The study of specific features of heavy metal accumulation in forest food resources

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Abstract. The accumulation of heavy metals in wild grown forest berries was investigated in ten regions of Russia. The studied species were cowberries (Vaccinium vitis-idaea L.) and blueberries (Vaccinium myrtillus L.). The accumulation of strontium, lead, arsenic, zinc, nickel, and chromium was studied. The most intensive accumulation was typical for strontium, zinc, and chromium in berries of both species. The level of pollution in average was lower than Eurasian pollution standard.

1. Introduction

Currently, in Russia there is an increase in the use of wild-grown berries in the food industry. The development of processing technologies in the regions of Russia, in particular, various types of industrial drying and freezing of berries and mushrooms, allows producers to harvest large volumes of forest food resources because of their long-term storage. This ensures year-round entry into trading enterprises and the possibility of transportation to regions with high consumer activity, such as megacities away from the collection sites. In megacities, forest food products from Russian regions compete with imported products grown on artificial plantations [1]. In this regard, the environmental safety of wild products is especially important for consumers [2]. One of the most common types of pollutants is heavy metal (HM) pollution, which can be considered dangerous because of a toxic effect on the human [3].

The two main sources from which plants can absorb HM are soil and air (atmosphere) [4]. Accordingly, the entry of these elements into the plant body occurs both from the soil (over the roots) and from the atmosphere (over the leaves) [5].

The main mechanisms for the entry of HM into plants by the root route are: passive ion transfer to the cell in accordance with the gradient of their concentration and the active (metabolic) process of absorption by the cell against the concentration gradient [6]. Absorption of HM by the root system is carried out by means of physicochemical adsorption, as well as by nonmetabolic binding of metal ions by active areas of the cell wall and apoplast. Cd, Zn, Cu, and some other metals enter the roots through exchange adsorption processes [7].

The ratio of passive and active mechanisms of HM entering plants largely depends on the concentration of these elements in the soil. If the concentration of metals in environment is higher than in the plant, the absorption is mainly non-metabolic, resulting from the diffusion of ions into the root [8]. The ions of Cd, Br, and Cs are extremely easily absorbed by plants, while Ba, Ti, and Se are accumulating weakly [9]. Pb enters plants and is transported to above-ground organs more slowly than other HM [10].

The main reason of HM pollution of the biotopes of blueberries and cowberries is the intensive development of roads. It increases the pollution of soils on adjacent territories [11]. The concentration
of HM in the soil decreases with distance from the roads [12, 13]. Salt containing chlorides used in road operation contributes to the release of HM from sedentary forms in soil, increasing their spread over longer distances and their bioavailability [14]. Pollution of plant biomass from soil depends on biological characteristics and species composition of vegetation cover [15]. The complex set of factors determining the accumulation of HM in berries also provides a strong variability in the accumulation of these toxicants. Within the collection regions, there may be areas that differ significantly in the HM contamination of the vegetation [16]. This can be the result of both natural causes (natural features of soils, the influence of meteorological conditions of the harvesting season) and the consequence of anthropogenic pollution. The highly pronounced mosaic HM accumulation in forest berries makes it difficult to identify geographical features and species-specific characteristics of blueberries and cranberries characteristic of unpolluted areas.

The information about pollutants accumulation in wild berries production is very important for correct planning of forest areas and areas of berries harvesting to ensure compliance of product quality with normative. In Russia, the regulation of HM concentration in wild berries, acceptable for food products, is done according to sanitary rules [17]. According to this document, the level of some HM in wild berries production should be checked. The maximal allowable concentration (MACs) is established for Cd, Cu, Zn, and Pb. The same HM concentrations in berries are established in the Technical Regulations of the Customs Union and the Eurasian Economic Union – TR CU and TR EAEU “On Food Safety” (TR CU 021/2011) [18].

The content of HM in forest food resources has been fragmentally investigated. There are only few valuable recent studies on this topic. There were single studies of the natural fluctuations in the content of various HM in forest food resources related to the species accumulative abilities and the properties of the growing areas.

2. Methods

The field study was conducted in 2018-2020. The content of HM in the production of wild cowberries (Vaccinium vitis-idaea L.) and blueberries (Vaccinium myrtillus L.) from ten different regions of Russia was investigated.

Blueberries and cranberries were collected in poorly damaged taiga ecosystems in the territories of the following regions of Russia: 1) Leningrad region, 2) Pskov region, 3) Novgorod region, 4) Vologda region, 5) Republic of Karelia, 6) Republic of Komi, 7) Murmansk region, 8) Irkutsk region, 9) Tyumen region, and 10) Republic of Yakutia.

The berries were collected in the summer period from July to August 2018, 2019, and 2020. They were thoroughly cleaned of foreign impurities, washed with drinking water and dried in the air to an air-dry state. For analysis, the berries were dried convectively at a temperature of 45-50°C for 10 h to a weight fraction of moisture of 10.0 ± 1.5%. After that they were ground to a particle size of not more than 0.2 mm and sieved.

Studies of HM accumulation in berries were carried out in 2019-2020 using an X-ray fluorescent spectroscopy method [19, 20] for analysing air-dry berries material using X-ray spectrometer “Spectroscan Max G”.

3. Results

It was established that the content of HM in wild berries of shrubs of the genus Vaccinium (cowberries Vaccinium vitis-idaea L. and blueberries Vaccinium myrtillus L.) from the background territories of different harvesting regions of Russia did not differ significantly between species (Figs. 1, 2).

An analysis of the average values of HM accumulation in the berries has shown that strontium, zinc, and chromium have the greatest accumulation in those in all the studied regions. Cobalt, vanadium, and titanium oxide were not detected within the sensitivity of the analytic method used. Content of manganese oxide in berries of investigated plants was 10-100 times higher than content of strontium, lead, arsenic, zinc, nickel, and chromium.
Figure 1. The HM accumulation in blueberry.

Figure 2. The HM accumulation in cowberry.

The species studied had a general tendency to accumulate manganese oxide, strontium, zinc, and chromium, preferably. Zinc accumulation is characteristic of plants due to the high physiological need for it, the other listed metals can be considered as potentially dangerous and should be controlled in production of wild berries.
4. Conclusion
The HM accumulation in the Vaccinium vitis-idaea L. and Vaccinium myrtillus L. berries has a similar character with more intensive accumulation of manganese oxide, strontium, zinc, and chromium in comparison to other HM. The berries from investigated regions of Russia have different content of HM, by the level in average not higher then normative. Nevertheless, the ecological control of wild berries production intensification is highly needed, especially for intensive accumulating group of pollutants, e.g., manganese oxide, strontium, zinc, and chromium.

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