Accumulation of heavy metals in melliferous plants in the territory of Nagaybaksy district of Chelyabinsk region

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Abstract. Due to rapid development of industry and transportation, mining intensity, and active use of chemicals in agriculture there is a sharp rise in the level of heavy metal pollution of natural environment, which mainly affects soil and plants. Excessive accumulation can lead to the destruction of the natural complex integrity. The pollution of heavy metal environment is one of the most pressing environmental problems. It has become particularly relevant in recent years since it closely intersects with another global problem – getting ecologically pure foodstuff. The studies concern the heavy metal content of the six species of inflorescence melliferous plants summer temporary generation grown in the territories around apiaries of Nagaybaksy district.

1. Introduction

In the conditions of large-scale development of industry and transportation, mining intensity and active use of chemicals in agriculture there is a sharp rise in the level of heavy metal pollution of the environment, which mainly affects soil and plants. The study of consequences of technogenic accumulation of heavy metals and anthropogenic pollution of the environment became critical for health and safety of the population [1-3].

Heavy metals (HM) are biochemically active technogenic agents influencing living organisms. They belong to the group of persistent pollutants, but many of them are extremely necessary for living organisms. Being “microelements” they actively participate in biochemical processes. Under natural conditions both soils and plants contain a certain amount of HM. However, their excessive accumulation may destruct the integrity of a natural complex. Plants serve the intermediate link for metals to transfer from water, air and, mainly, soil into bodies of humans and animals and thus cause the need to develop methods to protect food chains against intolerable concentration of toxic agents [4].

The most toxic heavy metals are the salts of cadmium, lead, zinc, nickel, copper, and cobalt having carcinogenic properties. Their migration and redistribution in ecosystem components depends both on the whole complex of natural factors and on intensity and nature of technogenesis.

Environmental pollution with heavy metals is one of the major environmental problems. It has become particularly relevant in recent years since it closely intersects with another global problem – getting ecologically pure foodstuff [5, 6].

In the course of their activity honey bees are closely connected with external habitat. The state of a bee family depends on abiotic, biotic and anthropogenic factors of the environment. It is possible to assess the ecological situation on the basis of the state of bee families, survival rate of insects, quantity and quality of nectar or pollen collected by bees.
The purpose of the study was to analyze the accumulation of heavy metals in melliferous plants from territories subject to anthropogenic influence.

Thus, the following tasks were defined:
1. To give physiographic characteristic of the region.
2. To analyze the content of salts of heavy metals in biogeocenosis objects.
3. To give complex assessment of pollution of melliferous plants with heavy metals.

2. Material and methods
The material of the study included inflorescence samples of melliferous taken from two private apiaries located in the territory of Nagaybasky district of Chelyabinsk Region. Nagaybasky district is located in the vast territory of a watershed between the basins of the Ural and Tobol Rivers in the southern part of the Trans-Ural region. The soil cover of the area is quite diverse and is in direct dependence on soil formation, climate, relief, vegetation, hydrogeology, source rocks. Chernozems occupying 75% of the area prevail in the region. JSC Aleksandrinsky Mining Company that produces and processes copper-bearing ore from one of the largest copper-zinc fields in Russia – Aleksandrinsky field, as well as from Chebachy field are powerful sources of technogenic pollution here. The choice of private apiaries was determined according to the following parameters:

1. Sovkhozny village (SG 1) located at a distance of 2-5 km south-east from the main pollution source – Aleksandrinsky Mining Company.
2. Berezovaya Roscha village (SG 2) located at a distance of 11-13 km north-east from JSC Aleksandrinsky Mining Company. The chosen apiaries were located in rural adjacent territory of the private sector. The main melliferous plants in Nagaybasky district are wild melilot, white and aliske clover, bird vetch, yellow alfalfa, brown knapweed. We studied the content of heavy metals in inflorescences of two species of melliferous plants – wild melilot, yellow alfalfa of summer temporary generation growing on chosen territories around apiaries of Nagaybasky district. The inflorescences of melliferous plants were cut off in full blossom in dry weather and were placed in clean paper bags, and then brought to laboratory for further analysis. The analysis of digital material was based on the list of maximum permissible concentration (MPC), maximum permissible level (MPL) and hygiene and sanitation regulations on the content of harmful substances in the studied objects.

The samples were preliminary transferred into a soluble state via the “dry” method. The content of nine heavy metals of various hazard class was defined: first hazard class (Pb, Zn, Cd), second hazard class (Cu, Ni, Co, Cr) and third hazard class (Mn).

The content of mobile forms of heavy metals was defined via atomic absorption method on KVANT-2A spectrophotometer in accordance with GOST 26929-94 “Raw materials and foodstuff. Preparation of samples. Mineralization to define the content of toxic elements” and GOST 30178-96 “Raw materials and foodstuff. Atomic absorption method for defining toxic elements”. The content of heavy metals was defined based on measurements of resonant absorption of light of a certain wavelength by metal atoms in excited atomic state.

