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# Ecomonitoring of sanitary protection zone of metallurgical enterprise: Snow and soil cover

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***Abstract***. The paper considers the issues related to monitoring the state of snow and soil cover in the zone of influence of industrial emissions into the atmosphere at the borders of the sanitary protection zone (SPZ) of the metallurgical enterprise JSC "EVRAZ United West Siberian Metallurgical Combine" (JSC EVRAZ ZSMK). Sanitary protection zone is the territory separating enterprises (their buildings and structures) with technological processes that serve as a source of impact on the environment and human health from residential development. SPZ is designed to reduce the impact of all factors beyond its limits to the required hygienic standards, to create a sanitary barrier between industrial and residential buildings. Ecomonitoring provides an objective analysis of depositing spheres (snow, soil) on the territory of the SPZ. The method of chemical laboratory analysis is important for the assessment of primary and secondary air pollution (samples of snow, soils and waters). The results of chemical analysis of snow water showed that the dry residue in meltwater is lower (7 – 8 times) MPC at all sites, the content of chloride ions does not exceed the MPC (350 mg/l), the content of sulfate ions at site *1* is 2 times lower than the MPC, at other sites below the detection limit by the methodology set out in RD 52.04.186 – 89. The content of heavy metals and arsenic in the soil at the SPZ test sites does not exceed the values of the established MPC. Soil analysis showed that the active acidity (*p*H of the water extract) is in the range of 6.30 – 7.40 units, which indicates the absence of technogenic acidification of soils. The content of petroleum products in the selected samples is below the threshold value, which makes it possible to attribute soils at all sites of the SPZ of JSC EVRAZ ZSMK according to the compound under consideration to conditionally pure. The content of benz(a)pyrene in the soil does not exceed the MPC (0.02 mg/kg) at all experimental sites, except site 7. The sulfur content does not exceed the MPC values at all test sites of the SPZ.

***Keywords:*** ecomonitoring, sanitary protection zone, atmospheric air, soil, snow cover, harmful emissions, chemical analysis, MPC, technogenic acidification of soils, heavy metals, benz(a)pyrene

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# Экомониторинг санитарно-защитной зоны металлургического предприятия: снежный и почвенный покровы

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***Аннотация***. Рассмотрены вопросы, связанные с мониторингом состояния снежного и почвенного покровов в зоне влияния промышленных выбросов в атмосферный воздух на границах санитарно-защитной зоны (СЗЗ) металлургического предприятия АО «ЕВРАЗ Объединенный Западно-Сибирский металлургический комбинат» (АО «ЕВРАЗ ЗСМК»). Санитарно-защитная зона – территория, отделяющая предприятия (их здания и сооружения) с технологическими процессами, служащими источником воздействия на среду обитания и здоровье человека, от жилой застройки. Территория СЗЗ предназначена для снижения за ее пределами уровня воздействия всех вредных факторов до требуемых гигиенических нормативов, создания санитарно-защитного барьера между промышленной и жилой застройками. Экомониторинг дает объективный анализ депонирующих сфер (снег, почва) на территории СЗЗ. Для оценки первичного (воздушной среды) и вто-

ричного (снежных проб, почв и вод) загрязнений применяется метод химического лабораторного анализа. Результаты химического анализа снеговой воды показали, что сухой остаток в талой воде ниже (в 7 – 8 раз) ПДК на всех площадках, содержание хлорид-ионов не превышает ПДК (350 мг/л), содержание сульфат-ионов на площадке *1* в два раза ниже ПДК, на остальных площадках ниже предела обнаружения методикой, изложенной в РД 52.04.186 – 89. Содержание в почве тяжелых металлов и мышьяка на пробных площадках СЗЗ не превышает ПДК. Почвенный анализ показал, что активная кислотность (*p*H водной вытяжки) находится в пределах 6,3 – 7,4 единиц, что указывает на отсутствие техногенного закисления почв. Содержание нефтепродуктов в отобранных пробах ниже порогового значения, что делает возможным отнести почвы на всех площадках СЗЗ АО «ЕВРАЗ ЗСМК» по рассматриваемому соединению к условно чистым. Содержание бенз(а)пирена в почве не превышает ПДК (0,02 мг/кг) на всех экспериментальных площадках, кроме площадки *7*. Содержание серы не превышает ПДК на всех пробных площадках СЗЗ.

