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Evaluation of the Influence of the Gorlovo Coal Deposit (Novosibirsk Region) on the State of the Surface Layer of the Atmosphere

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Abstract

Results of the field studies of the snow cover composition around dumps and a highway of the Gorlovo coal field are presented. The prevailing element in technogenic dust is carbon. The concentrations of almost all the elements in the dissolved and suspended parts of the snow cover exceed background values. The migration ability of the elements in snow samples collected near the dump and near the highway are similar. However, the distribution coefficients of the elements in snow samples from the highway region are lower, which is the evidence of their transfer in more mobile forms here. The influence of the Gorlovo anthracitic field on the surface layer of the atmosphere extends to more than 1000 m. At the same time, the highway along which the extracted coal is transported has a stronger influence on the state of the atmosphere than the dump for overburden and deads. The shielding effect of forests located along the road is shown.

Keywords: geoecology, coal dumps, air pollution, snow cover

INTRODUCTION

Open pits at coal deposits cause substantial pollution of the atmosphere by dust and gas emissions, both in the working zones of open-pit mines and over the adjacent territories. Atmospheric pollution brings substantial damage to the quality of the environment, causes negative consequences for the health of the personnel and population living in the vicinity of deposits [1].

The present pace of coal production in open pits increases every year, therefore, the problems connected with the effect of dumps on environmental components at the adjacent and remote territories are enhancing. Novosibirsk Region, with the Gorlovo coal basin under development at this territory, is no exception in this aspect [2].

Active development of the coal field entails a number of ecological problems. The first of them is connected with an intense growth of the area occupied by technogenic objects and therefore with the alienation of natural highly productive land. The second problem is determined by the properties of wastes brought into dumps, which are characterized by the exclusive specific features in a set of other coal-embedding rocks [3]. Their specificity is in the low rate of post-technogenic restoration of soil-ecological functions over the affected territories [4]. At the same time, the formation of technogenic landscapes is accompanied by environmental pollution in the regions of coal field development. Because of this, negative consequences of the damage of natural objects and the problems of restoration of the affected territories generally provide the urgency of the fundamental studies into the influence of human activities on the biosphere [5]. This is to a high extent connected with the enormous scale of wastes from the development of coal deposits, diverse geochemical composition of coal, with the most dangerous impurities such as arsenic, mercury [6, 7], and a broad range of the elements that are toxic for the environment [8–10]. The most substantial pollution of the atmosphere with dust from mining enterprises is due to dumps, rock transportation, and fuel combustion in the internal-combustion engines of mining machines. Exhaust gases emitted into the atmosphere contain aerosol and gaseous components. Among the gaseous components of diesel emissions, the most dangerous ones are NO, NO_2, CO and polycyclic aromatic hydrocarbons [1].

Investigation of snow cover is a convenient and economical method of obtaining the data on long-term (month, season) income of pollutants from the atmosphere onto the underlying surface because snow is a natural accumulator during the cold season [11].

The most intense studies of the pollution of snow cover have been carried out within the recent 30–40 years. It was demonstrated that snow may serve as an indicator of atmospheric pollution with dust, macrocomponents, heavy metals, polycyclic aromatic hydrocarbons from oil, protein-containing species, etc. Snow cover may be used for remote sensing of the parameters of territory pollution, including space-based sensing [12].

Results of the studies of snow cover are especially representative because they exclude variations (fluctuations of wind direction, the variability of emissions) and give a precise weighted average pollution value averaged naturally over a long period of time, that is, from the moment of snow cover formation till the moment of sampling.

The goal of the work was to evaluate the pollution of the ground layer of the atmosphere in the zone affected by the Gorlovo coal deposit (GCD) in winter. The present work continues the studies on the ecological monitoring of the environment in the zone of strong anthropogenic action [13–16].

EXPERIMENTAL

Objects of investigation

The Gorlovo coal deposit belongs to the group of deposits of the Gorlovo coal basin situated at the right-hand bank of the Ob river, within the administrative boundaries of the Novosibirsk Region, at a distance of 100 km to the south from Novosibirsk, in the southern part of the Iskitim District. The deposits of the basin are characterized by increased saturation with coal. Coal of the basin is represented by anthracite. It is distinguished by the high quality, it is low-ash, low-sulphur, high-carbon, with low specific resistance, high mechanical strength and thermal stability. According to the State Standard (GOST) 25543–88, the coal of this basin relates to grade A (anthracite) or (according to the international classification) to the Ultra High Grade (UHG). The coal-bearing layer is 640–940 m thick, it contains up to 55 coal beds and seams (the thickness of separate beds varies from 10–14 to 26–41 m), extended as a strip to the north-east for 120 km, with the average width 1.5–7.5 km. Predicted reserves down to the depth of 900 m are estimated as 6.5 billion t [17].

The first industrial developments of the deposit started in 1930. The deposit got its name from the Gorlovo settlement near which the best known mines were situated. High-quality anthracite was produced there through open-cut mining. Coal was transported to the enterprises of the mineral resource industry of Southern Siberia.

