Features of accumulation of trace elements in the soil-honey plants system in the Tyumen region

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Abstract: The life activity of living organisms depends largely on the ecological state of their habitat. Based on the environmental monitoring of apiaries in the Tyumen region, the content of chemical elements in the soil and honey plants was studied. Based on the results of assessing the content of trace elements in the soil and plants, the soil contamination coefficient (CO) and the biological absorption coefficient (BAC) of plants were calculated. Studies have shown that the level of chemical elements in the soils and plants of apiaries in certain areas differs significantly. The reason for this is the natural and geographical conditions of these areas, as well as the proximity of anthropogenic sources of pollution. In spring, the content of the studied elements in the soil and in honey plants is higher than in summer. This is due to the fact that the soil receives pollutants that have accumulated in the snow cover during the winter due to atmospheric transport. The analysis of the obtained results showed that apiaries of Tyumen, Yarkovsky and Nizhnetavdinsky administrative districts of the Tyumen region are experiencing the greatest technogenic load. The apiaries of Berdyuzhsky and Sladkovsky districts can be considered environmentally safe. The flowers of coltsfoot (Tussilago farfara L), dandelion, woundwort (Stachus gen.) and willow herb (Epilobium augustifolium) have a low BAC of the studied elements from honeybees.

1. Introduction

As we know, the body for its growth and development takes the necessary substances, including mineral from the environment. The latter play a large morphological and physiological role in the life of living organisms. They enter the cell structure and its membranes, create an osmotic pressure, due to which metabolic processes occur in the cell and intercellular space. But as a result of environmental pollution, a significant decrease in vital processes occurs, which creates the prerequisites for oppressing resistance and the development of diseases in various combinations and associations [1, 6]. Pollutants include heavy metals, radionuclides and pesticides. The main factor contributing to the accumulation of substances in products, reducing the vital activity of the body and the sanitary quality of their products, is the high level of technogenic contamination of the environment [2, 7].

The relevance of the issues discussed, as well as the shortage of information on the migration of chemicals in the soil – honey plant chain, necessitate comprehensive studies to evaluate and further monitor the ecological state of apiaries in the Tyumen Region.
Purpose of the work. Ecological assessment of the content of chemical elements in the system “soil - honey plants” of various apiaries of the Tyumen region.

2. Materials and research methods
The work was performed at the Department of Anatomy and Physiology at the Federal State Budgetary Educational Institution of Higher Education “State Agrarian University of the Northern Trans-Urals” and at the Tyumen Regional Veterinary Laboratory.

In the process of the research in the areas of plots located near apiaries in the Tyumen, Yarkovsky, Berdyuzh, Nizhnetavdinsky, Yalutorovsky and Sladkovsky districts of the Tyumen region, soil and flowers of honey plants growing on them were selected in spring and summer. White willow, coltsfoot, lungwort, medicinal dandelion, crab apple and pea-tree were used as spring honey plants. Common plant species were used as summer honey plants: small-leaved linden, pink clover, white clover, red clover, woundwort, tufted vetch, white melilot, yellow melilot, willow herb, great burdock, canada thistle, which bloom in summer.

In order to determine the content of chemical elements, soil and plant samples were previously subjected to autoclave mineralization using ANKON-AT-2 device. Mobile forms of heavy metals in soil samples were extracted with an acetate-buffer solution with pH 4.8, after which the content of chemical elements in the extract and mineralization was determined by the atomic absorption method on AAS-3 and "Quant-Z.ETA" spectrophotometer (State standard (GOST) 30692-2000 ) in the regional veterinary laboratory of the city of Tyumen.

Studies included the calculation of the contamination coefficient, which is determined by the formula (1):

\[ CO = \frac{C}{MAC} \]  (1),

where CO is the soil chemical contamination coefficient
C is the actual content of contamination components in the research object;
MAC is the maximum allowable concentration of a chemical in an object of research, according to the "Methodological guidelines for assessing the degree of danger of soil contamination by chemicals” (1987).

To assess the migration of heavy metals in the soil – plant system, the biological absorption coefficient (BAC) was calculated, which is equal to the ratio of the element content in the plant ash to its soil content in the soil.

At the end of the research, statistical processing of the obtained data was carried out.

3. Discussion of the results
In order to study the ecological conditions of the bee habitat, studies were conducted on soil and honey plants in the Tyumen, Yarkovsky, Berdyuzh, Nizhnetavdinsky, Yalutorovsky and Sladkovsky districts of the Tyumen region. Different soil covers are found in these areas, which in turn have a significant contribution to the content of minerals in them, as well as to the accumulation of chemicals in honey plants. So, on the territory of the Tyumen region, the soil cover is represented by soddy-strongly podzolic, contact-gley and gley, meadow-boggy, gray forest solodice, peaty-gley, meadow- chernozem mild, soddy-weakly podzolic and meadow-chernozem soils. In the floodplain of the Tura River, floodplain meadow and soddy-weakly podzolic soils are placed.