***Ключевые слова:*** экомониторинг, санитарно-защитная зона, атмосферный воздух, почва, снежный покров, вредные выбросы, химический анализ, ПДК, техногенное закисление почв, тяжелые металлы, бенз(а)пирен

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## Introduction

When evaluating the impact of large industrial enterprises, a crucial consideration involves mitigating the adverse effects on all environmental components. In resource-rich regions such as the Kemerovo Region (Kuzbass), both natural ecosystems and the urban environment, essential for ensuring the population's quality of life, are significantly affected. This study focuses on eco-monitoring within the sanitary protection zone (SPZ) using JSC "EVRAZ United West Siberian Metallurgical Combine" (JSC EVRAZ ZSMK) as a case study. The enterprise in question is situated in close proximity to ten specially protected natural reserves (SPNR) of various levels and categories, notable heritage sites of Kuzbass. Distances to the boundaries of these SPNRs are as follows: 17 km – Uvaly Luchshego regional reserve; 30 km – Chernovoy Naryk regional reserve; 35 km – Kostenkovskie Rocks regional natural monument; 55 km – Kuzedeevsky regional natural monument; 55 km – Kuzedeevo Linden Island federal natural monument; 56 km – Kuznetsky Alatau state nature reserve; 65 km – Karakansky regional reserve; 68 km – Artyshta regional natural monument; 75 km – Belsinsky regional reserve; 83 km – Bochatskiye sopki regional reserve. Preserving these unique natural complexes necessitates compliance with environmental protection requirements, including the establishment of a sanitary protection zone. The primary goal of this zone is to reduce atmospheric air pollution levels to specified emission limits after the enterprises have implemented all necessary measures to eliminate harmful substances.

The objective of the paper is to investigate and analyze the impact of industrial emissions on the environmental status of soil and snow cover within the SPZ of JSC EVRAZ ZSMK.

## Background

The set tasks to accomplish this objective were as follows:

– to explore the methods for investigating the soil-ecological condition within the sanitary protection zone;

– to analyze the findings derived from laboratory examinations of the snow cover and soil at the boundaries of the SPZ of JSC EVRAZ ZSMK.

Novokuznetsk is situated in the southern part of the Kemerovo Region within a vast depression amid the floodplains of the Kondoma and Tom' Rivers. It is encircled by the Kuznetsk Alatau and Salair Ridge mountain ranges. The metallurgical plant of JSC EVRAZ ZSMK is situated in the northeastern region of the city. The rationale behind its location was to position the plant in close proximity to energy and raw material sources while maximizing the distance from residential areas within the city. JSC EVRAZ ZSMK falls into the category of first-class enterprises concerning plant capacity, process specifications, as well as the nature and volume of pollutants released into the environment. The sanitary protection zone's radius for first-class metallurgical enterprises is typically 1 km (although in practice, it extends to 5 km), in accordance with SanPiN 2.2.1/2.1.1.1200 – 03[1] regulations. Landscaping involves the use of specialized tree species, constituting at least 50 % of the development footprint.

A modern metallurgical facility comprises various units that have the potential to emit pollutants into the surrounding air. Such emissions are virtually unavoidable. Hence, measures for safeguarding atmospheric air quality have been implemented, encompassing a system designed to ensure air purity and sustain it at levels safe for human life and health [1; 2].

