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SOME PHYSICAL AND CHEMICAL PROPERTIES OF SOILS DEVELOPED ON POST-MINING LANDS

Summary

The paper contains the data on the physical-chemical properties of soils developed during the long-term experiment run on the post-mining grounds. In the experiment different combinations of the NPK fertilization was applied (N, P, NK, NP., K, PK, NPK and 0NPK). The samples were taken from two layers: 0-30 cm and 30-60 cm. The analyzed soils after 30 years showed homogeneity of grain size. The results obtained in grain size analyses with different methods were different, however the soil samples could have been classified to the same agronomic category of medium soils. The methods of texture analysis gave different contents of granulometric fractions which led to different PTG classification of soils. The analyzed soils showed 39.85-99.58 g $CaCO_3 \cdot kg^{-1}$ and basic pH. 30-year-long complex NPK fertilization resulted in doubling the organic carbon and total nitrogen contents in the surface layer of soils. The most pronounced increase in bioavailable forms of K and P was obtained due to NPK fertilization. The DL and CAL methods of extraction of bioavailable P and K produce strongly correlated results and can be recommended as complementary methods.
***Key words**: texture, post-mining lands, chemical composition, available forms of phosphorus and potassium, DL and CAL methods*

WYBRANE WŁAŚCIWOŚCI FIZYCZNO-CHEMICZNE GLEB ROZWIJAJĄCYCH SIĘ Z GRUNTÓW POGÓRNICZYCH

Streszczenie

W pracy przedstawiono wyniki badań dotyczące właściwości fizyczno-chemicznych próbek glebowych pobranych z wieloletniego doświadczenia założonego na gruntach pogórniczych. Czynnikami doświadczenia były następujące kombinacje nawożenia mineralnego: N, P, NK, NP., K, PK, NPK oraz kontrola 0NPK. Próbki do badań pobrano z dwóch głębokości 0-30 oraz 30-60 cm. Analizowane gleby po przeszło trzydziestu latach prowadzenia doświadczenia charakteryzowały się wyrównanym uziarnieniem. Wyniki uziarnienia uzyskane za pomocą zastosowanych dwóch metod różniły się, jednak pozwoliły zaklasyfikować badane próbki glebowe do jednej kategorii agronomicznej – gleb średnich. Zastosowane w pracy metody uziarnienia dały zróżnicowaną zawartość analizowanych frakcji granulometrycznych, co w konsekwencji skutkowało zaklasyfikowaniem ich według kryteriów PTG do różnych grup granulometrycznych. Analizowane gleby zawierały od 39,85 do 99,58 g $CaCO_3 \cdot kg^{-1}$ i charakteryzowały się odczynem zasadowym oznaczonym zarówno w H_2O, jak i KCl. Stosowne przez ponad 30 lat kompleksowe nawożenie w kombinacji NPK przyczyniło się do podwojenia zawartości węgla organicznego oraz azotu ogólnego w wierzchniej warstwie tworzących się gleb. Największy wzrost zasobności w przyswajalne formy fosforu i potasu stwierdzono po zastosowaniu nawożenia mineralnego w kombinacji nawożeniowej NPK. Użyte metody DL i CAL do ekstrakcji w celu oznaczenia zawartości przyswajalnych form fosforu i potasu były ściśle skorelowane i mogą być równorzędnie stosowane.
Słowa kluczowe: uziarnienie, grunty pogórnicze, skład chemiczny, przyswajalne formy fosforu i potasu, metoda DL i CAL

1. Introduction

Post-mining soils occupy rather a small area in Poland. However in the regions where the open-cast mining is active their surface is considerably high. The Konin-Turek region is an example of such area. In the energy policy of the Polish government increasing demands for brown coal in the forthcoming years is presumed and consequently more dumping grounds requiring reclamation is to appear. Despite that reclamation of post-mining grounds has a local extent, it can be regarded as a great environmental challenge. In the Konin region the dumping grounds occupy c.a. 4000 ha and this area is expected to increase [2].

The dumping grounds are subject to agricultural or forest reclamation [6]. Reclamation includes mineral fertilization, which aims at regulating the chemical properties of the ground from which a soils develops [2].

