Review

Soil, Food and Agroproduct Contamination Monitoring in Poland

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Abstract

Monitoring of contaminants in different agricultural sectors has a long history in Poland. Regional Agrochemical Stations (OSCHR) and the Institute of Soil Science and Plant Cultivation (IUNG) in Pulawy have performed analyses of chemical contaminants in arable soils within two research programs on countrywide scale in the years 1991-2001.

Food and agroproduct contamination has been researched in a number of research institutions and the data were inconclusive. There was no coordination of these efforts until 1991, when the Polish Ministry of Agriculture launched a program entitled "Monitoring of the Quality of Soils, Plants, Food and Agroproducts". For this purpose a set of 100 sampling points for the period 1995-1997 was selected. This number was increased to 300 sampling points for 1998-2000, but due to analytical and financial limitations each sampling point was monitored only once every three years. The data obtained under this program were published in Polish in the form of two reports (1997 and 2000) [1].

This paper presents and discusses the data obtained under the above-mentioned programs. It was not the intention of the authors to summarise all the published work done in Poland during the last decade concerning soil, food and agroproduct analyses, but rather based on cited programs to give a general view of the state of the art in Poland.

Keywords: Contamination monitoring, heavy metals, PAHs, pesticide residues

Monitoring of Arable Soils in Poland

Soil contamination is one of most important factors influencing the quality of agricultural products. Usage of heavy farm equipment, the land drainage, an excessive application of agrochemicals, emissions originating from mining, metallurgical, and chemical and coal power plants and transport all generate a number of undesired substances (nitric and sulphur oxides, PAHs, heavy metals), which after deposition in soil may influence crop quality [2, 3]. Thus, input of these contaminants into the environment should be carefully monitored. A level of contamination of agriculture soils in Poland was evaluated in two countrywide programs. The first one "*Determination of heavy metals and sulphur in soils and agroproducts in Poland*" sponsored by the Ministry of Agriculture, included determination of selected heavy metals in relation to soil physicochemical properties in 45,000 soil samples. For that purpose the network of sampling points covering the whole country has been established. Each sampling point was established to represent about 400 ha (2 x 2 km) of agricultural area. Representative soil samples were collected from 100m^2 area from 0-20 cm layer of arable soil and from 0-10 cm layer in the case of green lands. The second program "*The Arable Soils Monitoring Programme*" sponsored by the Polish

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Ministry of the Environment recorded arable lands in Poland. Over 40 parameters describing soil properties and the content of contaminants such as heavy metals, PAHs, radionuclides etc. were determined in 216 soil samples during five years of studies (1995-2000).

Heavy Metals in Soil

The summarised results of soil contamination programs are given in Table 1. More detailed information on this program is given in a separate publication [3].

Cadmium

Cadmium is very mobile in the soil environment, especially in light and acid soils. Due to this fact even a moderate concentration of cadmium in the soil can considerably influence its uptake by plants. Natural cadmium content in soils depends on the soil bedrock, granulometric composition, age of soils, intensity of soil parent rocks weathering and their geological origin. Concentration of cadmium in soils in different parts of the world varies between 0.2-1.05 mg/kg, but generally does not exceed 0.5mg/kg [4]. The soils of Poland contain an average of 0.21 mg Cd/kg, with a variation range of 0.01-49.73 mg/kg [4]. The expected range (0.10-0.46 mg Cd/kg of soil, Table 1) obtained after rejection of 5% of extreme soil cadmium values gives the real state of cadmium content in soil. Using the expected range rather than observed range provides more realistic concentration of heavy metal contamination in a given area [5]. Mean concentration of cadmium in Polish soils (0.21 mg/kg, Table 1) is at similar levels as that reported for other countries and does not exceed 0.50 mg/kg. Some hot spots showing high cadmium concentrations in some areas of Poland (reaching 49.73 mg/kg, Table 1) has a local character, resulting from the vicinity of heavy industry plants.

