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PRELIMINARY STUDIES ON AGRICULTURAL APPLICABILITY OF SEWAGE SLUDGES FROM WROCŁAW

Physico-chemical and vegetation experiments on the agricultural applicability of preliminary sludges from Wrocław have been carried out. It has been shown that trace elements (mainly zinc, manganese, copper, nickel, and chromium) occur in sludges in relatively high concentrations, and were mostly assimilated by test plants, jeopardizing the use of at least the first harvest.

1. INTRODUCTION

One of the rational ways of sewage sludges disposal is to use them for agricultural purposes. Organic compounds, the NPK and microelements present in sludges make it a useful fertilizing material stimulating the growth of a new organic matter. Sewage sludges may be considered to be the most universal fertilizer, since their value is not limited to main macrocompounds serving as nutrients for plants. They provide the soil not only with the organic matter and microelements, but also with microorganisms and enzymes which affect markedly biochemical processes in the soil.

Positive effects of sludges application to the soil may be observed in high yields of various crops.

The results of recent investigations have shown the more and more frequent occurence of some undesirable components in sludges. Even in small amounts they are toxic to plants and consequently dangerous to man and animals. These are trace elements, pesticides, and chlorinated hydrocarbons coming mainly from industrial wastes discharged to the municipal sewage system. Harmful effects of trace elements on environment have been confirmed many times by the practical use of sludges in agriculture [11, 15, 19].

From the experimental results obtained so far it follows that the analysis of only the basic chemical and fertilizing components present in sludges is insufficient for the assessment of sludge applicability for agricultural purposes. In this respect a new important criterion

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is provided by vegetation experiments accompanied by the analysis of trace elements present in sludge, soil and plants.

Basing on the results obtained [3, 8, 11, 15, 19] a definite group of trace elements is pointed out in the literature. The occurence of the excessive amounts of these elements in sludge or soil may result in toxic effects. It may be also observed that for various trace elements the level of their occurence in sewage sludges as well as the degree of their potential toxic effect on the plants are different. The group includes the following elements As, Ba, B, Cr, Sb, Zn, Cd, Co, Mn, Co, Mo, Ni, Pb, Hg, Se, Ag, V.

Hence, the farm and household wastewater sludges containing low concentrations of trace elements turn out to be the most useful ones for agricultural purposes. However, there is a shortage of such sludges since constant development of towns increases the amount of industrial wastes being present in municipal sludges. The negative effects of the above-mentioned elements on the quality of various crops are well known from more and more frequent literature report. It, however, does not preclude the use of such sludges in agriculture. What should not be neglected is the analysis of real causes and effects, and the determination of explicit criteria for sludges applicability, from the stand point of both agricultural requirements and environment protection.

This paper presents the results of preliminary studies on agricultural applicability of sewage sludges from city of Wrocław.

2. TREATMENT AND APPLICATION OF SEWAGE SLUDGES FROM WROCŁAW

Central part of Wrocław is served by a combined sewage system, other districts have separate sewerage systems. Municipal wastes are treated mainly on the complex of irrigated fields of Osobowice — Rędzin — Świniary — Szewce region to which 93% ($Q_{d,\,av}$ ca 170.000 m^3/d — 1975) of the total municipal wastes are directed. Irrigated fields of Osobowice region were designed and built in the 1890's, and developed to 1500 ha at present.

Wastewater used for irrigation is clarified in 12 two-chamber settling tanks (each has capacity of 11–18.000 m^3) placed on the irrigated fields along the supply main sewer. Sludge lagoons have a 4–5 years storage capacity and the drying takes place in the summer months. Thus, nearly complete mineralisation of accumulated primary sludges takes place. Dewatered and dried sludge is removed from lagoons and sold; the emptied lagoon is prepared for the new cycle.

According to the assessment data [10] a yearly production of air-dry sludge is equal to about 5.000 m^3. A certain amount of this sludge (1500–3000 t) is purchased every year by City Cleaning Department to be applied to the composting of solid wastes. The remaining sludge is used as fertilizer on city lawns and in private gardens.

The design of central sewage treatment plant for Wrocław includes an alternative application of sludges to agricultural lands. The results presented in this paper, and concerning the toxicity of sewage sludge from large urban-industrial agglomerations will be utilized for evaluation of this alternative.

3. SCOPE AND METHODOLOGY OF EXPERIMENTS

The experiments included physico-chemical analysis of sewage sludges and vegetation experiments on the agricultural applicability of sludges to grass fertilization.