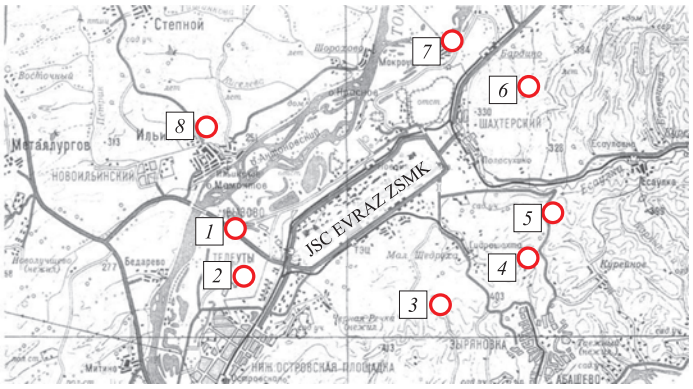
The sanitary protection zone of JSC EVRAZ ZSMK comprises eight designated test sites within the northern industrial hub, each representing distinct soil types:

*1* – floodplain granular soil near the Ilyinsky Bridge (east wind);

*2* – alluvial meadow soil close to Teleuty Village (northeast wind);

*3* – fertile leached chernozem behind Malaya Shchedrukha Village (north wind);

[1] SanPiN 2.2.1/2.1.1.1200 – 03. Sanitary protection zones and sanitary classification of enterprises, structures, and other facilities Sanitary and Epidemiological Rules and Regulations. URL: https://files.stroyinf.ru/Data1/52/52471/index.htm (accessed on: 09.12.2022).




Areas of experimental sites of SPZ of JSC EVRAZ ZSMK

Зоны опытных площадок СЗЗ АО «ЕВРАЗ ЗСМК»

*4* – leached chernozem in the area of Yubileynaya mine (north-west wind);

*5* – meadow heavy loamy soil along the road to Kuregesh – Esaulovka (west wind);

*6* – chernozem meadow heavy loamy soil near the road to Chistogorsk Settlement (south-western wind);

*7* – leached moderately deep light loamy chernozem in the vicinity of Mokrousovo Village (south wind);

*8* – leached moderately deep light loamy chernozem in the area of Ilyinka Village (southeast wind).

The Figure illustrates the respective areas of these test sites within JSC EVRAZ ZSMK.

The boundaries of the sanitary protection zone of the northern industrial hub extend at distances of 5 km to the north, 3.3 km to the northeast, 3.5 km to the east, 4.1 km to the southeast, 1.8 km to the southwest, 2.6 km to the west, 4 km to the northwest, and 4.2 km to the south from the boundaries of JSC EVRAZ ZSMK industrial site.

The assessment of environmental conditions in major cities and enterprises commonly involves individual environmental components: atmospheric air, surface and groundwater, soil (considering microflora), vegetation cover, and citizen health [3 – 7].

Snow cover, with its high sorption capacity, stands out as an informative indicator for detecting anthropogenic pollution not only in atmospheric precipitation but also in atmospheric air, subsequently affecting water bodies and soils [8].

Snow samples were collected following the guidelines of RD 52.04.186 – 89, utilizing a specific template (pipe) with a cross-sectional area of 50.3 $cm^2$, reaching from the top of the snow cover to the ground. These samples were then placed in plastic bags and transported to the laboratory for monitoring industrial waste, soils, fuels, and lubricants. In the laboratory, the samples underwent processing and analysis for *p*H, carbonate and bicarbonate content, chlorides, sulfates, dry residue, calcium, magnesium, and dust, in accordance with RD 52.04.186 – 89 procedures.

During the melting period, snowmelt enters water bodies and is categorized as atmospheric runoff[2] [9 – 11]. To assess its condition, regulatory limits established in SanPiN[1, 3, 4] were used as the basis of comparison. The findings of the snow water study are summarized in Table 1.

The data presented indicates that:

– dry residue in snowmelt water across all sites is (7 – 8 times) lower than the MPC;

– chloride ion content does not exceed the MPC (350 mg/l);

– sulfate ion content at site *1* is twice lower than the MPC, while at the other sites, it is below the detection limit outlined in RD 52.04.186 – 89 procedures;

– *p*H values at all sites fall within the normal range, confirming the absence of anthropogenic soil acidification within the SPZ territory.

Soil monitoring was conducted to oversee various soil parameters [12], encompassing data related to [13 – 15]:

– heavy metals such as vanadium, manganese, antimony, nickel, copper, zinc, lead, mercury, cadmium;

– arsenic;

– chemical indicators including *p*H (acidity), benz(a)-pyrene, petroleum products, and sulfur compounds.