Copper

Copper content in soils is strongly differentiated and indicates a relevant relation with clay content in soils [3, 4]. Unpolluted soils of the world contain as much as 1-140 mg Cu/kg, while in Poland this value ranges from 6 up to 53 mg/kg [3, 4]. Average copper content in soils in Poland is low and accounts for 6.5 mg/kg (Table 1) and ranges between 0.2 and 725.0 mg Cu/kg. Excepted range is 3.1-13.6 mg Cu/kg and does not exceed geochemical background values [4]. Nearly 97% of Poland's agricultural area is not contaminated with Cu {class 0<40 mg/kg (values given for particular classes all over the text are for heavy soils and most unfavourable pH); for classification system details see [6]}. Soils with an elevated copper content (class I<70 mg/kg), which can be used for growing all crops, except vegetables for children, account for 3% agricultural area. The limitation of vegetable cultivation on copper weakly contaminated soils (class II<100 mg/kg) concerns 0.2% of farmland in Poland. Summarising the results of research concerned with copper content in agricultural land of Poland and soil pollution with this element, it could be stated that copper is not significantly responsible for the quality of plant raw materials produced in Poland [3].

Nickel

Nickel content in soils mainly depends on its concentration in bedrock [3], soil clay content, sewage sludge application and nickel deposition from polluted atmosphere. Binding of nickel by soil colloids and ferrous hydroxides and intensive phosphor fertilisation, as well as soil liming, restrict Ni mobility in soils and decrease nickel phytoavailability.

Mean nickel content in soils of the world varies between 8-33 mg/kg and 10-92 mg/kg for the light and heavy soils, respectively [4]. Generally content of 100mg Ni/kg is recognised as an acceptable level in farmland soils [4]. The mean nickel concentration in arable soils of Poland is 6.2 mg/kg (Table 1) and ranged between 0.1 to 328.3 mg/kg and 2.6 to 14.7 mg/kg for established and expected values, respectively. This is lower than Ni content (10 mgNi/kg) recognised as nickel limit concentration in light soils [6].

Results of investigations shown in Table 1 indicate that nickel concentration in soils of Poland corresponds to natural nickel content levels in unpolluted soils of the world [4]. However, there are many places with higher natural Ni content in soils of Poland, which is a result of the geological background of soil bedrock [4]. However, analysing the nickel contamination of soils shows that over 95% of Polish farmland has only natural concentrations of nickel.

In conclusion it can be said that nickel content in soils and their contamination with this element (Table 1) from the ecological and agricultural point of view is not the limiting factor of agricultural land usefulness in Poland.

Lead

The occurrence of lead in soils mainly depends on soil bedrock origin, deposition level from industry and transport means as well as from utilisation of different kinds of industrial wastes and sewage sludge as fertilizer [4]. It is necessary to note that soils not directly influenced by industrial pollution do not show elevated accumulation of lead, and soil geochemical backgrounds in different parts of the world range between 25-40 mg Pb/kg [4].

The results of monitoring of lead concentration in soils of Poland proved that mean value for this element was 13.6 mg/kg, and oscillated from 0.1 to 5000.0 mg/kg (expected values range from 7.4 to 25.0 mg/kg (Table 1). This indicates that there are only small areas of highly contaminated lead soils in Poland. Data covering farmland soil contaminated with Pb show that nearly 97% of agricultural areas are not polluted with this element. Soils with lead (classes II- IV, 100-2000 mg/kg) make up about 0.7% arable area. These soils occur in highly industrialised areas (Silesia). Thus, the hazard of lead accumulation in soil environment is considerably lower than the one resulting from cadmium and zinc.

