Research of Particle Size Composition of Atmospheric Particulates in Several Communities of the Magadan Region

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Abstract. The paper presents the results of particle size distribution analysis of atmospheric particulate matter studied in the snow of several settlements in the Magadan Region (towns Magadan, Susuman, and Omsukchan). The study found a significant content of PM₁₀ particles in the air of Magadan town (28 to 65.7%), and a general dominance of particles under 50 µm in diameter (PM₅₀ fraction) – from 44.4 up to 100%. The content of environmentally significant PM₁₀ particles in the air of smaller settlements of the Magadan region (towns Susuman and Omsukchan) does not exceed 21.1%. We can conclude that the air in the Magadan town, due to the predominance of PM₁₀ and PM₅₀ particles is characterized by a pronounced micro-particles contamination. This level of pollution, in conjunction with the harsh climate of this region, is a constant source of respiratory diseases and a factor in reduction of the quality of life.

1. Introduction

The Magadan Region with a total population of just over 144 thousand people is one of the largest regions in the Russian Federation in the extraction of gold and silver. According to an official TASS publication dated January 15, 2018, almost 33 tons of gold were produced in 2017, which was 15.4% higher than the production level in 2016. Also miners extracted 779.5 tons of silver. It is this branch of the mining industry (in particular, ash dumps and tailings) that is the main source of environmental problems in the region [1, 2].

In addition to the mining industry, the most prominent sources of air pollution in the Magadan Region are energy companies (boiler houses and thermal power stations) and cars [3, 4, 5].

Beyond doubt, emissions of combined heat and power plants and boiler houses are greater in this region than in southern regions due to the long heating season. It is known that at certain conditions boiler houses and cars can impact the environment in greater extent than community-forming enterprises [6, 7, 8, 9]. Moreover, the concentration of airborne particles may vary depending on the season, increasing in winter [10, 11]. The average annual air temperature in the Magadan region is below zero degrees Celsius.

The motorization of the population of the Magadan region is not high: according to the analytical agency Autostat in 2016 there were 293 cars per 1000 people (for comparison, in Primorsky Krai there are 427 cars per 1000 people), however there studies showing that the exhaust of particles from cars is higher in winter season [12].
This work is relevant due to the fact that while more than a dozen publications are devoted to the environmental state of Magadan, little is known about the state of atmospheric pollution of small settlements in the Magadan Region (towns Susuman, Omsukchan and others).

2. Materials and methods
Atmospheric particulates were studied in fallen snow in the settlements of the Magadan Region (Magadan, Susuman and Omsukchan), which was collected during snowfalls in March 2018 (Figures 1-3, Tables 1-3).

Table 1. Description of sampling stations in Magadan (March 2018).

| No. | Address                                |
|-----|----------------------------------------|
| 6   | Magadan City Park                      |
| 7   | Crossroads of streets Nagaevskaya and Novaya |
| 8   | Marchekanskoye Shosse, 44              |
| 9   | Proletarskaya Str., 81                 |
| 10  | Proletarskaya Str., bus stop Dachnaya   |
| 11  | Kolymskoye Shosse, 4                   |
| 12  | Kolymskoye Shosse, fire department     |
| 13  | Rechnaya Str., 25                      |
| 14  | Transportnaya Str., 8                  |
| 15  | Small public park                      |

Magadan is the largest community in the Magadan region: 92,782 people, according to data from 2018. The population of Omsukchan and Susuman is 3758 and 4760 people, respectively.

Atmospheric particulates were analysed in the fallen snow that was collected at the time of snowfalls in March 2018. In order to exclude secondary pollution with anthropogenic aerosols only the top layer (5-10 cm) of freshly fallen snow was collected. It was placed in sterile 3 l containers. After the samples were delivered to the laboratory, melted snow was evaporated using a rotary...
evaporator at 40°C to obtain a more concentrated solution until its volume was reduced to 60 ml. The liquid was analysed using Analysette 22 NanoTec plus laser particle sizer (Fritsch GmbH, Germany). The measurements were carried out in the range from 0.08 to 200 μm.

**Table 2.** Description of sampling stations in Omsukchan (March 2018).

| No. | Address                                      |
|-----|----------------------------------------------|
| 1   | Crossroads of streets Mira and Podgornaya    |
| 2   | Lenina Str., 36                             |
| 3   | Industrialnaya Str, in vicinity of a boiler house |
| 4   | Lenina Str., 19                             |

**Figure 3.** Sampling stations in Susuman in March 2018. Description of stations in Table 2.

**Table 3.** Description of sampling stations in Susuman (March 2018).

| No. | Address                                      |
|-----|----------------------------------------------|
| 16  | Bilibina Str., 15                           |
| 17  | Crossroads of streets Lenina and Rakovskogo |
| 18  | Sovetskaya Str., 2, in vicinity of a boiler house |
| 19  | Bilibina Str., 3                            |
| 20  | Pervomayskaya Str., 5A                      |

3. **Results and discussion**

The data on the particle size distribution of atmospheric particulates of Magadan are presented in Table 4.
Table 4. Particle size distribution of atmospheric particulates in snow samples collected in Magadan.