The cultivated plants together with fertilization cause the formation of humus and humus horizon [18]. Among others P and K act as the most important macroelements stimulating the growth and development of plants. P and K supplied to the soil with fertilizers transform to the forms unavailable for plants. Potassium is subject to ion exchange sorption and fixation in the soil [17]. On the other hand, phosphorus is sorbed chemically and the intensity of this process is pH-controlled [1]. The reclamation of post-mining grounds is based on a concept of prof. Bandera which stresses the necessity of regulating of chemical properties of the soil and introducing the so called target plants. The regulation of soil chemistry is attained via very intense mineral fertilization within the first ten years of reclamation. Then plant-specific fertilization is applied.

The influence of long-term mineral fertilization on the contents of P and K in the soils is thoroughly studied [3, 7, 12,

22, 23, 25], however anthropogenic soils developed from the post-mining substrates has not been recognized. According to [19, 20, 21] the most reliable results are obtained from long-term experiments, which show the fate of chemical species introduced to the soil from fertilizers.

The goal of the current study was to demonstrate the influence of diversified mineral fertilizing (NPK combination) on the chemical properties of soils developed from post-mining ground using the results from the 30-year long experiment.

2. Materials and methods

Laboratory work was performed using samples taken from the experimental fields belonging to the University of Life Sciences, Poznan, Poland. Field experiment was started in 1978 by the prof. Jan Bander on an inner dumping ground of the Pątnów open-cast. The study area is located 10 km to the north of the city of Konin. During the experiment the fields were treated with 8 combinations of mineral fertilizing (tab. 1). Within the first 10 years the intense P-K fertilizing was applied. After that the doses of fertilizers were lowered and adjusted to the fertilizing requirements of the cultivated plants. For the N the dozes were constant throughout the experiment while those of P_2O_5 and K_2O were reduced to 80 and 40 kg·ha^{-1}, respectively.

Table 1. Mineral plant fertilization for the experiment up to 10 years
Tab. 1. Dawki nawożenia mineralnego stosowane przez pierwsze 10 lat

Fertilization treatment	Dose N	Dose K_2O	Dose P_2O_5
	kg·ha^{-1}		
NPK	160	270	140
NP	160	0	140
NK	160	270	0
N	160	0	0
PK	0	270	140
P	0	0	140
K	0	270	0
Kontrola	0	0	0

Source: own studies / Źródło: badania własne

The samples for the analyses were taken from each experiment field with a self-made soil sampler from the layer 0-30 and 30-60 cm after the harvest 2012. Prior to the analyses the samples were dried and sieved via 2 mm mesh.

The following analytical methods were used:
1) The grain size composition was analyzed using hydrometer method after Casagrande in Prószyński's modification and laser particle size analyzer Mastersizer 2000 (Malvern).
2) Total N was determined via elementary analyzer VarioMax CNS (Elementar).
3) Soil pH was measured potentiometrically in H_2O and KCl.
4) TOC was determined via Tiurin's method.
5) Plant available P and K in soil were analyzed using the method of Egner-Riehm (DL) and CAL In the first case bioavailable K and P were extracted with Ca lactate at pH of 3,6 with soil-to-extracting ratio of 1:50. The sample was shaken for 1,5 h [10]. In the second case the analytes were extracted with Ca acetate + Ca lactate+ acetic acid at pH 4.1 with soil-to-extracting ratio of 1:20 and shaken for 1,5 h [16].
6) Bioavailable Mg was analyzed using Sachtschabel method [10].

3. Results and discussion

The results of texture analysis of the analyzed samples is presented in tab. 2. The contents of granulometric fractions shall be regarded typical for post-mining grounds in the Konin coalfield [18]. Despite the fact that the soils were developed from different sedimentary rocks such as glacial tills, sands and clays overlying the brown coal seams the differences between the parent rocks were not reflected in the analyzed soil samples. After 30 year reclamation the soils revealed appreciable homogeneity which agrees with previous data [11, 19]. All the samples analyzed using the sedimentary method were classified as sandy loam (SL). The laser diffraction led to different contents of granulometric fractions in the studied samples than the sedimentary method. The sand fraction was underestimated. The percentage of clay was c.a. two fold lower. On the contrary, the silt was three fold enriched with respect to hydrometer method. Such discrepancies were reported by Ryżak et al. [15].

On the basis of laser diffraction two textural groups were distinguished in the studied soils: silty loam and sandy loam.