In the analysis of sludge constitution, attention was drawn to the presence of basic fertilizer components (substances containing nitrogen, phosphorus and potassium) and to the occurence of trace elements which can limit the applicability of sludges to meadow fertilization. Based on the developed analytical methods [9, 10] the occurence of eleven trace metals, i. e. As, B, Zn, Cd, Co, Mn, Cu, Ni, Pb, Hg, Ag, in the investigated sludge has been analysed. Sludge samples for the experiments were taken directly from settling tanks, within the irrigated fields.

From each of the tanks 10 averaged sludge samples were collected at various places and dephts in order to obtain possibly full characteristics of Wrocław sewage sludges.

The standard analysis of sludges was supplemented with the qualitative analysis of ashes in order to find a confirmation of the quantitative analysis results and to point at much wider range of the occurence of trace elements in sludges. The quantitative analysis of trace elements in sludges was done by atomic absorption spectroscopy (AAS); the qualitative analysis of the ashes was done on the Hilger EO 478 mass spectrograph. By comparing the results of physico-chemical analysis with the characteristics of organic fertilizers and cultivated soils the applicability of sludges to agricultural purposes could be preliminary estimated.

An essential criterion in the estimation of sludges usability was, however, provided by vegetation pot experiment station. They were carried out on a special experimental shown in fig. 1.

Barren test soil was enriched with various doses of sludge: 0%, 12.5%, 25%, 50%, 75%, and 100%. Disintegrated sludge was mixed with test soil at the appropriate weight

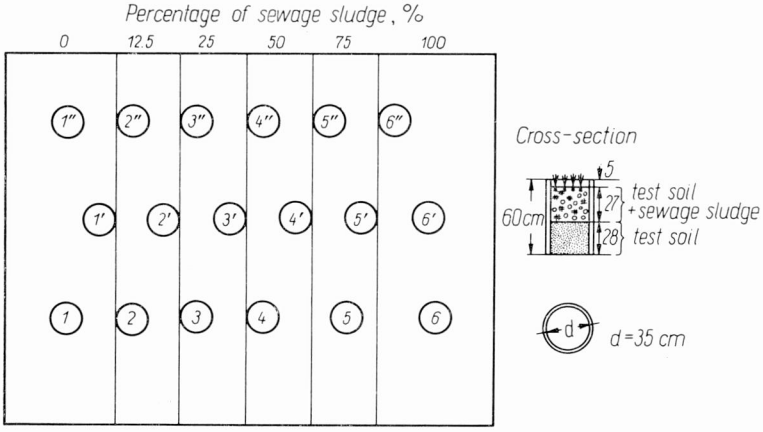


Fig. 1. Layout of the vegetation experimental set
Rys. 1. Schemat stanowiska doświadczalnego do badań wegetacyjnych

ratio, and each pot was filled with 27 cm thick layer of soil. Subsoil in all pots consisted of a 30 cm thick layer of barren soil. The Italian rye grass was applied as a test plant by seeding (the dose about 30 kg/ha).

During the first vegetation season, lasting from May to November, the grass was harvested 5 times. The growth and chemical constitution of test plants were observed as dependent on various doses of sludges and varying concentration of trace elements in test soils. The time of harvesting ending the grass vegetation period in a successive cycle was determined basing on the observations of plants size.

4. PHYSICAL AND CHEMICAL CHARACTERISTICS OF WROCŁAW SLUDGES

The chemical constitution of the sludges from irrigated fields of Osobowice region has not been analysed so far. The sludge was assumed to be a good fertilizing material.

Mechanical digested sludges dried in settling tanks resemble in consistence a damp humus soil (which is easy to sow), and are black in colour and earthy in smell. From the results of physico-chemical analysis of sludges, based on 120 samples (table 1), it follows that the degree of mineralization of sludges as well as their pollution with chemical substances are different in various settling tanks.

The calculated mean values of concentrations are, however, those of a typical sludge from a large city.

The sludges investigated are characterized by lowered pH value, which is due either to their incomplete digestion or to the content of certain amounts of acidic industrial substances.

The content of organic compounds in sludges is relatively high (above 65%), which is advantageous from agricultural view-point since such sludges may contain a considerable amount of soil-forming and humus substances.

The content of fertilizing compounds (substances containing nitrogen, phosphorus and potassium) in sludges is also relatively high. The concentrations of nitrogen and phosphorus in sludges are comparable with those of a typical manure [7]. The concentration of potassium is lower, which is characteristic of sewage sludges. A considerable amount of organic and biogenic substances present in Wrocław sludges suggests undoubtedly their applicability as a fertilizing material.

An important group of chemical indices for sludges is provided by trace elements. In spite of the fact that Wrocław is a large urban and industrial centre (machine industry and non-ferrous metallurgy) the concentration of trace elements in Wrocław sludges is relatively low (table 1). From the comparison of analytical data of chemical constitution of sludges (table 1) with the literature data [3, 5, 9, 11] it follows that only 5 of 11 analyzed trace elements have higher or considerably high concentrations in sludges. These are arsenic, zinc, cadmium, nickel, and copper.