In 1941–1945, anthracites of the basin were used for making steel. Since middle 1980-es, they were used as the main raw material for the production of electrodes at the Novosibirsk Electrode Plant, and since 2005 they are used mainly as a substituent of coke in blast-furnace production; in dust-coal injection; in the production of agglomerates of iron ore; iron ore pellets; electrodes. Mining is carried out in the basin by Sibantratsit group. The level of coal production at the deposit in 2017 was 7.4 million t.

Overburden rocks and deads are stored near the open pit mine. The old dump is situated to the north-west, while the new one is located to the east from the open pit mine. At present, active storage works are performed at the new Nagorniy dump. A technical road long which coal is transported, with the high degree of dustiness, passes near the open pit mine.

Methods of investigation

Field studies. The methodological basis which was used to carry out the studies included sampling and snow melting, filtration and chemical analytical studies of the suspended and dissolved parts of the snow cover.

Snow cover was sampled in the beginning of March to provide a more complete characterization of the period since the formation of the permanent snow cover till the start of snow melting. The survey was performed using the route method from the foot of the dump of overburden rocks at the GCD at a distance of 50, 100, 250, 500, 1000 m and directly at the dump, with its height reaching 40 m. The samples were collected in the direction of winds (north-eastern) prevailing in winter in the ground atmospheric layer (Fig. 1, *a*). To assess the effect of the motor road from the windward side, samples were collected near the road at a distance of 20, 40, 60, 100, 250, 500 and 1000 m (see Fig. 1, *b*). At the region of the road separated by a forest belt, the survey was carried out at a distance of 20, 50, 100 and 250 m. From the leeward side of the road, snow samples were taken at a distance of 50, 100, 250 and 500 m from the road (see Fig. 1, *b*). Sampling routes were drawn perpendicular to the source of pollution.

The background sample was taken separately, in the region at a large distance from the region affected by the technogenic source: in the south-western direction at a distance of 7.5 km from the open pit mine and 2.5 km from the road.

All samples were collected two times using a gravimetric snow sampler VS-43 (Russia), then the density and moisture content in the snow cover were determined. Measurements of the thickness of snow cover and GPS binding were made during sampling.

Laboratory studies. In the laboratory, snow samples were melted and filtered with the help of the device for vacuum filtration PVF-47/6 NB (PP) (Russia). Filtering was carried out with a Vladipor membrane of MFAS-OS-1 type (Russia) with the average pore size 0.22 μm. The membrane corresponds in the actual parameters to the requirements of TU 2265-01143153636-2015 for MFAS-OS-1.

Macro- and microelement composition in the filtered water obtained from snow melting was analyzed by means of atomic emission spectrometry with inductively coupled plasma (ICP-AES) using a quadrupole spectrometer iCAP 6500 Duo (ThermoScientific, USA) in the Institute of Inorganic Chemistry SB RAS (Novosibirsk). The relative standard deviation of measurements did not exceed 13 %. The intensity of spectral bands at the wavelengths characteristic of each element were recorded with a photosensitive device, measured and processed

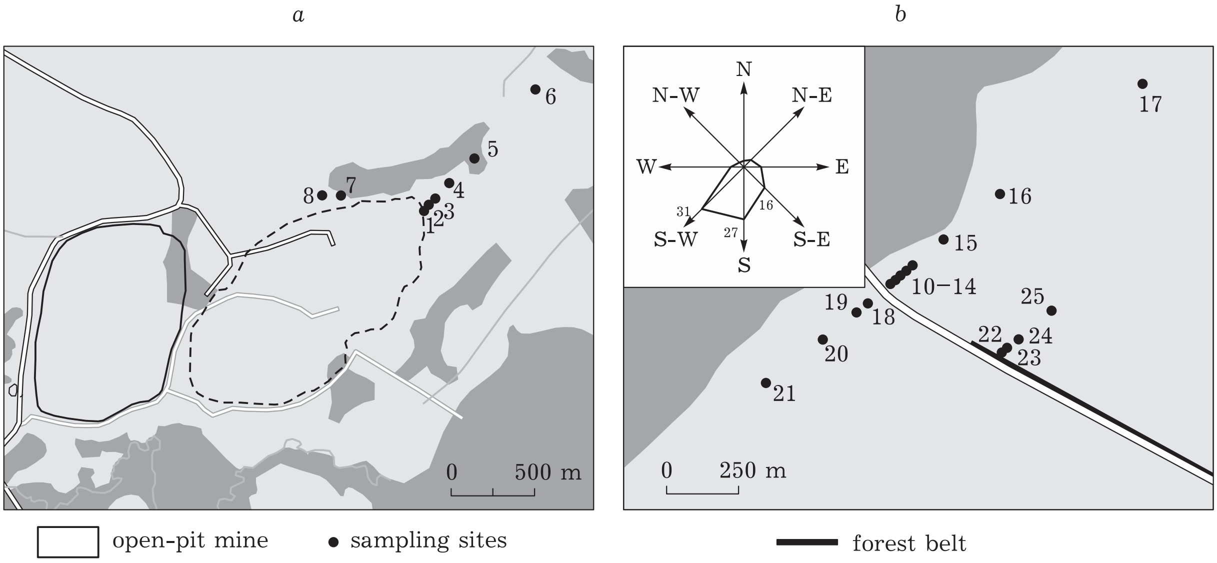

Fig. 1. The wind pattern and the scheme of snow sampling sites: *a* – near the Nagorniy dump of the GCD, *b* – near the road [13].

using a computer system according to GOST R 51309–99.

