Acta Agrophysica, 2001, 52, 71-77

SOME SOIL PROPERTIES AFFECTING ORCHARDS OF THE CRACOW PROVINCE

C. Jasiewicz, M. Zemanek

Department of Agricultural Chemistry, Agricultural University of Cracov
Al. Mickiewicza 21, 31-120 Kraków, Poland

A b s t r a c t. Soil samples for analyses were collected in the whole area of the Cracow province. Basic soil properties and content of heavy metals were determined in the soil samples. It was found out that 47% of the examined soils of the Cracow province should be classified as the soils with elevated cadmium levels, 10% are soils with elevated lead levels and 27% are the soils with elevated zinc levels. The remaining soils should be classified as the soils with a natural content of these elements. Nickel and copper concentrations in all the examined soils are in the range of the natural content. The calculated correlation coefficients show that the content of cadmium was determined by the soil pH and content of copper by the content of C-org.

K e y w o r d s: heavy metals, Cracow province, orchards.

INTRODUCTION

A single largest source of anthropogenic hazard to soils are industrial emissions coming from a combustion of energy sources (coal, crude oil, natural gas) as well as contaminants and geotechnical changes of grounds caused by mining and processing of natural resources [4,8]. The province of Cracow is very industrialized. About 50 large industrial plants are located here, but only few of them are responsible for over 90% of all the emission of gases and industrial dusts. Together with industry agricultural production is very intense in this region [12]. Orchards are taking 4.5% of the cropland area in Poland a country average is 1.7% of cropland [3].

Taking the above into consideration, an attmept to evaluate soil properties of the Cracow province, especially the content of heavy metals was undertaken.

MATERIALS AND METHODS

In our tests, soil samples (from the top layer of 0-20 cm after removing sod) were taken in September of 1997 from 30 orchards of the Cracow province. The

samples were air dried, then crushed in a porcelain mortar and sieved through a strainer with 1 mm diameter screen. Identification of basic properties was performed on the subject soil samples: granulometric composition by an areometric method after Bouyoucos-Cassagrande with Pruszynski's modification, pH in the soil suspension of 1 M KCl according to the potentiometric method, hydrolytic acidity after the Kappen's method, organic matter content after the Tiurin's method and total content of Pb, Zn, Cu, Cd and Ni in the soil samples after mixing in a solution of nitrogen acid and perchloric acid [9]. Identification of heavy metal contents in the soil solutions was carried out with an atomic absorption spectrophotometer made by Philips PU 9100X.

RESULTS AND DISCUSSION

The examined soil samples showed little differences in their granulometric composition: 27 were classified as heavy soils, 2 as medium and 1 as light soil. In regard to granulation silt loam formations, loam formations and medium-heavy loam formations were predominated. Reaction of the analyzed soils (pH_{KCL}) is in a range of 5.3 to 8.1. Among the analyzed soils: 3 were classified as acidic, 6 as medium acidic, 20 as neutral and 1 as alkaline. Hydrolytic acidity was in a range of 0.10 to 2.16 cmol (+) kg^{-1} of soil. Soils of the examined samples were different in their organic matter content, which was at the level of 0.65 - 3.29% (Table 1).

Some previously conducted tests [1,8,10,11] on the heavy metal contents in the soils showed that the Cracow province together with the Katowice province belong to the most contaminated territories in Poland as far as heavy metals are considered.

Heavy metals content in the examined soils shows large variation and the range of variation is different for different metals. The largest diversification in the value of a variation coefficient between individual points is observed in content of copper, lower in the case of zinc, lead and nickel, and the lowest in the case of cadmium (Table 2).