Zinc

Average zinc content in soils in different parts of the world varies between 30-235 mg/kg [4]. A main source of soil contamination with zinc is deposition of metallic dust in soils and utilisation of sewage sludge as fertilisers. The data presented in Table 1 demonstrate that the average zinc content in farmland soils in Poland is 32.4mg/kg. Expected range of zinc content in soils (16.1-65.2mg/kg) differs significantly from the stated range (0.5-5754.0 mg/kg). This clearly indicates that low as well as high zinc concentration in agriculturally used soils in Poland may appear only accidentally. Within the country-scale about 88% of the agricultural area is not contaminated (class 0<100 mg/kg) with zinc and 10.6% shows the elevated (class I < 300 mg/kg) zinc content. Thus non-contaminated Zn soils and soils with elevated Zn content represent together about 98.5% of agricultural area.

Presented above considerations regarding soil pollution with heavy metals in Poland indicate that about 80% of Polish farmland area is characterised by natural (class 0) and 17.6% slightly elevated (class I) content of heavy metals. Soils with elevated heavy metal content are suitable for growing all crops with the exception of vegetables to be processed or to be directly consumed by children. About 3% of arable soils are contaminated with heavy metals to various degrees (classes II+III+IV+V). Weakly (class II) and medium heavily (class III) contaminated soils, which account for 2.7% of the country arable area, should not be used for cultivation of crops for consumption purpose. They can be used to grow root crops, small grains and fodder crops, while monitoring their heavy metal content. Heavily (class IV) and very heavily (class V) contaminated soils account for 0.27% and 0.08% of the total area of agricultural land, respectively. They can be used to grow industrial crops such as flax, hemp, rapeseed, sunflower etc., to reproduce seed and nursery material.

Polycyclic Aromatic Hydrocarbons (PAHs) in Soils

Evaluation of content of PAHs in arable soils in Poland was based on the results of three projects carried out in IUNG in the years 1992-1998: two of them were on a regional scale and one countrywide. Regional-scale projects included one highly polluted area around the town of Tarnowskie Góry (Silesia region) and one area in the semi-rural Puławy region (Central-East Poland) [7]. Investigations on the countrywide scale were carried out within the framework of *The Arable Soils Monitoring Programme* sponsored by the Polish Ministry of the Environment [8]. The details of the projects have been given elsewhere [7, 8]. The data obtained are summarised in Table 2. The content of PAHs in 0-20 cm soil layer was expressed as the sum of 13 compounds from the US EPA list.

The results indicate a strong relationship between the level of soil contamination with PAHs and sample location. The mean content of PAHs in agricultural Pulawy region (213 µg/kg) was less than one-half of that for the country as a whole (520 µg/kg) and one-ninth of that in the highly industrialized and coal-mining region Tarnowskie Góry (1,920 µg/kg). Median content of PAHs in arable soils in Poland was 294 µg/kg (Table 2). Taking into consideration the fact that one-half of the soil samples from this programme [8] represented territories exposed to anthropogenic activity, this value is rather low and does not significantly exceed the median content of PAHs found in unpolluted agricultural soils in other European countries [9]. For further evaluation of the results, five levels of PAH content in soil (soil classes) were defined (Table 3). The justification for the applied limits (corresponding to selected international criteria) as well as more detailed discussion of these results was given elsewhere [7, 8].

Table 1. Content (mg/kg) of heavy metals in surface layer of arable soils in Poland and the degree of their pollution by these elements.

Element	Ranges (mg/kg)		Geometric mean (mg/kg)	Percentage of arable soils according to the pollution degree (% of total)							
	determined	expected		0**	I	II	III	IV	V	0 + I	II –V
Cd	0.01-49.73	0.10-0.46	0.21	88.87	9.53	1.06	0.29	0.17	0.08	98.40	1.60
Cu	0.20-725.00	3.10-13.6	6.50	96.56	3.04	0.25	0.07	0.08	0	99.60	0.40
Ni	0.10-328.30	2.6-14.7	6.20	95.36	4.23	0.34	0.06	0.01	0	99.59	0.41
Pb	0.10-5000.00	7.4-25.0	13.60	96.89	2.44	0.40	0.25	0.02	0	99.33	0.67
Zn	0.50-5754.00	16.1-65.2	32.40	87.84	10.63	1.27	0.25	0.03	0.01	98.47	1.53
Cd+Cu+ Ni+ Pb+Zn	-	-	-	79.34	17.63	2.18	0.50	0.27	0.08	96.97	3.03

**Pollution level: 0 – natural concentration; I – increased concentration; II – slightly polluted; III – medium polluted; IV – highly polluted; V – very highly polluted; Evaluation system proposed by the Institute of Soil Science and Plant Cultivation, Pulawy [6].

