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Ecological safety of ash-and-slag materials application in agriculture

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ABSTRACT

The results of field studies related to wheat growing with the use of ash-and-slag fertilizes are given. Concentration of some heave metals in wheat, depending on amount of ash-and-slag fertilizes, was observed. Results of mathematical processing of research results are discussed.

Present environmental problems connected with development of our civilization include a variety of aspects of all human activities, especially the industrial production. Official and unofficial sources give a lot of information on the environmental situation in the cities and country as a whole.

This work is devoted to research of one of the most important issues to resolve environmental problems of the Russian energy sector. The aim of the work was to investigate the environmental safety of ash and slag in such specific industry as agriculture.

Field trials with ash and slag materials (ASM) required special work on granulation of ash-and-slag mixtures before they are used as ameliorants or fertilizers. The reason is peculiarities of physical and chemical properties of ash-and-slag materials, being a fine dusting powder which is practically impossible to apply to the soil in doses by means of agricultural machinery in dry particulate form.

After granulating ash-and-slag materials two types of products have been obtained – ameliorant and fertilizer on the basis of ash and slag. These products represent cylindrical pellets of 5-8 mm in diameter, containing more than a half of the ash and slag materials and binder (the authors used gypsum as a binder). Nitrogen was also applied to the fertilizer in the form taken up by plants. Applying ash and slag fertilizer at a dose of 10 t/ha, the amount of nitrogen introduced was equivalent to 30 kg of the nitrogen applied by common mineral fertilizers. In general, all the works, associated with planning, trial establishment and field trials were carried out in accordance with the methodology of the field experiments [3].

Table 1. **Concentration of some heavy metals in the mixes of ash and slag from Omsk CHPPs***

	Mercury	Arsenic	Lead	Cadmium	Copper	Zinc	Nickel
Concentration of ash-and-slag, mg/kg	0,2	5,4	3,3	0,1	7,3	9,5	1,4
MPC/AAC** of elements, mg/kg	2	10	130	2	132	220	80

Notes: * - ash and slag mixes from Omsk CHPP-4 and CHPP-5, JSC TGC-11 were investigated

** - maximum permissible concentration (MPC) and approximately admissible concentration (AAC) according to GN 2.1.7.2511-09 [2] and GN 2.1.7.2041-06 [3]

First of all, the authors investigated concentration of some heavy metals in ash and slag from ash disposal areas of Omsk CHPP-4 and CHPP-5. Concentration of heavy metals is to be explored during the sanitary-epidemiological assessment of the soil in accordance with SanPin 2.1.7.1287-03. Thus, it was investigated the content of elements such as mercury, arsenic, lead, cadmium, copper, zinc and nickel in ash and slag. A purpose of this type of work is to get the contents of the heavy metals by means of atomic absorption method, being comparable with data obtained further, containing concentration of these elements in plant tissues, which has been determined using a similar method. The results are shown in table 1.

From data presented in table 1 it can be concluded that the slag mixtures of Omsk CHPPs 4 and 5 contain a certain amount of heavy metals, but their numbers are considerably lower than the ones set in MPC and AAC, suggesting their potential safety when used in the practice of agricultural production.

Further, after completion of harvesting and accounting of grain yield of spring wheat and carrots, concentrations of the same elements in the selected plant samples were investigated, as already mentioned, using the atomic absorption method. The obtained data were subjected to a careful statistical processing. The results of these types of work are shown in tables 2-4.

Table 2. **Effect of applying different doses of ash and slag ameliorant on the content of some heavy metals in grain of spring wheat**

№	Experience option	Maintenance of element, mg/kg			
		Lead	Cadmium	Copper	Zinc
1	Control	0,34	0,053	2,7	22,9
2	Ameliorant introduction 5 t/ha	0,33	0,050	3,1	23,5
3	Ameliorant introduction 10 t/ha	0,33	0,051	2,7	23,5
	The smallest essential difference (SED_{05})	–	–	0,017	–

Mathematical processing of the experimental data, presented in Table 2, allowed to determine the required values of indicators that can be used to identify the investigated dependence and make a conclusion about its character. So, an actual value of the Fisher's criteria at the 5% level of significance made the following: on lead - 0.067, cadmium - 0.591, zinc - 0.072; by this the Fisher's theoretical value was 6.94. Therefore, a reliable on-time relationship between the amount of ash and slag ameliorant introduced and the content of lead, cadmium and zinc in the grain of spring wheat hasn't been identified.

However, it should be noted that the actual value of copper according to the Fisher's criteria was 12.0, which exceeded the theoretical value. Thus, significant dependency is observed between the amount of ash and slag ameliorant applied and the copper content in grain of spring wheat. Further calculations showed that the index of the least significant difference for the 95% confidence level was 0,017 mg/kg. A character of the identified dependency is non-linear. Applying 5 t/ha it's observed the increase in concentration of the element in the grain tissues by 0.4 mg/kg compared to the control option, but with increase in the dose of ash and slag ameliorant up to 10 t/ha, the copper content is reduced to the control level.