In the Berdyuzh district, the most common soils are gray forest and solonetzes, and there are also solonetze chernozems.

In the Nizhnetavdinsky region, there are soils - soddy - podzolic with a second humus horizon, marsh, marsh - podzolic and soddy - gleyed.

Soils of the Yalutorovsky district are represented by chernozems, gray forest, alluvial, and meadow.

Among the soils of the Sladkovsky region, solonetze soils and solonetzes in combination with solods and solonchaks dominate. Meadow alkaline soils make up 28, meadow marshy soils - 13, solods - 18 percent.
Widespread soils of the Yarkovsky district are soddy-podzolic and gray forest soils. Soddy-podzolic soils are formed under birch grass mixed with pine and spruce forests. Soils of this type are represented by soddy-strongly podzolic, soddy-weakly podzolic. On the floodplain terraces of Tura and Tobol, which have a slight slope to the south, podzolized chernozems are found. Meadow-marshy soils are formed on the lowered relief elements of floodplains and low terraces, where an increased amount of precipitation and soil moisture leads to swamping of the land. The rest of the district is characterized by a wide distribution of hydromorphic soils, such as bog soils, which are formed on bare rocks and occupy reduced areas of terrace surfaces [5].

Despite the variety of soil cover in the areas, apiaries are mainly located on the chernozem territories. Therefore, the studied soil samples from the reserve areas were chernozems. As a result of the studies, it was revealed that the content of heavy metals in the soils of spring and summer selection was significantly different. So, the largest amount of lead was recorded in the Tyumen region, in spring the average content in the samples was $2.85 \pm 0.21$ mg / kg, in summer $2.35 \pm 0.11$ mg / kg. In soil samples of the Yalutorovsk region, the average spring lead content was $2.70 \pm 0.32$ mg / kg, and the summer content was $2.17 \pm 0.12$ mg / kg. The smallest lead content was observed in soil samples from the Sladkovsky and Berdyuzh districts. In spring samples, the average level of this element was $1.50 \pm 0.09$ mg / kg and $1.81 \pm 0.11$ mg / kg. In summer samples, the amount of lead in these areas was significantly low and averaged $0.73 \pm 0.02$ mg / kg and $0.85 \pm 0.03$ mg / kg.

According to the studies, it was found that the cadmium level in spring soil samples varied from $0.02$ mg / kg to $0.23$ mg / kg, the lowest indicator was recorded in samples from the Berdyuzh district: $0.02 - 0.03$ mg / kg, the highest - in Yarkovsky - $0.23 \pm 0.01$ mg / kg. In the samples of the summer period, the cadmium value ranged from $0.01-0.12$ mg / kg, the maximum value was $0.12 \pm 0.006$ mg / kg in the Tyumen region.

The average indication of arsenic in spring soil samples of the studied areas was $0.24 \pm 0.003$ mg / kg, in summer - $0.45 \pm 0.034$ mg / kg, which is 1.7 times lower than the first. The results of the studies showed that a significant difference in the average copper content in spring and summer soil samples of the apiary area was not observed. So, the average content of this element in samples of the spring period was $5.59 \pm 0.13$ mg / kg, and summer - $5.35 \pm 0.13$ mg / kg. But in some areas, the copper content of soil samples varied significantly. The maximum value was observed in spring samples of the Tyumen region. On average, the amount of this element was in Tyumen - $6.80 \pm 0.22$ mg / kg, Yalutorovsk - $6.21 \pm 0.21$ mg / kg and Nizhnetavdinsky district - $5.13 \pm 0.17$ mg / kg. In summer samples, a high copper content was recorded in Tyumen - $6.18 \pm 0.12$ mg / kg, Yalutorovsk - $5.87 \pm 0.14$ mg / kg and Yarkovsky - $5.52 \pm 0.14$ mg / kg. The smallest amount of copper in the spring was observed in the Ber-Duzhy district - $3.66 \pm 0.13$ mg / kg.

The average zinc reading in spring soil samples was $18.70 \pm 0.12$ mg / kg, summertime - $15.13 \pm 1.17$ mg / kg. The maximum value of zinc in spring soil samples was in samples of the Tyumen region, on average, it was $21.17 \pm 1.21$ mg / kg, the minimum value in the Berdyuzh district was $15.63 \pm 1.44$ mg / kg. In summer samples, the amount of this metal, respectively, was $19.03 \pm 1.0$ mg / kg and $16.69 \pm 1.35$ mg / kg.

Thus, studies showed that the content of heavy metals and arsenic in the soils of apiaries in different areas is different. The reason for this is the different level of anthropogenic pressure in these areas, as well as natural factors. Thus, it was found that the level of heavy metals is higher in spring soil samples than in summer samples.

