grams (dust sediments, feeds) of homogenised samples were completed with 2 ml of 10% $Mg(NO_3)_2$, carbonised on a heating plate with a temperature gradient up to 250°C, and subsequently mineralised in a muffle oven with a temperature gradient up to 470°C. The ash was quantitatively dissolved in 10.0 ml of HNO_3 (3 mol/l). Cadmium and lead were determined by atomic absorption spectrometry (AAS) in acetylene-air flame using the Perkin Elmer 3100 instrument (Perkin Elmer, USA) and mercury in the automatic mercury analyser AMA (Altec, Czech Republic) using the technique of mercury vapour generation and capture in an amalgamator. The parameters of the methods were as follows: sensitivity for mercury, cadmium and lead 0.001 mg/kg, 0.005 mg/kg, and 0.05 mg/kg, respectively; reproducibility for mercury 1.5% and for cadmium and lead less than 10%.

The contamination of the commercial feeds and porcine tissues was assessed according to current Czech legislation.

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.).

Mean concentrations of the pollutants in feeds, muscles, livers, and kidneys were borrowed from the annual reports on contamination of food chains by xenobiotics in the Czech Republic (Valcl, 2000).

RESULTS

Contents of heavy metals (mercury, cadmium, lead) in feed mixtures, barn dust sediments, and muscular, hepatic, and renal tissues are shown in Figures 1 through 15 and Tables 1 through 3.

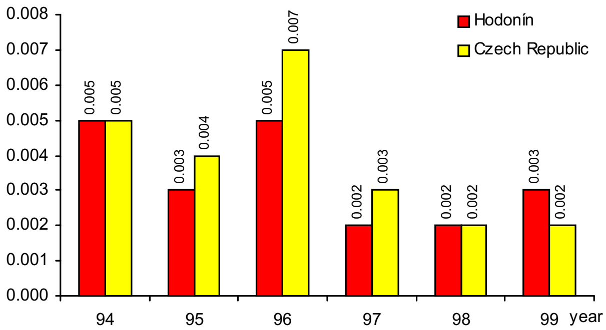

Figure 1. Mercury concentrations in commercial feeds for pigs (mg/kg) in the district of Hodonín (*n* = 85) and a comparison with mean values for the Czech Republic (1994–1999)

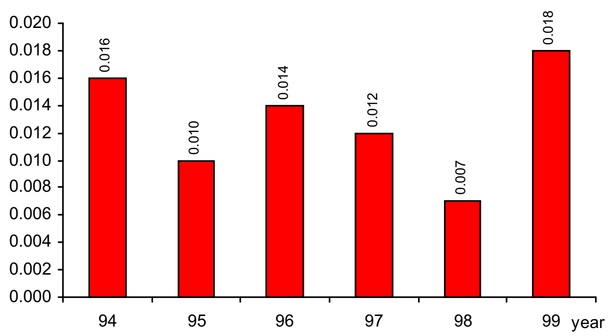

Figure 2. Mercury concentrations in barn dust sediments (mg/kg) collected on pig fattening farms in the district of Hodonín in 1994–1999 (*n* = 44)

Table 1. Mercury concentrations (mg/kg) in commercial feeds, barn dust sediments, and muscular, liver, and kidney tissues of fattened pigs in the district of Hodonín in 1994–1999