Cadmium content in the upper layer of the examined soils ranged from 0.34 to 1.86 mg kg^{-1} with an average content of 0.91 mg Cd kg^{-1} d.m. of the soil. The lowest cadmium level in the soil was noted in Sosnówka and the highest in Czerna (Table 2). Following Gambuś's [2] research, we can assume that in the Cracow province, the content of cadmium in the upper soil layer is in the range of 0.34-3.12 mg Cd kg^{-1} d.m. of the soil. Spatial distribution of cadmium content in the soil in the Cracow province is in agreement with previous research [1,2,13]. The largest concentration of this elements was present in north-west part of the province

Table 1. Basic properties of examined soils

Locality	Soil fraction content (%)			pH_{H_2O}	pH_{KCl}	Hydrolytic acidity (cmol(+) kg^{-1})	Corg. (%)
	<0.1 mm	<0.02 mm	<0.002 mm				
Polanka Hallera	4	50	46	6.77	5.99	0.55	1.48
Szarów	77	13	10	7.66	6.85	0.31	1.65
Niedary	9	25	66	7.17	6.37	0.51	1.64
Pleszów	13	50	37	6.91	6.35	0.33	1.67
Ruszcza	6	48	46	7.75	6.99	0.22	1.53
Igołomia	9	49	42	7.55	6.86	0.35	1.20
Nowe Brzesko	11	48	44	6.96	6.24	0.40	1.47
Łyszkowice	7	54	39	7.42	6.73	0.33	0.65
Wesoła	7	48	45	7.63	6.90	0.37	1.20
Cieplice	6	54	44	7.08	6.72	0.24	1.51
Grojec	6	52	42	7.12	6.39	0.69	2.34
Wola Filipowska	31	38	31	7.58	7.00	0.22	1.26
Ojców	8	56	36	7.53	7.02	0.22	1.70
Trzyciąż	9	56	35	7.85	7.16	0.20	1.79
Dąbrowa Szlach.	60	23	17	7.45	6.98	0.29	1.45
Świątniki Górne	15	36	49	7.67	6.91	0.33	1.91
Myślenice	44	35	21	9.25	8.11	0.10	1.69
Dobczyce	30	39	31	6.76	6.65	1.65	1.68
Raciborsko	8	48	44	6.37	5.35	1.13	1.95
Michałowice	3	56	41	7.88	7.18	0.26	1.88
Sosnówka	6	53	41	7.97	7.13	0.15	1.65
Modlnica	8	53	39	7.32	6.84	0.29	1.46
Czerna	0	65	35	7.67	7.04	0.24	1.32
Skawina	71	15	14	7.12	6.25	0.72	1.70
Peim	26	34	40	7.91	7.04	0.20	1.28
Wiśniowa	23	21	56	6.51	5.40	2.16	3.29
Tokarnia	49	24	27	7.52	6.87	0.51	1.93
Trzemeśnia	10	40	50	6.64	5.51	2.13	2.59
Trzebunia	24	33	43	6.99	6.56	0.29	3.18
Skomielna Czarna	23	27	50	6.77	6.75	0.47	1.73
Mean	-	-	-	7.12	6.6713	0.51	1.726
Coefficient of variation (%)	-	-	-	8	9	105	32

Table 2. Basic properties of examined soils

Locality	Total content of heavy metals (mg kg^{-1} d.m.)				
	Cd	Pb	Zn	Cu	Ni
Polanka Hallera	0.76	16.88	27.16	14.70	1.90
Szarów	0.83	21.27	32.60	2.83	3.24
Niedary	1.04	21.58	51.71	6.91	5.17
Pleszów	0.97	24.42	136.48	5.09	4.78
Ruszcza	0.84	26.21	50.12	10.32	5.98
Igołomia	1.31	67.96	250.15	8.05	7.56
Nowe Brzesko	0.46	35.24	40.56	4.70	4.10
Łyszkowice	0.47	14.90	26.61	5.16	2.52
Wesoła	0.99	19.85	32.48	3.81	2.82
Cieplice	1.46	22.59	65.13	2.37	1.96
Grojec	1.25	35.41	45.08	2.72	1.59
Wola Filipowska	1.18	30.05	53.46	2.50	0.96
Ojców	1.13	27.81	59.23	5.15	3.02
Trzyciąż	0.89	25.42	36.51	2.17	2.35
Dąbrowa Szlach.	0.60	20.75	73.30	2.73	0.79
Świątniki Górne	1.02	31.33	83.10	27.16	4.07
Myślenice	1.25	33.05	132.77	14.69	7.90
Dobczyce	0.64	16.14	176.45	6.25	2.20
Raciborsko	0.52	16.41	39.77	1.93	3.28
Michałowice	0.92	15.99	36.78	2.12	5.34
Sosnówka	0.34	7.21	18.85	1.32	4.62
Modlnica	0.59	17.27	52.52	4.25	2.96
Czerna	1.86	82.55	99.58	5.38	2.34
Skawina	0.53	18.76	43.08	3.87	1.50
Pcim	0.95	43.50	147.34	16.85	7.00
Wiśniowa	0.44	35.65	71.04	9.87	7.31
Tokarnia	1.20	72.94	281.42	13.30	5.90
Trzemeśnia	0.88	27.92	48.10	11.33	5.63
Trzebunia	1.06	85.07	229.22	35.06	6.17
Skomielna Czarna	0.96	20.46	19.40	4.01	3.31
Mean	0.91	31.15	82	7.88	3.94
Coefficient of variation (%)	37	64	86	98	52

