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Influence Of Urban Wastewaters Sludge And Zeolite On The Yield Of Agricultural Crops And Accumulation Of Heavy Metals In Plant Growing Production.

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ABSTRACT

The effect and consequences of meliorative rate of urban wastewaters sludge (UWWS) and their combination with zeolite on the yield of raw crops rotation and heavy metal content in cash crop was studied in conditions of forest-steppe of the Middle Volga region, on meadow-chernozem soil characterized by a low level of fertility. The studies have shown that the application of wastewaters sludge without zeolite into the soil increased the yield of winter wheat by 1.34-2.14 t/ha or by 56.3-89.9 %. Application of wastewaters sludge with zeolite increased the yield of winter wheat by 1.45-2.20 t/ha or by 60.9-92.4%. It was proved that the corn yield on the background of wastewaters sludge aftereffect without zeolite increased by 1.56-2.52 t/ha or by 38.0-61.5 %, with zeolite it increased by 1.95-2.90 t/ha or by 47.6-68.8 %. Yield of spring wheat on the background of wastewaters sludge aftereffect without zeolite increased by 1.55-2.11 t/ha or by 52.5-71.1 %, with zeolite it increased by 2.00-2.53 t/ha or by 37.8-85.6 %. Application of WWS with rates from 100 to 180 t/ha increased the heavy metal content in grain part of the yield 1.2-3.9 times, with zeolite 1.1-3.8 times. Despite the increased heavy metal concentration in the grain part of the yield, their content was 1.1 -6.6 times lower than MAC in the first year of wastewaters sludge effect, 1.1 – 7.4 times lower in the third year.

Keywords: wastewater sludge, zeolite, winter wheat, corn, spring wheat, heavy metals.

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INTRODUCTION

The main purpose of agriculture at the present stage of its development is to increase the volume of crop production of high quality. Successful development of agricultural production in the forest-steppe zone of the Middle Volga region is impossible without solving the problem of preserving and increasing effective fertility [2-4, 8].

In the present time on the background of reduced application of mineral fertilizes due to their high price it is trending to study the possibility to use more cheap local materials as fertilizers and ameliorants. In Penza region, it is possible to use widely the following local resources as fertilizers and ameliorants: WWS, straw, zeolite, dolomite powder, marl, etc. Using WWS as organic-mineral fertilizers for agricultural crops is limited by the content of heavy metals [1, 5-7, 9, 10].

Regarding this, the development and introduction into the agricultural practice of technological methods of increasing the productivity of agricultural crops and the quality of crop production is a trending direction of modern agriculture.

MATERIALS AND METHODS

The purpose of the study was to examine the effect and after effect of ameliorative rate of urban wastewater sludge and its combination with zeolite on the yield of raw crops rotation and content of heavy metals in grain part of the yield.

In order to reach the set objective on meadow-chernozem soil the field experiment was conducted according to the following scheme: 1. Without UWWS and zeolite (control); 2. Zeolite 10 t/ha; 3. UWWS 100 t/ha; 4. UWWS 120 t/ha; 5. UWWS 140 t/ha; 6. UWWS 160 t/ha; 7. UWWS 180 t/ha; 8. UWWS 100 t/h + zeolite 10 t/ha; 9. UWWS 120 t/ha + zeolite 10 t/ha; 10. UWWS 140 t/ha + zeolite 10 t/ha; 11. UWWS 160 t/ha + zeolite 10 t/ha; 12. UWWS 180 t/ha + zeolite 10 t/ha.

The experiment repeated three times, variants in the experiment are placed by method of random repetitions; area of one record plot is 4m^2. Study object is a grain of raw crop rotation. Wastewaters sludge of city of Penza was used as biological ameliorant. Concentration of heavy metals in dry matter did not exceed the maximum allowable concentration (MAC). Content of cadmium made up 6.98 mg/kg , nickel – 89.45, lead – 46.14, zinc – 389.73, copper – 168.42, mangan-174.36 mg/kg of residual matter. Zeolite agronomical ore from Lunino deposit with content of clinoptilolite of 41% was used as a chemical ameliorant in the experiment.

RESULTS

The experiments conducted in 2015 demonstrated high effectiveness of UWWS application both in pure form and mixed with natural zeolite in the cultivation of winter wheat (table 1).

