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USE OF DIFFERENT EXTRACTION AGENTS TO PREDICT ZINC UPTAKE BY PLANTS

WYKORZYSTANIE RÓŻNYCH EKSTRAHENTÓW W CELU PROGNOZOWANIA POBIERANIA CYNKU PRZEZ ROŚLINY

Abstract: The main aim of this work was to compare different extraction agents in order to identify those which are able to give us most reliable data for assessment of soil zinc content and for prediction of possible contamination of crop. In order to compare several extraction methods and to identify the most suitable one for the zinc transfer into plant and to examine behaviour of high doses of a sludge heavily contaminated with zinc (almost 7 000 mg Zn $\cdot$ kg^{-1}), a two year pot experiment was established in vegetation hall in 2005. There were chosen five soils with different pH value (from extremely acidic to neutral) and planted with four crops – spinach, carrot, spring wheat and maize. But for control combination there were treatments with lower dose of sludge (equivalent of 5 Mg (tons) of dry matter per hectare) and high dose (equivalent of 25 Mg (tons) of dry matter per hectare for spinach and carrot and 50 Mg (tons) for wheat and maize). Following extraction agents were used for soil analyses – *Aqua regia*, 2 mol $HNO_3 \cdot dm^{-3}$, 0.43 mol $HNO_3 \cdot dm^{-3}$, Mehlich III, CAT, DTPA, $CaCl_2$, and NH_4NO_3. Correlations of soil zinc content measured with particular extracting agents and zinc content in plants were calculated.

The best correlations were found with quantity of Zn soluble in weakest extraction agents – $CaCl_2$ and NH_4NO_3. They correlated with themselves and with zinc content in plans but not with other agents. The rest of agents mostly correlated among 0.43 mol $HNO_3 \cdot dm^{-3}$, Mehlich III, CAT and DTPA and between *Aqua regia* and 2 mol $HNO_3 \cdot dm^{-3}$. There were quite tight correlations between soil pH and zinc content in plants confirming that pH is a crucial factor for zinc soil mobility. It implies that knowledge of soil pH and (even) pseudo total zinc content can serve as a sufficient source of information about probable zinc status in the soil. Mehlich III, which is in the Czech Republic widely used for the Agrochemical Soil Testing (evaluation of P, K, Ca and Mg status of soil) can be used as a good screening tool (and perhaps for other microelements). Such use would provide a large scale of data without additional costs.

Keywords: zinc, extraction agents, availability

Zinc with its special position is one of the most important micronutrients, however, it can be also considered to be a contaminant. It depends on the situation in the soil. Low

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content of zinc combined with high pH can result in zinc deficiency. To the contrary, high zinc soil concentration and low pH can cause symptoms of toxicity or endanger the quality of a crop. For prediction of these effects we need some reliable tools, which can be represented by extraction agents of different strength and composition. The key requirement is that such extraction agent should allow predict the zinc content in plant based on its content in soil as precisely as possible. Stability under different soil conditions or low price of analysis can be advantage.

The main aim of this work was to compare different extraction agents in order to identify those which are able to give us most reliable data for assessment of soil zinc content and for prediction of possible contamination of crop.

Material and methods

In order to compare several extraction methods and to identify the most suitable one for the zinc transfer into plant and to examine behaviour of high doses of a sludge heavily contaminated with zinc (almost 7000 mg Zn $\cdot$ kg^{-1}), a two year pot experiment was established in vegetation hall in 2005.

There were chosen five soils (Sudice, Budisov, Netin, Ricky and Orechov) with different pH value, from extremely acidic to neutral (Table 1) and planted with four crops – spinach, carrot (after spinach harvest, in the same pot), spring wheat and maize. There was no crop rotation so for example wheat was followed by wheat etc. The only exceptions were spinach and carrot, which were planted in the same pot.

