Assessment of snow cover pollution of the mining area

Ya T Suyundukov¹,², I N Semenova¹,², R F Khasanova¹,², Yu S Rafikova¹, M B Suyundukova¹,², G R Ilbulova² and E E Papyan²

¹Institute of Strategic Studies of the Republic of Bashkortostan, 1, Kutuzov St., Sibay, 453837, Russia, Republic of Bashkortostan
²Bashkir State University, 21, Belov St., Sibay, 453837, Russia, Republic of Bashkortostan

E-mail: rezeda78@email.ru

Abstract. The purpose of the work is to assess snow cover pollution of Sibay city with sulfates and heavy metals. The paper presents snow cover study conducted in January-February 2019 in accordance with the requirements of generally accepted regulatory and procedural documents [11–12]. The site near the pond in the northern part of the city was as a conditional background. The paper describes the analysis of samples for the content of heavy metals carried out by atomic absorption spectrophotometry, the sulfate concentration measured by the photometric method. The study used pH-meter to determine the pH. To calculate the total pollution indicator the study used obtained results. Snow sulfate pollution was at the admissible level. The highest content of sulfates was in the area of industrial enterprises (the excess of background indicators was in the range of 5.1–11.1 times). The study revealed polyelement pollution of snow with such metals as (Fe, Mn, Cu, Zn) in the zone of quarry emissions. Snow cover next to the pit dumps has a moderately dangerous pollution category. Copper and zinc make the main contribution to pollution. Thus, the activity of mining enterprises contributes to the accumulation of elevated concentrations of metals in the atmospheric surface layers, which negatively affects the ecological and hygienic situation in the region.

1. Introduction
Numerous ethnic groups have long inhabited Zauralskaya zone of the Republic of Bashkortostan, located in the southern Urals. For a long time, the main branch of the economy was pasture cattle breeding. At the beginning of the last century, people discovered various minerals, mainly non-ferrous metal ores, in the depths of this region, after which intensive development of their deposits began. Since then, the living conditions of the population have changed dramatically and they have adversely affected environment. The development of mining production reflected not only in the structure of the regional economy, in the ecological condition of the environment, but also in the medical and demographic situation: many diseases of people also depend on ecological situation [1–4].

The city of Sibay with a population of more than 60 thousand is the largest settlement of the Trans-Ural zone of the Republic of Bashkortostan, which in essence is the cultural, educational and industrial center of the region. The Sibay branch of Uchalinsky mining and refining plant (UMRP) (previously called BMSK), founded in 1948, and is engaged in mining and enrichment of polymetallic ores. The main objects of the mining and processing plant, which are sources of pollution of the environment, are the quarry, the processing plant and the tailings dam. In addition, a large thermal power station has been
operating in the city for more than 10 years. The long-term exploitation of mining and other industrial enterprises has led to the formation of technogenic provinces in the region, which, overlapping with the natural geochemical background, further aggravated the ecological situation. One of the environmental problems of the city is contamination with various pollutants, first, heavy metals (HM). According to Roshydromet, presented in the State report “On the state and environmental protection of Russian Federation in 2017”, Sibay city was included in the list of Russian Federation with a moderately dangerous category of soil pollution by heavy metals for 2007-2017 [5]. The report noted that the priority heavy metals are copper, cadmium, zinc and plumb. The total indicator of soil pollution in one-kilometer zone belongs to the dangerous category. Long-term studies of a number of authors have confirmed this fact [6–9].

The tense of environmental situation of the Trans-Ural zone of the Republic of Bashkortostan affected the health of the population. An increased level was in its territory compared to the average republican indicators of circulatory system diseases, respiration and digestion, skin and nervous system in adults and diseases of the respiratory organs, digestion, endocrine system and metabolism, nervous system and sensory organs in children [10].

Of particular relevance to Sibay city is the study of environmental risks acquired in the last months of 2018 due to emissions of toxic substances from the Sibay open-cast mine into the atmosphere of the city. This event received a vivid media coverage and caused serious public unrest. At this time, citizens of Sibay complained of headache, sore throat, cough, and tears. There was an excess of the admissible concentration limit (ACL) of sulfur dioxide in the air. For the rest of the other studied parameters there were no exceeding. This fact aims to conduct studies of the state of the atmospheric air using non-standard methods, which, along with generally accepted indicators, would perhaps more fully allow for assessing the environmental risks to the population from mining facilities.

There are various methods for assessing the state of atmospheric air, but one of the most accessible is monitoring of snow cover. This method is a relatively cheap and informative indicator of pollution by emissions from industrial enterprises and vehicles in winter period. Snow has a high sorption capacity and is a carrier of not only wet, but also dry precipitation, and therefore gives an objective assessment of all atmospheric pollution during the winter period. Due to the natural processes of concentration of pollutants in the snow, the content of pollutants in it is one of the most significant criteria for assessing the ecological state of the atmosphere [10].

The purpose of this study was to assess the ecological state of snow cover in Sibay based on the accumulation of heavy metals and sulfates.

