Chemical composition of the small mammal reproductive system as an indicator of enterprise technogenic impact on the environment

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Abstract. In this paper we consider the indicative role of chemical composition of the small mammal (specifically, the bank vole, or Myodes glareolus) reproductive system with the purpose of studying the impact of a large-scale nonferrous metal-processing enterprise on living organisms through the expample of Middle Ural copper-smelting plant OJSC. We have analysed the chemical composition of the placenta-embryo system in the areas which are 2 km and 30 km away from the plant.

1. Introduction

Under the conditions of urban environment technogenic impact the living organism is constantly exposed to multiple effects of diverse factors. Polluting the adjacent areas with waste products, nonferrous metal-processing enterprises cause environmental changes and acceleration of natural landscape degradation [8]. Contamination by heavy metals and other chemicals is one of the negative impacts on the environment and living organism in particular. From this perspective, modern industrial cities tend to be extreme habitats [1, 7, 10]. The barrier systems of the living organism are intended for its defense from negative environmental impact. Each of the organ systems functions as a barrier in its own way. In this paper we consider functioning of the placental barrier included in the reproductive system. The placental barrier plays an essential part in the formation of the embryo as a future organism. Chemical analysis of organs and tissues, the function of which is to reduce migration ability of chemicals by accumulating them, enables us to draw conclusions about the state of the environment and its technogenic transformation.

2. Research materials and methods

2.1 Research subject

The research subject is the biological material (placenta-embryo) of small mammals, namely, the bank vole (Myodes glareolus), which represent rodents of Myodes genus. The animals are characterized by a relatively short lifecycle, high level of metabolism, and high sensitivity to ambient conditions [9]. Small mammals are a traditional and very informative subject of bioindicative research which gives the possibility to effectively study biosystem reaction to pollutant impact at the level of populations and cenosis [6]. The reproductive system is a marker and biological indicator of the environment state

[5], as adverse environmental factors have a significant impact on the state of the mother-placenta-foetus system, in which the placental tissue holds a central position. On the one hand, the placenta implements relations between the mother and the foetus, on the other hand, it plays an exceptional part in protection of the foetus from negative impacts [3].

2.2 Sampling and research methods

The research is based on the materials collected by staff members of the Institute of plant and animal ecology UB RAS with the article author's participation when they were studying small mammals in the operating area of the large-scale copper-smelting plant (the town of Revda, Middle Ural) from 2005 to 2013. Based on the content of heavy metals in the natural deposit environment (soil, leaf-litter, and snow cover) we distinguished background, or reference (conditionally 'clean', 30 km off the plant) and impact (heavily and moderately polluted, 2 km) areas. The animals were caught during a snowless period in both areas simultaneously. For the purpose of the analysis we only used embryos and placentas at late stages of gestation (18-20 days). For sample assaying we used the method of instrumental neutron activation analysis, the analyst was A.F. Sudyko, senior researcher. Compared to the others, this method has a number of advantages, including capability to detect chemicals content in a wide range (from n.1 to n.10–6%). In addition to this, chemical preparation of samples is not used, which excludes errors caused by adding or removing elements together with reagents [11].

3. Geoecological characteristics of the object

Middle Ural copper-smelting plant OJSC is located in Sverdlovsk Oblast, the town of Revda near Pervouralsk. Revda is situated 47 km west of Yekaterinburg, in that part of Middle Ural which geographically demarcates Europe from Asia. The town is located on the banks of a pond and the river Revda in the place where it flows into the river Chusovaya. Middle Ural copper-smelting plant OJSC is the largest plant, which smelts copper from fresh raw materials, in Ural, it produces up to 100 000 tonnes of blister copper a year. The plant uses zinc-copper ore supplied by the Gaiskoye copper-pyrite deposit.

Main sources of hazardous substances emissions from engineering buildings in nickel industry are burning and smelting furnaces and converters. Unorganized sources of atmosphere pollution, such as unsheltered warehouses, slag disposal areas and end products shipping, are also present.

Main pollutants are inorganic dust, sulphur dioxide, copper, cupric oxide, lead and its compounds, arsenic, zinc, zinc oxide, cadmium, and iron [2].