Year	*n*	Mean	SD	Min.	Max.
Commercial feeds					
1994	15	0.005	0.003	0.001	0.013
1995	4	0.003	0.001	0.001	0.004
1996	11	0.005	0.007	0.002	0.027
1997	24	0.002	0.002	0.001	0.008
1998	12	0.002	0.001	0.001	0.003
1999	19	0.003	0.003	0.001	0.010
Barn dust sediments					
1994	11	0.016	0.004	0.010	0.025
1995	5	0.010	0.008	0.005	0.023
1996	6	0.014	0.009	0.005	0.030
1997	8	0.012	0.005	0.005	0.023
1998	6	0.007	0.003	0.003	0.011
1999	8	0.018	0.012	0.009	0.045
Muscles					
1994	14	0.009	0.006	0.002	0.022
1995	3	0.006	0.003	0.003	0.008
1996	7	0.002	0.001	0.001	0.003
1997	6	0.002	0.001	0.001	0.003
1998	6	0.006	0.007	0.001	0.018
1999	6	0.001	0.001	0.001	0.002
Liver					
1994	13	0.010	0.005	0.002	0.018
1995	3	0.010	0.006	0.006	0.017
1996	7	0.003	0.001	0.002	0.006
1997	6	0.004	0.002	0.002	0.006
1998	6	0.064	0.097	0.002	0.227
1999	6	0.004	0.002	0.002	0.006
Kidney					
1994	14	0.014	0.009	0.005	0.035
1995	3	0.010	0.004	0.006	0.013
1996	7	0.008	0.002	0.006	0.012
1997	6	0.009	0.005	0.003	0.016
1998	6	0.114	0.162	0.004	0.396
1999	6	0.012	0.006	0.004	0.019

Table 2. Cadmium concentrations (mg/kg) in commercial feeds, barn dust sediments, and muscular, liver, and kidney tissues of fattened pigs in the district of Hodonín in 1994–1999

Year	*n*	Mean	SD	Min.	Max.
Commercial feeds					
1994	15	0.048	0.012	0.031	0.070
1995	4	0.045	0.012	0.035	0.063
1996	11	0.066	0.019	0.044	0.096
1997	24	0.058	0.021	0.032	0.126
1998	12	0.076	0.117	0.016	0.440
1999	19	0.075	0.136	0.014	0.630
Barn dust sediments					
1994	11	0.271	0.273	0.097	1.084
1995	5	0.106	0.027	0.060	0.132
1996	6	0.111	0.030	0.076	0.144
1997	8	0.092	0.048	0.046	0.196
1998	6	0.100	0.055	0.026	0.170
1999	8	0.092	0.042	0.040	0.168
Muscles					
1994	14	0.008	0.009	0.002	0.037
1995	3	0.005	0.001	0.004	0.005
1996	7	0.014	0.003	0.011	0.019
1997	6	0.011	0.002	0.009	0.014
1998	6	0.007	0.003	0.004	0.011
1999	6	0.008	0.003	0.005	0.014
Liver					
1994	13	0.032	0.010	0.021	0.051
1995	3	0.028	0.003	0.026	0.032
1996	7	0.047	0.019	0.030	0.084
1997	6	0.031	0.013	0.019	0.050
1998	6	0.026	0.021	0.010	0.067
1999	6	0.020	0.002	0.018	0.023
Kidney					
1994	14	1.147	0.048	0.055	0.212
1995	3	0.110	0.017	0.094	0.128
1996	7	0.144	0.052	0.073	0.244
1997	6	0.125	0.043	0.073	0.188
1998	6	0.146	0.104	0.054	0.269
1999	6	0.086	0.029	0.053	0.140

Mercury (Figures 1–5, Table 1)

The statutory limit (hereinafter limit) for mercury was exceeded in two liver samples (0.143 and 0.227 mg/kg) and two kidney samples (0.225 and 0.396 mg/kg) collected in 1998 (Table 1). It should be emphasised that the limit for mercury in muscular tissue was increased in the Czech Republic from 0.01 to 0.05 mg/kg in 1997. Decreasing trends were observed in tissue samples in 1994–1996, and in commercial feeds and barn dust sediments in 1996–1998. The concentrations in tissue, liver and kidney samples collected in 1998 were markedly higher than the mean values for the Czech Republic (Figures 1–5). This deviation was due to an isolated contamination of two pigs on the farm D.