Table 1

Physicochemical characteristics of Wrocław sludges

Index	Unit	Concentration range[a]	Mean value
pH	pH	4.8–7.0	6.0
Hydration	%	46–72	65.8
Inorganics	% s·m	30.6–41.2	34.1
Organics	% s·m	58.8–69.4	65.8
Total itrogen N tot.	% s·m	0.61–5.27	2.5
Ammonium nitrogen N_{NH_4}	% s·m	0.02–1.08	0.35
Organic nitrogen N org.	% s·m	0.28–4.19	2.10
Fatty acids	mg/g s·m	1.95–23.2	9.47
Acidity	mval/dm³	2.0–27.0	9.1
Alkalinity	mval/dm³	0–57.0	19.5
Phosphates	mg PO_4/g s·m	1.1–11.2	6.6
Phosphorous P_2O_5	% s·m	0.14–1.44	0.46
Organic carbon[b]	% s·m	38.1–49.0	41.57
Organic hydrogen[b]	% s·m	5.0–6.6	5.8
Organic nitrogen[b]	% s·m	1.4–3.2	2.4
C : N ratios	—	12 : 1–35 : 1	17 : 1
Calcium (flame phot.) Ca	% s·m	1.12–2.88	1.6
Sodium (flame phot.) Na	% s·m	0.06–0.2	0.11
Potasium (flame phot.) K	% s·m	0.03–0.09	0.05
Arsenium (colorimetar)	μg/g s·m[c]	3.0–36.0	9.4
Borum (colorimeter)		14.1–50.8	22.7
Mercury (colorimeter)		0.1–1.2	0.4
Zinc (ASA)		3637–10037	6213
Cadmium (ASA)		52–103	88
Manganeze (colorimeter)		100–228	159
Copper (ASA)		738–1650	1088
Nickel (ASA)		125–281	179
Lead (ASA)		335–860	474
Silver (ASA)		8–49	25
Cobalt (ASA)		4–13	6.7

a) Established from 120 samples.
b) Determined on CHN — Hewlett Packard analyser.
c) 20–30 units μg/g s·m.

The periodicity of the occurence of trace elements (fig. 1) confirms the results presented in table 1 and indicates that the main trace elements in Wrocław sludges are zinc, copper, lead, and nickel, as well as manganese and cadmium. The remaining elements i.e. silver, boron, cobalt, arsenic, and mercury are of secondary importance. It should be noted, however, that the concentrations of mercury, cobalt and boron in the sludges investigated are higher than those in the farm and house-hold sludges.

The analysis of ashes performed on about 70 samples (table 2) and providing information on the chemical constitution of sludges allows to determine their fertilizing value or toxicity. High fertilizing value of sludges is due to the presence of trace elements, which has been found basing on the spectral analysis and which makes sludges more universal

Table 2

Distributions of concentrations of some trace elements in ashes of Wrocław sludges

Index	Auxiliary number	Range of ash concentration μg/g						
		0–1	1–10	10–10^2	10^2–10^3	10^3–10^4	10^4–10^5	10^5
Barium	64			1.5	26.6	[71.9]		
Borum	66		36.4	[56.1]	7.5			
Bismuth	65		16.9	[67.7]	15.4			
Chromium	66			1.5		[98.5]		
Tin	66		1.5	21.2	[77.3]			
Zinc	66				36.4	[63.6]		
Phosphorus	55			38.2	[43.6]	18.2		
Galium	65	8.0	[84.0]	8.0				
Aluminium	42					2.4	[97.6]	
Cadmium	65		1.5	22.2	[76.3]			
Cobalt	66		22.7	[77.3]				
Silicon	9						[88.9]	11.1
Magnezium	66					[78.8]	21.2	
Manganaze	66				[100.0]			
Copper	66			6.1	31.8	[62.1]		
Molybdenum	65	7.7	[66.2]	24.6	1.5			
Nickel	66		6.0	28.8	[65.2]			
Lead	66			3.0	[77.3]	19.7		
Silver	66			[90.9]	9.1			
Titanium	66			1.5	12.1	[86.4]		
Vanadium	66			34.8	[65.2]			
Calcium	66				1.5	18.2	[80.3]	
Iron	49						[100.0]	

than those not so rich in microelements manures. The question is however, whether such large number of elements does not pose a danger to plants and consequently to food-chain in case of prolonged sludges application.