Pollution indicators were assessed for eight chemical elements (V, Mn, As, Sb, Ni, Cu, Zn, Pb). Table 2 presents the specifics of soil contamination caused by heavy metals within the confines of the SPZ. The concentration of heavy metals and arsenic at the SPZ test sites remains below the MPC values.

[2] Procedure for arrangement and operation of sanitary protection zones of industrial enterprises. URL: http://www.centreco.ru/szz_6.php (accessed on: 09.12.2022).

[3] SanPiN 1.2.3685 – 21. Hygienic standards and requirements for ensuring safety and (or) harmlessness to humans from environmental factors. URL: https://rkc56.ru/documents/4538 (accessed on: 09.12.2022).

[4] SanPiN 2.1.3684 – 21. Sanitary and epidemiological requirements for the maintenance of the territories of urban and rural settlements, for water bodies, drinking water and drinking water supply, atmospheric air, soils, residential premises, operation of industrial and public premises, organization and conduct of sanitary and anti-epidemic (preventive) measures. URL: http://www.consultant.ru/document/cons_doc_LAW_376166/ (accessed on: 09.12.2022).

Table 1

**Результаты анализа снеговой воды**

*Таблица 1*. **Results of analysis of the snow water**

| Indicator | MPC, mg/l | Indicator value at the site | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | *1* | *2* | *3* | *4* | *5* | *6* | *7* | *8* |
| *p*H | 6.5 – 8.5 | 7.8 | 7.6 | 7.6 | 7.9 | 7.4 | 7.6 | 8.4 | 7.9 |
| Chlorides | 350.0 | 18.46 | 19.84 | 21.3 | 18.46 | 21.3 | 15.62 | 17.1 | 18.46 |
| Sulfates | 500.0 | 225.6 | bdl | bdl | bdl | bdl | bdl | bdl | bdl |
| Dry residue | 1000.0 | 126.0 | 124.0 | 114.0 | 110.0 | 118.0 | 158.0 | 22.0 | 104.0 |
| Ca | – | 120.0 | 100.0 | 120.0 | 60.0 | 80.0 | 80.0 | 140.0 | 100.0 |
| Mg | – | bdl | 36.5 | bdl | 24.3 | bdl | bdl | 60.8 | bdl |

N o t e . bdl stands for below the detection limit.

The outcomes from chemical analyses of soils are outlined in Table 3. The active acidity (*p*H of the water extract) ranges between 6.30 and 7.40 units, signifying the absence of technogenic soil acidification. The petroleum product content (PNDF 16.1.41–04) observed in the selected soil samples remains below the threshold value (less than 20 mg/kg). Consequently, soils across all sites can be categorized as conditionally clean concerning this compound. Similarly, the concentration of benz(a)pyrene does not surpass the MPC values (0.02 mg/kg) at all test sites except for site *7*. Additionally, the sulfur content (according to GOST 8606 – 93) does not exceed MPC values of 160 mg/kg.

To assess the degree of soil pollution, the technogenic concentration coefficient $K_c$ is calculated [16]:

$$K_c = K_{tot}/K_{bg},$$

where $K_{tot}$ and $K_{bg}$ are the element contents in the examined soil and in background soil, respectively.

Table 2

**Content of heavy metals and arsenic in the soil in boundaries of SPZ**

*Таблица 2*. **Содержание тяжелых металлов и мышьяка в почве в границах СЗЗ**

| Site | Content of substances, mg/kg, in soil | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | V | Mn | As | Sb | Ni | Cu | Zn | Pb |
| *1* | 70 | 1500 | bdl | bdl | 50 | 130 | 200 | 50 |
| *2* | 70 | 1500 | bdl | bdl | 50 | 70 | 200 | 50 |
| *3* | 70 | 1500 | bdl | bdl | 50 | 100 | 150 | 50 |
| *4* | 70 | 1000 | bdl | bdl | 30 | 70 | 100 | 50 |
| *5* | 70 | 1500 | bdl | bdl | 50 | 70 | 200 | 50 |
| *6* | 70 | 1000 | bdl | bdl | 50 | 70 | 200 | 50 |
| *7* | 70 | 1500 | bdl | bdl | 50 | 70 | 150 | 50 |
| *8* | 70 | 1000 | bdl | bdl | 50 | 70 | 150 | 50 |
| MPC | 150 | 1500 | 2 | 4,5 | 80 | 132 | 220 | 130 |