Table 2. The content (μg/kg) of ∑13PAHs in arable soils in Poland [7, 8].

Parameters	Area		
	Region Tarnowskie Góry [7]	Region Puławy [7]	Countrywide (Poland) [8]
n [1]	51	72	216
Mean	1,920	213	520
Median	825	180	294
Percentile 90	4,866	372	1,024
Range	64 – 12,760	70 -737	75 – 11,391

[1)] number of soil samples

Table 3. Evaluation of PAH contamination levels of studied arable soils.

Content of PAHs in soil (μg/kg)*	Percent of total		
	Region Tarnowskie Góry	Region Puławy	Countrywide (Poland)
< 200	7	60	33
201-1000	58	40	55
1 001 – 3 000	21	0	10
3 001 – 8 000	6	0	1
8 001 – 10 000	4	0	0
10 000 – 50 000	4	0	0
> 50 000	0	0	0
Total	100	100	100

[*)] data were normalised to soil with organic matter content 2.0%.

As can be seen from the data presented in Table 3, about 1/3 of the soil from the arable area in Poland contain PAHs at <200 μg/kg and nearly 90% of these territories - including areas exposed to anthropogenic activity - at a level <1000 μg/kg (1000 μg/kg, is according to the latest proposal of the Polish Ministry of the Environment, a maximum acceptable PAH content in arable soils) [10]. Less than 2% of the samples represented areas with PAH content above 3000 μg/kg. These results indicated that arable soils from rural areas of Poland are characterised by very low PAH levels. Elevated content of PAHs, which may create a hazard to plant products and human health, occurs mainly in soils from territories with strong anthropogenic stress [8]. Very high point-source contamination by PAHs was observed only on very small areas exposed to intensive industrial activity. The median content of PAHs in Polish arable soils corresponds with that found in similar areas of neighbouring European countries [9].

Food and Agroproduct Monitoring

Country monitoring of food contamination covers several basic pollutants and basic products in which they are tested. They include crops (cereals, vegetables and fruits) and processed products (bread, flour, macaroni, etc.), but also meat and processed products derived of meat and milk. These are all listed in Table 4.

The results of measurements of heavy metals content in selected agroproducts are presented in Table 5. These data indicate that over 95% of agroproducts show safe levels of heavy metals. Average levels in these samples were much lower than accepted concentrations for particular groups of products. The lowest concentrations were found in apples, cucumbers and cabbage, while the number of samples with exceeded levels was the highest for wheat grain, especially in the samples collected in the eastern part of Poland (soil type and pH influence), but the level has been stable over several years of monitoring. A higher number of samples (2.04%) had exceeded acceptable levels of cadmium than that of lead (1.5% of samples) [12]. A similar situation was found for milk and meat products, where concentrations in meat and liver were in all cases below the accepted limits. Exception was meat of wild animals (game), where 14% of samples showed elevated levels of heavy metals. It was also

Table 4. Food contamination monitoring in Poland (modified from [11]).