4. Results and discussion

4.1 Chemical analysis of the placenta-embryo system

Results of biological material research conducted in the operating area of Revda copper-smelting plant are presented as diagrams in Figures 1 and 2.

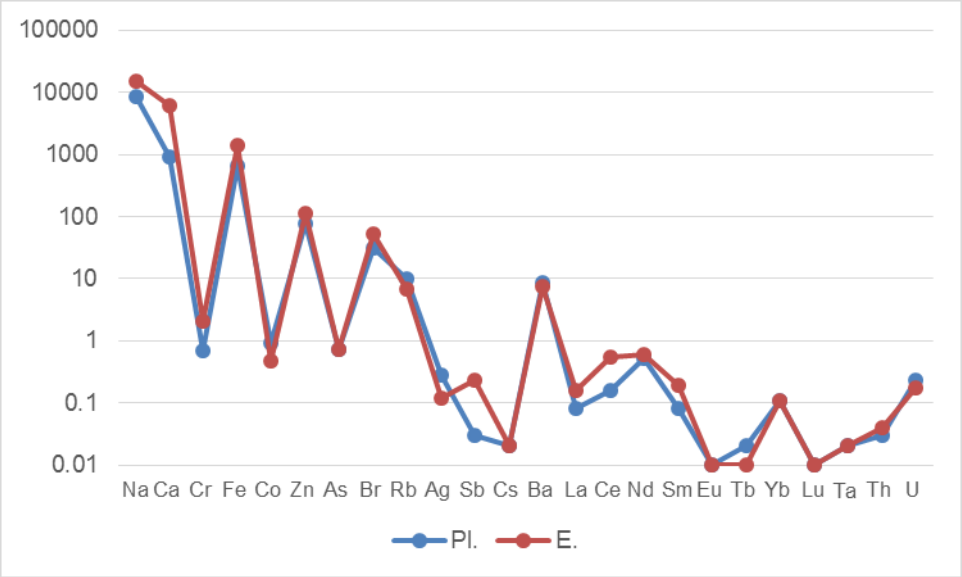

Figure 1. Chemical substance content in placenta (Pl.) and embryos (E.) of small mammals, taken in the area 2 km away from Middle Ural copper-smelting plant OJSC (impact zone), mg/kg of ignition residue

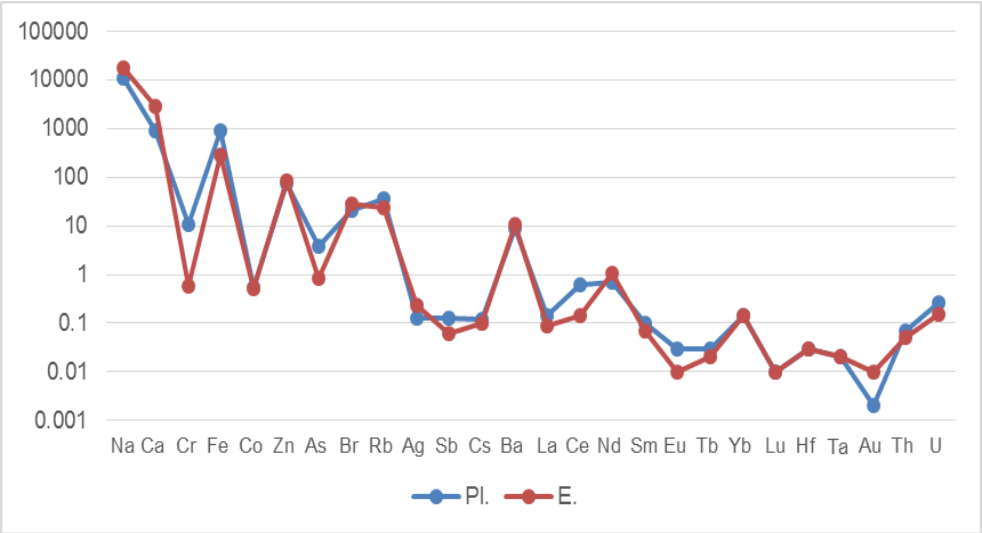

Figure 2. Chemical substance content in placenta (Pl.) and embryos (E.) of small mammals, taken in the area 30 km away from Middle Ural copper-smelting plant OJSC (background zone), mg/kg of ignition residue