Mean annual mercury concentrations in feed samples ranged from 1 to 5%, in muscle samples from 2 to 18%, in liver samples from 4 to 64%, and in kidney samples from 8 to 118% of the respective statutory limits (0.100 mg/kg, 0.050 mg/kg, 0.100 mg/kg, and 0.100

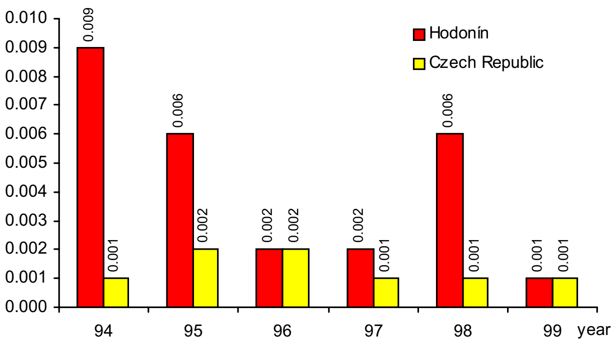

Figure 3. Mercury concentrations in muscular tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 42) and a comparison with mean values for the Czech Republic (1994–1999)

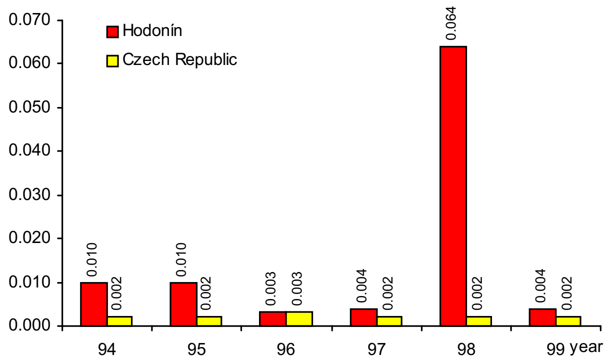

Figure 4. Mercury concentrations in liver tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 41) and a comparison with mean values for the Czech Republic (1994–1999)

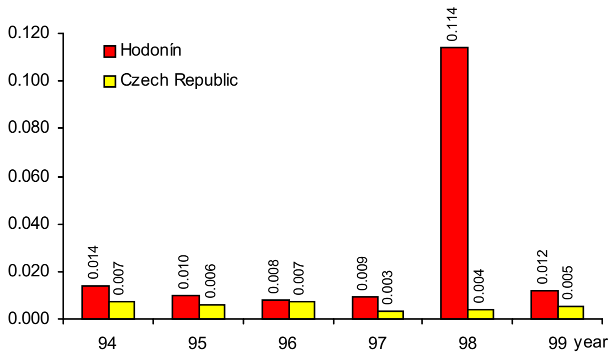

Figure 5. Mercury concentrations in kidney tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 42) and a comparison with mean values for the Czech Republic (1994–1999)

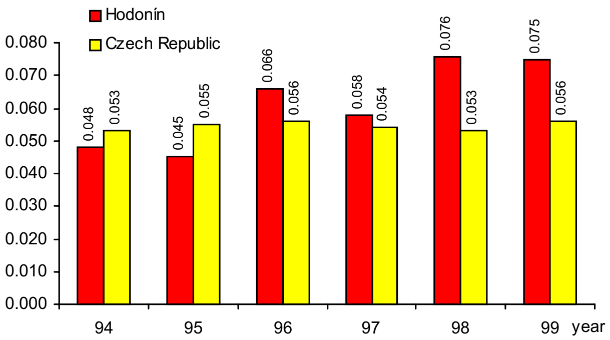

Figure 6. Cadmium concentrations in commercial feeds for pigs (mg/kg) in the district of Hodonín (n = 85) and a comparison with mean values for the Czech Republic (1994–1999)

mg/kg, respectively). Meeting of the statutory limits for the period 1994–1999 was roughly evaluated using annual mean values.

Cadmium (Figures 6–10, Table 2)

The limit for cadmium was exceeded in one feed sample (0.630 mg/kg) collected in 1999 (Table 2). Decreasing trends were observed in muscle (1996–1998) and liver samples (1996–1999). On the other hand, a moderately increasing tendency of cadmium concentration in feed samples was apparent in 1994–1999. Apart from a decrease in 1995, no variations in its content in barn dust sediments were observed. The concentrations in feed and tissue samples collected in 1996–1998 were moderately higher than the mean values for the Czech Republic (Figures 6–10).