Table 1

Input parameters of soils

Soil	pH	P	K	Ca	Mg	Zn extracted with 2 mol $HNO_3 \cdot dm^{-3}$
		[mg $\cdot$ kg^{-1}]				
Sudice	4.4	127	209	987	103	22.9
Netin	5.5	120	283	1130	100	21.2
Budisov	4.9	225	157	1480	131	21.2
Ricky	6.2	50	133	2660	297	35.0
Orechov	7.1	393	798	5080	433	49.6

There were three combination, control and two doses of sludge. Each combination was repeated six times.

Sludge originated in wastewater treatment Modrice was dried and lime treated, its pH/$CaCl_2$ was 7.5 and moisture content 11.9 %. Its composition is presented in Table 2.

But for control combination there were treatments with lower dose of sludge (equivalent of 5 Mg (tons) of dry matter per hectare – 20.75 g $\cdot$ pot^{-1}) and high dose (equivalent of 25 Mg (tons) of dry matter per hectare for spinach and carrot – 103.75 g $\cdot$ pot^{-1} and 50 Mg (tons) for wheat and maize – 207.5 g $\cdot$ pot^{-1}).

Table 2

Chemical composition of sludge

Elements	Content [mg · kg^{-1} d.m.]				
Nutrients	P	K	Mg	Ca	Na
	20900	2260	4060	49400	565
Trace elements	As	Cd	Cr	Cu	Hg
	6.5	4.1	129	347	3.8
	Pb	Zn	Mo	Ni	Al
	242	6810	6.2	85.5	12800
	Be	Co	Fe	Mn	V
	0.6	13	51800	452	35.1

Fertilizing was performed before sowing. Nitrogen was applied to all pots (0.43 g · pot^{-1} for spinach and carrot and 0.85 g · pot^{-1} for wheat and maize) in urea form and soil from Ricky was fertilized also with phosphorus (0.5 g · pot^{-1} spinach, carrot and wheat and 0.62 g · pot^{-1} for maize) as a superphosphate approximately 7 cm below the soil surface.

Table 3

Factors of trial

Factor	Level of factor	Factor	Level of factor
Soil origin	Sudice	Crop	spinach/carrot
	Budisov		wheat
	Netin		maize
	Ricky		
	Orechov	Sludge dose	control
Year	2005		sludge I
	2006		sludge II

Pots were filled with 8 kg of soil. Deionised water was used for irrigation. After sprouting plants were singled to final number of 26 for spinach and wheat, 4 for maize and 12 for carrot.

Soil samples were taken after harvest separately from each pot. There was no sampling after the last harvest.

Following analyses were performed:

– pH/$CaCl_2$,

– content of Zn extracted with: *Aqua regia*, 2 mol HNO_3 · dm^{-3}, 0.43 mol HNO_3 · dm^{-3}, Mehlich III, CAT, DTPA, $CaCl_2$, NH_4NO_3.

Procedures of used extraction methods were as follows:

– *Aqua regia* – soil sample was extracted by hot mixture of hydrochloric acid and nitric acid (3:1, v/v; nitric acid c = 14.4 mol · dm^{-3}, hydrochloric acid c = 11.7 mol · dm^{-3}) and was regarded as total zinc content;

– 2 M HNO_3 – soil sample was extracted by nitric acid at room temperature with concentration of 2 mol HNO_3 · dm^{-3};

Table 4

Zinc content in soils in 2005 (average of all pots)

Locality	Zinc content in extract [mg · kg^{-1}]											
	Aqua regia			2 M HNO_3			0.43 M HNO_3			Mehlich III		
	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II
Sudice	42.9	49.3	91.5	22.4	28.8	73.5	12.2	17.1	56.1	7.8	11.7	41.7
Budisov	48.2	55.2	113.0	20.5	27.4	90.8	8.1	15.1	70.9	4.2	9.0	46.5
Netin	53.5	59.9	101.4	20.1	26.1	65.5	6.9	11.8	48.1	4.6	8.5	32.8
Ricky	62.0	65.5	111.7	31.7	45.5	87.0	20.7	27.4	67.9	12.0	15.0	43.3
Orechov	89.1	96.3	131.1	41.5	47.8	89.8	27.2	33.3	69.7	16.5	20.5	43.6
Locality	Zinc content in extract [mg · kg^{-1}]											
	CAT			DTPA			$CaCl_2$			NH_4NO_3		
	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II
Sudice	7.2	8.3	27.1	4.9	7.3	24.7	3.4	4.9	13.9	3.8	5.4	17.4
Budisov	7.0	7.1	27.8	2.3	5.1	28.2	3.0	3.0	6.3	1.1	2.0	6.9
Netin	7.0	7.5	22.7	2.7	5.1	21.0	3.0	3.0	3.3	0.9	1.1	2.8
Ricky	8.3	9.5	23.3	7.8	10.3	27.0	3.0	3.0	3.2	0.9	1.0	2.8
Orechov	11.5	14.5	32.9	6.7	8.9	24.6	3.0	3.0	3.0	0.9	0.9	0.9

