The role of diatomite in the cultivation of legume grasses in modified black soil models

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Abstract. In the Article, the data of vegetation model experiments conducted in field conditions are analyzed. As the baseline criterion of leached black soil contamination, the criterion of ecological and toxicological content of mobile forms of high-density metals in the soil corresponding to the bottom boundary of environmental disaster areas of soil contamination was used. The assessment of the effect of diatomite in contaminated agricultural soil in plantings of yellow sweet clover and purple medic test plants was conducted according to the quantity of metal accumulated by the crop. The use of diatomite in models of soils contaminated by high-density metals contributed to the decrease of accumulation in plants of sweet clover and medic of lead by 1.1-1.3 order of magnitude, of zinc 2.5-2.8 fold, and of cadmium 1.8-2.5 fold.

1. Introduction
The contamination of the environment in the contemporary technology intensive world is one of the most urgent ecological issues. The degradation of the soil continuum, changes in the physical and chemical and agricultural and ecological characteristics of soils has an adverse impact in living organisms and constitutes a serious hazard for humans [1-5].

Heavy metals, as one of the most dangerous and persistent compounds, enter the soil with emissions from industrial enterprises, vehicles, when fertilizing and using agrochemicals. The use of land in agriculture entails many negative consequences: the environmental condition of soils deteriorates, humus reserves are lost, acidity increases, the particle size distribution is facilitated, as a result of which the strongly bound forms of metals become mobile and readily available for plants [6, 7].

Contamination of cultivated soils, according to many researchers, has become a relatively common occurrence today and is likely to continue. The period of removal of toxicants from the soil layer reaches several thousand years, while there is no complete self-cleaning ability [8,9].

The excessive content of trace elements in soil and plants, their unfavorable ratio leads to the occurrence of endemic diseases of animals and humans, reducing the productivity and quality of crops [10].

Preservation and restoration of the fertility of soils contaminated with toxic compounds is now becoming a major economic task. To determine and control the degree of impact of heavy metals on plant and animal organisms, it is necessary to know the mechanism and regularity of their receipt [11]. The development of environmentally friendly methods and biotechnologies for the cultivation of industrial lands is a priority area of scientific research in recent decades.

Numerous studies have established the positive effect of introducing natural mineral components, including diatomite, on soils with anomalies in the content of heavy metals. Remediation with silicon-containing ameliorants makes it possible to ensure the sorption of mobile forms of heavy metals in the...
soil cover, to reduce their entry into plant products, to improve the agrophysical properties of soils, to increase the yield of agricultural crops and the quality of the products obtained [11-13].

The purpose of the research was to assess the effect of diatomite in contaminated black soil on the accumulation of high-density metals by crops of legume grasses.

Diatomite is a natural adsorbent made of siliceous skeletons of various species of diatomic algae [14], it has environment-friendly properties, high porosity, and acid resistance, which is especially important for acidic anthropic soils.

The cultivation of legume grasses on modified black soils was chosen by us for a reason: sweet clover and medic can give several hay crops in a vegetation period, contributing to the decontamination of soils and to the improvement of their fertility and agro-physical properties. The inclusion into cultivation agricultural technologies of biological preparations based on legume bacteria will have a favorable impact on the process of symbiosis and circulation of elements in the rhizosphere.

2. Subjects and Methods
Experimental researches were conducted in micro-field conditions. For creation of models, film vessels with a hole in the bottom part were used. The soil was taken from the upper plowing horizon in the quantity of 5 kg/vessel. As text objects, legume plants were chosen: yellow sweet clover (*Melilotus officinalis*) and purple medic (*Medicago sativa*). Preliminary, highly soluble salts of zinc, copper, lead and cadmium were separately dispensed in concentrations corresponding to the bottom boundary of “very severe” level of soil contamination [15]. The application of the diatomic ore material and the inoculation of seed with the bacterial preparation were done before seeding. For inoculation, strains of legume bacteria of Rizotrophine preparation were used [16, 17]. In laboratory conditions, the first hay crop of legume grasses of was analyzed. The quality of products was assessed according to VMDU-87 Regulation “Temporary Maximum Allowable Limit (MAL) of the Content of Certain Chemical Elements and of Gossypol in Feedstuff for Agricultural Animals and Feedstuff Additives” [18-20]. According to the content of metals in plants, the role of diatomite as the remediator of contaminated soils was assessed.

3. Results and discussions
Results of the analysis of the vegetative mass of yellow sweet clover and of purple medic are presented in figures 1-4. It can be noted that legume plants do not respond to the accumulation of metals uniformly. The greatest level of the green mass content of lead and zinc after the introduction of their salts into the soil is characteristic for yellow sweet clover. The introduction of cadmium into the model samples contributed to greater accumulation by medic plants. The quantity of copper was low and had no expressed gradation, both in the case with yellow sweet clover and medic.

The concentration of lead and copper (Figure 1-2) in medic varied insignificant across all researched variants and was below the level of the set standard: in the control variants its values were the lowest and were 1.88 and 3.69 mg/kg respectively; the addition into model variants of metal salts in the concentration of 6 LOC for lead and of 10 LOC of copper did not contribute to high accumulation of the content of these elements in the green mass; the greatest quantity was identified in the contaminated model without the ameliorant: 2.8 mg/kg of lead, 4.3 mg/kg of copper, while the LOC = 5 and 30 mg/kg respectively.

When reviewing the manner of accumulation of lead and copper by yellow sweet clover plants (Figure 1-2), the following can be mentioned: an increased level of accumulation of lead in model variants as compared to control variants: 4.8 – 5.42 mg/kg, while the control value was 1.17 mg/kg and MAL is 5 mg/kg; the application of copper in soil samples insignificantly increased its content in plants as compared to control samples, but remained low across all researched variants.

The content of cadmium and zinc in plants had the greatest excess in relation to MAL across all researched metals (Figure 3-4). The maximum quantity was found in the variant with application of highly soluble salts without absorbent and was: of cadmium: 0.67 mg/kg in medic plants and 0.48 in yellow sweet clover plants; of zinc: 140.05 mg/kg and 158.5 mg/kg respectively. The level of accumulation of cadmium in this variant was higher than the permissible level 2.23-fold for medic and 1.6-fold for yellow sweet clover; for lead the figures were 2.8-fold and 3.17-fold respectively.
Figure 1. Content of lead in plants, mg/kg.

Figure 2. Content of copper in plants, mg/kg.

Figure 3. Content of cadmium in plants, mg/kg.
Figure 4. Content of zinc in plants, mg/kg.

According to the data of analysis of the vegetative mass of medic and yellow sweet clover, the application of diatomite to soil samples contributed to the decrease in the content of lead, cadmium and zinc in plants. As compared to the contaminated variant without using the absorbent, the positive effect from using diatomite was the decrease by 11.4% of the concentration of the metal in medic and by 23% in yellow sweet clover; in the variant with cadmium the figures were 45.8% and 59.7% respectively; and for zinc they were 60.9% and 64% respectively.

4. Conclusion
Having assessed the results of researches conducted, it is possible to make a judgment about the possibility of use of diatomite in soils contaminated with high-density metals as the absorbent of lead, zinc and cadmium. The efficacy of this mineral component is reasoned by the 1 to 2.8-fold decrease of the content of toxicants in the vegetative mass of yellow sweet clover and medic. Speaking of the researched plants, yellow sweet clover, in given conditions, accumulated lead and zinc to greater extent, and medic accumulated more cadmium. The concentration of copper in plant samples had a low level of accumulation, which is, obviously, associated with the insignificant initial content of the element in the soil.

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