In agricultural practice to delimitate the classes of abundance of soils, liming requirements etc. the agronomic classes are used. With this respect, the studied samples were classified as medium soils. The pH of the analyzed samples, from both 0-30 cm and 30-60 cm, was basic. This was due to the content of $CaCO_3$ of 46.92-99.58 g· kg^{-1} (tab. 3). The values of $pH_{(H2O)}$ were between 7.94-8.55 and $pH_{(KCl)}$ varied from 7.63 to 7.91. Lower pH occurred in the samples from 0-30 cm layer. The differences in pH were linked to the combinations of fertilizing applied in the experiment.

It was established that the complex NPK fertilization led to the decrease in soil pH (both pH_{H2O} and pH_{KCl}). Similarly, Spychalski and Gilewska [19] obtained lowering in pH of upper layers of soils after long-term intense NPK fertilization in relation to unfertilized fields.

Long-term diversified mineralization fertilization resulted in diversification of the basic chemical properties of soils developing on post-minig lands. Those changes are reflected in the contents of TOC and TN (tab. 3). The content of TOC in analyzed soil samples varied between 3,70 and 7,00 g· kg^{-1}. It was dependent on the mode of fertilization applied. The maximum content of 7,00 g C · kg^{-1} was obtained in the surface layer of soil under NPK fertilization. In the same soil there was also the highest content of TN - 0,86 g· kg^{-1}. Hence, 30 y-long mineral NPK fertilization caused doubling of the contents of soil C and N in relation to control sample (0NPK). On the basis tab. 3 it is concluded that in the fields fertilized with N in different combinations the contents of TOC and TN rose to 43-59% in relation o 0 NPK. Appreciably lower increase in TOC and TN was obtained in the field where the fertilization were N-fertilization not applied. It has been observed that the lower fertilization, the maximum abundance of organic compounds between 30 and 60 cm. the highest contents of TOC and TN were obtained in the fields subjected to N fertilization and the content of C and N were double in relation to the similar samples from the control site.

Table 2. Texture of investigated soils - PTG 2011 [14]
Tab. 2. Skład granulometryczny analizowanych gleb - PTG 2011 [14]

Fertilization treatment	Depth	Hydrometer method				Laser diffraction method			
		sand	silt	clay	Textural group	sand	silt	clay	Textural group
		2-0,05	0,05-0,002	< 0,002		2-0,05	0,05-0,002	< 0,002	
		mm				mm			
0	0-30	66	20	14	SL	45,31	48,06	6,63	SL
	30-60	68	19	13	SL	55,08	38,64	6,28	SL
N	0-30	65	21	14	SL	46,23	48,41	5,36	SL
	30-60	62	24	14	SL	37,24	54,87	7,89	SiL
P	0-30	64	21	15	SL	41,87	52,16	5,97	SiL
	30-60	66	20	14	SL	44,12	48,58	7,30	SL
NK	0-30	64	21	15	SL	37,27	57,14	5,59	SiL
	30-60	64	21	15	SL	39,91	52,53	7,56	SiL
NP	0-30	61	23	16	SL	40,42	54,07	5,51	SiL
	30-60	62	23	15	SL	35,50	55,89	8,61	SiL
K	0-30	61	23	16	SL	34,40	58,24	7,36	SiL
	30-60	64	22	14	SL	39,37	53,97	6,66	SiL
PK	0-30	61	23	16	SL	41,55	52,53	5,92	SiL
	30-60	61	23	16	SL	35,86	55,49	8,65	SiL
NKP	0-30	60	25	15	SL	40,83	52,87	6,30	SiL
	30-60	55	27	18	SL	35,48	55,76	8,76	SiL

Table 3. Basic chemical properties of investigated soils
Tab. 3. Podstawowe właściwości chemiczne badanych gleb

Fertilization treatment	Depth	pH		N total	C org.	C:N	$CaCO_3$ g· kg^{-1}
		H_2O	KCl	g· kg^{-1}			
0 NPK	0-30	8,32	7,80	0,42	3,70	8,8	39,85
	30-60	8,55	7,91	0,24	1,90	7,9	49,31
N	0-30	8,20	7,75	0,63	5,30	8,4	46,92
	30-60	8,24	7,88	0,41	3,80	9,3	71,82
P	0-30	8,10	7,78	0,52	4,50	8,7	55,72
	30-60	8,45	7,93	0,27	3,50	13,0	74,75
NK	0-30	8,19	7,74	0,61	5,90	9,7	62,49
	30-60	8,20	7,89	0,34	3,10	9,1	82,05
NP	0-30	8,08	7,71	0,67	5,90	8,8	79,47
	30-60	8,14	7,84	0,28	2,90	10,4	99,58
K	0-30	8,18	7,74	0,49	4,40	9,0	78,88
	30-60	8,15	7,74	0,25	2,00	8,0	59,12
PK	0-30	8,08	7,70	0,54	4,80	8,9	79,98
	30-60	8,25	7,76	0,27	3,10	11,5	89,48
NPK	0-30	7,94	7,63	0,86	7,00	8,1	75,68
	30-60	8,05	7,71	0,41	2,50	6,1	47,88

