Snow cover study in the zone of influence of the Severonickel plant

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Abstract The article discusses the problems associated with the anthropogenic impact of the Severonickel plant on the environment in the Murmansk region of the Russian Federation. Due to the operation of this plant, sulfur compounds and metal-containing aerosols prevail in the structure of atmospheric emissions of the Murmansk region. In order to identify the main areas of impact of the Severonickel plant, snow samples were taken directly near the industrial site, as well as at points north and south of the plant, as well as in the city of Monchegorsk and its environs. The evaluation of the concentration of heavy metals was carried out in the ecological and analytical laboratory of the Department of Environmental Management and in the laboratory of atomic absorption of the Department of Landscape Geochemistry, Faculty of Geography, Moscow State University. The highest values of the index of total pollution with heavy metals of snow are observed at sampling points located 750-1000 m north of the industrial zone, as well as at the point located 2.5 km northeast of Monchegorsk, at the intersection of the Kola highway and the railway station highway. According to 2017, the reaction rim of influence of the enterprise can be traced much further south and north. If according to the data of 2019, the points with significant indices of total pollution are located 2.5–3 km to the north and south of the plant, then, according to 2017, the influence of production can be traced in the radius of 8–10 km. Most likely, this difference in indicators is due to the frequency of winds. In 2019, the transfer of pollutants was much less active.

1. Introduction
The research area is located in the central part of the Murmansk region. One of its key features is that at the end of the 20th - beginning of the 21st centuries it was a man-made wasteland formed as a result of the long-term activity of the Severonickel mining and metallurgical plant. Largely due to the operation of this plant, sulfur compounds and metal-containing aerosols prevail in the structure of atmospheric emissions of the Murmansk region [1].

This study is relevant because it touches on the problem of preservation of fragile Arctic landscapes in the era of their intensive economic development [2]. The aim of this work is to assess the current level of pollution of the snow cover under the influence of the Severonickel plant, as well as to study the dynamics of this pollution from 2017 to 2019. The latter is also necessary for an objective assessment of the effectiveness of measures taken by the Severonickel plant to minimize environmental impact.

The theoretical and methodological basis of this work is the work of scientific researchers of ecological problems of the North of Russia in general and the Kola Peninsula in particular (Evseev AV, Krasovskaya TM, Ershov VV, Lukina NV, Orlova MA, Zukert NV) [3-4], as well as regulatory
documents and official statistics. It is also worth noting that the materials of the expeditions of the Department of Environmental Management of Moscow State University in the Murmansk Region in the winter of 2017 and 2019 were used to write this work.

The area around the Severonickel plant which is of particular interest in this work is characterized by a high potential for atmospheric pollution with weak atmospheric transfer in most directions and moderate in the southwest - northeast direction [5].

Geomorphological factors also have a great influence on the accumulation of aerotechnogenic pollutants in the natural landscapes of the Kola Peninsula [6]. There are no high mountain ranges, but, for example, the Severonickel plant mentioned above is located in the basin and is surrounded by the mountains of Monchetundra, Sopchuayvench, Nyduayvench, Poazuayvench with an average height of 700-800 meters. This enhances the effect of local accumulation of heavy metals, sulfur oxides and other pollutants.

It is also worth mentioning that the prevalence of weak winds (up to 5 m / s) is typical for the Monchegorsk district of the city. In winter, the frequency of surface inversions is also increased in this region, which creates conditions for stagnation of industrial emissions. According to the classification of the Main Geophysical Observatory named after A.I. Voeikov, according to the climatic conditions of dispersion of contaminants in the atmosphere, the territory of the city of Monchegorsk belongs to the zone with a moderate pollution potential [7].

2. Methods and methodology

In order to assess the level of environmental pollution in the winter of 2019, during the period with stable snow cover, snow samples were taken at pre-designated points of field routes. The selection points were located in accordance with the current Guidance Document (RD) [8].

In order to identify the main areas of impact of the Severonickel plant, samples were taken directly near the industrial site, as well as at points 1, 2, 3, 5, 10, 15, 20, 25, 30 km north and south of the plant, as well as in the city of Monchegorsk, in its vicinity, etc. When sampling and their subsequent study, the main directions of the winds, the features of the relief and urban development were taken into account.

It is worth noting that snow is an excellent indicator of environmental pollution, especially informative for areas of the Far North, where snow cover can persist for 8-9 months a year. As a depositing medium, snow has a high sorption capacity and precipitates a significant part of technogenesis products from the atmosphere onto the earth's surface. A study of the chemical composition of the snow cover makes it possible to identify spatial ranges of pollution and quantitatively calculate the actual supply of pollutants to landscapes during the period with stable snow cover [9].

During the work, 42 snow samples were taken. The research was carried out according to the generally accepted methodology [9-10]. At each key site, a mixed sample consisting of 10 separate samples was taken with a plastic pipe with a cross-sectional area of 20 cm². The primary processing of samples (filtering melt water, measuring its pH and mineralization) was carried out at the Khibiny educational base of Moscow State University.

Subsequent analysis (evaluation of the concentration of heavy metals) was carried out in the environmental-analytical laboratory of the Department of Environmental Management and in the laboratory of atomic absorption of the Department of Landscape Geochemistry.