The evaluate agricultural applicability of sludges investigated the results of physico-chemical analysis (table 1, table 2, fig. 2) have been compared with the chemical consti-

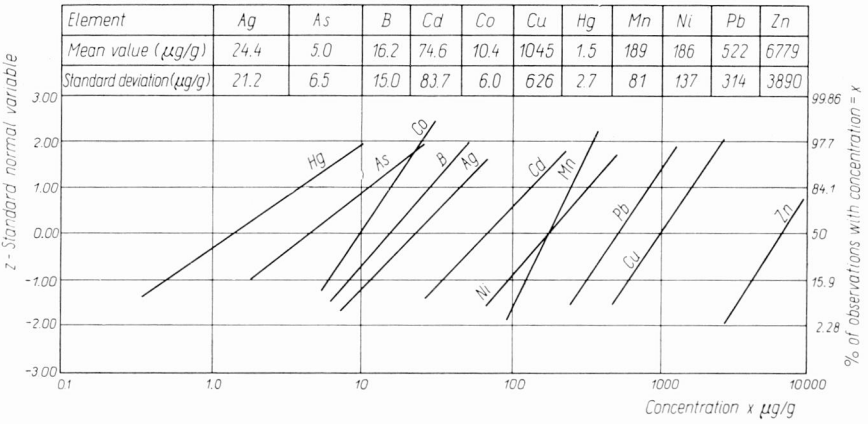


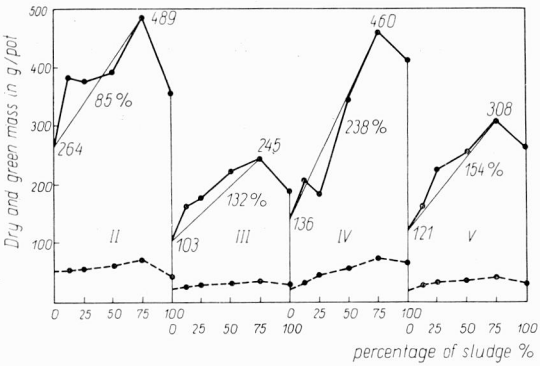
Fig. 2. Periodicity of trace element occurence in Wrocław municipal sludge
Rys. 2. Okresowość występowania elementów śladowych w osadach wrocławskich

tution of organic fertilizers [7] and soils [13, 17, 18, 20, 21]; it has been found that concentrations of the trace elements, except for manganese, markedly exceed the natural concentrations both in fertilizers and in soils. From the comparison of analytical results with the chemical constitution of municipal sewage sludge [2] it follows that the concentrations of only two elements cadmium and zinc are higher in sludges investigated, of cadmium — 4 times, and of zinc — 3 times. According to the latest report of EPA [22] on the toxicity of metals in sludges cadmium and zinc belong to the group of 5 elements (Cd, Zn, Mo, Ni, Cu) which are potentially the most dangerous ones to environment, in certain definite conditions.

In view of the above considerations, the agricultural applicability of sludges seems rather doubtful and should be regarded with extreme caution.

5. VEGETATION EXPERIMENTS

Vegetation experiments have shown the influence of sewage sludge addition on the growth of test grass. The increase of sludge dose resulted in the increase of green and dry mass of test grass; the best results were obtained for the 75% sludge dose (fig. 3). The increase of green mass of plants ranged from 85% to 238% in relation to the effect of control test.



sludge dose, %	green mass, g				dry mass, g			
	II	III	IV	V	II	III	IV	V
0	264	103	136	121	50.3	21.0	21.7	19.8
12.5	383	164	207	164	54.0	28.1	33.1	27.3
25	377	176	181	225	55.0	29.1	45.1	34.1
50	392	223	346	256	61.2	33.5	55.2	36.5
75	489	245	460	308	71.8	34.1	73.5	42.1
100	332	189	413	260	43.7	29.3	65.9	33.0

Fig. 3. Increase of green and dry mass of test grass

Vegetation period: havesting: I — 10.VI.76 — 31 days, II — 19.VII.76 — 70 days, III — 13.VIII.76 — 95 days, IV — 17.IX.76 — 130 days, V — 9.XI.76 days