Source: own studies / Źródło: badania własne

Bioavailable forms of P and K in soil samples for experimental fields were analyzed using the method of Egner-Reihm and CAL. The former is widely used in Poland to determine the abundance of bioavailable forms of K and P. In the method the elements are extracted with calcium lactate at pH=3.6. The CAL method according to Schüller [15] is recommended to alkaline soils. The method is hardly used in Poland and the Ca acetate and lactate as well as acetic acid at pH=4.1 are used to extract the elements. The results obtained via the above methods are shown in table 4 and 5.

Long term treatment of soils with diversified mineral fertilizers not only caused the changes in the contents of organic carbon and nitrogen but also bioavailable forms of phosphorus and potassium. Among the combinations of fertilizers used in the experiment the NPK combination had the strongest influence on bioavailable forms of P and K. The content of K in the surficial layer of the studied soils determined with the Egner-Reihm method was 180.6 mg K · kg^{-1} and with CAl method was 146.24 mg K · kg^{-1}. The data from both methods show that the 30-year-long mineral fertilization using the NPK combination resulted in two-fold increase in the contents of bioavailable forms of K in relation to the control field (0NPK). When compared with standard K abundances for the two analytical methods applied it can be concluded that the control samples (0NPK) were characterized with medium abundance of bioavailable forms of K and after 30 years of NPK fertilization it increased to the very high level. Many authors [8, 9,13, 22, 24] confirm the role of mineral fertilization for the abundance of K in arable soils.

The fertilization in the combinations with potassium not only led to the enrichment in bioavailable K in the surface soil layer but also in deeper layers. This indicate leaching of K downward in the soil profile. The same was observed by Fotyma and Gosek [4].

Table 4. Content of available forms of phosphorus and potassium in DL methods and magnesium in $CaCl_2$
Tab. 4. Zawartość przyswajalnych form fosforu i potasu oznaczona metodą DL oraz magnezu w $CaCl_2$

Fertilization treatment	Depth	K	Class of abundance	P	Class of abundance	Mg	Class of abundance
		mg · kg^{-1}					
0 NPK	0-30	147,18	III	46,21	III	121,41	I
	30-60	117,09	III	17,26	V	88,45	II
N	0-30	157,44	III	53,14	III	114,54	I
	30-60	130,81	III	11,41	V	103,52	I
P	0-30	165,20	III	110,62	I	148,54	I
	30-60	132,03	III	37,35	IV	125,36	I
NK	0-30	203,04	II	47,85	III	121,35	I
	30-60	194,70	II	40,11	IV	117,85	I
NP	0-30	201,92	II	93,64	I	129,21	I
	30-60	175,74	II	54,36	III	96,35	I
K	0-30	208,16	I	56,35	III	148,52	I
	30-60	174,47	II	20,85	V	109,11	I
PK	0-30	206,66	I	77,62	III	126,45	I
	30-60	191,33	II	21,32	V	145,11	I
NPK	0-30	239,82	I	104,36	I	121,56	II
	30-60	180,62	III	7,41	V	155,12	I

Source: own studies / Źródło: badania własne

Table. 5. Content of available forms of phosphorus and potassium in CAL methods
Tab. 5. Zawartość przyswajalnych form fosforu i potasu oznaczona metodą CAL