2. Materials and methods
The paper presents snow cover study pollution conducted in January-February 2019 in accordance with the requirements of generally accepted regulatory and procedural documents [11-12]. Researchers have taken snow samples manually using a plastic cylinder with a diameter of 10 cm and a height of 20 cm in plastic bags. Sampling was out with visually clean and flat areas of snow cover; each plot area was of 10 sq.m. At each site by the envelope method, researchers have taken 5 samples, which then have mixed into 1 combined sample. The study comprised a total number of 11 composite samples. The site next to pond in the northern part of the city was as a conditional background. Then researchers delivered snow samples to the laboratory and laid out of the packages in plastic containers (pots) for natural thawing. Analysis of melt water samples for HM content was carried out by atomic absorption spectrophotometry (spectrophotometer Contr AA, Analytik Jena). By the photometric method (KFK-2 photometer) researchers measured the sulfate concentration and used pH-meter “HI 2211 HANNA” to determine the pH.

Polyelement pollution causes big problems when rationing the degree of pollution of the environment. At present, it is customary to use a formal calculation of total pollution factors (Zc). Sanitary and hygienic standards do not only approve the calculation of total pollution factors, but also conventionally classify into classes of danger: $Zc= \sum K_{ki} - (n-1)$, where $K_{ki} = \frac{C_{idet}}{C_{iback}}$; $C_{idet}$ –
determined content of the i-th toxicant in the soil; \( C_{\text{back}} \) – the value of the ground content of the i-th toxicant; \( n \) – total number of toxicants used in the calculation [13].

Critical values that characterize the total pollution of \( Z_c \) by danger are as follows: when \( Z_c < 16 \) pollution is admissible; when \( 16 < Z_c < 32 \) – moderately dangerous; when \( 32 < Z_c < 128 \) – high dangerous; when \( Z_c > 128 \) – extremely dangerous.

3. Results and discussion

3.1. Sulphates cover
First, the researchers studied aerotechnogenic substances containing sulfur in snow samples. As part of sulfur dioxide, which adversely affects the health of people and animals, sulfur is a priority pollutant of the atmosphere. However, sulfurous anhydride loses this status when adsorbed by soil and oxidized to sulfate. Sulphates can migrate in the form of soluble salts and be temporarily deposited by a soil-absorbing complex as part of mineral salts, or absorbed by soil biota. The proportions between sulfate pools depend on the soil properties, all sulfates can participate in the prolonged fixation of sulfur in the soil organic matter. The contribution of sulfate to the change in pH of the soil solution depends on the buffer of the soil capacity [14].

Sulfur compounds, like all pollutants, are removed from the atmosphere in two ways: dry deposition and wet – with precipitation. Mainly sulfates are to be out with wet removal. The amount of sulfates in sediments, as a rule, correlates well with their content in the air [14].

Despite the high content of sulfur dioxide in the atmospheric air of Sibay city, pollution with snow sulfates was admissible. The highest content of sulfates was in the area of industrial enterprises – the Bashkir mine control department (BSMCD) (ground exceedance by 11.1 times), the Drilling reagent plant (8.1 times) and quarry dumps (5.1 times).

| Table 1. Assessment of acidity and sulfate content in snow samples |
|----------------------------------|-----------------|-----------------|-----------------|-----------------|
| Sampling location                | Hydrogen indicator, pH | Sulfate ion, mg/dm³ | Concentrations of sulfate ions relative to the ground | Pollution category |
| Ground (next to the pond, district Fisherman’s House) | 6,5 | 5,35 | 1,0 | admissible |
| Pervomayskaya st.,41 / 1         | 6,8 | 6,58 | 1,2 | admissible |
| Quarry dumps                     | 7,6 | 27,16 | 5,1 | admissible |
| Small town Zoloto                | 6,4 | 13,7 | 2,6 | admissible |
| District Fisherman’s house       | 7,1 | 8,64 | 1,6 | admissible |
| Small town Gornuy                | 8,6 | 17,28 | 3,2 | admissible |
| Small town Gornuy                | 8,7 | 20,16 | 3,8 | admissible |

3.2 Assessment of snow cover pollution with heavy metals
As a result of the investigations performed, the researchers have revealed polyelement pollution of snow in the zone of the quarry emissions with metals (Fe, Mn, Cu, Zn).

As a result of the study, the researchers found that snow cover in the small towns Zoloto and Gornuy had admissible pollution category. Nurimanov street, next to quarry dumps, had moderately dangerous category of pollution. Copper and zinc made the main contribution to pollution.
Table 2. The content of HM in snow samples (concentration ratios with respect to the ground)

| Sampling location          | Cu  | Zn | Fe  | Mn | Zc | Pollution category |
|----------------------------|-----|----|-----|----|----|-------------------|
| Village (ground)           | 1.0 | 1.0| 1.0 | 1.0| 1.0| admissible        |
| Turkmenovo                 |     |    |     |    |    |                   |
| Small town Zoloto          | 3.7 | 3.9| 1.4 | 1.3| 7.3| admissible        |
| Nurimanov st. (next to the quarry dumps) | 10.9| 9.3| 2.9 | 2.3| 22.3| moderately dangerous |
| Small town Gornuy         | 3.4 | 1.3| 0.8 | 2.1| 4.5| admissible        |

4. Conclusion
Thus, the activity of mining enterprises contributes to the accumulation in the surface layers of the atmosphere of elevated concentrations of heavy metals that adversely affects the ecological and hygienic situation in the region.

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6. Conflict of interest
The authors of the article confirm the absence of a conflict of interest.

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