When the soil is contaminated by two or more elements, the total pollution index $Z_c$ is calculated as follows:

$$Z_c = \sum_{i=1}^{n} K_c - (n - i),$$

where $K_c$ is the technogenic concentration coefficients that are greater than unity; $n$ is the number of elements with $K_c > 1$.

The level of contamination is categorized as low if $Z_c$ falls within the range of 0 – 16; medium (moderately hazar-

Table 3

**Results of chemical analysis of the soil samples**

*Таблица 3*. **Результаты химических анализов почвенных образцов**

| Site (sampling points) | Depth of sampling, cm | *p*H of aqueous extract | Benz(a)pyrene, mg/kg, ISO 13877 (MPC = 0.02 mg/kg) |
|---|---|---|---|
| *1* | 0 – 5 | 7.16 | 0.0044 |
| | 5 – 20 | 7.40 | 0.0037 |
| *2* | 5 – 20 | 7.27 | 0.0010 |
| *3* | 0 – 5 | 7.38 | 0.0021 |
| | 5 – 20 | 7.23 | 0.0022 |
| *4* | 0 – 5 | 6.30 | 0.0033 |
| | 5 – 20 | 6.41 | 0.0029 |
| *5* | 0 – 5 | 7.07 | 0.0010 |
| | 5 – 20 | 7.05 | 0.0013 |
| *6* | 0 – 5 | 6.62 | <0.0010 |
| | 5 – 20 | 6.53 | <0.0010 |
| *7* | 0 – 5 | 6.91 | 0.0158 |
| | 5 – 20 | 6.76 | 0.0197 |
| *8* | 0 – 5 | 6.44 | <0.0010 |
| | 5 – 20 | 5.75 | <0.0010 |

Table 4

**Categories of soil chemical contamination**

*Таблица 4*. **Категории химического загрязнения почв**

| The site and its location | Metal concentration coefficient | | | | | | | $Z_c$ | Pollution category |
|---|---|---|---|---|---|---|---|---|---|
| | Cd | Cu | Ni | Pb | Zn | As | Hg | | |
| *1* – Ilyinsky Bridge area | 1.67 | 1.50 | 0.82 | 1.13 | 1.39 | 1.88 | 5.75 | 14.13 | Acceptable |
| *2* – Teleuty Village area | 1.67 | 1.36 | 0.82 | 1.04 | 1.52 | 1.96 | 3.13 | 11.48 | Acceptable |
| *3* – Malaya Shchedruha Village area | 1.67 | 1.25 | 0.94 | 1.16 | 1.26 | 2.50 | 6.88 | 15.65 | Acceptable |
| *4* – Yubileinaya mine area | 1.67 | 1.14 | 0.98 | 0.92 | 1.27 | 2.59 | 8.88 | 17.44 | Moderately hazardous |
| *5* – area of the road to Kurugesh-Esaulovka | 1.67 | 1.28 | 0.92 | 0.85 | 1.26 | 2.50 | 8.50 | 16.98 | Moderately hazardous |
| *6* – area of the road to Chistogorsk | 1.67 | 1.17 | 0.98 | 0.54 | 1.37 | 2.05 | 7.25 | 15.03 | Acceptable |
| *7* – Mokrousovo Village area | 1.67 | 1.70 | 1.01 | 1.08 | 3.76 | 1.96 | 13.88 | 25.07 | Moderately hazardous |
| *8* – Ilyinka Village area | 1.67 | 1.44 | 0.95 | 0.67 | 4.31 | 1.43 | 11.00 | 21.47 | Moderately hazardous |

dous) if $Z_c = 16 \div 32$; high (hazardous) if $Z_c = 32 \div 128$; very high (extremely hazardous) if $Z_c > 128$.