Table 5

Relative zinc content in soils in 2005 (average of all pots) – *Aqua regia* as 100 %

Locality	[%]											
	Aqua regia			2 M HNO_3			0.43 M HNO_3			Mehlich III		
	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II
Sudice	100.0	100.0	100.0	52.1	58.4	80.4	28.5	34.7	61.3	18.3	23.7	45.6
Budisov	100.0	100.0	100.0	42.5	49.6	80.4	16.7	27.4	62.8	8.7	16.3	41.2
Netin	100.0	100.0	100.0	37.5	43.6	64.5	12.8	19.7	47.4	8.5	14.2	32.3
Ricky	100.0	100.0	100.0	51.1	69.4	77.9	33.4	41.8	60.8	19.3	22.8	38.7
Orechov	100.0	100.0	100.0	46.6	49.6	68.5	30.5	34.6	53.1	18.5	21.3	33.3
Locality	[%]											
	CAT			DTPA			$CaCl_2$			NH_4NO_3		
	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II
Sudice	16.7	16.9	29.7	11.3	14.7	27.0	7.8	9.9	15.2	8.7	11.0	19.0
Budisov	14.5	12.9	24.6	4.8	9.2	25.0	6.2	5.4	5.6	2.2	3.6	6.1
Netin	13.1	12.6	22.4	5.1	8.4	20.7	5.6	5.0	3.2	1.7	1.8	2.7
Ricky	13.4	14.5	20.8	12.6	15.8	24.2	4.8	4.6	2.8	1.5	1.5	2.5
Orechov	12.9	15.0	25.1	7.5	9.3	18.8	3.4	3.1	2.3	1.0	0.9	0.7

Table 6

Zinc content in soils in 2006 (average of all pots)

Locality	Zinc content in extract [mg · kg^{-1}]											
	Aqua regia			2 M HNO_3			0.43 M HNO_3			Mehlich III		
	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II
Sudice	45.4	54.2	109.3	22.1	30.3	82.9	11.1	18.6	73.2	6.8	11.9	42.9
Budisov	48.3	54.9	112.7	21.1	29.5	91.2	8.3	14.3	67.5	4.2	9.0	35.2
Netin	57.2	63.7	116.0	21.1	28.4	74.3	6.5	14.1	54.0	4.5	7.5	31.7
Ricky	60.3	69.7	124.9	31.2	40.8	93.3	19.4	27.9	75.0	10.5	15.1	39.6
Orechov	90.2	98.9	168.9	41.4	50.3	119.8	27.8	37.4	101.7	15.7	19.3	52.3
Locality	Zinc content in extract [mg · kg^{-1}]											
	CAT			DTPA			$CaCl_2$			NH_4NO_3		
	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II
Sudice	7.0	9.8	38.8	6.1	13.0	43.4	3.5	6.0	18.9	6.1	7.5	24.5
Budisov	7.0	7.0	32.9	2.5	5.7	40.2	3.0	3.0	9.6	1.0	3.0	13.2
Netin	7.0	7.0	28.1	3.1	5.1	30.7	3.0	3.0	4.6	0.9	1.2	5.4
Ricky	9.3	13.6	38.8	9.4	14.0	38.4	3.0	3.0	4.8	1.2	1.5	6.2
Orechov	10.8	14.1	41.5	6.8	8.8	29.9	3.0	3.0	3.0	0.9	0.9	0.9