Rys. 3. Przyrost zielonej i suchej masy traw w zależności od dawki osadów

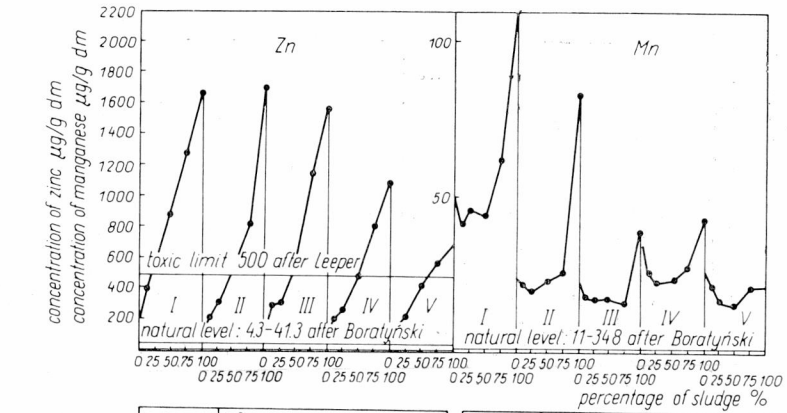
Okres wegetacji i zbiory I — 10.VI.76 — 31 dni, II — 19.VII.76 — 70 dni, III — 13.VIII.76 — 95 dni, IV — 17.IX.76 — 130 dni, V — 9.XI.76 — 180 dni

The yields obtained for 100% sludge dose (i.e. sludge with-out soil) were relatively high, but lower than for 75% sludge dose.

The decrease of yield at 100% sludge dose, observed regularly in each vegetation cycle, may be due to inappropriate structure of this kind of soil, since under the influence of humidity sludge has been squeezed into a uniform mass, not porous enough and therefore not easy to aerate. The chemical substances which in this case reach the highest concentration may also have a restraining effect.

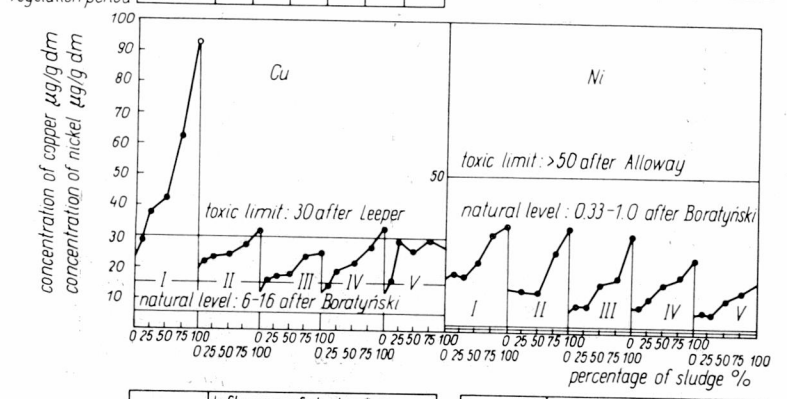
From the above observations it follows that sludge should not be applied as a soil layer, but when added to poor sandy soil it may be an effective enrichment factor.

The analysis of chemical composition of test plants has shown, that they assimilate trace elements from sludge proportionally to the concentration of these elements in test soil. The increase of the sludge dose and consequently the increase of the concentration of a certain element in soil results in the increase of its content in plant leaves. This dependence has been presented for the chosen elements: Zn, Mn, Cu, Pb, Fe, Cr, and Cd in figs. 4 and 5. Assimilation of elements by plants decreases with the vegetation time. The highest concentrations were observed in plants from the first harvesting. In succesive vegetation cycles the concentration decreases steadily because of the removal of metals from the subsoil due to the growth of plants and to rinsing out taking place during irrigation or rainfalls. The results of the analysis of subsoil (performed after the termination of vegetation period) presented for chosen elements in figs. 4 and 5 confirm the decrease of their concentration in soil. The concentrations of trace elements in test plants when compared with those of plants growing in natural conditions [6] turned out to be higher in each case analysed. Particularly high level of concentration was observed for zinc, manganese, copper, nickel, and chromium i.e. for those elements which also in soil (sludge)



	Influence of sludge dose on zinc concentration in the soil					
percent of sludge %	0	12.5	25	50	75	100
beginning of the experiment: concentr. of Zn, µg/g	140	1125	2375	4219	—	9208
termination of 1st vegetation period: concentr. of Zn, µg/g	189	823	1120	2973	4473	7020

	Influence of sludge dose on manganese concentration in the soil					
percent of sludge %	0	12.5	25	50	75	100
concentr. of Mn, µg/g	225	296	320	350	351	377



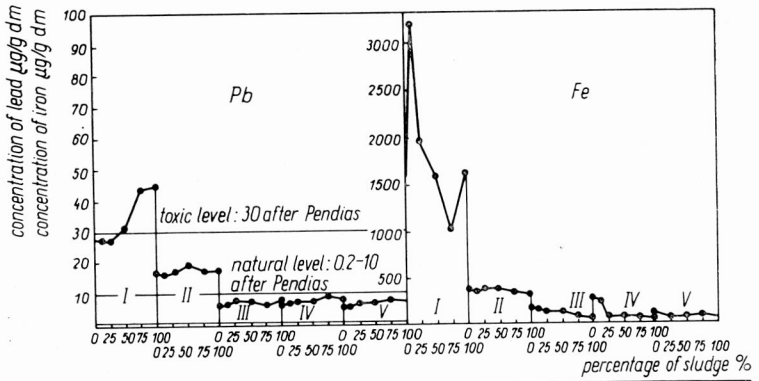
	Influence of sludge dose on copper concentration in the soil					
percent of sludge %	0	12.5	25	50	75	100
beginning of the experiment: concentr. of Cu, µg/g	236	232	755	1098	1130	1401
termination of 1st vegetation period: concentr. of Cu, µg/g	85	166	180	338	713	1073