in places such as Czerna, Cieplice, Wola Filipowska and Grojec. This can be the result of heavy industrialization, but mainly emission of industrial dust from the mine and steelworks "Bolesław".

A natural content of lead in the soils is difficult to determine because of secondary contaminants. It ranges from several to about 200 mg Pb kg^{-1}. Nevertheless it is accepted that the level does not exceed 20 mg Pb kg^{-1} d.m. of soil in the Polish soils. [10]. An average content of lead in the upper layers of the examined soils is

31.15 mg kg^{-1} d.m. of the soil. With a large diversification in a range from 7.21 mg · kg^{-1} (Sosnówka) to 85.07 mg kg^{-1} d.m. of the soil (Trzebunia) (Table 2). Spatial analysis of lead content in the soils showed a significant area diversification between individual sites. This diversification did not allow to identity the sites in the Cracow province where lead concentration would be significantly higher.

As the data in Table 2 shows, in the case of nickel, it was concluded that there is a significant diversification of this element level in the examined soils. A 10 times higher difference between the highest and lowest nickel content was noted. The lowest nickel content was observed in Dąbrowa Szlachecka (0.79 mg kg^{-1}) and the highest in Myślenice (7.9 mg kg^{-1}) with an average for the province reaching 3.94 mg kg^{-1}. The obtained results of nickel content are close to the results that covered the entire province [5].

The natural zinc content in the soil is diversified in a range from 5 to 100 mg kg^{-1} with an average content of this metal of 40 mg kg^{-1} in the Polish soils [7]. The lowest zinc content in the soil was noted, similarly to the cadmium content, in Sosnówka and the lowest in Tokarnia. The analyzed soils were characterized by high diversification, which can be backed up by the variation coefficient reaching 86%. The highest zinc content was noted in the sites located in the south-west parts of the province.

An average copper content in the Polish soils is 6.3 mg kg^{-1} with a wide range from 1 to 140 mg kg^{-1} [7]. In the examined soils, an average content of this metal was 7.88 mg kg^{-1} and ranged from 1.32 mg kg^{-1} (Sosnówka) to 35.06 mg kg^{-1} (Trzebunia). Copper content was very diversified, which was proved by the variation coefficient reaching 98%. The highest levels were found in the sites located in the southern parts of the province.

Evaluating the results from the point of view of contamination with heavy metals, one should base the assessment on the guidelines for agriculture worked out by the Institute of Soil Science and Plant Cultivation (IUNG) "Evaluation of soil contamination in plants by heavy metals and sulfur" [6]. In the above mentioned work, four levels of soil contamination with heavy metals were defined (from I to IV); with the level "0" - a natural content of the element. On each level, three groups were identified, showing soil reaction and granulometric composition. As it was concluded from the analytical data, 16 soils were classified as having natural cadmium content, which constituted 53%. All kind of plants can be cultivated on these soils, regardless of their orientation. 14 soils were classified as belonging to the group I (first level of soil contamination) which stands for 47%. Soils qualified to the first level of contamination can be used for any food growing

with the exception of fruit and vegetables for children. When evaluating contamination of soils with lead, it should be mentioned that 27 soils (90%) are characterized as having a natural level, but 3 of the soils (10%) have elevated levels of this metal content. The analyzed data showed that among the 30 examined soils of the Cracow province, 22 (73%) had a natural zinc content, but 8 (27%) had elevated levels. Copper and nickel concentrations in the analyzed soils did not exceed the levels characterized as a natural level of these metals in the soils.