Table 4 presents the assessment of chemical pollution at the test sites for several elements. The evaluation outcomes can be summarized as follows:

– the total pollution index for sites *1*, *2*, *3*, *6* is less than 16, indicating that soil pollution at these sites falls within the "acceptable" category;

– for sites *4*, *5*, *7*, *8* the integral pollution index ranges between 16 and 32, classifying soil pollution at these sites as "moderately dangerous.

## Conclusions

The analysis of snow cover revealed that the concentrations of heavy metals, including arsenic, dry residue in meltwater, chloride ions, and sulfate ions at the test sites within the SPZ of JSC EVRAZ ZSMK, do not surpass the MPC limits. Similarly, in the soil cover at these SPZ test sites, the levels of heavy metals (V, Mn, As, Sb, Ni, Cu, Zn, Pb), arsenic, sulfur, oil products, and *p*H values are within the normal range. The benz(a)pyrene level slightly exceeds the norm at only one out of the eight sites.

The total pollution index categorizes the contamination levels at four out of the eight test sites as "acceptable".

## References / Список литературы


1. Turos O.I., Petrosyan A.A., Anan'єva O.V., Kartavtsev O.M. Expanding the possibilities of sanitary and epidemiological expertise in justifying the establishment of size of sanitary protection zone for a ferroalloy enterprise at the risk management stage. *Gigiena naselenikh mists'*. 2013;(61):62–70. (In Ukr.).

   Турос О.І., Петросян А.А., Ананьєва О.В., Картавцев О.М. Розширення можливостей санітарно-епідеміологічної експертизи при обгрунтуванні встановлення розміру санітарно-захисної зони для феросплавного підприємства на етапі управління ризиком. *Гігієна населених місць*. 2013;(61):62–70.
2. Alimbaev T., Mazhitova Zh., Beksultanova C., TentigulKyzy N. Activities of mining and metallurgical industry enterprises of the Republic of Kazakhstan: environmental problems and possible solutions. In: *XIII Int. Sci. and Pract. Conf. "State and Prospects for the Development of Agribusiness – INTERAGROMASH 2020"*. 2020;175:14019. https://doi.org/10.1051/e3sconf/202017514019
3. Casas A., Ferrero G., Tapias J.C., Rivero L., Font X., Viladevall M. Mapping heavy metal pollution of soils affected by metallurgical point-source pollution near Barcelona (Spain). In: *68th European Association of Geoscientists and Engineers Conference and Exhibition incorporating SPE EUROPEC 2006, EAGE 2006: Opportunities in Mature Areas.* 2006;4: 2091–2095. https://doi.org/10.3997/2214-4609.201402202
4. Medvedev M.A., Medvedev A.N., Kolomytseva A. On the use of cluster analysis for interpretation of soil pollution monitoring data obtained near mining enterprise. In: *44th Int. Conf. on Applications of Mathematics in Engineering and Economics*. 2018;2048(1):060016. https://doi.org/10.1063/1.5082131
5. Zhukorskyi O., Nykyforuk O. Assessment of snow cover in sanitary protection zone of pig complexes of different capacities. *Агроекологічний журнал*. 2014;(3):64–69.
6. Brimblecombe P., Lefèvre R.-A. Weathering of materials at Notre-Dame from changes in air pollution and climate in Paris, 1325–2090. *Journal of Cultural Heritage*. 2021;50: 88–94. https://doi.org/10.1016/j.culher.2021.06.007
7. Kozłowski R., Jóźwiak M., Jóźwiak M.A., Rabajczyk A. Chemism of atmospheric precipitation as a consequence of air pollution: The case of Poland's holy cross mountains. *Polish Journal of Environmental Studies*. 2011;20(4):919–924.
8. Pilecka J., Valujeva K., Grinfelde I., Eihe P., Purmalis O. Snow in the cities as an indicator of air pollution caused by traffic. In: *19th Int. Multidisciplinary Sci. GeoConference Surveying Geology and Mining Ecology Management, SGEM, 2019*. 2019;19(4.1):1069–1076. https://doi.org/10.5593/sgem2019/4.1/S19.136
9. Pilecka J., Grinfelde I., Purmalis O., Valujeva K., Ulcugacevs V. The heavy metal deposition in snow: case study of Jelgava city. In: *20th Int. Multidisciplinary Sci. GeoConference Surveying Geology and Mining Ecology Management, SGEM 2020.* 2020;20(4.1):507–514. https://doi.org/10.5593/sgem2020/4.1/s19.063