The suspended component of snow cover was analyzed by means of X-ray fluorescence analysis using synchrotron radiation (XPA-SR) at the VEPP-3 station for elemental analysis in the Institute of Nuclear Physics, SB RAS (Novosibirsk). The relative standard deviation in the determination of the above-mentioned elements was 10–15 %, the lower detection limits were down to 0.1 ppm. Emission spectra were processed with the help of AXIL software. To study the dust particles, we used standard samples SGKhM-3, carbonate-silicate sediments No. 3485-86, SGKhM-4, aluminosilicate sediments No. 3486-86, BIL-1, Baikalian silt No. 272-7126-94, IAEA standard. The range of recordable excitation energy was from 8 to 45 KeV. The following chemical elements may be determined under these conditions: K, Ca, Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Ga, Ge, As, Se, Br, Rb, Sr, Y, Zr, Nb, Mo, Ru, Rh, Pd, Ag, Cd, In, Sn, Sb, Te, I, Cs, Ba, La, Ce, Pr, Nd.

The CHN analysis of suspended particles was carried out by means fo dry burning using a 2400 Series II analyzer (Perkin Elmer, USA) in the Institute of Soil Science and Agrochemistry, SB RAS (Novosibirsk). The accuracy of determination was <0.3 %.

The morphology and composition of mineral particles were investigated using a MIRA 3 LMU scanning electron microscope (SEM) (Tescan, Czechia) at the Institute of Geology and Mineralogy, SB RAS (Novosibirsk).

RESULTS AND DISCUSSION

Dust pollution

The results of the studies showed that the effect of the GCD on the adjacent territories in winder is manifested mainly through the transfer of dust particles. Dust content in the snow sampled near technogenic objects varies from 0.03 to 7.17 g/dm^3. The minimal values of this parameter were detected at the background level (0.02 g/dm$^{3)}$, while the maximal ones were detected in the points situated near the motor road.

Dust content in the snow cover of the territories adjacent to the motor road was higher than the background value (by more than two orders of magnitude) and near the dump (by one order of magnitude).

A clear dependence of a decrease in the concentration of dust in snow with an increase in the distance from the road is observed at the territories adjacent to the motor road (Fig. 2.). The maximal amount of suspended matter (552.5 g/m^2) was detected at the site near the forest belt. At another point located at the same distance from the road but without the screening action of the forest belt, dust concentration was detected to be two times lower on average because a substantial part of the dust is carried

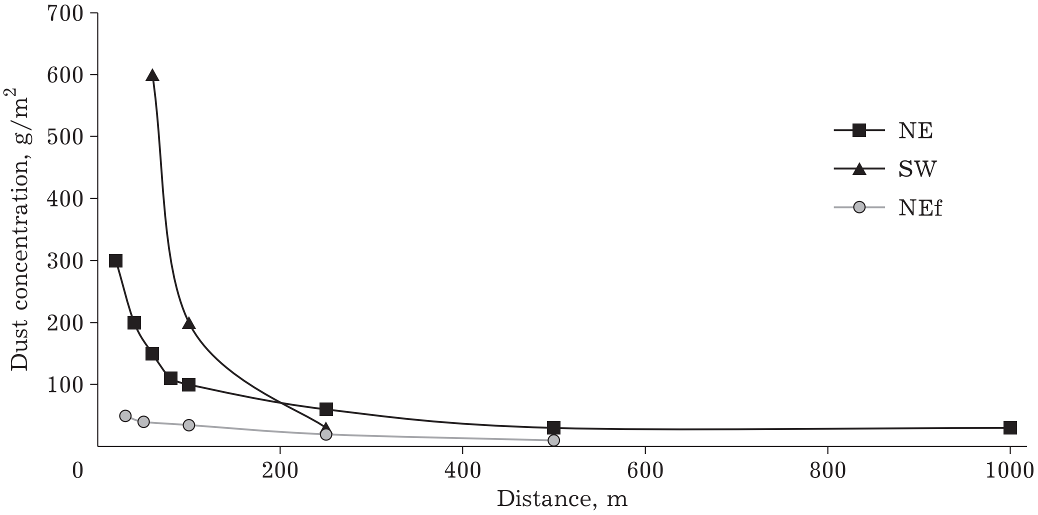

Fig. 2. Distribution of suspended substances in the snow cover near the road. Directions: NE – north-east, SW – south-west, NEf – north-east screened by the forest belt.

