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MOBILE ALUMINIUM IN SOUR SOILS FERTILIZED WITH POWER PLANT FLY ASHES

A vegetative experiment with rye was carried out on four soils according to the Neubauer – Schneider method to study the effect of various doses of power plant fly ashes developed from coal burning on mobile aluminium content in soils and plants.

It has been found that fly ashes applied in low doses (1–2 weight per cent of fly ashes in soil) did not neutralize efficiently the soil souring. Aluminium brought in soil with this waste material caused the increase in mobile aluminium content in it. On the plots containing low doses of fly ashes, inhibition of plant growth (noticed as the drop in mean weight of a plant), browing of conical growing points, and decrease in available phosphorus forms content in soil were observed.

Neutralization of hydrolytic acidity by applying higher doses of fly ashes (3–5%) and changing soil reaction to values higher than $pH_{KCl} = 5.8$ resulted in immobilization of aluminium and in the increase of mean weight of investigated plants.

1. INTRODUCTION

Aluminium reveals high mobility in strongly acidic soil solutions. Large amounts of trivalent aluminium cations can be released from clay minerals as readily soluble native alums, aluminium sulfate, etc. Hydrolysis of such compounds leads to accumulation of aluminium hydroxide. Mobile aluminium content in soil increases rapidly at pH below 5 and, therefore, its effect upon plants can be a toxic one. A critic pH value, at which aluminium appears in toxic concentration, depends on a few factors such as quantity and quality of clay minerals prevailing in soil, concentration of organic matter, concentration of ions, and sensitivity of plants [1], [2].

It is assumed that 2–4 mg Al^{3+} in 100 g of soil affect negatively the growth of most cultivated plants. Toxic effect of aluminium cations appears first of all as inhibition of root growth, browing of conical growing points, and whitening of leave edges.

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FLEMING and FOY [3] suggested the possibility of treating the effect of root growth inhibition in the presence of aluminium as the biological indicator of aluminium toxicity in sour soils. Basing on the ability of organic matter to form complexes with aluminium ions due to surface adsorption, HOYT and TURNER [2] tried to find out whether the application of organic matter could replace liming in preventing aluminium toxicity. Despite the benevolent effect of organic matter, the authors concluded that the addition of large amounts of organic materials could not replace liming.

NOWACZYKOWA and BORYS [4] have shown another possibility of prevention of aluminium toxicity by application of stronger phosphorus fertilization and liming.

Since souring of arable soils is growing, it is important to utilize intensely all the available sources of calcium, including waste power plant fly ashes. However, high concentration of aluminium oxide (15–20%) in that material creates a danger that a part of it can be mobilized in acidic soil environment in a relatively short time. Taking into consideration the low concentration of alkaligeneous compounds in fly ashes, the soil neutralization cannot be always effective. It happens often that the dose of fly ashes calculated according to hydrolytic acidity must be increased 4–5-fold to reach satisfactory results.

A brief review of the results of investigations of the effects of aluminium from power plant fly ashes on soils and plants demonstrates the necessity of more intense studies of this problem.

2. EXPERIMENTAL PROCEDURES

Fly ashes originated during coal burning were used in the study. They were characterized by a highly fine structure (74% of grain fraction demonstrating dimensions below 0.066 mm), specific surface 3425 cm^2/g, and the following chemical composition (in per cent): Ca – 6.3, Mg – 2.4, K – 0.2, P – 0.1, C – 2.7, SO_3 – 2.0, Fe_2O_3 – 9.1, Al_2O_3 – 20.1, and SiO_2 – 36.2. Heavy metal content did not exceed the average litosphere composition and amounted to (in mg/kg fly ashes): Cu – 29, Zn – 36, Pb – 21, Mn – 64, Co – 3.

A metod based on biological extraction method of Neubauer–Schneider was used in the experiment. Aluminium was absorbed by fast growing rye plants under controlled conditions. The crop was harvested after twenty days and aluminium content was determined colorimetrically in soil and plants. Doses of fly ashes were as follows: 1, 2.5, 5.0, 10.0, and 15 weight per cent in relation to soil. Aluminium concentrations in the soil and plants growing on the plots fertilized with fly ashes were compared with the control without that material.