It was proved that the application of UWWS into the soil increased the yield of winter wheat depending on the rate of biological ameliorant by 1.34 (UWWS 100 t/ha) – 2.14 t/ha (UWWS 180 t/ha) or by 56.3-89.9 %.

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Table 1: Influence of urban wastewater sludge and zeolite on the yield of winter wheat

Variant	Winter wheat, 2015			Corn, 2016			Spring wheat, 2017		
	yield, t/ha	deviation from control		yield, t/ha	deviation from control		yield, t/ha	deviation from control	
		t/ha	%		t/ha	%		t/ha	%
1. Without zeolite and UWWS (control)	2.38	–	–	4.10	–	–	2.96	–	–
2. Zeolite 10 t/ha	2.49	0.11	4.8	4.47	0.37	9.0	3.48	0.52	17.6
3. UWWS 100 t/ha	3.72	1.34	56.3	5.66	1.56	38.0	4.51	1.55	52.5
4. UWWS 120 t/ha	3.99	1.61	67.6	5.98	1.88	45.9	4.68	1.72	58.3
5. UWWS 140 t/ha	4.23	1.85	77.7	6.29	2.19	53.4	4.82	1.86	62.7
6. UWWS 160 t/ha	4.46	2.08	87.4	6.58	2.48	6.5	5.05	2.09	70.6
7. UWWS 180 t/ha	4.52	2.14	89.9	6.62	2.52	61.5	5.07	2.11	71.1
8. UWWS 100 t/ha + zeolite 10 t/ha	3.83	1.45	60.9	6.08	1.95	47.6	4.96	2.00	67.6
9. UWWS 120 t/ha + zeolite 10 t/ha	4.10	1.72	72.3	6.34	2.24	54.6	5.05	2.09	70.8
10. UWWS 140 t/ha + zeolite 10 t/ha	4.31	1.93	81.1	6.62	2.53	61.7	5.19	2.23	75.3
11. UWWS 160 t/ha + zeolite 10 t/ha	4.52	2.14	89.9	6.92	2.82	68.8	5.48	2.52	85.2
12. UWWS 180 t/ha + zeolite 10 t/ha	4.58	2.20	92.4	7.00	2.90	70.7	5.49	2.53	85.6
least significant difference (LSD) p=0,05		0.20			0.28			0.17	

It should be noted that at one-component application of UWWS reliable differences were observed between variants with UWWS rates of 100 and 120 t/ha, 120 and 140 t/ha, 140 and 160 t/ha. Difference in winter wheat yield on variants with rate 160 and 180 t/ha of UWWS was not reliable and made up 0.06 t/ha at value of HCP_{05} 0.20 t/ha.

Application of UWWS combined with natural zeolite increased the winter wheat yield depending on the rate of bioameliorant by 1.45 (UWWS 100 t/ha + zeolite 10 t/ha) – 2.20 t/ha (UWWS 180 t/ha + zeolite 10 t/ha), or by 60.9-92.4 %. At over time growing of winter wheat yield and using different rates of UWWS in combination with zeolite the pattern analogous to application of pure UWWS was noted.

Corn yield in 2016 on variants with UWWS without zeolite changed within the range from 5.66 to 6.62 t/ha, reliably exceeding the control variant by 1.56-2.52 t/ha, or by 38.0-61.5 %. Application of UWWS in combination with zeolite increased the corn yield by 1.95-2.90 t/ha, or by 47.6-70.7 %. Maximum corn yield was obtained at application of UWWS with rates 160 and 180 both in pure and mixed with zeolite form (table 1).

On the background of urban wastewater sludge after effect the yield of spring wheat in 2017 varied depending on the sludge rate from 4.51 (UWWS 100 t/ha) to 5.07 t/ha (UWWS 180 t/ha), reliably exceeding the control by 1.55 – 2.11 t/ha, or by 52.5-71.1 %. Urban wastewater sludge after effect combined with zeolite reliably increased the yield of spring wheat by 2.00 (WWS 100 t/ha + zeolite 10 t/ha) – 2.53 t/ha (WWS 180 t/ha + zeolite 10 t/ha), or by 37.8-85.6 % (table 1).