Simple correlation coefficient showed that from the considered soil properties, pH had an influence on the cadmium content and also copper content was correlated with organic matter. But none of the considered soil properties had a significant influence on lead, zinc or nickel content in the soil (Table 3).

T a b l e 3. Simple correlation coefficients (r) between heavy metals content in the soils and the investigated soil properties

Property	Pb	Zn	Cu	Cd	Ni
pH_{KCl}	0.100	0.171	0.014	-0.383*	0.057
C-org	0.262	0.170	0.432*	-0.073	0.349
Hydrolytic acidity	-0.098	-0.004	0.009	-0.323	0.122

r - significant at: *p=0.05.

CONCLUSIONS

1. It was found out that 47% of the examined soils of the Cracow province should be classified as the soils with elevated cadmium levels, 10% are soils with elevated lead levels and 27% are soils with elevated zinc levels. The remaining soils should be classified as the soils with a natural content of these elements. Nickel and copper concentrations in all the examined soils are in the range of the natural content.

2. Analyzing the calculated correlation coefficients it has been determined that there is a definite correlation between cadmium content in the soils and soil reaction. Copper concentration was correlated with the organic matter content.

REFERENCES

1. **Curzydło J.:** Akumulacja metali ciężkich w roślinach uprawianych w rejonie strefy ochronnej kombinatu Huty im. Lenina. Zesz. AGH, 1031, 141-155, 1986.
2. **Gambuś F.:** Metale ciężkie w wierzchniej warstwie gleb i w roślinach regionu krakowskiego. Zesz. Nauk. AR w Krakowie, Rozp. hab., 176, 1993.
3. **Główny Urząd Statystyczny:** Ochrona środowiska 1997. Informacje i opracowania statystyczne. Warszawa, 1997.
4. **Grodzińska K.:** Monitoring ekologiczny województwa krakowskiego w latach 1993-95. Kraków, 1996

5. **Jasiewicz C., Antonkiewicz J.:** Zawartość niklu w glebach województwa krakowskiego. Zesz. Probl. Post. Nauk Roln., 448a, 167-172, 1997.
6. **Kabata-Pendias A., Motowicka-Terelak T., Piotrowska M., Terelak H., Witek T.:** Ocena stopnia zanieczyszczenia gleb i roślin metalami ciężkimi i siarką. Ramowe wytyczne dla rolnictwa. IUNG, Puławy, 1993.
7. **Kabata-Pendias A., Pendias H.:** Biogeochemia pierwiastków śladowych. Wyd. Nauk. PWN, Warszawa, 1993.
8. **Motowicka-Terelak T., Terelak H.:** Obszary ekologicznego zagrożenia gleb w Polsce w wyniku oddziaływania czynników antropogenicznych. Zesz. Probl. Post. Nauk Roln., 422, 43-54, 1995.
9. **Ostrowska A., Gawliński S., Szczubiałka Z.:** Metody analizy i oceny właściwości gleb i roślin. katalog. Wyd. Inst. Ochr. Środ., Warszawa, 1991.
10. **Terelak H., Piotrowska M., Motowicka-Terelak T., Stuczyński T., Budzyńska K.:** Zawartość metali ciężkich i siarki w glebach użytków rolnych Polski oraz ich zanieczyszczenie tymi składnikami. Zesz. Probl. Post. Nauk Roln., 418, 45-60, 1995.
11. **Terelak H., Stuczyński T., Motowicka-Terelak T., Piotrowska M.:** Zawartość Cd, Cu, Ni, Pb, Zn i S w glebach województwa katowickiego i Polski. Mat. Konf. Nauk. "Gospodarka terenami zniszczonymi działalnością człowieka". Zabrze, 1996.
12. **Turzański K. P., Godzik B.:** Ocena stanu zanieczyszczenia gleb województwa krakowskiego metalami ciężkimi i siarką. Biblioteka Monitoringu Środowiska, Kraków, 1996
13. **Turzanski K. P., Wertz J.:** Raport o stanie srodowiska w województwie krakowskim w 1996 roku. Biblioteka Monitoringu Środowiska, Kraków, 1997.