	Influence of sludge dose on nickel concentration in the soil					
percent of sludge %	0	12.5	25	50	75	100
concentr. of Ni, µg/g	34	41	89	128	173	223
	46	53	61	85	100	127

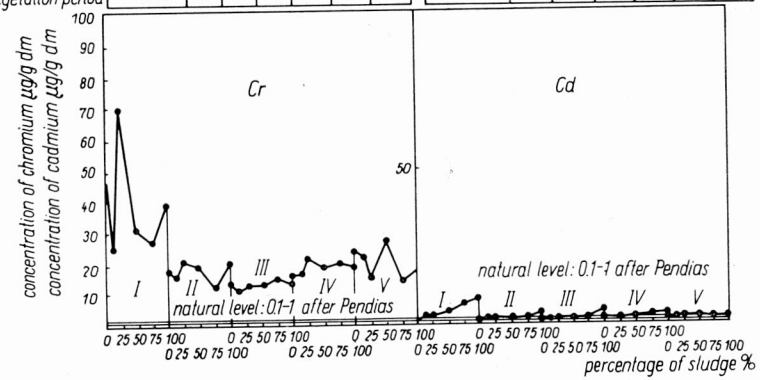
Fig. 4. Concentration of trace elements Zn, Mn, Cu, Ni in test grass versus sludge dose
Rys. 4. Koncentracja elementów śladowych Zn, Mn, Cu, Ni w trawie testowej w zależności od dawki osadu

occur in higher concentrations. These observations have been confirmed by the analysis of test plant ashes (table 4). In some cases (Zn, Cu, and Pb) the concentration of trace elements exceeded the toxicity level, determined after LEPPER or PENDIAS [1, 15].

During the whole vegetation period, however, no important toxic effects were observed, except for varying mass increase which was due rather to the changing weather conditions.



beginning of the experiment	Influence of sludge dose on lead concentration in the soil.						Influence of sludge dose on iron concentration in the soil.						
	percent. of sludge %	0	12.5	25	50	75	100	percent. of sludge %	0	12.5	25	50	75	100
termination of 1st vegetation period	concentr. of Pb; µg/g	0	68	200	337	570	585	concentr. of Fe; µg/g	10000	10000	15000	16500	17300	19500
		59	64	70	70	85	85		11000	11000	11500	12500	13300	15000



	Influence of sludge dose on chromium concentration in the soil.						Influence of sludge dose on cadmium concentration in the soil.						
	percent. of sludge %	0	12.5	25	50	75	100	percent. of sludge %	0	12.5	25	50	75	100
beginning of the experiment	concentr. of Cr; µg/g	0	96	256	386	412	510	concentr. of Cd; µg/g	0	9	20	40	60	168
termination on 1st vegetation period									2.3	9.3	13.7	29.7	45	76

Fig. 5. Concentration of trace elements Pb, Fe, Cr, Cd, in test grass versus sludge dose
Rys. 5. Koncentracja elementów śladowych Pb, Fe, Cr, Cd, w trawie testowej w zależności od dawki osadu

Considering the problem of sewage sludge application to agriculture from point of view of trace elements it should be stressed firstly that the concentrations of trace elements in sludges are relatively high, and, in addition they mostly occur in an available form and are easily assimilated by plants and secondly that the concentration of trace elements in plants decreases markedly due to the growth of plants as early as in the first vegetation period. The level of concentration is supposed to decrease proportionally during the su-

Table 3

N, P, K and Ca contents in test soils

Definition of sample	pH	Organics in % of dry weight	Inorganics in % of dry weight	Total nitrogen in % of dry weight	Total phosphorus P_2O_5 in % of dry weight	Total potasium in % of dry weight	Calcium Ca in % of dry weight
Control soil	7.9	4.1	95.9	0.61	0.09	0.02	0.29
Control soil with 12.5% addition of sludge	7.7	8.9	91.1	1.25	0.18	0.02	1.33
Control soil with 25% addition of sludge	7.7	12.8	87.2	1.88	0.25	0.02	1.08
Control soil with 50% addition of sludge	7.6	21.9	78.1	2.18	0.55	0.032	1.82
Control soil with 75% addition of sludge	7.5	31.3	68.7	2.86	0.73	0.040	3.75
Sludge	7.1	43.9	56.1	3.25	1.21	0.05	3.85

The beginning of experiment: may 1976

ccesive periods and to reach the level of control tests or of natural concentrations. The measurements of the decrease of concentration in successive vegetation periods allow to determine the sludge fertilization cycles for the same lands.