Kind of contamination	Agroproducts
Cadmium	cereals: wheat, rye, triticale, barley, oats, rapeseed, potatoes*, vegetables, bread and other processed cereal products, meat (including kidneys and liver), poultry and eggs, milk, processed meat and milk products
Lead	cereals: wheat, rye, triticale, barley, oats, potatoes, vegetables, fruits, processed cereals, bread, meat (including kidneys and liver), animal fat, poultry and eggs, milk, processed meat and milk products, fish
Mercury	potatoes and vegetables, cereals: wheat, rye, triticale, barley, oats, bread and processed cereals, fish, milk and processed milk, meat (including kidneys and liver), poltry, processed meat
Arsenium	potatoes and vegetables, cereals: wheat, rye, triticale, barley, oats, bread and processed cereals, meat (including kidneys and liver), milk, processed milk, fish
Nitrates	vegetables and potatoes
Chloroorganic pesticides	milk and processed milk, meat, poultry, animal fat, vegetables, fish
DDT and ΣDDT	eggs, potatoes, bread
Lindan (γ-HCH)	milk, processed milk, meat, poultry, animal fat, fish, eggs, bread, processed cereals, vegetables, potatoes
Phosphoorganic pesticide residues	vegetables, fruits, cereals
PCBs	milk, processed milk, meat, animal fat, poultry, fish
PAH	cereals, bread, processed cereals, apple juice and concentrates
Radionuclides	milk, meat, poultry, vegetables, fruits

*underlined – product to which more attention for particular contamination was paid

Table 5. Average concentration of cadmium and lead (mg/kg of fresh matter) in selected agroproducts (modified from [12, 15]).

Agroproduct	Cadmium	Lead	Percent not exceeding acceptable level [14]
Grain crops and processed grains			
rye	0.037 ± 0.027	0.25 ± 0.20	98.1
wheat	0.060 ± 0.032	0.22 ± 0.13	95.0
rape-seed	0.040 ± 0.015	0.11 ± 0.13	97.5
margarine	Ns ± 0.003	0.07 ± 0.003	100
cooking oils	0.005 ± 0.003	0.05 ± 0.01	100
Fruits and vegetables			
strawberries	0.014 ± 0.001	0.07 ± 0.09	98.6
cucumbers	0.006 ± 0.008	0.04 ± 0.06	99.7
cabbage	0.008 ± 0.006	0.05 ± 0.07	100
carrot	0.024 ± 0.021	0.07 ± 0.06	98.0
apples	0.006 ± 0.005	0.04 ± 0.03	100
potatoes	0.023 ± 0.013	0.10 ± 0.09	97.0
Meat, processed meat and milk			
pork	0.002 ± 0.001	0.025 ± 0.015	100
beef	0.002 ± 0.002	0.029 ± 0.017	100
game	0.055 ± 0.203	4.872 ± 20.12	86.0
carp	0.004 ± 0.011	0.028 ± 0.015	100
milk	0.007 ± 0.011	0.007 ± 0.011	100

found that the level of heavy metals in kidneys was higher than accepted limits (1 mg/kg, EU) in 14% cases for pigs and 27% in cows. This indicates the necessity of careful monitoring of these products used for consumption [13].

Monitoring of pesticide residues performed in 1999, where 793 samples were analysed, showed that only in 69 samples (8.7% of total) were 13 residues of 32 analysed pesticides present. Most often traces of pesticides were monitored in samples of strawberries (20.8% of total number of samples tested), carrots (19.2%), potatoes (12.2%) and apples (8.2%).

This trend continued over the years of 1995-1999. Comparison of these data with values given for the EU [14] where from between 41,000 samples tested about 40% showed pesticide residues, indicates that pesticide residues in agroproducts in Poland has only an incidental nature and create no hazard for consumers. Some data of pesticide residues are presented in Table 6.

Analyses of pesticide residues in animal fat and milk showed that 98% of samples contained very low concentrations of chloroorganic pesticides (Table 7). Only in two samples (0.3% of total) did concentrations of ∑-DDT exceeded the acceptable level of 1 mg/kg. This happened in fat tissue of wild pigs. Milk, pig and cow fats as well as fish containing low concentrations of pesticides and none of the tested samples exceeded acceptable minimal levels.

Analyses of the presence of mycotoxin, ochratoxin A in grains [12] showed that it could be found in 50% of wheat and rye samples and in 100% of oats. However, the number of samples, in which ochratoxin A exceeded accepted value (5μg/kg), make up 24% of total for wheat and rye and 88% for oats. Over the range of several years and in different regions of Poland these values may significantly differ.