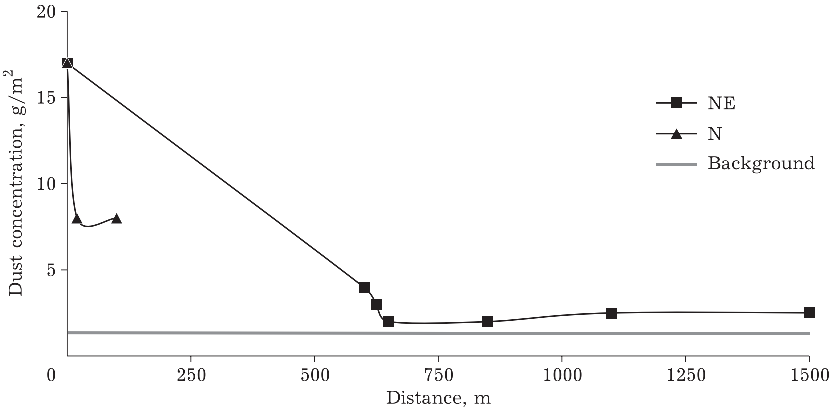

Fig. 3. Distribution of suspended substances in the snow cover near the dump. Direction: NE – north-eastern; N - northern.

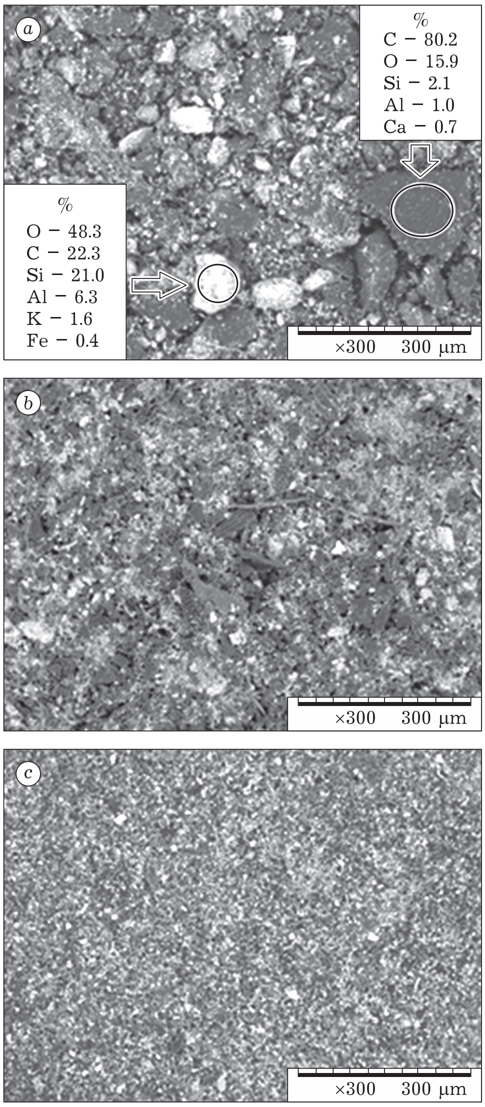

Fig. 4. Micrographs of dust particles from snow samples taken: *a* – 20 m from the highway in the northeastern direction (T10); *b* – in the same place, but at 1000 m (T17); *c* – in the background area (T26).

away over a longer distance. Dust concentration in the point located at a distance of 50 m from the road to the south-west was about 4 times lower than at the same distance but in the north-eastern transect. The minimal dust accumulation (3.8 g/m^2) near the road was detected from the windward side at a distance of 500 m, it exceeded the background level nearly by a factor of 3.

The process of dump landfilling affects the adjacent territories to a less extent. Here dust retention in snow per unit area is 1.9 to 17.3 g/m^2 (Fig. 3).

Evaluation of the composition of dust present in the snow was carried out with the help of micro-morphological methods. It allowed us to reveal the differentiation of the granulometric composition with an increase in the distance from the sources of pollution (Fig. 4, 5). Separate inclusions (with the maximal diameter up to 300 μm) were detected in all samples collected near the sources, independently of the direction and the presence of trees. The smallest particles (up to 30 μm) were detected in snow samples taken from the background sites.

Snow samples taken at the sites directly adjacent to the road are distinguished by the substantial content of organic components, mainly coal. Judging from the elemental composition of the surface, the mineral part of dust is composed of the fine fragments of coal-containing overburden rocks (see Fig. 4). The predominance of the mineral part is detected in the samples taken at the sites both in the vicinity of the dump and at a larger distance from it (see Fig. 5). It is noteworthy that a definite amount of coal particles was also detected in the samples taken from the background region.