Wastewater sludge, natural zeolite and complex application of sludge with zeolite definitely affected the content of heavy metals in the grain of winter wheat and corn (table 2).

Table 2: Content of heavy metals in the grain of winter wheat, mg/kg

Variant	Heavy metals names				
	Zn	Cu	Pb	Ni	Cd
1. Without zeolite and UWWS (control)	14.3	116	0.050	0.032	0.010
2. Zeolite 10 t/ha	11.2	1.01	0.030	0.024	0.006
3. UWWS 100 t/ha	20.6	1.70	0.112	0.070	0.014
4. UWWS 120 t/ha	24.3	2.05	0.133	0.085	0.016
5. UWWS 140 t/ha	28.5	2.37	0.152	0.099	0.021
6. UWWS 160 t/ha	32.0	2.70	0.175	0.114	0.024
7. UWWS 180 t/ha	34.5	3.02	0.194	0.130	0.026
8. UWWS 100 t/ha + zeolite 10 t/ha	17.1	1.52	0.108	0.062	0.011
9. UWWS 120 t/ha + zeolite 10 t/ha	20.9	1.80	0.129	0.076	0.012
10. UWWS 140 t/ha + zeolite 10 t/ha	25.0	2.12	0.149	0.086	0.016
11. UWWS 160 t/ha + zeolite 10 t/ha	28.2	2.46	0.171	0.101	0.019
12. UWWS 180 t/ha + zeolite 10 t/ha	30.9	2.75	0.190	0.118	0.020
MAC	50.0	10.0	0.2	0.3	0.03

Application of natural zeolite reduced the zinc content in the grain of winter wheat by 3.1 mg/kg, of copper – by 0.15, of lead – by 0.20, nickel – by 0.008, cadmium – by 0.004 mg/kg of grain.

Using of urban wastewater sludge without zeolite increased the content of zinc in the grain of winter wheat depending on the rate of sludge, by 6.3 (UWWS 100 t/ha) – 20.2 mg/kg (UWWS 180 t/ha), copper content – by 0.54-1.86 mg/kg, lead content – by 0.062-0.144 mg/kg, nickel content – by 0.038-0.098 mg/kg, cadmium content – by 0.004-0.016 mg/kg. Nevertheless, despite the significant increase of heavy metal concentration in the grain of winter wheat due to the effect of urban wastewater sludge, their contents was still lower than MAC.

Using of urban wastewater sludge combined with natural zeolite reduces the accumulation of heavy metals in the grain of winter wheat. Zinc content in the grain of wheat at complex use of sludge with zeolite decreased if compared with variants where the sludge was applied without a chemical ameliorant, by 3.4-3.8 mg/kg, copper content decreased by 0.24-0.28 mg/kg, of lead – by 0.003-0.004 mg/kg, of nickel – by 0.008-0.013 mg/kg, of cadmium – by 0.003-0.006 mg/kg.

In 2016 one-component use of natural zeolite reduced the accumulation of zinc in corn if compared with the control variant by на 4.6 mg/kg, copper – by 0.17 mg/kg, lead – by 0.030 mg/kg, nickel – by 0.009 mg/kg, of cadmium – by 0.004 mg/kg (table 3).

Table 3: Content of heavy metals in corn, mg/kg

Variant	Heavy metals names				
	Zn	Cu	Pb	Ni	Cd
1. Without zeolite and UWWS (control)	14.2	1.15	0.050	0.031	0.009
2. Zeolite 10 t/ha	10.9	0.98	0.020	0.022	0.005
3. UWWS 100 t/ha	20.0	1.67	0.101	0.064	0.013
4. UWWS 120 t/ha	23.9	2.03	0.121	0.080	0.015
5. UWWS 140 t/ha	28.0	2.36	0.141	0.092	0.016
6. UWWS 160 t/ha	31.4	2.68	0.163	0.110	0.019
7. UWWS 180 t/ha	33.6	3.00	0.183	0.124	0.022
8. UWWS 100 t/ha + zeolite 10 t/ha	16.0	1.40	0.070	0.050	0.010
9. UWWS 120 t/ha + zeolite 10 t/ha	20.0	1.76	0.099	0.060	0.011
10. UWWS 140 t/ha + zeolite 10 t/ha	23.9	2.09	0.121	0.071	0.013
11. UWWS 160 t/ha + zeolite 10 t/ha	27.4	2.39	0.132	0.092	0.015
12. UWWS 180 t/ha + zeolite 10 t/ha	29.5	2.68	0.153	0.102	0.018
MAC	50.0	10.0	0.2	0.3	0.03