Table 7

Relative zinc content in soils in 2006 (average of all pots) – *Aqua regia* as 100 %

Locality	[%]											
	Aqua regia			2 M HNO_3			0.43 M HNO_3			Mehlich III		
	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II
Sudice	100.0	100.0	100.0	48.8	56.0	75.8	24.4	34.4	67.0	14.9	21.9	39.2
Budisov	100.0	100.0	100.0	43.7	53.7	81.0	17.2	26.0	59.9	8.8	16.5	31.2
Netin	100.0	100.0	100.0	36.8	44.6	64.0	11.4	22.1	46.5	7.9	11.8	27.3
Ricky	100.0	100.0	100.0	51.8	58.6	74.7	32.1	40.1	60.1	17.3	21.7	31.7
Orechov	100.0	100.0	100.0	45.8	50.8	70.9	30.8	37.8	60.2	17.4	19.5	31.0
Locality	[%]											
	CAT			DTPA			$CaCl_2$			NH_4NO_3		
	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II	0	Slud I	Slud II
Sudice	15.4	18.1	35.5	13.4	24.0	39.7	7.7	11.0	17.3	13.4	13.8	22.4
Budisov	14.5	12.8	29.2	5.1	10.4	35.7	6.2	5.5	8.5	2.1	5.5	11.7
Netin	12.2	11.0	24.2	5.4	8.0	26.5	5.2	4.7	4.0	1.6	1.9	4.7
Ricky	15.4	19.5	31.1	15.6	20.0	30.7	5.0	4.3	3.8	2.0	2.2	5.0
Orechov	11.9	14.3	24.5	7.5	8.9	17.7	3.3	3.0	1.8	1.0	0.9	0.5

– 0.43 M HNO_3 – soil sample was extracted by nitric acid at room temperature with concentration of 0.43 mol $HNO_3 \cdot dm^{-3}$;

– Mehlich III – soil was extracted by acidic solution containing ammonium fluoride, ammonium nitrate, acetic acid, nitric acid and EDTA (*ethylenediaminetetraacetic acid*) in room temperature;

– CAT – soil was extracted by solution containing in 1 dm^3 14.7 g of $CaCl_2 \cdot 2\ H_2O$ and 7.88 g DTPA (*diethylenetriaminopentaacetic acid*), for extraction was this solution ten times diluted, room temperature;

– DTPA – extraction was performed in soil – DTPA solution ratio 1 : 2 (m/v) in exactly defined conditions with solution containing 0.1 mol $\cdot$ dm^{-3} triethanolamine, 0.01 mol $\cdot$ dm^{-3} calcium chloride and 0.005 mol $\cdot$ dm^{-3} DTPA at room temperature;

– $CaCl_2$ – solution of calcium chloride 0.01 mol $CaCl_2 \cdot dm^{-3}$ in room temperature;

– NH_4NO_3 – solution of ammonium nitrate 1 mol $NH_4NO_3 \cdot dm^{-3}$ in room temperature.

Final measurement in *Aqua regia* extract was performed by ICP-OES and in the rest extracts by AAS.

Concerning the plant material shoot biomass of spinach and maize was analysed, root of carrot and straw and grain of wheat. Samples were mineralised on a dry way in muffle furnace. Ash was dissolved in diluted nitric acid and zinc content was measured using ICP-OES.

Correlations of soil zinc content measured with particular extracting agents and zinc content in plants were calculated. Data was processed using STATISTICA 8. Correlations were evaluated using Pearson's correlation test.

Results and discussion

Comparison of extraction agents

On combination sludge II was observed increase in zinc content in *Aqua regia* extract in 2006. This can be partly explained by ongoing mineralisation of sludge. However, increase is not in line with theoretical increase based on amount of zinc applied, which is 14.7 mg $\cdot$ kg^{-1} for 5 Mg (tons), 73.2 mg $\cdot$ kg^{-1} for 25 Mg (tons) and 146.5 mg $\cdot$ kg^{-1} for 50 Mg (tons) of sludge. This "disappearing" of zinc was reported also in other works [1].