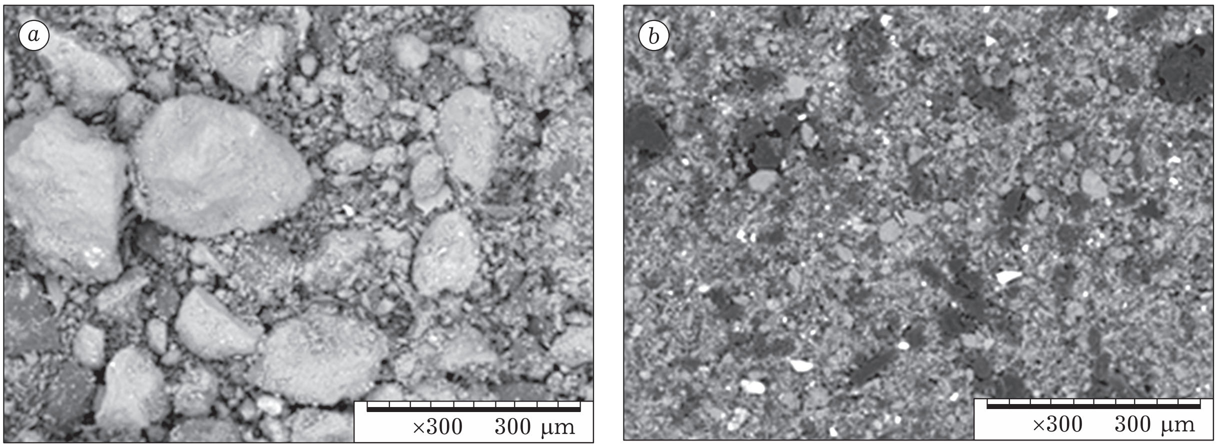

Fig. 5. Microphotographs of dust particles from snow samples taken: *a* – at the boundary of dump filling region (T9); *b* – at a distance of 1500 m to the north-east from the dump filling boundary (T6).

Organogenic elements in snow

Carbon content in the suspension of the snow samples under investigation varies from 34.8 to 64.1 % for the regions situated in the vicinity of the motor road (Fig. 6) and from 11.6 to 30.5 % for the regions adjacent to the dump (Fig. 7). Carbon content in the samples from the background region is 52.2 %, which is the evidence of the predominance of organic compounds in the composition of the dust. Changes in carbon content in the dust with an increase in the distance from the road are multidirectional at different sites. To the north-east, the maximal content of organic substances is detected near the edge of the road surface unprotected by the forest belt, however, at a distance of 100 m, carbon content in the suspension decreases sharply. An opposite trend is detected at the regions located to the south-west or screened by the forest belt. In general, the carbon content in the dust is within the range (50±3) % for all regions at a distance of 400 m from the road.

The ratios of C/N and C/H decrease in all directions with a decrease in the distance from the road (see Fig. 7), which is the evidence of a decrease in the fraction of coaly particles in the organic substance of snow.

A different situation is observed at the sites situated in the zone affected by the dump. In this case, due to the high concentration of mineral particles in snow dust, carbon content turns out to be minimal in the point situated at the boundary of the dump filling zone (see Fig. 7) and increases with an increase in the distance from the dump.

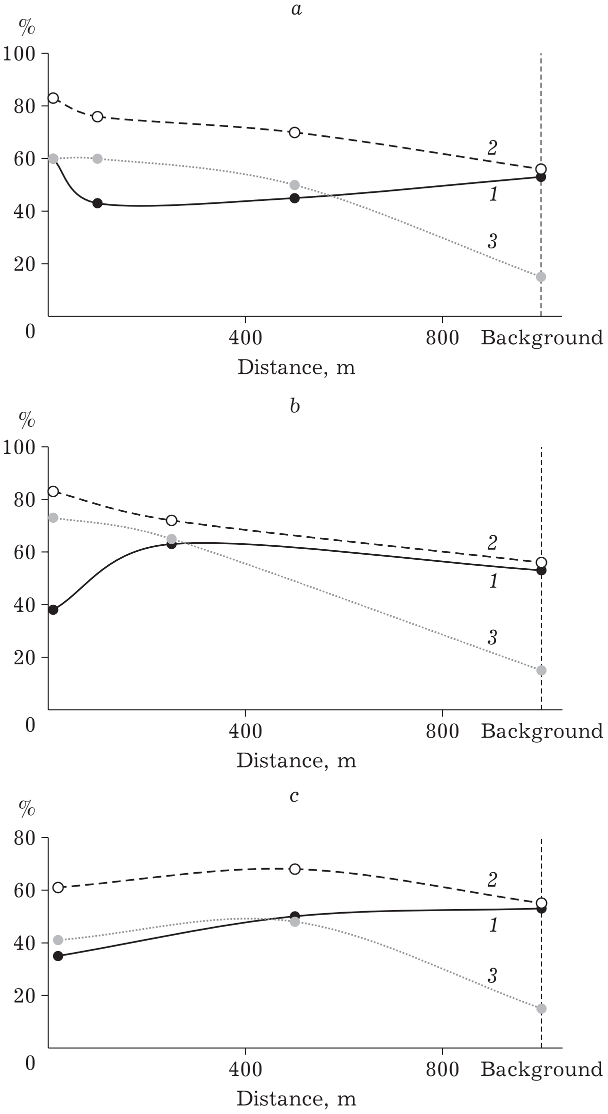

Fig. 6. Carbon content (*1*), the ratios of C/N (*2*) and C/H (*3*) in snow samples taken near the motor road: *a* – in the north-eastern direction (T10, T14, T16); *b* – in the south-western direction (T18, T21); *c* – in the north-eastern direction, at the region with the forest belt (T22, T25).