Four mineral soils taken from production fields (horizon A_1) were chosen for the experiment taking into account their low reaction as well as their relatively low, middle, and high carbon concentrations. Reaction and some chemical properties of the soils are compared in tab. 1.

Table 1

Properties of the soils used

Soil	pH 1M KCl	Hh	Content of 0.02 mm fraction %	C_{total}	Al_{mobile}	$P_{available}$
				mg/100 g of soil		
1	3.3	3.71	7	630	10.41	1.6
2	4.1	3.43	14	980	8.26	1.9
3	4.8	2.61	37	1720	6.61	2.7
4	5.3	2.36	27	1210	3.33	2.2

3. RESULTS AND DISCUSSION

A high usability of Neubauer–Schneider test in determining the effect of aluminium supplied to soil with power plant fly ashes on pants has been corroborated. The results obtained by biological extraction confirmed those of chemical analysis. Significant effect of the applied fly ash doses on plant growth was noticed, which was evident particulary on the soils 1, 2, and 4 (tab. 2).

Negative effect of fly ashes on plants was ascertained at their low doses (1 and 2.5%), i.e., those neutralizing soil souring ineffectively. Only in the high doses (10 and 15%) they acted stimulatively, improving conditions of plant growth. The highest concentration of aluminium was recorded on the plots treated with the lower doses of fly ashes (1 and 2,5%). On the contrary, the higher doses of fly ashes added to the soils decreased the aluminium content in the cultivated plants. The results presented in tab. 3 show that higher doses (5 and 10%) caused distinct decrease in mobile aluminium content in soil. The optimal dose (15% of fly ashes) caused a slight increase of aluminium concentration, induced probably by increasing solubility of aluminium at pH close to 9.

Too small doses of fly ashes, not neutralizing soil souring, favoured, however, the increase of mobile aluminium. Furthermore, highly dispersed silica contained in fly ashes can react with limestone creating hydrated silicates. The latter process can also decrease soil pH despite the application of alkaline fly ashes.

The decrease of mean weight of the plants on the plots enriched with 1 and 2.5% addition of fly ashes was a result of plant root system reduction which made the absorption of water and nutrients from the soil impossible. The results compared in tab. 3 reveal that the reason of physiological disturbances must be perceived in relatively high mobile aluminium content and low available phosphorus content in soil at the same moment. The application of the low doses of fly ashes had only slight

Table 2

Changes in aluminium content in plants and mean weight of plants affected by the increasing doses of fly ashes (determined after twenty days of vegetation)

Soil	Fly ashes added %					
	Control	1.0	2.5	5.0	10.0	15.0
	Mean weight of plants from plots g					
1	5.6	2.1	3.0	6.1	6.1	6.0
2	4.4	3.6	4.1	3.7	6.1	6.7
3	8.5	5.3	6.5	7.2	7.4	6.5
4	4.9	3.9	4.8	4.9	5.8	6.0
Mean	5.85	3.72	4.85	5.47	6.35	6.30
	Aluminium content in plants mg Al/100 g d.w.					
1	17.1	25.0	22.5	11.8	12.3	13.7
2	16.4	18.4	19.1	10.6	10.7	12.4
3	16.1	19.2	17.1	9.5	9.7	12.0
4	15.0	19.9	17.6	9.2	9.3	11.9
Mean	16.15	20.63	19.07	10.28	10.5	12.5

effect on changing of soil reaction, hovewer, not big enough to immobilize aluminium. Only the higher doses (more than 5%) acted effectively.

Increasing aluminium content in the bedding caused the increase in aluminium concentration in plants and inhibition of the growth. More significant decrease of mean weight of plants was observed on soil poor in organic matter. Higher doses brought into the bedding resulted in relatively moderate increments of aluminium in plants and did not affect negatively their weight. Evaluation of the effect of various doses of fly ashes on mobile aluminium content in the four investigated soils gives the assumption that a real danger of harmful increasing of aluminium content in strongly acidic soils, poor in organic matter, exists, unless the added amount of fly ashes will not neutralize effectively soil souring. The conclusion is that the correct prediction and calculation of fly ash doses must be considered the most important among all the elements of their rational utilization in agriculture. Essential changes in soils expected as the result of fly ash applications are conditioned by the presence of not only fertilizing components but also balast compounds (sometimes highly active) in fly ashes. Those balast compounds may react depending on changing environmental conditions and may have crucial effect on plant vegetation.