Basing on the fact that test plants have shown no toxic effects and on the above-mentioned favourable characteristics the applicability of sludges to grass fertilization should be recognized as possible. Precautions should be taken, however, while utilizing the hay obtained from those lands, particularly the first harvesting after fertilization.

5. CONCLUSIONS

1. The analysis of sewage sludges from Wrocław has shown that they are rich in organics and nutrients and as such are applicable to agricultural lands. They contain, however, some trace elements whose concentrations exceed the concentration of the same elements occurring in manures, soils or municipal wastes. The highest concentrations are those of zinc and cadmium which belong to the group of 5 elements (Cd, Zn, Mo, Ni, and Cu) classified as the most dangerous to environment. For these reasons the agricultural applicability of sludges seems rather doubtful and should be regarded with reservations.

2. Vegetation experiments have shown that fertilization with sludge results in the increase of plant mass. On the other hand, however, since a great number of trace elements are assimilated by plants, the permissible toxic thresholds of zinc, copper and lead in the grass from the first harvesting were exceded.

Table 4

Distribution of the concentrations of some trace elements in ashes of test plants (grass: Italian rye grass)

Index	Auxiliary number	Concentration range in μg/g of ashes					
		0–1	1–10	10–10^2	10^2–10^3	10^3–10^4	10^4–10^5
Borium	15	20.0	[66.7]	13.3			
Chromium	15	[33.3]	33.3	13.4	20.0		
Tin	15	[86.7]	13.3				
Zinc	15		13.3	40.0	[46.7]		
Phosphorus	15			26.6	[66.7]	6.7	
Galium	15	[100.0]					
Aluminium	15			33.3	26.7	[40.0]	
Cobalt	15	[100.0]					
Silicon	15			6.7	[60.0]	33.3	
Magnesium	15			13.3	13.3	[46.7]	26.7
Manganeze	15		13.3		[86.7]		
Copper	15	6.7	[73.3]	20.0			
Molibdenum	15		13.4	[80.0]	6.6		
Nickel	15	6.6	[46.7]	46.7			
Lead	15		20.0	[73.3]	6.7		
Potassium	15						
Sodium	15						[100.0]
Silver	15	[60.0]	40.0				
Strontium	15	[93.3]		6.7			
Titanium	15	[73.3]	26.7				
Vanadium	15	40.0	[46.7]	13.3			
Calcium	15			20.0	33.3	[40.0]	6.7
Iron	15		20.0	[53.4]	13.3	13.3	

Considering all the analytical results of investigations on the agricultural applicability of sewage sludges from Wrocław irrigated fields it seems advisable to proceed with caution while utilizing the hay from the first harvest.

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WSTĘPNE BADANIA NAD ROLNICZĄ PRZYDATNOŚCIĄ OSADÓW ŚCIEKOWYCH MIASTA WROCŁAWIA

Analiza składu osadów ściekowych Wrocławia wykazała, że są one bogate w nawozowe substancje organiczne i biogenne, a zatem z tego punktu widzenia są w pełni przydatne do celów rolniczych. Osady ściekowe zawierają jednak wiele elementów śladowych, z których część ma stężenie znacznie wyższe od stężenia tych elementów w nawozach naturalnych w glebach czy osadach komunalnych. Porównawczo najwyższe stężenia wykazują cynk i kadm, które zalicza się do grupy pięciu głównych pierwiastków (Cd, Zn,

Mo, Ni i Cu) stwarzających potencjalnie największe zagrożenie środowiska. Z tego względu rolnicza przydatność osadu może budzić wątpliwości i zastrzeżenia.

Badania wegetacyjne wykazały efektywne działanie nawozowe osadów wrocławskich mierzone przyrostem masy roślinnej. Z drugiej jednak strony ujawniły, że znaczna część elementów śladowych w osadach występuje w formie dobrze przyswajalnej przez rośliny, w których, jak wykazała analiza składu, stwierdzono przekroczenie poziomu toksycznego cynku, oraz miedzi i ołowiu w trawach pierwszego pokosu.