The value of chemicals in the soil is higher if the coefficient of chemical contamination (CO) exceeds one. The data obtained indicate that the CO of lead, cadmium, zinc and arsenic was lower than unity. In the soils of apiaries of all administrative regions in the spring and summer, the CO of copper slightly exceeded one. A comparatively high CO of copper was observed in spring samples of the Tyumen
(2.20), Nizhnetavdinsky (2.19), Yalutorovsky (2.00), in the summer period of the Tyumen (1.93), Yalutorovsky (1.95) and Yarkovsky (1.84) regions.

The results of the work showed that heavy metals were determined in a larger number in the soils of the Tyumen, Yalutorovsky, Yarkovsky regions, in a smaller number – in the Berdyuzhsky and Sladkovsky regions.

Further work was devoted to the determination of the biological absorption coefficient of heavy metals by honey plants. The level of chemical elements in plants depends not only on the geographical area of growth, but also on the cumulative characteristics of plants, including the phase of development and flowering [8]. For honey plants, the last phase is of particular importance.

We found that the coefficient of biological absorption of lead by the flowers of spring honey plants in the region was in the range from 0.01 to 0.93. The high cumulative activity was shown by flowers of crab tree and pea tree (0.92), the low - by coltsfoot (0.01). The biological absorption coefficient of cadmium ranged from 0.08 to 0.25, apple flowers had high rates. Arsenic was more actively absorbed by flowers of pea tree (0.83), copper - of crab apple (1.49), pea tree (1.32), zinc - lungwort (1.44), crab apple (1.21), pea-tree (1.19) and white willow (1.01).

Based on the accumulation of HM by spring honey plants, the following decreasing rows can be constructed:

\[ \text{Pb} = \text{pea tree} > \text{crab apple} > \text{white willow} > \text{medunic dandelion} > \text{coltsfoot}; \]
\[ \text{Cd} = \text{crab apple} > \text{dandelion} > \text{lungwort} > \text{white willow} > \text{coltsfoot} > \text{pea tree}; \]
\[ \text{As} = \text{pea tree} > \text{medunic dandelion} > \text{crab apple} > \text{lungwort} > \text{coltsfoot} > \text{white willow}; \]
\[ \text{Cu} = \text{crab apple} > \text{pea tree} > \text{coltsfoot} > \text{medunic dandelion} > \text{white willow} > \text{lungwort} \]
\[ \text{Zn} = \text{lungwort} > \text{crab apple} > \text{pea tree} > \text{white willow} > \text{medunic dandelion} = \text{coltsfoot}. \]

The biological absorption coefficient of HM by summer honey plants in the region varied within different limits. Pink clover flowers (0.57) had a high level of lead accumulation, field burdock (0.08) had a low level. Cadmium was more intensively absorbed by flowers of linden (0.18), slightly by flowers of woundwort (0.06), of pink and white clover (0.06), of white and yellow melilot (0.06). Arsenic was actively absorbed by the colors of tufted vetch (1.81), zinc by willow herb (2.42), copper by flowers of yellow melilot (1.34). All honey plants exhibit high BAC to copper (0.97 - 1.34).

Based on the accumulation of HM by summer honey plants, the following decreasing rows can be constructed:

\[ \text{Pb} = \text{pink clover} > \text{medunic} > \text{canada thistle} > \text{linden} > \text{dandelion} > \text{willow herb} > \text{red clover} > \text{woundwort} > \text{white clover} > \text{field burdock} > \text{tufted vetch} > \text{white melilot} > \text{yellow melilot}; \]
\[ \text{Cd} = \text{linden} > \text{canada thistle} > \text{red clover} > \text{medunic} > \text{willow herb} > \text{woundwort} = \text{pink clover} = \text{white clover} = \text{white melilot} = \text{yellow melilot} = \text{field burdock} = \text{tufted vetch} = \text{dandelion}; \]
\[ \text{As} = \text{tufted vetch} > \text{red clover} > \text{medunic} > \text{canada thistle} > \text{woundwort} > \text{linden} > \text{willow herb} > \text{pink clover} > \text{dandelion} > \text{white clover} = \text{field burdock} > \text{white melilot} > \text{yellow melilot}; \]
\[ \text{Cu} = \text{yellow melilot} > \text{white clover} > \text{red clover} > \text{medunic} > \text{tufted vetch} > \text{field burdock} > \text{white melilot} > \text{willow herb} = \text{pink clover} = \text{dandelion} > \text{linden} = \text{woundwort} > \text{canada thistle}; \]
\[ \text{Zn} = \text{willow herb} > \text{yellow melilot} > \text{tufted vetch} > \text{white melilot} > \text{field burdock} > \text{medunic} > \text{pink clover} > \text{linden} = \text{woundwort} > \text{red clover} > \text{canada thistle} = \text{white clover} > \text{dandelion}. \]

Thus, the analysis of the obtained results showed that the flowers of coltsfoot, dandelion, woundwort and willow herb possess low or relatively low biological absorbability for the studied elements from honey plants. This is an important indicator of the selection of honey plants for honey collection of bees.

