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FOREST RECLAMATION OF THE POSTMINING DUMPS. I. CHANGES IN THE PROPERTIES OF MIOCENE SEDIMENTS MATERIAL

Key words: Miocene sediments, dumps reclamation, forest reclamation, anthropogenic soils

S u m m a r y

Miocene sediments, collected during brown coal excavation, have generally mechanical composition of loamy sand. The most negative feature of them is a very low pH-value, in a consequence of pyrite-oxidation. 20 years after technical reclamation and dump areas afforestation, a few conclusions about effects of the reclamation have been drawn: 1). The soil material in layer from 1 to 2 m deep is not homogenous. The layer from 0 to 20 cm is more homogenous as the result of mechanical cultivation before the sowing; 2). After the slopes leveling intensive erosion processes have been occurred. About 25% of the total area has been damaged by water erosion. This effect should be connected with the absence of plant-cover; 3). Soil-formation is related to anthropogenic activity, especially intensive liming, mineral fertilizing and afforestation. The influence of afforestation on soil is yet not very high. Clearly visible is a thin duff-layer (A_0)– about 1 cm; 4). Nevertheless the heavy machines using during leveling, physical and water properties of the soils are quite good; 5). The high lime doses (35-50 $Mg \cdot ha^{-1}$) causing rising the pH of top-soil-material (20-30 cm deep) to the value about 5-8. The soluble forms of Ca and Mg have been elevated considerably; 6). The mineral fertilizing has caused an increase in the available forms of K and P; 7). In the effect of waste lime use (from the smelting work) a distinct increase of the heavy metal content in the soil (especially Cu, Pb, Zn, Cd, Mn and Co) has been noted.

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Introduction

As a result of brown coal exploitation with the open-pit method, the wide excavations surrounded by overburden dumps are originating. Very oft the grounds of these dumps have extremely bad properties and can not be covered with plants simple and fast ways. Areas like these are characterized by the absent of normal formed soil-cover. Presented grounds are very poor of plant-nutrients and microflora and microfauna are not stable. Their defective chemism make recultivation very problematic at the all stages. Additionally the situation of such grounds is more complicated after wrong made technical recultivation stage.

A good example of such situation can be the large area near Łęknica-city in southern part of Lubuskie Province, strongly transformed by pit-mining of the brown coal.

Methods

For the experimental purposes were chosen two fields near Bobrowice-village (in the Łęknica-city locality). Both of them were located on the dump-top, formed after ending of the brown coal exploitation (fig. 1). Before the beginning of field experiment technical stage of recultivation (slopes forming and dump-tops leveling), first part of the chemical (liming with 35-50 t/ha lime doses) and biological stages (planting of the pine-trees) were leaded.

A few years after this recultivation-point many negative occurrences were observed, which have shown how the all reclamation process can be ended with bad result.

Both of experimental fields were founded to show all imperfections of primarily employed methods and techniques, and to drive recultivation to the proper direction. For this purpose the fertilizing field-experiment was founded.

In the experiment's beginning first area (called "A") was planted with 6-years old pine trees, the second one (called "B") – with 1-year old pine trees.

In the both experimental areas (objects "A" and "B") plots were established with different fertilizing treatments. Schema of the fertilizing combinations is shown below – in table 1.

First of all the fields was liming with additional doze of carbonate-magnesium-lime from the zinc smelter (after-flotation-lime), done 12th of November 1986. Mineral fertilizing (in accordance to experiment's schema) was made 09th of April 1987. Used fertilizers: N – ammonium nitrate, P – superphosphate, K – 50% potash salt.

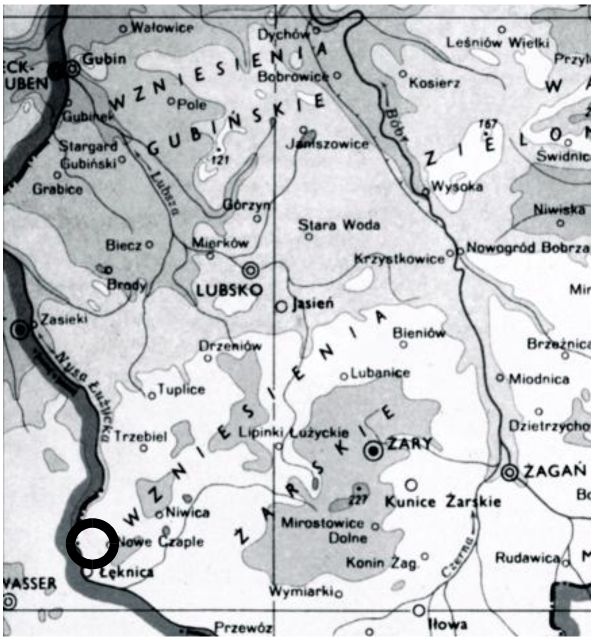

Fig. 1. Localization of the experimental fields (selected by the black ring)