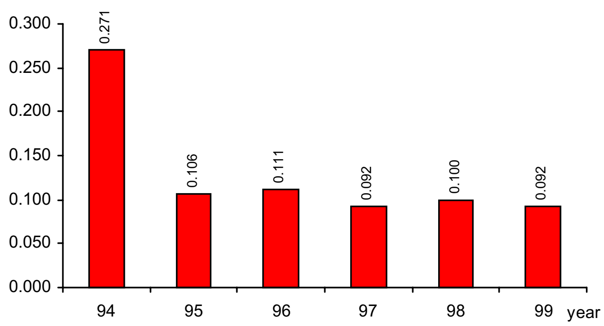

Figure 7. Cadmium concentrations in barn dust sediments (mg/kg) collected on pig fattening farms in the district of Hodonín in 1994–1999 (n = 44)

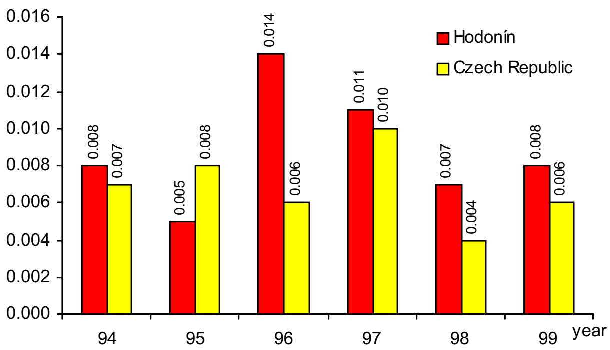

Figure 8. Cadmium concentrations in muscular tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 42) and a comparison with mean values for the Czech Republic (1994–1999)

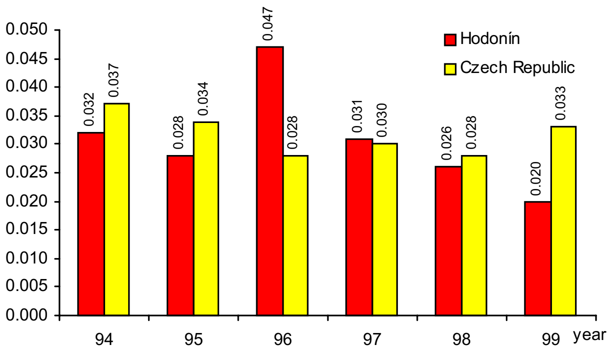

Figure 9. Cadmium concentrations in liver tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 41) and a comparison with mean values for the Czech Republic (1994–1999)

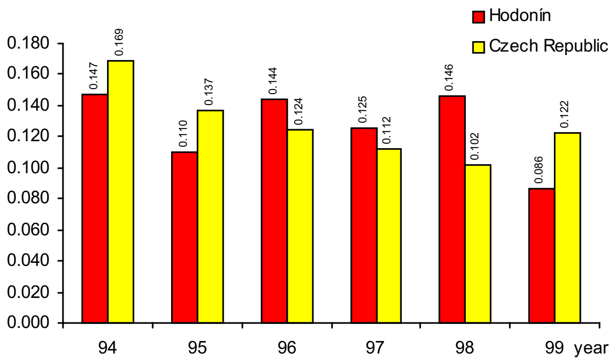

Figure 10. Cadmium concentrations in kidney tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 42) and a comparison with mean values for the Czech Republic (1994–1999)

Mean annual cadmium concentrations in feed samples ranged from 9 to 15%, in muscle samples from 5 to 14%, in liver samples from 4 to 9%, and in kidney samples from 4 to 7% of the respective statutory limits (0.500 mg/kg, 0.100 mg/kg, 0.500 mg/kg, and 2.0 mg/kg, respectively).

Lead (Figures 11–15, Table 3)

The limit for lead was exceeded in 16 muscle samples (0.11 to 0.23 mg/kg) collected in 1994–1999 and in two kidney samples collected in 1996 (0.74 mg/kg) and 1997 (0.77 mg/kg), respectively (Table 3). Decreasing trends were observed in feed, muscle, and kidney samples collected in 1997–1999. The concentrations found in feed and kidney samples (1994–1998), muscle and liver samples (1994–1999) were higher than the mean values for the Czech Republic (Figures 11–15).