Analiza składu chemicznego roślin testowych wykazała, że elementy śladowe zawarte w osadzie są przyswajane przez te rośliny w większości przypadków, jak wykazały badania, proporcjonalnie do stężenia tych pierwiastków w glebie testowej. Ze wzrostem dawki osadu, a zatem ze wzrostem koncentracji danego elementu w glebie, wzrasta jego zawartość w liściach roślin.

Stopień przyswajania elementów przez rośliny maleje z czasem wegetacji. Biorąc pod uwagę wszystkie analizowane wyniki badań można zasugerować rolniczą przydatność osadów ściekowych z wrocławskich pól irygacyjnych z zachowaniem ostrożności w wykorzystywaniu plonów z pierwszego okresu wegetacyjnego.

VORVERSUCHE ZUR LANDWIRTSCHAFTLICHEN VERWERTUNG DER KLÄRSCHLÄMME VON WROCŁAW

Eine Untersuchung der Klärschlämme von Wrocław hat erwiesen, daß sie reichlich biogene und organische Dungstoffe enthalten. Sie dürften sich daher für eine landwirtschaftliche Verwertung eignen. Andererseits, enthalten sie zahlreiche Spurenelemente, die zum Teil die Konzetration dieser Elemente in Naturdüngern und in Kommunalschlämmen wesentlich überschreiten. Höchste Konzentrationen weisen Zink und Kadmium auf. Beide Elemente gehören zu den fünf die Umwelt gefährdenden Schwermetallen (Cd, Zn, Mo, Ni, Cu) und eine landwirtschatliche Verwertung solcher Schlämme kann mit Recht beanstandet werden.

Die Verwendung dieser Schlämme zu Vegetationsversuchen, resultierte in guten Zuwachsraten der Pflanzenmasse. Es wurde jedoch festgestellt, daß ein wesentlicher Teil der Spurenelemente in einer von den Pflanzen gut aufnehmbarer Form vorliegt; die toxische Grenze von Zn, Cu und Pb wurde in Gräsern des ersten Mahdes überschritten.

Eine chemische Analyse der Testkulturen hat erwiesen, daß die im Schlamm enthaltenen Spurenelemente in den meisten Fällen gut durch die Pflanzen resorbiert werden und die Aufnahmerate proportional zu den Metallkonzetrationen im Testboden ist. Wächst die Schlammdose an, wird die Konzentration im Boden höher und das Resultat ist eine erhöhte Konzentration des gegebenen Elements in den Pflanzenblättern.

Die Aufnahmerate der Elemente durch Pflanzen klingt während der Vegetationsperiode langsam ab. Zieht man alle Testergebnisse in Betracht, so kann man wohl eine landwirtschftliche Verwertung der Klärschlämme aus den Vorbecken der Wrocławer Rieselfelder zulassen, aber bei der Verwertung des Mahdes der ersten Vegetationsperiode ist äusserste Vorsicht zu empfehlen.

ПРЕДВАРИТЕЛЬНЫЕ ИССЛЕДОВАНИЯ ПРИГОДНОСТИ ОСАДКОВ ИЗ СТОЧНЫХ ВОД ГОРОДА ВРОЦЛАВА ДЛЯ ЗЕМЛЕДЕЛИЯ

Анализ состава сточных осадков г. Вроцлава показал, что они изобилуют удобряющими органическими и биогенными веществами и, с этой точки зрения, оказываются вполне пригодными для земледелия. Однако, в них содержится ряд микроэлементов, часть которых отличается концентрацией, заметно превосходящей концентрацию в естественных удобрениях, в почвах и коммунальных осадках. Наиболее высокую концентрацию обнаруживают цинк и кадмий которые относятся к группе пяти главных элементов (Cd, Zn, Mo Ni и Cu), создающих потенциально самую большую опасность для природной среды. По этому соображению пригодность осадка для земледелия может вызывать сомнения и оговорки.

Вегетационные испытания выявили эффективное удобряющее действие осадков из вроцлавских сточных вод, измеряемое приращением растительной массы. С другой стороны, однако, они показали, что значительная часть микроэлементов в осадках — выступает в виде, обеспечивающем им усвояемость растениями, у которых, как показал анализ состава, отмечено превышение токсического уровня цинка, а также меди и свинца в травах первого укоса.

Анализ химического состава тест-растений показал, что микроэлементы в осадках усвояются этими растениями в большинстве случаев пропорционально концентрации этих элементов в испытательной почве. С увеличением дозы осадка, следовательно — с ростом концентрации данного элемента в почве, увеличивается содержание его в листьях растений.

Усвояемость элементов растениями снижается с продолжительностью вегетации. Принимая во внимание все проанализированные результаты испытаний, можно говорить о пригодности осадков из вроцлавских сточных вод для земледелия, но с соблюдением необходимой осторожности при использовании урожая от первого вегетационного периода.