Tab. 1. Schema of the fertilizing field experiment

Plot No		Lime	N	P_2O_5	K_2O
Object "A"	Object "B"	[Mg/ha]	kg/ha		
1	11	0	0	0	0
2	12	8	0	0	0
3	13	0	100	70	0
4	14	0	100	0	160
5	15	0	100	70	160
6a	16a	0	200	140	320
6b	16b	0	400	140	320
7	17	8	100	70	0
8	18	8	100	0	160
9	19	8	100	70	160
10a	20a	8	200	140	320
10b	20b	8	400	140	320
N	N	0	100	0	0

Before during and after the experiment, all the parameters important for the proper describing of recultivation process have been measured. They were: soil physical and chemical properties, pine trees mass increase, pine trees chemical composition. Also natural succession on the each experimental field was observed and noted. Experimental fields were subdivided to the rows – 10 rows pro plot. For statistical tendencies description, occurred during experiment, each of measurements was 5-times repeated (using material from 2 rows pro 1 mixed sample). All of measurements were statistically worked out, using variation analysis module of “Statistica for Windows” software.

Results

Primarily ground’s properties

Before the experiment’s beginning (7 years after first liming, with high dozes) the ground of both dump areas had mechanical composition of the loamy sand. The organic matter content was high, cause the brown coal admixture (tab. 2).

Tab. 2. Physical and chemical properties of the post mining dump material (surface layer 0-20 cm) before biological recultivation (after mechanical recultivation)

Ground properties	Range	Average value (from 20 samples)
Mechanical composition [%]		
1,0-0,1 mm	52-69	63
0,1-0,02 mm	20-31	24
< 0,02 mm	11-22	13
Organic matter [%]	0,81-3,10	1,83
Total N [%]	0,011-0,067	0,035
Total S [%]	0,17-0,65	0,39
pH in H_2O	2,00-3,80	-
pH in 1m KCl	1,98-3,28	-
Hydrolitycal acidity [cmol/kg]	9,68-16,13	14,03
P_2O_5 (available for plants) [ppm]	1,0-15,0	6
K_2O (available for plants) [ppm]	10-70	24
Mg (available for plants) [ppm]	3-186	29
Ca (available for plants) [ppm]	12-91*	13
Na (available for plants) [ppm]	0,8-3,2	2,0
Bulk density [g/cm^3]	1,16-1,64	1,42
Capillary water capacity [$\%_{weight}$]	20,9-36,4	25,6

* - single result

The ground physical properties have been quite good, similar to this noted on the arable soils with mechanical composition of loamy sands. Chemical properties of analyzed ground were extremely different. Very low pH values (pH_{KCl} 1,98-3,28) and high hydrolytical acidity (9,68-16,13) made the ground toxic for plants and not suitable in this stand for biological recultivation. Additionally the content of macro- and micronutrients was very low. As a result of high C-content the situation of very bright C:N relation occurs, what clearly shows that the cultivated plants have not chance for good growing.

Ground's properties after first stage of bio-chemical recultivation

Leveled and formed area of the former brown coal pit-mine was biochemical recultivated for first time at the 1978. Reclamation processes were driven till the 1985. The high dozes of lime (35-50 t/ha) and typical for the forest growing fertilizing were applied. 10 years after these processes properties of the ground were analyzed. Results are shown in table 3 of this paper.