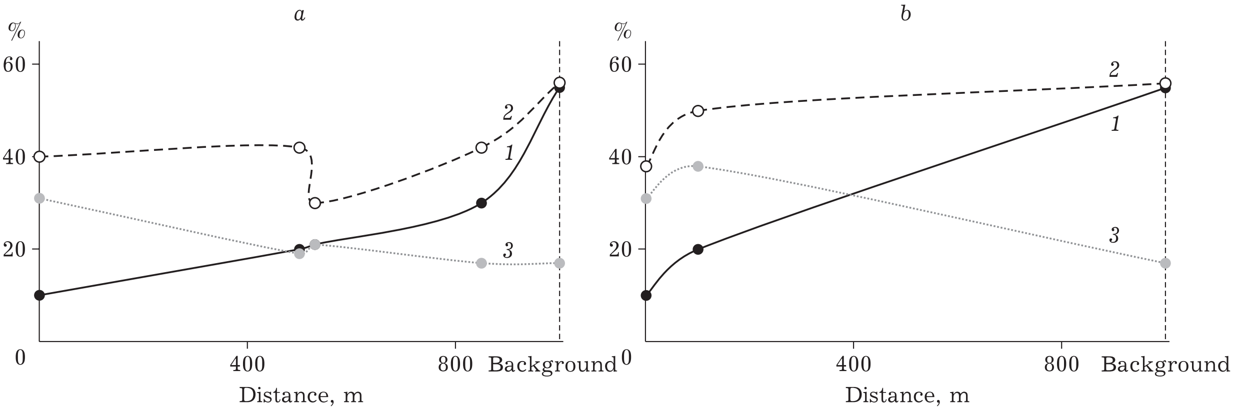

Fig. 7. Carbon content (*1*), the ratios of C/N (*2*) and C/H (*3*) in snow samples taken near the dump: *a* – in the north-eastern direction (T9, T1, T2, T4); *b* – in the northern direction (T9, T8).

So, due to the transport of coal dust from the surface of the motor road, adjacent territories receive an additional amount of coal 2–200 g/m^2 in winter, while near the dump the additional amount is not more than 2 g/m^2. At a distance of only 600 m from the dump, carbon content does not exceed the background level.

TABLE 1

Elements content in the dissolved part of snow cover, g/dm^3

Elenemt	Average	Minimal	Maximal
Ca	12.0	2.1	36.0
Na	4.2	0.15	23.0
K	0.77	0.14	2.4
Mg	0.54	0.047	2.2
Si	0.45	0.006	2.0
Fe	0.041	0.01	0.09
Sr	0.033	0.004	0.11
Al	0.026	0.005	0.07
Zn	0.022	0.002	0.065
Ba	0.022	0.008	0.049
Sb	0.008	0.008	0.008
Cu	0.006	0.004	0.008
Pb	0.004	0.004	0.004
Ni	0.0016	0.0005	0.004
Ti	0.0013	0.0008	0.003
Cr	0.0007	0.0004	0.0013
Li	0.0007	0.0002	0.0032
V	0.0006	0.0003	0.0009
Co	0.0004	0.0001	0.0012
Cd	0.0003	0.00018	0.0004

Chemical composition of the dissolved part of the snow cover

The chemical composition of the dissolved part of snow cover shows the fraction of components emitted and transported as the gas-aerosol phase. The gas-aerosol phase is a disperse system composed of the gas medium in which solid or liquid particles 0.1–10 μm in size are suspended.

Elements may be attributed to three groups according to their content in the dissolved part of snow cover. The first group incorporates macrocomponents with concentrations 0.1 to 30 g/dm^3, it includes alkaline metals: Ca, Na, K, Mg (Table 1). This group includes the most widespread cations of natural waters. It should be noted that Ca and Na dominate in the solution with the concentrations 1 to 30 mg/dm^3, while the content of K and Mg varies within the range 0.1–1 g/dm^3. The second group contains microelements within the concentration range 0.01 to 0.1 g/dm^3 (Ba, Zn, Al, Sr), and the third group (Cr, Li, V, Co, Cd) – from 0.01 to 0.0001 g/dm^3 (see Table 1). The listed microcomponents are less widespread both in the Earth's crust and in surface waters.

The concentrations of almost all elements except Ba, Cr and Zn exceed background levels [13]. In the dump region, the excess over background concentrations is insignificant – up to 1.5 times (Ca, Na, K, Sr, Co). Quite the contrary, substantial excess is observed in the region of the road: the content of some elements (Ca, Na, K, Al, Sr, Si, Mg) is 5–10 times higher than the background levels. With an increase in the distance from the road, a regularity of elements spreading depending on wind direction and the presence of forest belt is outlined. In particular, for Ca (Fig. 8), the maximal concentrations are