Mean annual lead concentrations in feed samples ranged from 0.01 to 0.05%, in muscle samples from 47 to 124%, in liver samples from 17 to 34%, and in kidney samples from 4 to 45% of the respective statutory limits (10.000 mg/kg, 0.100 mg/kg, 0.500 mg/kg, and 0.700 mg/kg, respectively).

Table 3. Lead concentrations (mg/kg) in commercial feeds, barn dust sediments, and muscular, liver, and kidney tissues of fattened pigs in the district of Hodonín in 1994–1999

Year	n	Mean	SD	Min.	Max.
Commercial feeds					
1994	15	0.420	0.142	0.220	0.740
1995	4	0.337	0.233	0.160	0.680
1996	11	0.568	1.112	0.114	3.900
1997	24	0.459	0.275	0.160	1.470
1998	12	0.174	0.180	0.100	0.730
1999	19	0.167	0.183	0.005	0.630
Barn dust sediments					
1994	11	8.545	7.340	1.970	25.900
1995	5	17.990	18.595	0.960	41.990
1996	6	2.170	1.179	0.460	4.080
1997	8	2.125	1.958	0.970	6.880
1998	6	8.210	15.155	0.440	38.700
1999	8	5.338	8.398	0.021	24.400
Muscles					
1994	14	0.124	0.028	0.070	0.170
1995	3	0.093	0.015	0.080	0.110
1996	7	0.106	0.011	0.100	0.130
1997	6	0.122	0.053	0.100	0.230
1998	6	0.065	0.005	0.060	0.070
1999	6	0.047	0.033	0.020	0.110
Liver					
1994	13	0.141	0.076	0.070	0.380
1995	3	0.137	0.025	0.110	0.160
1996	7	0.169	0.068	0.100	0.280
1997	6	0.157	0.073	0.100	0.280
1998	6	0.085	0.023	0.070	0.130
1999	6	0.127	0.141	0.040	0.410
Kidney					
1994	14	0.125	0.054	0.050	0.270
1995	3	0.127	0.006	0.120	0.130
1996	7	0.236	0.232	0.100	0.740
1997	6	0.318	0.253	0.100	0.770
1998	6	0.085	0.006	0.080	0.090
1999	6	0.027	0.008	0.020	0.040

DISCUSSION

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

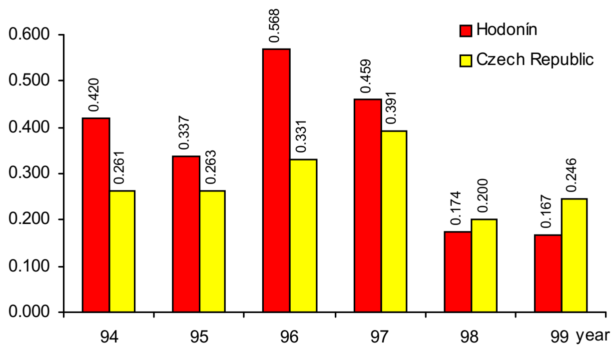

Figure 11. Lead concentrations in commercial feeds for pigs (mg/kg) in the district of Hodonín (n = 85) and a comparison with mean values for the Czech Republic (1994–1999)

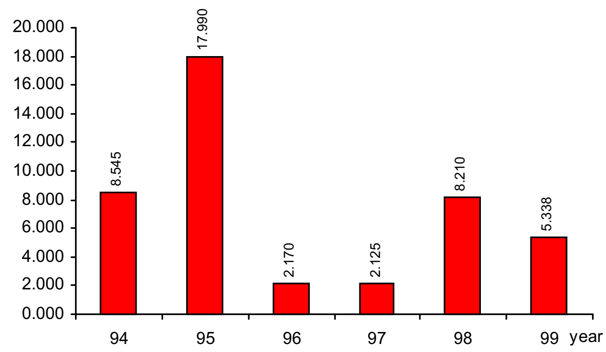

Figure 12. Lead concentrations in barn dust sediments (mg/kg) collected on pig fattening farms in the district of Hodonín in 1994–1999 (n = 44)