The environmental and economic assessment of territories was based on the method of rapid evaluation of environmental situation proposed by V.G. Kashkovsky and A.A. Plakhova and simultaneous observation over the quantity of bees on melliferous plants. The number of insects was observed on two soil grounds (SG): SG 1 – Sovkhozny village and SG 2 – Berezovaya Roscha village used by private beekeepers and filled with melliferous plants. The conclusion on ecological cleanness was made against the difference between the established number of insect species of studied soil grounds: the area with more species of insects was considered environmentally friendly and safe.

3. Results
The study revealed that the bees are mostly active on inflorescences of melliferous plants in intensive beekeeping territories of Nagaybasky district (wild melilot, yellow alfalfa) (Table 1).
**Table 1. Number of insects of different species acting within melliferous plants, pcs. ( \( \bar{X} \pm Sx \) )**

| Species      | SG 1   | SG 2   |
|--------------|--------|--------|
| Bumblebee    | 0      | 5.02±0.05 |
| Wasp         | 5.64±0.28 | 8.48±0.19 |
| Bee          | 10.32±0.18 | 22.04±0.36 |

According to obtained data, the bees most actively visited melliferous plants in Berezovaya Roscha village (SG 2) and their number over 3 hours made 22.04±0.36 pieces. In Sovkhozny village (SG 1) this indicator was much lower and made 10.32±0.18 pieces, which is 2.1 times lower in relation to the first soil ground. This is caused by the fact that these insects can only prevail in environmentally-safe area. Analyzing the attendance of melliferous plants by bumblebees, we shall note their low number. Thus, the attendance of melliferous plants by bumblebees in SG 2 (Berezovaya Roscha village) made 5.02±0.05 pieces. In Sovkhozny village their number was not recorded. It appears probable that direct proximity of Sovkhozny village (SG 1) at a distance of 2.5 km south-east to the main pollution source Aleksandrinsky Mining Company leads to the death of insects useful for beekeeping and the total absence of bumblebees within the observed period. This fact may indicate the environmental trouble of the studied territory.

Regarding the content of heavy metals in inflorescences of melliferous plants it was established that except iron, cadmium and zinc the content of heavy metals in the samples of melliferous plants did not exceed the maximum permissible level (MPL) (Table 2). However, it was revealed that the content of heavy metals in flowers of melliferous plants of SG 1 is higher than those of SG 2 regarding all nine elements. Thus, high content of iron in the sample from the apiary of Sovkhozny village was established, where its content made 130.1±0.19 mg/kg, which in percentage terms made 30.1% of MPL, the content of zinc made 57.41±0.17, which exceeded the MPL by 7%. The accumulation of copper, cobalt, lead, manganese, nickel happens in two soil grounds is not even. The content of heavy metals in inflorescences of melliferous plants of the first soil ground exceed the second 1-3 times. The excess of the MPL on cadmium is recorded in samples of inflorescences from the apiary of SG 1 and made 0.50 mg/kg or 16%. The obtained data shows that the excess of heavy metals is recorded in SG 1 – Sovkhozny village.

Thus, on two soil grounds the amount of pollutants in inflorescences of melliferous plants is mainly caused by environmental condition in locations of apiaries and results from close- and long-range transport of anthropogenic pollutants. The environmental and economic assessment of chosen territories proves that on the second soil ground (Berezovaya Roscha village) the anthropogenic environmental influence is minimum, there are numerous species of nectarivorous and palynivore insects confirming relative environmental safety of the area.

**Table 2. Content of heavy metals in inflorescences of melliferous plants, mg/kg (n =10)**

| Chemical element | MPL   | SG 1         | SG 2         |
|------------------|-------|--------------|--------------|
| Iron             | 100.0 | 130.1±0.19   | 57.41±0.20   |
| Copper           | 30.0-100.0 | 31.84±0.20   | 10.81±0.19   |
| Zinc             | 50.0-100.0 | 57.41±0.17   | 17.16±0.22   |
| Cobalt           | 1.0-2.0 | 0.13±0.10    | 0.05±0.17    |
| Lead             | 5.0   | 2.42±0.02    | 0.64±0.19    |
| Manganese        | 60.0-80.0 | 31.84±0.16   | 10.81±0.2    |
| Chrome           | 20.0-50.0 | 0            | 0            |
| Cadmium          | 0.3   | 0.50±0.11    | 0.009±0.14   |
| Nickel           | 1.0-3.0 | 0.73±0.2     | 0.53±0.22    |
Direct proximity of Sovkhozny village to Aleksandrinsky Mining Company negatively influences the number and biodiversity of insects, namely bees and bumblebees. These species of insects only prevail in nature in case of favorable conditions for reproduction and ecologically safe area.

4. Conclusion
1. The growth of technogenic pollution of agroecosystems fosters the accumulation of heavy metals in inflorescences of melliferous plants. Plants have different extent of accumulation of chemical elements. In many respects the quantitative composition of chemical elements in plants depends on geographic location of melliferous plants in relation to the pollution source.
2. The small number of bumblebees and honey bees or their total absence on flowers of melliferous plants may indicate the environmental trouble of territories.

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