Analysis of Technogenic Risk in the Assessment of Dust Emissions from the Metallurgical Complex on Cultivated Crops

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Abstract. The paper presents empirical data on technogenic emissions from the Ust-Kamenogorsk metallurgical plant (East Kazakhstan). The study was conducted on dark chestnut soil and indicator test plants (cereals: Secale cereale L., Triticum aestivum L.; cruciferous: Brassica juncea L., Lepidium sativum L.; legumes: Pisum sativum L.). Artificial dust pollution of industrial enterprises was produced in the following proportions 0.1%, 0.5%, 1.0%, 5.0%, 10.0% and 15.0% to the air-dry mass of the soil. During the laying of the model experiments used plastic containers. The soil was composted for 7 days at room temperature under conditions of full field moisture capacity.

Environmental monitoring showed an intensive accumulation of lead in the root system of the test cultures. Eco-Toxicological analysis showed the phytotoxic effect of lead poisoning, which was manifested with minimal dust emission of industrial emissions (0.1% of dust in the soil), in which the biomass of germinated crops decreased by 11.1% relative to the control variant.

Analysis of the dust load of the lead-zinc plant showed that at doses of 0.1-1% heavy metal (HM): Cd, Pb,Cu,Zn, there is a decrease in the growth processes of the test crops studied. With an increase in HM in the dust load (1.0%), a high level of bioaccumulation of HM was noted in cereals (Secale cereale L.) and cruciferous (Brassica juncea L.). It was found that the least accumulation of zinc, copper and lead ions was observed in cereals (Triticum aestivum L.) and legumes (Pisum sativum L.), and cadmium ions – in cruciferous (Lepidium sativum L.).

With a further increase in the HM concentration of 5%, a phytotoxic effect was detected, which amounted to 78% and with a dust load of 10-15%, the death of all the studied plants was noted.

1. Introduction

Dust emissions from industrial enterprises are one of the technogenic factors that have a significant impact on the quality of the environment and public health [1]. Therefore, technogenic contamination with various toxicants, in particular heavy metals (HM), can lead to their accumulation in the upper horizons of the soil layer and have a significant impact on the vital activity of soil biota and vegetation [2]. This, in turn, can lead to a gradual change in the chemical and physical composition of soils and a violation of the unity of the geochemical environment, a failure of trophic connections and interaction of living organisms.
Research data show that most of the HM in the form of various oxides accumulates in the arable soil horizon and can pose a great threat to plants, reducing growth processes and biomass. The study of plant resistance to toxicants, using the method of seedlings, allows us to determine the optimal harmless and phytotoxic dose, at which the growth and development of the plant organism can be harmonious [3,4].

Thus, the purpose of the presented research is to identify and provide an eco-toxicological analysis of technogenic emissions of the Ust-Kamenogorsk (East Kazakhstan) metallurgical complex on the processes of accumulation of heavy metals in cultivated crops.

2. Materials and methods

To assess the impact of dust emissions from the Ust-Kamenogorsk metallurgical combine, we used a model vegetation experiment according to the method of Z. I. Zhurbitsky [5]. For this purpose, samples of dark chestnut medium – loamy soil of the arable horizon, which are located around the metallurgical complex, were selected at different distances.

The study was conducted on indicator test plants (cereals: *Secale cereale* L., *Triticum aestivum* L.; cruciferous: *Brassica juncea* L., *Lepidium sativum* L.; legumes: *Pisum sativum* L.).

Artificial dust pollution of industrial enterprises was produced in the following proportions 0.1%, 0.5%, 1.0%, 5.0%, 10.0% and 15.0% to the air-dry mass of the soil. During the laying of the model experiments used plastic containers. The soil was composted for 7 days at room temperature under conditions of full field moisture capacity.

3. Results and discussion

Kazakhstan (the Republic of Kazakhstan) is a state in the center of Eurasia, most of which belongs to Asia, and a smaller part to Europe. The area of the territory — 2 724 902 km². (figure)

The population, according to the state statistics Committee as of April 1, 2020, is 18,690,200 people [6]. The population density is one of the lowest: less than 6 people per square kilometer. The capital is Nur-Sultan. The largest city with a population of more than 1.8 million people is Alma-Ata. It ranks 9th in the world in terms of territory, 2nd among the CIS countries (after Russia), 42nd in terms of GDP by PPP, and 64th in terms of population. It is bordered to the North and West by Russia (7548.1 km long), to the East by China (1782.8 km), to the South by Kyrgyzstan (1241.6 km),
Uzbekistan (2351.4 km) and Turkmenistan (426 km). Administratively, it is divided into 14 regions and 3 cities of national significance: Nur-Sultan, Alma-Ata and Shymkent [7].

According to natural, climatic and economic conditions, Kazakhstan is divided into 5 major regions: East Kazakhstan, West Kazakhstan, North Kazakhstan, Central Kazakhstan, South Kazakhstan.