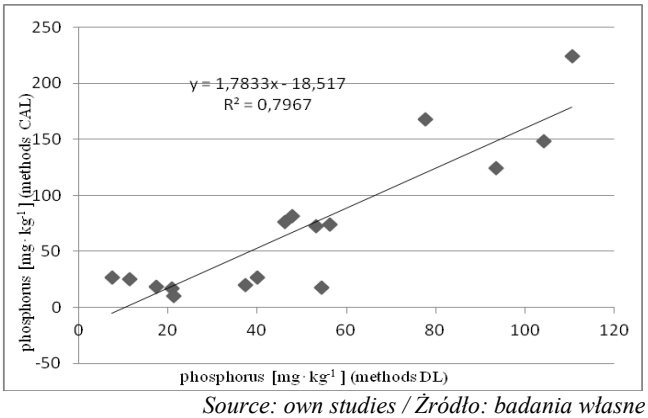
Fertilization treatment	Depth	K	Class of abundance	P	Class of abundance
		mg · kg^{-1}			
0 NPK	0-30	77,07	III	76,31	IV
	30-60	59,96	III	18,74	V
N	0-30	97,35	II	72,13	IV
	30-60	73,06	III	25,52	V
P	0-30	104,49	II	224,11	II
	30-60	66,61	III	19,85	V
NK	0-30	119,61	II	81,40	IV
	30-60	87,15	III	26,44	V
NP	0-30	109,02	II	124,30	III
	30-60	79,36	III	17,63	IV
K	0-30	115,87	II	73,80	IV
	30-60	86,22	III	17,10	V
PK	0-30	121,73	II	168,10	III
	30-60	88,38	III	9,86	V
NPK	0-30	146,24	I	147,99	III
	30-60	99,93	II	26,83	V

Source: own studies / Źródło: badania własne

The determination of bioavailable forms of P with the DL and CAL methods revealed the increase in the content of P in the in the plough layer due to fertilization in combinations with P (tab. 4 and 5). The content of P was between 46.21 and 110.62 mg P · kg^{-1} according to the DL method and 76.31-224.11 mg · kg^{-1} for the CAL. Compared to standard abundances the surface layers of soils were characterized by low (IV class) to high (I class) abundance. After 30-year-long fertilization the contents of phosphorus doubled with respect to control field.

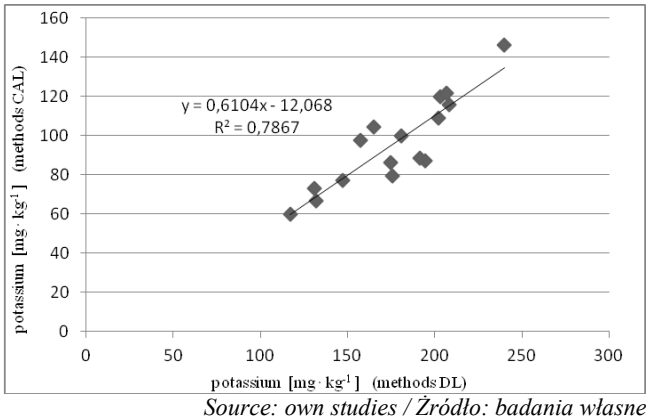
The analyzed soil samples in most cases were characterized by very high contents of bioavailable Mg between 88.45 and 145.11 mg Mg · kg^{-1}. It seems that the fertilization has no influence on the abundance of bioavailable Mg.

In Figures 1 and 2 the contents of bioavailable forms of P and K obtained from the CAL method are plotted against the results from the DL method.



Source: own studies / Źródło: badania własne

Fig. 1. Phosphorus determined DL depending on Phosphorus determined at CAL
Rys. 1. Zależność pomiędzy ilością fosforu oznaczonego metodą DL i CAL



Source: own studies / Źródło: badania własne

Fig. 2. Potassium determined DL depending on Potassium determined at CAL

Rys. 2. Zależność pomiędzy ilością potasu oznaczonego metodą DL i CAL

The determination coefficients indicate the very strong correlations between the two analytical methods. In addition to this, using the regression line it is possible to predict the mean value of the elements determined in the calcium lactate on the basis of their CAL concentrations.

4. Conclusions

1. The texture of the soils samples after 30 years of the experiment was uniform.
2. The distribution of grain size determined with the use of two different methods was different, however it enabled classification of the analyzed samples to the same agronomic category of medium soils.
3. The method of texture analysis applied in the study showed different content of the granulometric fractions, and consequently the analyzed soils were attributed to different PTG categories.
4. The basic reaction of analyzed soils resulted from the presence in the parent material of the carbonate of calcium.
5. The 30-year-long fertilization with the NPK combination led to two-fold increase in the content of organic carbon and total nitrogen in the surface layer of the developing soils.
6. The most pronounced increase in the abundance of bioavailable P and K was observed after mineral fertilization in the NPK combination.
7. The results of the DL and CAL methods were strongly correlated and these approaches can be recommended as equivalent methods for the extraction of bioavailable P and K.

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