4. Conclusion
The vital activity of living organisms largely depends on the ecological state of their environment. Ecological monitoring of apiaries of the Tyumen region was carried out, the content of chemical elements in the soil and their accumulation in the flowers of honey plants were studied. Based on the results of assessing the content of trace elements in the soil, the soil contamination coefficient (CO) was calculated.

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The analysis of the results indicates that the CO of lead, cadmium, zinc and arsenic was below one. In the soils of apiaries of all administrative regions in spring and summer, the KO of copper exceeded one. High CO of copper was observed in spring samples of the Tyumen (2.20), Nizhnetavdinsky (2.19), Yalutorovskiy (2.00), in summer - of Tyumen (1.93), Yalutorovsky (1.95) and Yarkovsky (1.84) regions.

In plants, the biological absorption coefficient (BAC) of plants was calculated. Studies showed that the level of chemical elements in apiary plants in individual areas varies significantly. The reason for this is the geographical conditions of these areas, the proximity of anthropogenic sources of pollution, and species features and periods of plant growth. In spring, the content of the studied elements in the soil and in honey plants is higher than in summer. This is due to the fact that in spring pollutants enter the soil to a greater extent, which accumulated in snow cover during the winter period due to atmospheric transfer.

We also found that the coefficient of biological absorption of lead by flowers of spring honey plants in the region ranged from 0.01 to 0.92. Flowers of crab apple and pea tree (0.92) were distinguished by a high coefficient of biological absorption coefficient, coltsfoot (0.01) – by low. The biological absorption coefficient of cadmium ranged from 0.075 to 0.25; flowers of apple had high rates. Arsenic was more actively absorbed by the flowers of pea tree (0.83), copper - by crab apple (1.49), small-leaved acacia tree (1.32), zinc - by lungwort (1.44), forest apple tree (1.21), pea tree (1.19) and white willow (1.01)

Based on the accumulation of elements by spring honey plants, the following descending rows can be constructed:

- Pb – pea tree = crab apple> white willow> - willow herb > medicinal dandelion> coltsfoot
- Cd - crab apple > dandelion> willow herb > white willow> coltsfoot> pea tree
- As – pea tree > medicinal dandelion> crab apple > willow herb> coltsfoot> white willow
- Cu - crab apple > pea > tree> coltsfoot> medicinal dandelion> white willow> willow herb
- Zn - lungwort> crab apple> pea tree> white willow> medicinal dandelion = coltsfoot

The biological absorption coefficient of HM by summer honey plants in the region also varied widely. Pink clover flowers have a high level of lead absorption (0.57), field burdock (0.08) have a low level. Cadmium was more intensively absorbed by the colors of linden (0.18), slightly by the colors of cyst (0.06), clover of pink and white (0.06), sweet clover of white and yellow (0.06). Arsenic was actively absorbed by the colors of mouse peas (1.81), zinc by ivan tea (2.42), copper by flowers of yellow melilot (1.34). All honey plants exhibit high KBP to copper (0.97 - 1.34).

Based on the accumulation of chemical elements by summer honey plants, the following decreasing rows can be constructed:

- Pb - pink clover> medunok> canada thistle> small-leaved linden> willow herb> red clover> woundwort> white clover> field burdock> tufted vetch> white melilot> yellow melilot;
- Cd - small-leaved linden> canada thistle> red clover> medunok> willow herb> wound wort = pink clover = white clover = white melilot = yellow melilot = yellow field burdock = tufted vetch;
- As – tufted vetch> red clover> medunok> canada thistle> canada thistle> linden> willow herb> pink clover> white clover = field burdock> white melilot> yellow melilot
- Cu – yellow melilot> white clover> red clover> medunok> tufted vetch> field burdock> white melilot> willow herb = pink clover> small-leaved linden = woundwort>canada thistle
- Zn willow herb> yellow melilot> tufted vetch> white melilot> field burdock> medunok> pink clover> small-leaved linden> wounwort> red clover> canada thistle> white clover.

The analysis of the results showed the following sequence of redistribution by mobile forms of HM in soils - honey plants of beekeeping regions:
Tyumen> Yalutorovsky> Yarkovsky> Nizhnetavdinsky> Sladkovsky> Berdyuzhsky.

Thus, the apiaries of the Tyumen, Yarkovsky and Nizhnetavdinsky administrative districts of the Tyumen region are experiencing the relatively greatest technogenic load. Ecologically safe zones include apiaries of Berdyuzh and Sladkovsky districts.
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