Summary

Monitoring programs run in Poland during the last decade provided valuable data indicating that in general soils and agroproducts in Poland do not show significant pollution with heavy metals or organic contaminants. The majority of soils in Poland contain nearly natural concen-

Table 6. Characteristics of pesticide residues in Polish agroproducts (modified from [12]).

Pesticide	Sample	Number of samples		Average concentration (mg/kg)
		Total tested	With residues	
Lindan (γ-HCH)	potato	99	3	0.023
p,p'DDE	carrots	99	11	0.015
	wheat	101	1	
	rye	96	1	
p,p'DDT	carrots	99	7	0.017
p,p'DDD	carrots	99	1	
ΣDDT	carrots	99	12	0.024
	wheat	101	1	
	rye	96	1	
HCB	carrots	99	2	0.0075
Fenitrotion	apples	98	2	0.07
Fozalon	apples	98	1	
Ditiocarbamide	apples	98	1	0.7
	strawberries	101	21	0.4
	cucumbers	99	3	0.1
	potatoes	77	9	0.12
Pirykarb	cabbage	99	1	
Dimetoat	cabbage	99	2	0.06
Diazinon	carrots	99	1	
Linuron	carrots	99	5	

Table 7. Concentration of pesticide and PCB residues in animal tissues (modified from [13]).

Pesticide	Sample	Number of samples		Average concentration (mg/kg)
		Total tested	With residues	
HCB	pig fat	200	21	<0.001
	cow fat	152	152	0.004 ± 0.002
	game fat	109	104	0.004 ± 0.003
	fish	101	69	0.003 ± 0.003
	milk	150	85	0.002 ± 0.002
Σ-HCH (γ and α-HCH)	pig fat	200	3	0.002 ± 0.019
	cow fat	152	4	<0.001
	game fat	109	1	<0.001
	fish	101	78	0.010 ± 0.012
	milk	150	8	0.001 ± 0.005
Σ-DDT (p,p'-DDT, p,p'-DDD, p,p'DDE)	pig fat	200	187	0.069 ± 0.146
	cow fat	152	152	0.057 ± 0.044
	game fat	109	109	0.160 ± 0.267
	fish	101	101	0.138 ± 0.135
	milk	150	149	0.044 ± 0.032
PCB	pig fat	200	44	0.004 ± 0.014
	cow fat	152	151	0.017 ± 0.037
	game fat	109	107	0.026 ± 0.016
	fish	101	98	0.034 ± 0.032
	milk	150	100	0.009 ± 0.011

trations of these chemicals which, combined with low pesticide application results in clean and no-contaminated agroproducts. Comparison of these data with the daily intake of food or processed agroproducts by individuals shows that the determined level of contamination does not create a hazard for consumer health. Exceptions are the highly industrialised areas where concentrations of the pollutants are elevated and agroproducts produced in this area need special careful monitoring.

While concentration of heavy metals in pork or beef is very low and creates no hazard, more attention should be paid to consumption of products such as kidneys. In the European Union a kidney that shows cadmium concentration higher than 1 mg/kg should not be consumed. In Poland there is no regulation in this aspect, and high concentrations of cadmium found in some kidney samples indicate necessity for such regulation.

Analyses of milk indicated that there is no problem with heavy metal contamination. However, in 4-6% of samples during 1995-1997 some inhibitory substances were monitored. This percentage was much lower during 1998-1999, but still the problem existed and this is against Polish regulations, which do not allow such substances to be present in milk [11].

Some special care should also be paid to the contamination of grain with ochratoxin A. This micotoxin is present in a high percentage of grain used for processing and this creates a hazard of the transfer of this chemical to grain derived groceries and also to the livestock feedstuffs. Monitoring of ochratoxin A may also be crucial in grain export; therefore, this question needs more research on the possibility of avoiding ochratoxin A from grains.

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