Table 3. **Effect of different doses of ash and slag fertilizers on the content of some heavy metals in grain of spring wheat**

№	Experience option	Concentration of elements, mg/kg			
		Lead	Cadmium	Copper	Zinc
1	Control	0,34	0,053	2,7	22,9
2	Application of 5 t/ha of the fertilizer	0,36	0,049	3,0	24,1
3	Application of 10 t/ha of the fertilizer	0,32	0,054	3,0	24,0
	SED_{05}	–	–	–	–

Statistical processing of the data presented in Table 3 allowed to calculate mathematical indicators, characterizing the studied relationship. So the actual values of the Fisher's criteria at 5% level of significance made the following: for lead - 1,041, cadmium - 0,981, copper - 0.548, zinc - 0.174. By that the theoretical value of the Fisher's criteria is 6.94, so the reliable relationship between the amount of ash and slag fertilizers applied and the content of these heavy metals in grain of spring wheat has been identified.

Table 4. **The effect of applying different amounts of ash and slag on concentration of heavy metals in carrot**

№	Experience option	Concentration of elements, mg/kg			
		Lead	Cadmium	Copper	Zinc
1	Control	0,15	0,020	0,703	3,303
2	Application of 5 t/ha of ASM	0,10	0,019	1,003	2,100
3	Application of 10 t/ha of ASM	0,17	0,018	0,603	2,603
4	Application of 20 t/ha of ASM	0,19	0,017	0,503	2,097
	SED_{05}	0,0004	–	0,008	0,034

Processing the data, given in Table 4, allows to conclude that there is no any significant relationship between the amount of ash and slag mix, being in the soil, and cadmium content in the carrot tissue as the actual value of the Fisher's criteria on 5% significance level is below the theoretical one and makes 1,514.

I should be noted that the analysis revealed the presence of significant relationships between the amount of ash and slag material in the soil and the content of lead, copper and zinc in carrot. So the actual value of the Fisher's criteria made the following: for lead - 11.15, copper - 20.31, zinc - 33.54. By that the theoretical value of the Fisher criterion is 4.76. Indicators of the least significant difference for the investigated elements made 0.0004, 0.008 and 0.034 mg/kg for lead, copper and zinc, respectively.

The character of the identified dependencies is not the same. Thus, as for lead a practically linear relationship is observed. Application of 5 t/ha of ash and slag resulted in decrease in the lead content in carrot by 0,05 mg/kg compared to the control option; further increase in the amount of ash applied up to 10 and 20 t/ha leads to gradual increase in the lead content in the carrot to 0.19 mg/kg at the control parameter of 0.15 mg/kg.

Dependencies relating to copper and zinc are nonlinear. Thus, when applying 5 t/ha of ash and slag increases the copper content in carrot by 0.3 mg/kg compared to the control option, but with a further increase in the amount of ash and slag it is observed a gradual reduction of the copper concentration by 0.5 mg/kg compared to the dose of 5 t/ha. As for zinc, the dependence is somewhat different because when applying ash and slag doses it is firstly observed a gradual increase in the zinc concentration in carrot. Applying 10 t/ha of ash, the concentration of zinc is increased by 0.5 mg/kg compared to the option of 5 t/ha, however, the concentration is then gradually reduced, and at the option of 20 t/ha is already 2,097 mg/ha, which is 0.6 mg/kg lower than for the 5 t/ha. It should be noted that in all options while applying ash and slag, the total zinc content didn't exceed the control one, and was even much lower.

It should be noted that for the plant samples lead and cadmium are normalized. Their MPC is - 0.5 and 0.1 mg/kg, respectively. Copper and zinc in grains and roots are not standardized. Perhaps this is due to the fact that copper and zinc are microelements of plant nutrition and actively participate in the processes of metabolism. Therefore, their content depends not only on their concentration in the soil, but also on the physiological stage of plant development, the current status of a particular plant body and content of other nutrients in the environment.

However, the conducted investigations have been limited, since they were carried on only thanks to the enthusiasm of the authors and completely at their expense. Drawing up a complete picture on the environmental safety of applying ash and slag in agriculture, which can play the role of scientific and methodological basis in the implementation of technologies relating to use of ash and slag in this industry requires more expansive and detailed investigations.

CONCLUSION

The use of ash and slag materials for growing spring wheat and carrots showed that, in general, applying ash and slag at the dose below 10 t/ha there is no any reliable effect on the heavy metal content in the grain. However, the cultivation of carrots showed the existence of significant relationships between the content of elements such as lead, copper and zinc in the roots and the amount of ash and slag introduced. In this regard, for a more complete investigation of this issue it is necessary to conduct more extensive and detailed researches.

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