This increase in second year was not so apparent in other extraction agents. For calcium chloride and ammonium nitrate we observed clear dependence between soil pH and extracted zinc quantity. This is in accordance with other sources and furthermore those report that such differences (between extremely acidic and neutral soils) can be tens of percent [2].

In 2005 2 mol $HNO_3 \cdot dm^{-3}$ yielded on control up to 53 % of zinc extracted with *Aqua regia*, one year after up to 50 %, on sludge II up to 85 % and 80 %, respectively. Weaker concentration of nitric acid extracted up to 35 % and 30 % of total zinc content on control and on sludge II up to 66 % in both years. Mehlich III provided 20 % and 17 % of zinc extracted with *Aqua regia* on control and 42 % and 36 % on sludge II.

CAT yielded 17 % and 13 % of total zinc content on control, and on sludge II 34 % and 32 %, respectively. DTPA dissolved 11 % and 13 % of zinc extracted with *Aqua regia* on control and 27 % and 40 % on sludge II. $CaCl_2$ on control extracted 8 % and 7 %, and 18 % and 15 % of total zinc content on sludge II. Finally NH_4NO_3 dissolved 13 % and 9 % of zinc quantity extracted with *Aqua regia* on control, and on sludge II 22 % and 21 %. This illustrates the fact that applied zinc was quite mobile. If we compare our results with other sources it is obvious that in our case weak extraction agents extracted pretty high percentages of total content. In a study comparing different extractions from soils after sludge application was reported that $NaNO_3$ (which is comparable with NH_4NO_3) extracted around 1 % of zinc extracted by *Aqua regia*, $CaCl_2$ even only 0.3 % [3]. Other work offers very similar results especially for 2 mol $HNO_3 \cdot dm^{-3}$. Little bit higher results assigns to DTPA (8 %) and also to weak agents as NH_4NO_3 and $CaCl_2$, but also highlights the fact that in case of anthropogenic contamination contents assessed by weak extraction agents can easily exceed 10 % of total content [2]. In neutral soil (pH 7) $CaCl_2$ extracted only 0.05 % of total zinc content after long term application [4]. In contrary, another work reports $CaCl_2$ extracting 42 % of total zinc content many years after sludge application [5]. These results demonstrate fundamental influence of soil properties on zinc mobility and also illustrate complexity of this issue. It is also interesting to confront with conclusions of Slovak study which designates critical zinc content extracted by ammonium nitrate as 2 $mg \cdot kg^{-1}$ soil [6]. Our results indicate that such value could be too strict.

Correlations between extraction agents

All described correlations are statistically significant on a level $p < 0.05$. All localities and sludge combinations were evaluated.

There were only slight differences between years 2005 and 2006. There was an important finding that extraction agents as per their zinc extraction ability created in fact 4 groups according to their common correlations:

– *Aqua regia* and 2 mol $HNO_3 \cdot dm^{-3}$,
– 0.43 mol $HNO_3 \cdot dm^{-3}$, Mehlich III and CAT,
– DTPA,
– $CaCl_2$ and NH_4NO_3.

Correlations out of these groups exist, however, practically only between first two groups. Similar findings can be found in literature. It was quite surprising that DTPA became very isolated, there were hardly few correlations with stronger agents and even no with weaker used for zinc extraction. The only few correlations were found with Mehlich III and CAT. Both weakest agents correlated only with each other. Tight correlations of zinc quantity dissolved in $CaCl_2$ and NH_4NO_3 and additionally their relation to pH of soil are confirmed in other studies [7].