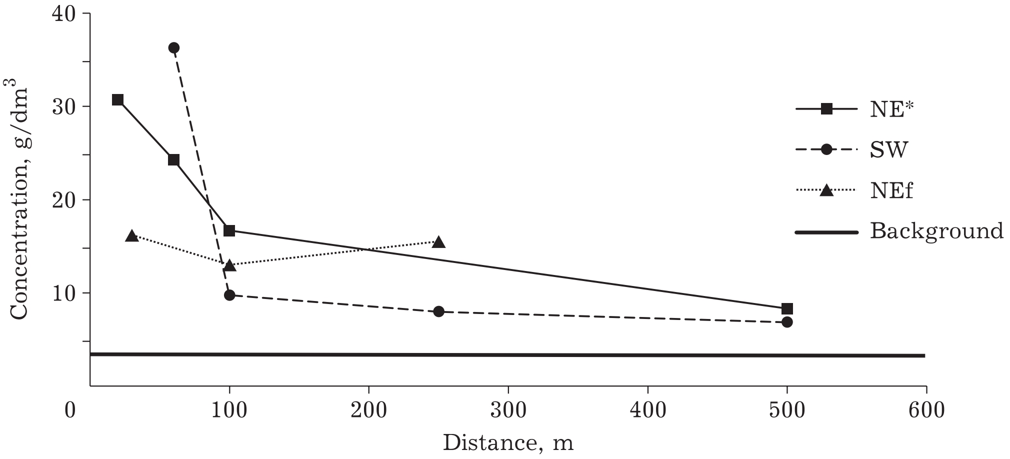

Fig. 8. Distribution of Ca in the dissolved part of snow cover depending on the distance from the road. Direction: NE – north-eastern; SW – south-western, NEf – north-eastern screened by the forest belt.

observed directly near the road (the first 50 m), and then they decrease sharply even by the distance of 100 m. At a distance of 500 m from the road, the concentrations of the elements under consideration approach the background level or coincide with it.

It should be stressed that the concentrations of all elements under analysis are higher at the leeward side than at the windward side. This confirms the effect of wind pattern on the propagation of impurities. Results of the analysis of samples taken behind the forest belt show its screening effect. Here the content of elements in the dissolved part of the snow cover is noticeably lower than from the leeward side. This is the evidence that the forest belt creates an obstacle for air motion and hinders the transport and dissemination of elements in the gas-aerosol phase.

Chemical composition of the suspended part of snow cover

The chemical composition of the suspended part of the snow cover shows the fraction of dust components emitted and transported in the main form. These are small solid particles of organic or mineral origin 10–100 μm in size.

TABLE 2

Elements content in the suspended part of snow cover

Element	Content, %			Element	Content, mg/kg		
	Average	Minimal	Maximal		Average	Minimal	Maximal
Ca	1.678	0.17	3.6	Ga	8.3	4.05	17
Fe	1.134	0.66	2.3	As	7.6	3.8	21
K	0.597	0.46	1.1	Th	6.6	4.7	11
Ti	0.147	0.08	0.35	Mo	4.5	0.8	24
Mn	0.026	0.016	0.05	Cr	4.2	0.81	14
Zr	0.017	0.010	0.03	Te	3.1	2.3	3.7
Zn	0.016	0.003	0.069	Sn	3.0	1.5	5.2
Sr	0.013	0.011	0.015	U	2.0	0.9	4.0
Pb	0.009	0.001	0.054	Sb	1.7	0.29	5.9
Rb	0.005	0.003	0.007	Ag	0.90	0.14	3.6
V	0.003	0.001	0.009	Cd	0.58	0.16	1.0
Ni	0.002	0.001	0.004	Se	0.57	0.19	1.2
Cu	0.002	0.001	0.005	Ge	0.52	0.15	0.98

The distribution of chemical elements in the suspended part of the snow cover allows us to distinguish four groups of elements. The first group includes macrocomponents with the content from 0.1 to 3.5 % (from 1000 to 35 000 mg/kg), this group incorporates metals Ca, Fe, K, Ti (Table 2) – they are among the most widespread elements in the Earth crust. The concentrations of the elements of the second group are within the range 0.001–0.1 % (from 10 to 1000 mg/kg), and this group includes rather mobile metals: Mn, Zr, Zn, Sr, Pb, Rb, V, Ni, Cu. The third group includes not only metals but also anion-forming elements (see Table 2) with the concentrations from 0.0001 to 0.004 % (from 1 to 40 mg/kg): Ga, As, Sb, Mo, Th, Te, Cr, Sn. The lowest concentrations are those of the elements of the fourth group: not more than 0.0001 % (1 mg/kg and lower), this group includes impurity elements of coal (U, Ge, Se) and rare metals (Ag, Cd).

For the suspended part of snow cover, the concentrations of all elements except Mo exceed the background values [13]. It should be stressed that substantial excess over the background levels was observed for the dissolved part in the region of the road, while in the suspended part of snow samples from this region the background level is exceeded only slightly, by a factor of 1.5–2 on average. However, increased content of the elements of the second, third and fourth groups (with the concentrations from 1000 to 1 mg/kg) is detected in the region of the dump, in comparison with the background and with the road region. So, it may be concluded that the effect of dumps on the adjacent territories is substantial.