The territory of the metallurgical complex (JSC "KazZinc") is located in the city of Ust-Kamenogorsk in the studied territory of East Kazakhstan. A General view of the metallurgical complex located in Ust-Kamenogorsk is shown in figure 2.

![Metallurgical complex (JSC "KazZinc"), Ust-Kamenogorsk.](image)

Eco-toxicological analysis of the TM content in the dust emissions of the plant (JSC "KazZinc") showed that the total content of zinc was 58330 ±0.7 mg/kg; copper – 15600 ±0.5 mg/kg; lead – 20450 ±0.6 mg/kg and cadmium – 47000±0.8 mg/kg (table).

### Table 1. Comparative analysis between the HM content in the emissions of the East Kazakhstan region lead-zinc plant and the established MPC, mg/kg.

| Indicators                                                        | Cu      | Zn      | Pb      | Cd      |
|------------------------------------------------------------------|---------|---------|---------|---------|
| Lead-zinc plant                                                 | 15600±0,5 | 58330±0,7 | 20450±0,6 | 47000±0,8 |
| Clark in the soil (A. P. Vinogradov, 1962)                       | 20,0    | 50,0    | 10,0    | 0,5     |
| MPC (Kabata-Pendias A, 1989)                                     | 100     | 300     | 32,0    | 3,0     |
| MPC, in Kazakhstan (Joint order of the Ministry of health (No. 99 DD 30.01.2004) and the Ministry of environment protection of Kazakhstan (No. 21or 27.01.2004)) | 33,0 | 23,0 | 32,0 | 0,5 |

The analysis of the obtained data on the total content of HM (copper, zinc, lead and cadmium) in the soil when applying the specified doses of lead-zinc combine dust in comparison with the background soil revealed an excess of: Cu – 1.9-146.4 times (16.0 mg/kg); Zn – 2.7-2509.9 times (35.0 mg/kg); Pb – 1.84-139.6 times (22.0 mg/kg), Cd – 65.8-9412.3 times (0.73 mg/kg), and also corresponded to the MPC in the soil by Clark: 1.65-23.4 MPCcu, 1.1-29.3 MPCzn, 1.27-95.98 MPCpb and 16.0-2290.33 MPCcd.
According to the concentration of the gross content, the studied HM were arranged in the following descending order: Zn>Cd >Pb>Cu.

According to the concentration of the studied metals in various forms of compounds were arranged in the following descending order:

- in water-soluble form: Cd > Pb > Cu > Zn.
- in acid-soluble form: Cd > Cu > Zn > Pb.
- in exchange form: Cd > Pb > Zn > Cu.

The content of water-soluble forms of HM in dust emissions was 0.24-4.42%, acid-soluble 9.41 – 20.77% and exchange forms 1.41-8.84% of their total content.

The largest percentage of water-soluble and acid-soluble forms of compounds from the total amount accounted for cadmium and copper, the exchange form for lead and cadmium.

Analysis of the dust load of the lead-zinc plant showed:

- at doses of 0.1-1%, there was a decrease in the growth processes of the test cultures studied;
- at a dust load (1.0%), a high level of TM bioaccumulation was observed in cereals (*Secale cereale* L.) and cruciferous (*Brassica juncea* L.). The weakest accumulation of zinc, copper and lead ions was found in cereals (*Triticum aestivum* L.) and legumes (*Pisum sativum* L.), and cadmium ions – in cruciferous (*Lepidium sativum* L.);
- at a dust load of 5%, a phytotoxic effect was detected, which is 78%;
- with an increase in the dose of dust load (10-15%), the death of the studied plants is noted.

Taking into account the amount of dust emissions per year (217.14 t/year) and the content of HM in them, we calculated the amount of HM entering the atmosphere with dust emissions from the metallurgical production of JSC KazZinc.

Calculations have established that the dust emissions of the lead-zinc plant in the atmosphere of Ust-Kamenogorsk receives 3387 kg of zinc, 12666 kg of copper 4441 kg of lead and 10 206 kg of cadmium per year.

4. Conclusion

Thus, the analysis of the dust load of the lead-zinc plant showed that at doses of 0.1-1% HM (Cd, Pb,Cu,Zn), there is a decrease in the growth processes of the studied test crops; with an increase in HM in the dust load (1.0%), a high level of bioaccumulation of HM was noted in cereals (*Secale cereale* L.) and cruciferous (*Brassica juncea* L.). The weakest accumulation of zinc, copper and lead ions was found in cereals (*Triticum aestivum* L.) and legumes (*Pisum sativum* L.), and cadmium ions – in cruciferous (*Lepidium sativum* L.). With a further increase in the concentration of HM at a dust load of 5%, a phytotoxic effect was detected, which amounted to 78%, and at a dust load of 10-15%, the death of the studied plants was noted.

5. References

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Acknowledgments
The publication has been prepared with the support of the “RUDN University Program 5-100”.