Tab. 3. Physical and chemical properties of the post mining dump material (surface layer 0-20 cm) after biological recultivation in the 1985

Ground properties	Range	Average value (from 20 samples)
Organic matter [%]	0,85-3,00	1,80
Total N [%]	0,012-0,070	0,040
pH in H_2O	3,90-8,00	-
pH in 1m KCl	3,70-7,70	-
Hydrolitycal acidity [cmol/kg]	0,30-8,30	3,25
P (available for plants) [ppm]	11-40	25,7
K (available for plants) [ppm]	22-42	31,6
Ca (available for plants) [ppm]	360-6890	600
Na (available for plants) [ppm]	1,2-3,4	2,4
Bulk density [g/cm^3]	1,25-1,48	1,38
Capillary water capacity [$\%_{weight}$]	12,19-31,69	21,55

Distinctly visible is the P- and K-soluble forms content in the ground increase. The organic matter and total nitrogen content have left without changes. Also physical properties were analogical to the former results. Very important changes were noted in acidity value, but they are referred only to a few investigation slops and additionally to the thin surface layer of ground (0-5 cm).

Ground's properties after 10 years of experiment

Start point of the field fertilizing experiment was 10 years after mechanical recultivation of brown coal mine area.

Distinct influence of the applied fertilizing combinations was observed in the ground sample analytical results. It was visible as good in the chemical properties and composition of the ground (tab. 4, 5), as in the ground's biosphere as well.

Tab. 4. The physical and chemical properties of ground's surface layer (0-20 cm) 10 years after experiment ending (20 years after mechanical recultivation)

Plot No.	Bulk densi-ty	Capill. wat.cap.	Air cap.	pH - H_2O	pH_{KCl}	Hydrolit. acidity	Bases sum	CEC
	g/cm^3	$\%_{weight}$	$\%_{vol.}$			cmol/kg	cmol/kg	cmol/kg
1/A	1,38	20,70	8,24	8,0	7,7	0,3	9,2	9,5
2/A	1,37	24,46	5,76	6,7	6,5	3,4	7,0	10,4
3/A	1,28	21,28	11,25	7,5	7,2	0,6	18,5	19,1
4/A	1,38	12,19	10,93	7,2	7,0	1,5	14,5	16,0
5/A	1,32	20,83	15,51	6,5	6,4	3,8	9,2	13,0
6/A	1,35	20,31	9,74	7,0	6,9	1,5	13,2	14,7
7/A	1,34	19,42	10,52	6,0	5,8	5,3	6,7	12,0
8/A	1,34	26,48	8,52	6,7	6,5	2,2	7,2	9,4
9/A	1,37	22,98	8,36	5,9	5,7	5,1	7,3	12,4
10/A	1,35	12,58	25,72	4,7	4,1	7,9	3,0	10,9
1/B	1,48	21,72	2,32	5,6	5,1	3,7	2,5	6,2
2/B	1,46	21,75	2,73	7,4	7,1	0,8	9,0	9,8
3/B	1,43	21,17	12,84	6,9	6,8	1,3	5,5	6,8
4/B	1,46	22,84	1,71	6,8	6,6	1,4	6,5	7,9
5/B	1,42	23,59	3,65	7,3	7,1	0,9	8,3	9,2
6/B	1,37	23,33	3,92	7,3	6,7	2,3	12,9	15,2
7/B	1,25	31,69	0,69	6,8	6,6	2,2	18,8	21,0
8/B	1,31	28,60	2,58	4,5	4,3	5,9	2,6	8,5
9/B	1,46	15,40	20,24	4,2	4,0	6,6	2,5	9,1
10/B	1,42	17,62	12,98	3,9	3,7	8,3	1,2	9,5

Tab. 5. The chemical composition of ground's surface layer (0-20 cm) 10 years after experiment ending (20 years after mechanical recultivation)