Table 3

Changes in aluminium and phosphorus content and soil reaction affected by the increasing doses of fly ashes (determined after twenty days of vegetation)

	Fly ashes added %					
	Control	1.0	2.5	5.0	10.0	15.0
	Mobile aluminium content mg Al/100 g of soil					
1	8.5	17.3	11.4	1.8	0.0	0.0
2	7.1	12.1	8.7	1.4	0.0	0.0
3	5.9	7.4	2.1	0.4	0.0	0.0
4	4.1	6.9	2.9	0.1	0.0	0.0
Mean	6.4	10.92	6.28	0.93	0.0	0.0
	Available phosphorus content mg P/100 g of soil					
1	1.4	0.3	0.2	1.5	1.7	1.9
2	1.6	0.4	0.4	1.3	1.4	1.6
3	2.3	2.0	1.6	2.1	2.2	2.3
4	1.7	1.8	1.4	2.1	2.1	2.7
	pH (1M KCl)					
1	3.4	3.7	4.1	5.8	8.6	8.9
2	4.1	4.3	4.8	5.7	8.5	8.8
3	4.6	4.9	5.3	6.0	8.7	8.9
4	4.9	5.2	5.6	6.1	8.7	9.0
Mean	4.25	4.53	4.95	5.9	8.63	8.9

4. CONCLUSIONS

The most important conclusions from the presented study are as follows:

Application of power plant fly ashes, in doses which do not neutralize effectively soil souring, results in mobilization of aluminium brought in with that waste material.

Aluminium in sour soil is the cause of physiological disturbances in plants, which are manifested as inhibition of root growth, browning of conical growing points, and lowering of plant weight.

Lowering of the content of phosphorus forms available to plants informs of the necessity for the increase of doses of phosphorus fertilizers in the case of agricultural utilization of power plant fly ashes.

Soils more rich in organic matter are less susceptible to toxic effects of higher aluminium concentrations is sour soils.

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RUCHOMY GLIN W GLEBACH KWAŚNYCH NAWOŻONYCH POPIOŁAMI ELEKTROWNIANYMI

Podczas doświadczenia wegetacyjnego z żytem, wykonanym metodą Neubauera-Schneidera na czterech glebach kwaśnych, badano wpływ różnych dawek popiołów elektrownianych powstałych z węgla kamiennego na zawartość glinu ruchomego w glebie i roślinach.

Stwierdzono, że popioły w niskich dawkach (1–2% popiołu w stosunku wag. do gleby) nie neutralizowały skutecznie zakwaszenia, a wniesiony z nimi glin powodował zwiększenie zawartości glinu ruchomego w glebie. Na poletkach z niskimi dawkami popiołów obserwowano zahamowanie wzrostu roślin (obniżenie ich masy), brunatnienie stożków wzrostu oraz zmniejszenie zawartości przyswajalnych form fosforu w glebie.

Usunięcie kwasowości hydrolitycznej za pomocą wyższych dawek popiołu (3–5%) oraz podniesienie odczynu gleby (pH_{KCl}) powyżej wartości 5.8 powodowało unieruchomienie glinu oraz przyrost masy badanych roślin.

ПОДВИЖНЫЙ АЛЮМИНИЙ В КИСЛЫХ ПОЧВАХ, УДОБРЯЕМЫХ ПЕПЕЛАМИ ИЗ ЭЛЕКТРОСТАНЦИЙ

Во время вегетационного эксперимента с рожью, выполненного методом Нойбауэра–Шнейдера на четырех кислых почвах, исследовано влияние разных доз пепелов из электростанций, возникших из каменного угля, на содержание подвижного алюминия в почве и растениях.

Установили, что пепелы в низких дозах (1–2% пепела в весовом отношении к почве) не нейтрализовали достаточно подкисления, а внесенный с ними алюминий вызывал повышение содержания подвижного алюминия в почве. На делянках с низкими дозами пепелов наблюдали замедление роста растений (понижение их массы), становление коричневыми конусов нарастания, а также понижение содержания усваиваемых форм фосфора в почве.

Удаление гидролитической кислотности при помощи высших доз пепела (3–5%), а также поднятие реакции почвы (pH_{KCl}) выше значения 5.8 вызывало остановление алюминия и прирост массы исследуемых растений.