Correlations between plants and soils zinc content

Zinc content in spinach biomass was practically the only with correlations with one of stronger agents, particularly with DTPA. The relatively strong correlation was found

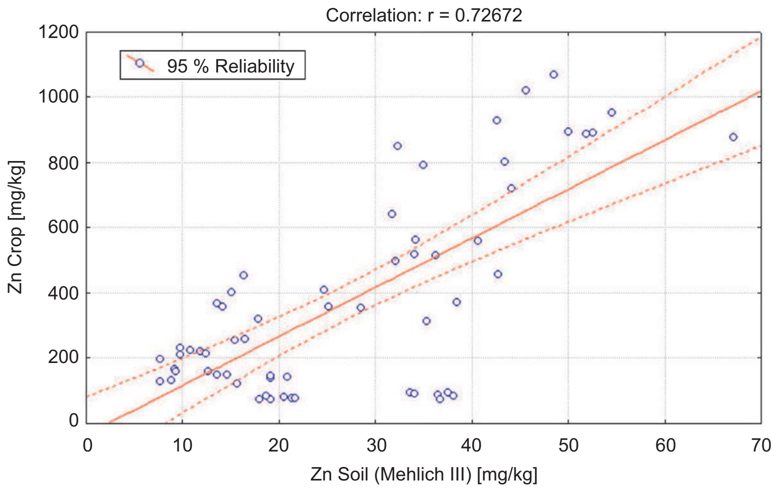

Fig. 1. Correlation between zinc content in soil (Mehlich III) on sludge I+II combinations and zinc content in spinach (2006)

between zinc extracted by Mehlich III from soils of all experimental objects and its spinach content (Fig. 1). The rest of plants (respectively their zinc content) correlated only with quantity of this metal extracted by NH_4NO_3 and $CaCl_2$. And ammonium nitrate provides pretty stronger correlations. We cannot omit the role of soil pH which is, however, stronger with separated combinations and especially under normal conditions represented by control (zero treatment) or lower sludge dose. We can state that soil pH is better tool for zinc uptake prediction than strong and medium strong extraction agents. This ability is mentioned in literature to [8]. This option for zinc uptake prediction is limited under more extreme conditions.

Generally speaking this is due to higher mobility of zinc in low soil pH and these mobile forms are extracted by weak agents. It is interesting to observe behaviour of DTPA. This agent created its own "group" and we can agree upon the fact that this agent fulfils just its original intention – to assess the nutrition level of zinc in soil. However, it fails if used for uptake prediction.

Detailed testing revealed no correlations (even with weak agents) for soil from Orechov, which has quite high pH value. This effect is confirmed by other sources to [9].

According to our expectations there were no correlations with strong extraction agents ability to zinc dissolving. This is supported by more studies [7], even though there exist also different conclusions, which demonstrate correlations with strong agents such as 2 mol $HNO_3 \cdot dm^{-3}$ [10, 11]. However, this is the case in which nitric acid correlates also with ammonium nitrate and it was found under natural conditions [11].

As the most appropriate extraction agent for zinc uptake prediction we considered ammonium nitrate. It is recommended in other studies, often together with calcium chloride [7]. It is important to mention that even this agent (NH_4NO_3) was not able to predict all increased contents of zinc in plants. On the contrary, even use of some of stronger agents (0.43 mol $HNO_3 \cdot dm^{-3}$, CAT, Mehlich III) in combination of knowledge of soil pH can be sufficient clue to predict possible risk of plant contamination and probably even phytotoxicity of zinc. Extreme soil condition represented by very low pH and very high concentrations of zinc can complicate use of extraction methods for uptake prediction. In that case the only reliable method for evaluation of contamination is analysis of plant material.