The results of the analysis of snow (melt water) samples were compared with the background values obtained during the analysis of samples taken at three sampling points on the western shore of Lake Lovozero during the scientific-student’s expedition of the Department of Environmental Management of Moscow State University named after M.V. Lomonosov in 2017. The point data can be considered as background because of their distance from the industrial site of the plant by more than 80 km, and also due to the orographic factor - Lovozero is separated from the studied source of pollution by the Khibiny and Lovozero massifs.
The average value of the pollutant content at these three points was taken as the background. A comprehensive assessment was carried out on the basis of the index of total pollution Zc, the assessment of different components was based on the local accumulation index Qi, which was calculated for the two most specific chemical elements for such production copper and nickel.

3. Results and discussion
As mentioned above, 40 snow samples were taken to study the modern aspects of the impact of the Severonickel plant on the environment. Test points were located along the route along the R-21 Kola highway, in the direction south and north of the enterprise, as well as in the vicinity of the city of Monchegorsk.

In order to make an overall assessment of the content of heavy metals (Cu, Ni, Zn associations) in the snow cover of the sampling points, the index of total pollution Zc was calculated [11]. For a more detailed assessment, the local accumulation index Qi was calculated [5]. It is worth noting that the latter index was calculated only for copper and nickel, since the accumulation indices of precisely these elements are the main components of the total index.

![Total contamination in snow cover](image)

**Figure 1.** The total contamination of the snow cover for the association of the elements Cu, Ni, Zn (2019)

As can be seen on the map (Figure 1), the highest values of the index of total pollution are observed at the sampling points located 750-1000 m north of the industrial zone (points 2.2, 2.3, 2.4), as well as at point 1.6, located in 2.5 km northeast of Monchegorsk, at the crossroads of the Kola highway and the Privokzalnoe highway. The highest total pollution index (1304) is at point 2.3. It is worth noting that the points with the highest indices are located north of the industrial zone.
The sampling points located east of the industrial site (including the points in the city of Monchegorsk) are characterized by generally insignificant total pollution index, which characterizes the low intensity of the transfer of pollutants from west to east and confirms the validity of the choice of background points located to the east from the industrial sites. To the north and south of Monchegorsk, high indices of total pollution (for the association of the elements Cu, Ni, and Zn) were not detected.

If we compare the above map with that constructed according to the data of 2017 (Figure 2), it is easy to notice several similar features in the overall picture of the distribution of pollution indices. So, for the testing points of 2017 located east of the industrial site, as well as for similar points in 2019, low indices are calculated. The most significant indicators are observed at the points located north of the plant. However, according to 2017, the reaction rim of influence of the enterprise can be traced much further south and north. If, according to the data of 2019, the points with significant Zc index are located 2.5 - 3 km north and south of the plant, then, according to 2017 data, the influence of production can be traced in the radius of 8-10 km. Most likely, this difference in indicators is due to the frequency of winds. In 2019, the transfer of pollutants was much less active.

Figure 2. Total heavy metal pollution of the snow cover using Zc index (Cu, Ni, Zn) (2017)
To study in detail the pollution of the snow cover of the study area we used another index - the local accumulation index Qi, calculated by the ratio of the concentration of the element in the snow of the sampling point to that in the background point [5]. Copper and nickel have the highest rates of this index, which prevail in the polymetallic dust coming from the enterprise into the environment. The main polluting element is copper. It prevails over nickel at all points with the highest index of total pollution, with the exception of point 1.6. As can be seen on the map (Figure 3), the highest Qi indices are in points 2.2, 2.3, 2.4, located 750-1000 m north of the industrial site. They are 202, 1305 and 133, respectively.

![Figure 3. The index of local accumulation for copper](image)

According to these indices, a high copper content can be traced at point 2.10, located east of the industrial site, on the southern slope of Mount Poazuaiwench. This point also stands out from the others surrounding it with an increased Zc index. This allows us to judge that the transfer of pollutants from the plant is sub-latitude northern to the east, nevertheless, although it is much less intensive than the transfer of submeridional ones. In addition, it is worth considering that point 2.10 is located on the side of the mountain facing the plant, which once again confirms the high barrier role of the mountains and justifies the choice of background points.

As can be seen on the map (Figure 4), for nickel, Qi values above the background are observed only at four points - 1.6, 1.7, 1.8, 1.10. It is worth noting that the index at point 1.6, located 5 km north of the industrial zone, is almost two times greater than that at point 1.10, located 50 m from the industrial zone.

In addition to assessing the copper and nickel contents, the samples taken were examined for zinc, chromium, cadmium, cobalt, lead and strontium. However, in the vast majority of sampling points, the values of the accumulation index did not exceed the background ones.
In general, copper prevails in the polymetallic dust that has entered the environment from the Severonickel plant and has settled on the snow cover. Therefore, the features of the transfer of metal-containing aerosols are most objectively judged by the Qi index calculated for copper. According to these data, there is a weak sub-latitudinal transfer from west to east, submeridional transfer, also expressed in relation to copper. The highest pollution of snow cover is observed within the radius of 5 km from the industrial site.

4. Conclusion
The results of studies of snow samples allow us to conclude that the area of contamination of the surrounding natural environment has reduced. So, in the case of snow cover samples obtained in 2019, the most polluted points are located within the radius of 2.5-3 kilometers from the plant. As a result of field studies in the winter of 2017, it was found that such points are present at a distance of 8-10 km south of the plant. The highest indices of local accumulation are copper and nickel, which prevail in the polymetallic dust coming from the enterprise into the environment. The main polluting element is copper. It prevails over nickel at almost all points with the highest total pollution coefficient. Other trends in research [12] also indicate a general trend towards a decrease in pollution.

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