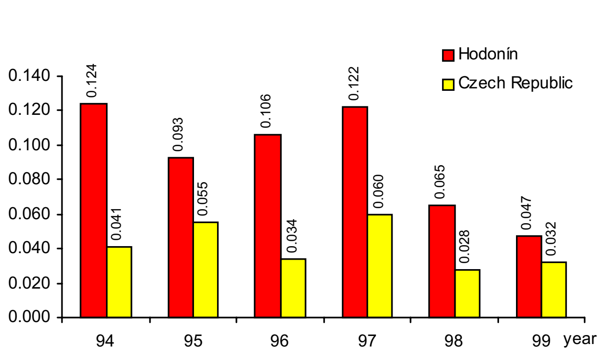

Figure 13. Lead concentrations in muscular tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 42) and a comparison with mean values for the Czech Republic (1994–1999)

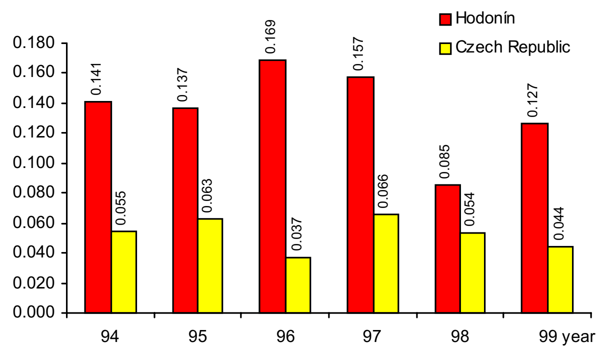

Figure 14. Lead concentrations in liver tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 41) and a comparison with mean values for the Czech Republic (1994–1999)

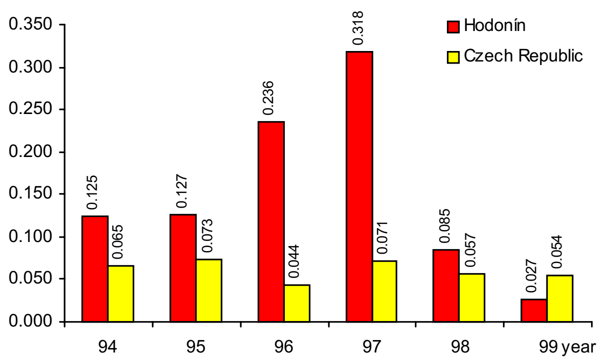

Figure 15. Lead concentrations in kidney tissue of pigs (mg/kg) fattened in the district of Hodonín (n = 42) and a comparison with mean values for the Czech Republic (1994–1999)

3) locations of farms. In our studies, the limits for lead were exceeded in 18 (8.6%; 16 muscle and 2 kidney samples), those for mercury in 4 (1.9%; 2 liver and 2 kidney samples), and those for cadmium in 1 (0.5%; feed sample) of the 210 tested samples.

In terms of sample types, the limits were most frequently exceeded in muscle tissue (16 of 42 samples; 38.1%), followed by renal tissue (2 of 42 samples; 4.8%), hepatic tissue (2 of 41 samples; 5%), and feed (1 of 85 samples; 1.2%). The mean cadmium concentration in kidney tissue for 1995–1998 is comparable with the data (0.11 mg/kg) published by Grawe *et al.* (1997) and our data for 1999 (0.086 mg/kg) did not exceed significantly the mean value established in Sweden (0.071 mg/kg) by Linden *et al.* (1999). On the other hand, mean cadmium concentrations in feed mixtures for 1998 and 1999 (0.076 and 0.075 mg/kg) were more than twice as high as that reported from Sweden (0.037 mg/kg).