Conclusions

All used extraction agents were able to identify differences in zinc content of different combinations including the fact that sludge applied was released rapidly. Amount of applied zinc was higher than revealed by *Aqua regia*, part of this zinc remained undetected. Soil of high quality with neutral pH was able to immobilise applied zinc and protect crops even against very high level of contamination. On contrary, soils with low pH are not able to eliminate even low quantities of zinc and high uptake of zinc occurs. There are strong correlations of zinc content dissolved in *Aqua regia* and 2 mol $HNO_3 \cdot dm^{-3}$. Correlations of the same strength were detected between 0.43 mol $HNO_3 \cdot dm^{-3}$, Mehlich III and CAT, with some correlations with *Aqua regia* and 2 mol $HNO_3 \cdot dm^{-3}$. Zinc content in DTPA leach was hardly ever correlated with zinc in other extracts. Very strong correlations were found between zinc content in NH_4NO_3 and $CaCl_2$ extracts, but its amount soluble in these agents did not correlate with the rest. Contents of zinc in NH_4NO_3 and $CaCl_2$ extracts were in a good accordance with soil pH. Extraction with NH_4NO_3 shown the best correlation with plant zinc, a bit worse was $CaCl_2$. There were good results for soil pH and plant zinc for controls and lower sludge doses. DTPA was not applicable for prediction of elevated uptake. Strong agents in combination with soil pH value can offer very good information on possible risk of excessive plant uptake. Mehlich III which is used for assessment of soil nutrient status in the Czech Republic could be used as an appropriate extraction agent for screening of soil zinc (and perhaps other microelements) content.

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Abstrakt: Celem pracy było porównanie różnych ekstrahentów w celu identyfikacji tego, dzięki któremu będzie można uzyskać najbardziej rzetelne dane dla oceny zawartości cynku w glebie i prognozowania możliwości zanieczyszczenia roślin. W celu porównania kilku metod ekstrakcji i rozpoznania najbardziej odpowiadającej pobieraniu cynku przez rośliny oraz zbadania zachowania się dużych dawek osadów silnie zanieczyszczonych cynkiem (prawie 7 000 mg Zn $\cdot$ kg^{-1}), w 2005 r. założono dwuletnie doświadczenie wazonowe w hali wegetacyjnej. Wybrano pięć gleb o różnej wartości pH (od bardzo kwaśnych do obojętnych) i uprawiano pięć gatunków roślin – szpinak, marchew, pszenicę jarą i kukurydzę. Kombinacją kontrolną były obiekty z mniejszą dawką osadu (równoważną 5 Mg (tonom) suchej masy na 1 ha) i wysoką dawką (równoważną 25 Mg (tonom) suchej masy na 1 ha pod szpinak i marchew oraz 50 Mg (tonom) pod pszenicę jarą i kukurydzę). W badaniach użyto następujące ekstrahenty: woda królewska, 2 mol $HNO_3 \cdot dm^{-3}$, 0,43 mol $HNO_3 \cdot dm^{-3}$, Mehlich III, CAT, DTPA, $CaCl_2$ i NH_4NO_3. Obliczono współczynniki korelacji pomiędzy ilością cynku ekstrahowanego z gleby przez poszczególne ekstrahenty a zawartością cynku w roślinach.

Stwierdzono najsilniejszą korelację pomiędzy ilością cynku rozpuszczalnego w najsłabszym ekstrahentach – $CaCl_2$ i NH_4NO_3. Ilości te były skorelowane ze sobą oraz z zawartością cynku w roślinach, ale nie z ilością cynku rozpuszczalnego w innych ekstrahentach. Ilości cynku ekstrahowane przez pozostałe odczynniki ekstrakcyjne: 0,43 mol $HNO_3 \cdot dm^{-3}$, Mehlich III, CAT i DTPA, a także ekstrahowane wodą królewską i 2 mol $HNO_3 \cdot dm^{-3}$ były najczęściej skorelowane ze sobą. Stwierdzono dość ściśle korelacje między pH gleby a zawartością cynku w roślinach potwierdzające, że pH jest kluczowym czynnikiem mającym wpływ na mobilność cynku w glebie. Oznacza to, że znajomość pH gleby i (nawet) zbliżonej do całkowitej zawartości cynku w glebie może służyć jako wystarczające źródło informacji o możliwym statusie cynku w glebie. Odczynnik Mehlich III, który jest szeroko stosowany w Czeskiej Republice w badaniach chemiczno-rolniczych (oceniających stan P, K, Ca i Mg w glebie), może być stosowany jako dobre narzędzie do badań przesiewowych (być może też do innych mikroelementów). Takie jego zastosowanie zapewni dużą liczbę danych bez dodatkowych kosztów.

Słowa kluczowe: cynk, ekstrahenty, przyswajalność