The regularities of the spread of chemical elements in the suspended part with an increase in the distance from the road is observed not for all elements. The distribution of Ca, a macrocomponent with the maximal concentration in the samples under study, is shown in Fig. 9. With an increase in the distance from the road, Ca content decreases down to the background level and even lower. From the leeward side of the road, Ca concentration is almost 2 times higher than from the windward side. However, the effect of the forest belt is less substantial for dust particles than for the gas-aerosol phase (see Fig. 9). The screening effect of the forest belt is still observed but it is not so strongly pronounced.

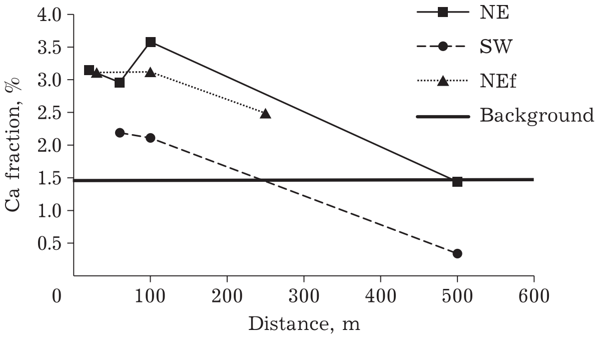

Fig. 9. Ca distribution in the suspended part of snow cover depending on the distance from the road. Direction: NE – north-eastern; SW – south-western, NEf – north-eastern screened by the forest belt.

Migration capacity of elements

To evaluate the migration capacity of elements in the system 'dissolved part of snow cover – suspended part of snow cover', distribution coefficients K_d were used:

$K_d = \log (\mathrm{Me}_{sus}/\mathrm{Me}_{dis})$

where Me_{sus} and Me_{dis} are element concentrations in the suspended and dissolved parts of snow cover, respectively. The lower is K_d, the more mobile is an element in the system [18]. Distribution coefficients were calculated for the road and for the dump. Two groups of elements may be distinguished: mobile ($K_d < 10$) and inert ($K_d > 10$). Mobile elements are Ca, Cu, Cr, Sr, K, inert elements are V, Fe, Ti. For snow samples taken near the road, K_d is lower by 15–20 % than in the samples taken near the dump. So, the higher migration capacity of the elements is characteristic of snow cover near the road.

In general, migration capacities of elements near the dump and near the road are similar and agree with the chemical properties of the elements. The most mobile elements are Ca and Cu, the most inert ones are V, Fe, Ti. However, Cr, Zn and Pb in more mobile forms were detected near the dump rather than near the road.

The obtained sequences of element mobility are as follows:

Dump: Ca > Cu > Cr > Zn > Pb > Sr > K > V > Fe > Ti

Road: Ca > Cu > Sr > Cr > K > Zn > Ni > V > Fe > Ti

The results presented above allow us to characterize the geochemical settings of the formation of macro- and microcomponent composition of the ground atmospheric layer and, as a consequence, the composition of snow cover near coal dumps. The presence of carbon particles in the air causes the redistribution of chemical substances between the suspension and the solution, and the mobility of well soluble elements (for example, potassium) decreases with respect to other elements, while the mobility of elements with lower solubility (for example, copper) increases.

CONCLUSION

The effect of the Gorlovo coal basin on the ground atmospheric layer spreads over more than 1000 m from the leeward side of the road (north-eastern direction) and 500 m from the windward side (south-western direction). The maximal effect is caused by the motor road along which the produced coal is transported, and the minimal effect is caused by the dump in which overburden rocks and deads. Dust content varies within the range from 3.9 to 552.5 g/m^2 near the road and from 1.9 to 17.3 g/m^2 near the dump.

The screening effect is caused not only by the rock dumps but also by the forest belts growing along the roads, which accumulate a substantial fraction of dust and hinder its further transport. Dust content and the concentrations of elements in the dissolved part of snow cover are noticeably lower in the samples taken behind the forest belt than at the leeward side which is not screened by the forest belt.

The prevailing element in technogenic dust is carbon. Its content in the suspended matter of all the samples under study is within the range 34.8–64.1 and 11.6–30.5 % for the regions located near the road and near the dump, respectively. A substantial part of carbon in all the samples is present in the form of coaly particles.

In the dissolved part of the snow cover, the concentrations of the major part of elements (except Ba, Cr and Zn) exceed the background values. The excess is not great in the region of the dump: 1.5 times (Ca, Na, K, Sr, Co), while in the region of the road the excess for some elements (Ca, Na, K, Al, Sr, Si, Mg) reaches 5–10 times.

For the suspended part of snow cover, the concentrations of all elements (except Mo) exceed background values. Higher concentrations of microelements in comparison with the background were detected in the samples taken near the dump.

With an increase in the distance from the road, independently of the wind pattern, Ca content in the suspended part decreases to the background values; at the leeward side of the road it is almost 2 times higher than at the windward side. The effect of the forest belt on dust particles turns out to be less substantial than for the gas-aerosol phase. The screening effect of the forest belt is present, but it is not so clearly pronounced.

The migration capacities of elements in the samples taken near the dump and near the road are similar. However, the coefficients of element distribution in snow samples taken near the road are lower, which is the evidence of the transport of elements in more mobile forms.

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