In the impact zone the following groups of elements are mainly accumulated in the tissues of the embryo: essential and necessary elements: Ca, Na, Fe, and Zn; accompanying elements: Cr, Sb, and Br; rare-earth elements: La, Ce, Nd, and Sm; radioactive elements: Th. In the reference zone chemical substance content in the embryo tissues changes in the following way: content of such elements as Na, Ca, Zn, Nd, and Sm in the embryo still exceeds the content of the same elements in the placenta, and the content of Ag and Yb additionally increases. Such metals as Na, Ca, Zn, Nd, and Sm overcome the placental barrier in the area that is close to the plant as well as in the remote one. Na and Ca are vital for new organism development, and Zn content can be related to its biological function as well as a

specific character of the enterprise emissions. The placenta barrier does not protect against rare-earth elements (Sm, Nd, and Yb) and they enter into the embryo.

4.1 Chemical analysis of the embryo systems of small mammals selected in the areas in question
The content of chemical elements in the embryo samples of the reference and impact zones enables us to draw a conclusion about the state of the small mammals' natural habitat. To visualize the analytical material we constructed a scatter diagram showing distribution of chemical elements in small mammals' embryos.

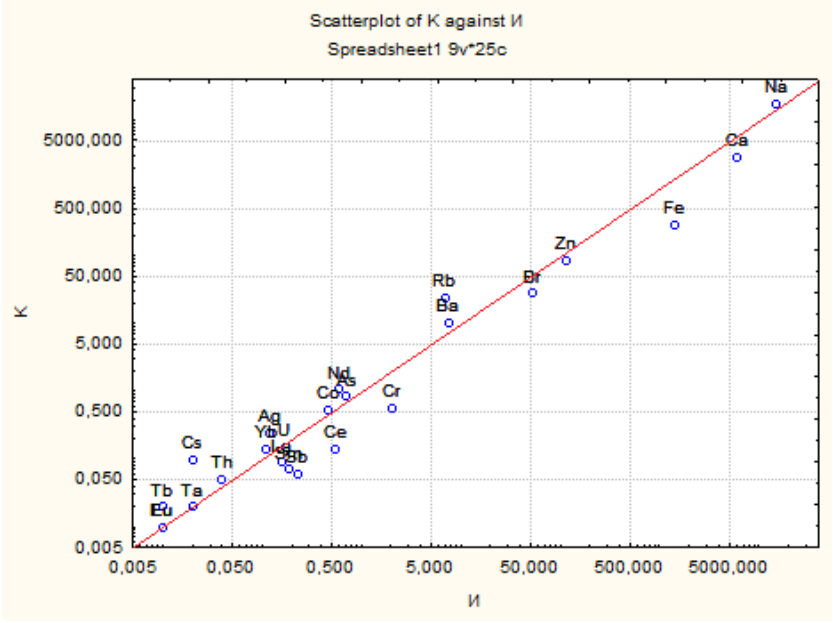

Figure 3. Distribution of chemical elements in small mammals' embryos in the impact and background areas, mg/kg of ignition residue