In variant of urban wastewater sludge application without a chemical ameliorant the zinc content in corn varied depending on the rate of sludge within the range from 20.0 (UWWS 100 t/ha) to 33.6 mg/kg (UWWS 180 t/ha), of copper – from 1.67 to 3.00 mg/kg, lead – from 0.101 to 0.183 mg/kg, nickel – from 0.064 to 0.116 mg/kg, cadmium - from 0.013 to 0.022 mg/kg. Increase relative to control made up: for zinc 5.8 (UWWS 100 t/ha) – 19.4 mg/kg (UWWS 180 t/ha), for copper – 0.52-2.85 mg/kg, for lead – 0.051-0.133 mg/kg, for nickel – 0.033-0.093 mg/kg, for cadmium – 0.004-0.013 mg/kg.

Zinc content in corn at complex application of urban wastewater sludge with natural zeolite was lower if compared with variants where the sludge was used without a chemical ameliorant by 4.0-4.1 mg/kg, copper content – by 0.22-0.35 mg/kg, lead – by 0.20-0.32 mg/kg, nickel – by 0.014-0.022 mg/kg, cadmium – by 0.003-0.004 mg/kg.

Analysis of plants grown in 2017 on the background of different UWWS rates have shown that more significant accumulation of heavy metals in the grain part of the spring wheat was observed at application of urban wastewater sludge in maximum rates. Zinc content on the background of one-component effect of urban wastewater sludge with rate 180 t/ha exceeded control by 18.6 mg/kg, copper – by 1.82 mg/kg, lead – by 0.133 mg/kg, nickel - by 0.097 mg/kg, cadmium – by 0.012 mg/kg (table 4).

Table 4: Content of heavy metals in the grains of spring wheat, mg/kg

Variant	Heavy metals names				
	Zn	Cu	Pb	Ni	Cd
1. Without zeolite and UWWS (control)	14.1	1.13	0.049	0.030	0.009
2. Zeolite 10 t/ha	10.1	0.93	0.019	0.021	0.005
3. UWWS 100 t/ha	19.2	1.63	0.100	0.063	0.012
4. UWWS 120 t/ha	23.1	1.98	0.119	0.079	0.015
5. UWWS 140 t/ha	27.0	2.30	0.139	0.092	0.015
6. UWWS 160 t/ha	30.6	2.62	0.162	0.109	0.017
7. UWWS 180 t/ha	32.7	2.95	0.182	0.123	0.021
8. UWWS 100 t/ha + zeolite 10 t/ha	15.1	1.36	0.069	0.048	0.009
9. UWWS 120 t/ha + zeolite 10 t/ha	19.0	1.73	0.099	0.059	0.010
10. UWWS 140 t/ha + zeolite 10 t/ha	23.1	2.06	0.120	0.071	0.012
11. UWWS 160 t/ha + zeolite 10 t/ha	26.2	2.32	0.132	0.090	0.015
12. UWWS 180 t/ha + zeolite 10 t/ha	29.0	2.63	0.153	0.101	0.017
MAC	50.0	10.0	0.2	0.3	0.03

Natural zeolite decreased the accumulation of heavy metals in the grain part of spring wheat from the effect of wastewater sludge.

On the background of complex effect of urban wastewater sludge and zeolite zinc content was lower than at one-component application of sludge by 3.7-4.4 mg/kg, copper – by 0.25-0.32 mg/kg, lead – by 0.02-0.03 mg/kg, nickel – by 0.015-0.022 mg/kg, cadmium – by 0.002-0.005 mg/kg.

CONCLUSION

Thus, the application of ameliorative rates of urban wastewater sludge and their combination with natural zeolite significantly affected yield of raw crops rotation. Yield of winter wheat increased by 56.3-92.4 %, of corn – by 38.0-70.7 %, of spring wheat – by 52.5-85.6 %. Use of ameliorative rates of urban wastewater sludge increased the concentration of heavy metals in cash crop but their content did not exceed MAC.

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