**10.** Chen L., Zhi X., Shen Z., Dai Y., Aini G. Comparison between snowmelt-runoff and rainfall-runoff nonpoint source pollution in a typical urban catchment in Beijing, China. *Environmental Science and Pollution Research*. 2018;25(3): 2377–2388. https://doi.org/10.1007/s11356-017-0576-z

**11.** Rogulya L.I. Snow cover – an indicator of atmospheric pollution. *Molodoi uchenyi*. 2018;(39):48–51. Available at URL: https://moluch.ru/archive/225/52866/ (Accessed: 14.09.2023). (In Russ.).

Рогуля Л.И. Снежный покров – индикатор загрязнения атмосферы. *Молодой ученый*. 2018;(39):48–51. URL: https://moluch.ru/archive/225/52866/ (Дата обращения: 14.09.2023).

**12.** Bezrukova V.V., Samokhvalova O.A., Il'ina A.S., Khoroshikh P.S., Vorob'eva D.N. Ecomonitoring of snow and soil cover in the boundaries of sanitary protection zone of JSC EVRAZ ZSMK. In: *Science and Youth: Problems, Searches, Solutions. Proceedings of the All-Russ. Sci. Conf. of Students, Postgraduates and Young Scientists, May 14-16, 2019 Novokuznetsk*. SibGIU, 2019; 23(6):342–347. (In Russ.).

Безрукова В.В., Самохвалова О.А., Ильина А.С., Хороших П.С., Воробьева Д.Н. Экомониторинг снежного и почвенного покровов в границах санитарно-защитной зоны АО «ЕВРАЗ ЗСМК». В кн.: *Наука и молодежь: проблемы, поиски, решения. Труды Всероссийской научной конференции студентов, аспирантов и молодых ученых, 14-16 мая 2019 г. Новокузнецк*, ИЦ СибГИУ, 2019;23(6):342–347.

**13.** Kicińska A. Environmental risk related to presence and mobility of As, Cd and Tl in soils in the vicinity of a metallurgical plant – Long-term observations. *Chemosphere*. 2019;236: 124308. https://doi.org/10.1016/j.chemosphere.2019.07.039

**14.** Paliulis D., Uselyte I., Couch W. J. Experimental investigations of heavy metals concentrations in the ground of section Kazlu Ruda – Jure. In: *7th Int. Conf. on Environmental Engineering, ICEE 2008 – Conf. Proceedings*. 2008:267–273.

**15.** Stevanović J., Serbula S.M., Trujić V. Arsenic heavy metals and $SO_2$ derived in: A mining-metallurgical production process. In: *Hazardous Materials: Types, Risks and Control*. 2011:187–223.

**16.** Achkasov A.I., Basharkevich I.L., Onishchenko T.L., Pavlova L.N., Revich B.A., Saet Yu.E., Sarkisyan S.Sh., Smirnova R.S., Trefilova N.Ya., Yanin E.P. *Geochemistry of the Environment*. Moscow: Nedra; 1990:335. (In Russ.).

*Геохимия окружающей среды* / А.И. Ачкасов, И.Л. Башаркевич, Т.Л. Онищенко, Л.Н. Павлова, Б.А. Ревич, Ю.Е. Сает, С.Ш. Саркисян, Р.С. Смирнова, Н.Я. Трефилова, Е.П. Янин. Москва: Недра; 1990:335.

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***O. S. Andreeva*** – literary review, analysis of experimental data.
***K. I. Domnin*** – processing of the results, data analysis, revision of the text.

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