In terms of farms, the limits were exceeded on the farm D. in 14 of the 76 tested samples (18.4%; 7 muscle, 4 kidney, 2 liver and 1 feed samples), on the farm M. in 5 of the 73 tested samples (6.8%; 5 muscle samples), and on the farm T. in 4 of the 61 tested samples (6.5%; 4 muscle samples). The data of the long-term investigation of the Hg, Cd and Pb concentrations stressed a discrepancy between the limits for lead in feeds and porcine tissues. The current limit for lead in feeds (10 mg/kg) appeared to be high and should be reduced to a value around 2 mg/kg.

Monitoring of pollutant concentrations in barn dust sediments provides the basic information for the assessment of indoor contamination rate in animal houses. Considering the internal limits for heavy metals in barn dust sediments, excessive concentrations were found in 8 of the 44 samples tested in 1994–1999 (18.2%; lead 7 samples, cadmium 1 sample); the majority of the contaminated barn dust samples were found most frequently on the farm T. (5 of 12 samples; 41.7%), followed by the farm M. (2 of 18 samples; 11.1%), and the farm D. (1 of 14 samples; 7.1%).

Heavy metals present in dust sediments apparently did not contribute significantly to their content in animal tissue. This was evident from the results obtained on the farm T., where the highest number of barn dust samples and the lowest number of tissue samples with excessive concentrations were found. A comparison of heavy metal concentrations in barn dust sediments and feeds showed that the former were invariably higher.

The concentration of mercury in barn dust sediments followed its concentration in feed mixtures. We can therefore assume that feed mixtures were the major source of mercury found in dust sediments. The concentration of cadmium in barn dust sediments varied within a narrow range (0.08 to 0.11 mg/kg) and only small fluctuations (0.04 to 0.08 mg/kg) were observed in feed mixtures throughout the monitoring period. No relation was found between lead concentrations in barn dust sediments and feeds. We can therefore assume that the major source of lead found in dust samples was other than the mixtures fed on the farms.

In our previous studies, analyses of barn dust sediments proved to be a useful tool for the identification of pollution sources (Raszyk *et al*., 1998). Investigations done on the farm D. in 1998 showed excessive concentrations of mercury in hepatic and renal samples, but not in muscle samples. We assume that in this case the source of mercury may have been phenylmercury-treated grain that inadvertently got its way into a feed mixture. The assumption of accidental contamination is supported by findings of lower mercury concentrations in porcine tissues in the preceding (1994–1997) and the subsequent (1999) years.

The limit for cadmium was exceeded in only one feed sample collected in 1999. The limits for cadmium in muscular and renal tissues were increased in the Czech Republic in 1997 from 0.05 to 0.10 mg/kg and from 1.00 to 2.00 mg/kg, respectively. The major sources of cadmium on swine farms include cadmium-contaminated mineral components of commercial feeds and phosphate fertilisers (Linden *et al*., 2001).

The concentrations of lead were found to exceed the limits most frequently, which applied particularly to pork (to muscular tissue samples). This fact may have been due, among other reasons, to the decision of the Czech authorities to tighten from 1997 the limits for lead in muscular, hepatic and renal tissues from 0.5 to 0.1 mg/kg, from 1.0 to 0.5 mg/kg, and from 1.0 to 0.7 mg/kg, respectively. Therefore the most hazardous among the three heavy metals monitored on the swine farms in the district of Hodonín in 1994–1999 was apparently lead. Its major sources may include paint coats containing more than 0.6 g lead per kg, mineral components of commercial feeds, scrap lead batteries put away somewhere in barns, and lead-coated guide bars of electricity distribution systems.

CONCLUSIONS

The limit for lead was exceeded in 38.1% of muscular tissue samples collected in 1994–1999.

Also concentrations of lead in other samples collected in the district of Hodonín in 1994–1998 were higher than mean values for the Czech Republic.

Hence, lead poses the most serious health hazard.

Increased concentrations of mercury and cadmium were found in several samples only. Decreasing tendencies were observed for mercury and cadmium in majority of samples.

The major sources of mercury, cadmium, and lead on swine farms in the district of Hodonín were suggested.

Heavy metals present in dust sediments apparently did not contribute significantly to their content in animal tissue.

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