Plot No.	Org. matter	Al exch.	$S-SO_4$	N_{total}	$P_{suit.}$	$K_{suit.}$	Ca_{total}	C:N
	%	cmol/kg	ppm	ppm	ppm	ppm	ppm	-
1/A	1,25	0,0	0,0	448	12	42	109	16,2
2/A	2,35	0,0	80,1	448	14	42	89	30,4
3/A	1,71	0,0	0,0	224	32	32	208	41,7
4/A	2,42	0,0	40,1	448	11	32	139	31,3
5/A	2,64	0,0	80,1	224	24	26	147	120,1
6/A	3,10	0,0	16,0	336	20	28	103	53,7
7/A	2,45	0,0	8,0	224	20	29	149	63,4
8/A	2,35	0,0	16,0	224	27	30	147	60,8
9/A	2,88	0,0	32,0	336	20	30	109	49,7
10/A	1,90	0,59	80,2	224	29	32	127	40,2
1/B	0,81	0,0	112,2	12	25	28	111	41,9
2/B	0,89	0,0	104,2	224	31	34	120	23,0
3/B	0,93	0,0	72,1	224	31	30	119	24,0
4/B	1,01	0,0	96,1	448	35	22	105	13,1
5/B	0,82	0,0	0,0	484	19	26	86	9,8
6/B	2,20	0,0	232,0	672	38	34	128	19,0
7/B	1,57	0,0	96,1	448	40	34	208	20,3
8/B	1,71	1,00	264,4	448	22	36	71	22,1
9/B	1,71	1,27	80,1	560	39	30	119	17,7
10/B	1,83	2,44	192,3	560	25	36	158	20,0

It was observed, that additional lime doze caused in top layer of the ground pH value increase, but such simple relation was not a rule. In the layers lying deeper (below 10 cm) the pH values were more similar to the primarily values.

The side effect of the waste lime from zinc smelter was an increase of heavy metals content in the ground (tab. 6). It was noted very distinct relation between heavy metals content in ground and depth of the ground layer, caused by the high sorption capabilities of the humid organic matter from the plants leavings (in top layer 0-5 cm).

The nutrient content in ground was very low, much lower than plant needs in spite of the intensive fertilizing. However the highest fertilizers dozes have caused increase in nutrients content in dump's ground comparing to the primarily situation.

The ground physical properties were not bad, in spite of the heavy machines using during leveling and slopes forming, and bulk density had values similar to the arable soils.

Tab. 6. Heavy metal content in the additional limed plots ground, 10 years after experiment ending (lime material from zinc smelter) [mg·kg^{-1} d.m.]

Depth [cm]	Cu	Zn	Cd	Pb	Ni	Co	Mn	Fe
0-5	49,1	168,1	1,28	10,9	84,2	7,1	244,0	7360
5 10	2,0	27,0	0,08	4,1	3,6	1,6	14,8	3700
10 15	3,2	31,7	0,18	5,6	4,6	2,0	9,1	4200
15-20	1,8	16,2	0,92	6,8	4,2	2,0	9,1	2940
20-30	1,9	19,1	0,90	6,6	3,8	2,6	9,1	3080
30-50	1,8	24,4	0,91	6,8	3,5	2,2	10,3	2900
50-100	2,0	16,6	0,94	7,0	3,6	2,0	9,1	2600

Erosion processes in the areas under investigation

The both experimental fields were located on the dumps tops, about 50 m from the slope-edges. This situation have caused safety for the fields from intensive erosion processes. Only the surface- and flute-water erosion were observed. In the object “B” strong erosion occurrences, like ravines (2-5 m deep) have been observed during the experiment period at the experimental field’s edges.

All the rest of dump areas were year by year after mine exploitation and mechanical recultivation very strong eroded. 20 years after this primarily recultivation stage the area shows truly cosmic landscape (fig. 2).

Fig. 2. A view on reclaimed area 20 years after leveling and slopes forming. The strong erosion processes (ravine erosion) are observed

They are two reasons of such situation. First of them is mechanical composition of the ground (loamy sand reach in silt and fine sand fractions). The second one is plant cover absent, connected with defective chemical properties of the ground (fig. 3).

Fig. 3. The absent of plant cover is a main reason of erosion processes intensity

Discussion

The recultivation was made on the ground with good mechanical composition. Maciak [1996] has classified loamy sands in the category of grounds - "good or defective – usable for forest and agricultural recultivation after water relations regulation (if necessary) – potentially productive". This mechanical composition is good enough for most of the cultivating plants.