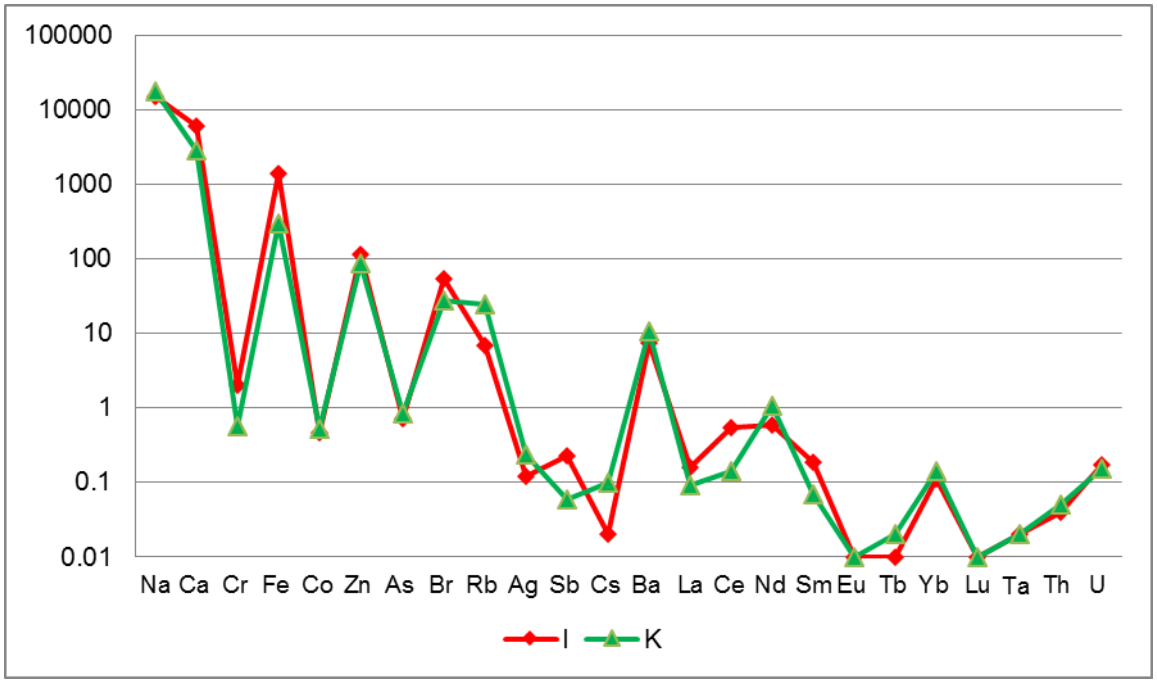

Figure 4. Content of chemical elements in the small mammals' embryos selected in the areas 2 km

(impact zone) and 30 km (background zone) away from the enterprise, mg/kg of ignition residue

In the area, which is 2 km away from the plant (impact zone), such chemical elements as Fe, Zn, Cr, La, and Ce concentrate in a greater degree than in the districts located 30 km away. Fe, Zn, and Cr are typical pollutant metals emitted by nonferrous metal enterprises. The content of these metals in the samples selected in impact and background zones ranges from 1396±75 to 292±50 mg/kg, from 114±5 to 86±7 mg/kg, and from 2±0.4 to 0.6±0.06 mg/kg for Fe, Zn and Cr respectively. La and Ce refer to rare-earth elements (REE), which flames and smokes of industrial emissions contain. REE can enter living organisms together with drinking water and atmospheric dust, the content changes from 0.2±0.02 to 0.9±0.01 mg/kg for La, and from 0.6±0.3 to 0.1±0.02 mg/kg for Ce.

Embryos, selected in areas which are more distant from the plant (30 km), accumulate a larger amount of Na as compared to those selected in areas closer to it, Na concentration varies from 15120±785 mg/kg in the impact zone, to 17313±807 in the reference one. Na is a vital (essential) element, without which healthy functioning of the future living organism is impossible.

4. Conclusion

1. Chemical elements are classified into three groups by their content in the samples of embryos and placentas selected in the studied areas as well as by their content in the human body regardless of the location. A number of researchers stated that such elements as Na, Ca, and Fe are more concentrated in the human body than the others, which is also confirmed by the research of the small mammals. In both cases high concentration of the macroelements (Na, Ca, and Fe) is observed. The barrier mechanism to protect a foetus from environmental impacts better operates in the background area, which is connected with its remoteness from the source of the impacts. In both zones under study the placental barrier is overcome by Na, Ca, and by the rare-earth elements - samarium and neodymium - as well.

2. Embryos selected in the areas located in the vicinity of the source of environment pollution (2 km) accumulate a larger amount of nonferrous industry pollutants than those selected in the distant areas (30 km). It is estimated that the above mentioned elements enter embryos due to malfunction of the placental barrier caused by technogenic impact increase.

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