The negative side of described area is it's very defective chemism. The pH_{KCl} value of the ground is classified as strong acid [Dobrzański i Zawadzki 1993]. Additionally situation is complicated by the high hydrolitycal acidity value (10-16 cmol/kg). It is connected with a big pyrite content in dump-ground. In the oxide conditions a reaction occurs, driven to sulphur acid origination [Katzur 1976; Krzaklewski 1986; Greinert 1988]:

$$2\ FeS_2 + 7\ O_2 + 2H_2O \rightarrow 2\ FeSO_4 + 2\ H_2SO_4$$

$$4\ FeSO_4 + 2\ H_2SO_4 + O_2 \rightarrow 2\ Fe_2(SO_4)_3 + 2\ H_2O$$
$$Fe_2(SO_4)_3 + 6H_2O \rightarrow Fe(OH)_3 + 3\ H_2SO_4.$$

For the most of plants optimal pH_{KCl} value is between 5 and 7 [Nowosielski 1974]. So, the effective biological recultivation of areas like this must to be preceded by very intensive liming (using high dozes of lime). Because of this need biological live of the limed area is totally changed [Greinert 1988, 1996].

Additionally many different chemical occurrences are noted. Brady [1984] has pointing at the antagonistic effects of the large amount of Ca^{++} ions in soil moisture for the K^{+}, Mg^{++} and other cations collecting possibilities by plants as a result of physiological blocking these ions by Ca^{++} ions. Also good known is antagonistic effect between Ca^{++} and P [Rodina 1968; Filipek 1994], as a result of chemical sorption (forming of the indissoluble compounds of P). It has leading to the nutrients deficit occurrence in soil and results in worse plant growing, what was observed in described experiment.

Many authors have given information about the necessity of the high NPK applying after recultivation lime input [Bender i Gilewska 1988, Bender 1995].

For the recultivation should be used lime material without large amounts of heavy metals. Owing to this, waste lime material (per example from smelters) applying must be made with special attention, each time under chemical station control. It is very important when are using a large amounts of potential danger (in long-term scale) waste materials.

Conclusions

- Recultivation of strong acid Miocene sediments on the dumps after brown coal open-pit exploitation is difficult and expensive.
- To make possible biological recultivation of the pyrite containing dumps high lime dozes must be used (50 Mg/ha and higher). This process effects different ways for the environment.
- After leveling, slopes forming and liming the high dozes of plant nutrients (above 400 kg NPK/ha) must be applied.
- Reclaimed grounds must be under long-term control, because their instability.
- Materials used for reclamation purposes should be as pure as possible, especially without heavy metals and other long-term stable, toxic elements.
- The areas after open-pit mining must be fast covered by plants to avoid erosion processes.

References

1. BENDER J.: *Rekultywacja terenów pogórniczych w Polsce*. Zesz. Probl. Post. Nauk Roln.PAN; t.418; z.1; s.75-86. Warszawa 1995
2. BENDER J., GILEWSKA M.: *Rekultywacja w ujęciu aktów prawnych, badan naukowych i gospodarczej praktyki*. Zesz.Nauk. AGH, nr 1222, zesz. 26, s. 53-68, Kraków 1988
3. BRADY N.C.: *The nature and properties of soils*. Macmillan Publ.Comp. 1984
4. CHWASTEK J.: *Miejsce rekultywacji w ochronie środowiska terenów górniczych*. Zesz.Nauk. AGH, nr 1222, z. 26, s. 27-36, Kraków 1988
5. DOBRZAŃSKI B., ZAWADZKI S.: *Gleboznawstwo*. PWRiL Warszawa 1993
6. FILIPEK T.: *The content of exchangeable aluminum in soils and plant growth*. J.Ecol.Chem., 3, 3, 367-375. 1994
7. GILEWSKA M.: *Rekultywacja biologiczna gruntów pogórniczych na przykładzie KWB „Konin”*. Roczniki Akademii Rolniczej w Poznaniu. Rozprawy Naukowe. Nr 211. 1991
8. GREINERT A.: *Efekty związane ze stosowaniem wysokich dawek wapna odpadowego w rekultywacji silnie kwaśnych utworów mioceńskich*; Zesz.Probl.Post.Nauk Roln. PAN; 456; 329-334, 1998
9. GREINERT H.: *Charakterystyka właściwości gleb powstałych w wyniku rekultywacji terenów po eksploatacji węgla brunatnego w rejonie Łęknicy*. Zesz. Nauk. WSInż. 84: 93-104. Zielona Góra 1988
10. GREINERT H.: *Rekultywacja leśna utworów pokopalnianych w rejonie Łęknicy (The reforestation of the surface mine area in the Łęknica vicinity)* Politechnika Zielonogórska. Zeszyty Naukowe nr 114. Inżynieria Środowiska 6: 91-111. 1996
11. GREINERT H., GREINERT A.: *Ochrona i rekultywacja środowiska glebowego*; Wyd. Politechniki Zielonogórskiej 1998
12. KATZUR J.: *Die Grundmelioration von schwefelhaltigen extrem sauren Kipprohböden*. Technik u. Umweltschutz. 18: 52-62. 1976
13. KRZAKLEWSKI W.: *Rekultywacja terenów poeksploatacyjnych byłej Kopalni Węgla Brunatnego „Przyjaźń Narodów” w Łęknicy*. Ogólnopolski Zjazd PTG. Zielona Góra 1985
14. MACIAK F.: *Ochrona i rekultywacja środowiska*. Wydawnictwo SGGW. Warszawa 1996
15. MERCIK St., SAS L.: *Ujemny wpływ nadmiernego zakwaszenia gleby na rośliny*. Zesz. Probl. Post. Nauk Roln. PAN, 456, s. 29-39. 1998
16. NOWOSIELSKI O.: *Metody oznaczania potrzeb nawożenia*. PWRiL Warszawa 1974

17. RODINA A.: *Mikrobiologiczne metody badania wód*. PWRiL Warszawa 1968
18. SIUTA J., KUCHARSKA A.: *Wieloczynnikowa degradacja środowiska. Komentarz do mapy w skali 1:750000*. Biblioteka Monitoringu Środowiska. PIOŚ, IOŚ. Warszawa 1996
19. STRZYSZCZ Z.: *Ocena przydatności odpadów górniczych Górnośląskiego Zagłębia Węglowego do rekultywacji biologicznej*. Archiwum Ochrony Środowiska 1-2: 91-123. 1989
20. STRZYSZCZ Z.: *Przyrodnicze podstawy rekultywacji hałd po kopalnictwie głębinowym węgla kamiennego*. Zesz.Nauk. AGH, nr 1222, zesz. 26, s. 159-173, Kraków 1988

REKULTYWACJA LEŚNA HAŁD POKOPALNIANYCH. I. ZMIANA WŁAŚCIWOŚCI GRUNTU ZWAŁOWEGO POCHODZENIA MIOCEŃSKIEGO

Słowa kluczowe: Depozyty mioceńskie, rekultywacja hałd, rekultywacja leśna, gleby antropogeniczne

S t r e s z c z e n i e

Depozyty mioceńskie hałdowane w trakcie wydobycia węgla brunatnego w okolicy Łęknicy mają na ogół skłąd granulometryczny piasków gliniastych. Ich najbardziej negatywną właściwością jest niskie pH, w wyniku utleniania nagromadzonego pirytu. Po 20 latach Rekultywacji można wysnuć kilka zasadniczych wniosków co do zastosowanej technologii: 1). Materiał jest niejednorodny do głębokości 1-2 m p.p.t. Poziom wierzchni (0-20 cm) jest bardziej jednolity w następstwie zastosowanej agrotechniki; 2). Skarpy, po ich wstępnym uformowaniu, podlegają silnym zjawiskom erozyjnym. Około 25% powierzchni ogólnej byłej kopalni jest obecnie erozyjnie zdewastowana. Zjawisko to łączyćnależy z nienależytą pokrywą roślinną; 3). Proces glebotwórczy na hałdach jest antropogenicznie sterowany, głównie poprzez wapnowanie, nawożenie mineralne I zasiedlenie roślinnością. Oddziaływanie glebotwórcze lasu do tej pory nie jest bardzo znaczące. Wyraźny jest poziom ściółki (O) – o miąższości około 1 cm; 4). Pomimo użycia w fazie technicznej Rekultywacji ciężkiego sprzętu budowlanego, właściwości fizyczne gruntów są niezłe; 5). Wysokie dawki wprowadzonego wapna (35-50 Mg·ha^{-1}) spowodowało wyraźne podniesienie pH w poziomach wierzchnichl (do 20-30 cm) do wartości 5-8. Formy dostępne dla roślin Ca i Mg także wzrosły; 6). Minerlane nawożenie spowodowało skok zawartości przyswajalnych form K I P; 7). W reultacie zastosowania jako wapna materiału odpadowego z huty cynku, odnotowano wzrost zawartości w gruntach Cu, Pb, Zn, Cd, Mn and Co.