| Fraction, µm / Sampling point No. | 6   | 7   | 8   | 9   | 10  | 11  | 12  | 13  | 14  | 15  |
|-----------------------------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Under 1                           | 3.9 | 4.2 | 17.2| 5.4 | 8.5 | 8.7 | 3.3 | 6.1 | 4.5 | 2.7 |
| 1 - 10                            | 33.2| 32.6| 48.5| 42.6| 47  | 37.6| 27.6| 39.5| 36.7| 25.3|
| 10 - 50                           | 23.3| 50.4| 29.7| 52  | 41.6| 24.2| 39.1| 35.5| 26.4| 16.4|
| 50 - 100                          | 1   | 7.7 | 4.6 | 0   | 2.9 | 0   | 6   | 10.7| 0   | 0.1 |
| 100 – 400                         | 1   | 0.1 | 0   | 0   | 0   | 0.2 | 5.2 | 2.9 | 0   | 5.5 |
| 400-700                           | 8.3 | 0.1 | 0   | 0   | 0   | 10.8| 6.9 | 2.7 | 1.5 | 8.1 |
| Over 700                          | 29.3| 4.9 | 0   | 0   | 0   | 18.5| 12.1| 2.6 | 30.8| 41.9|

*PM$_{10}$ particles are in gray

As shown in Table 4, the percentage of atmospheric particulates with diameter under 10 µm varies from 28 to 65.7% at all sampling points. If the trend does not change, then the prognosis for bronchopulmonary diseases in the region is unfavorable.

In general, apart from the environmentally significant PM$_{10}$ fraction, the highest concentration of particulates was found for particles under 50 µm in diameter. The only exception is sample No. 15, which mainly contains particles larger than 700 µm. This sample was collected in the park area full of trees. There were no large particles found at points No. 8, 9 and 10 (diameter over 100 µm). This phenomenon can be explained by a single source of pollution (for instance, industrial emissions), especially considering that the sites, next to which the samples were collected, are industrial zones and warehouses. It is necessary to verify these fractions using scanning electron microscopy and Raman spectrometry.

For convenience, the samples from Susuman and Omsukchan are presented in the same Table 5.

Table 5. Particle size distribution of atmospheric particulates in snow samples collected in Omsukchan and Susuman.

| Fraction, µm / Sampling point No. | Omsukchan | Susuman |
|-----------------------------------|-----------|---------|
|                                    | 1         | 2       | 3       | 4   | 16  | 17  | 18  | 19  | 20  |
| Under 1                           | 3.5       | 0.4     | 0.4     | 1.5 | 2.4 | 1.7 | 0.9 | 1.2 | 0.9 |
| 1 - 10                            | 16.6      | 2.4     | 1.6     | 7.8 | 18.7| 13.6| 7.8 | 8.9 | 7.3 |
| 10 - 50                           | 41.5      | 10.4    | 22.4    | 45.6| 37.6| 44.3| 41.4| 53.7| 46.8|
| 50 - 100                          | 13.1      | 11.7    | 36.7    | 31.7| 11.7| 23.6| 30. | 31.5| 31.5|
| 100 – 400                         | 3.3       | 54      | 38.2    | 13.2| 3.7 | 6.1 | 20.1| 4.7 | 12  |
| 400-700                           | 4.2       | 20.5    | 0.7     | 0.2 | 0.4 | 0.2 | 0   | 0   | 1.5 |
| Over 700                          | 17.8      | 0.6     | 0       | 0   | 25.3| 10.5| 0   | 0   | 0   |

As follows from Table 5, the quantity of particles under 10 µm in diameter is much lower in these small settlements than in Magadan. The particle size profiles of atmospheric particulates of Omsukchan and Susuman are similar to each other. We assume that the largest contribution to the pollution of atmospheric air by particulate matter is made by coal-burning boiler plants, because the soot particles were visible with the naked eye in the melted water samples. Other air pollution sources in these communities include mining companies: Mining and Processing Plant Dukat in Omsukchan and OAO Susumanzoloto in Susuman, with industrial sites located in close proximity to the residential areas.

4. Conclusion

We can make a preliminary conclusion about the particle size distribution of atmospheric particulates in a number of settlements in the Magadan Region. In particular, as we have demonstrated that the
atmospheric air of Magadan has a pronounced micro-sized contamination with particles of unknown origin. Most likely, this is the result of activities of mining and fuel-energy enterprises, which was described in research papers [1, 2]. From the point of view of the complex impact of large mining enterprises and thermal power stations, it is not surprising that the results are manifested not only in the atmosphere, but also in the hydrosphere [4, 13, 14]. It is necessary to consider the transfer of combined heat and power plants to gas and to increase the measures of dust suppression at mining enterprises.

Small towns Susuman and Omsukchan showed a low level of air pollution with microparticles of the PM$_{10}$ fraction. This is due to the low level of the industrial press and a small number of cars, and these results are in agreement with the results of similar research conducted by us in other territories [15].

5. References

[1] Shapovalova T A and Lapina Z A 2009 Predicting the impact of environmental factors on the quality of life indicators of the population of the North-East region Bulletin of the North-Easter State University 11 pp 91-93
[2] Volobuyeva N G and Blagovestnaya N Yu 2013 Ecological problems of the Magadan Region and Magadan Proc. IV Conf. Ecological and geographical problems of Russian regions pp 128-133
[3] Tsyplakova E G, Shapovalova T A and Yankevich Yu G 2006 Estimation of environmental danger of the objects of motor transport complex and their impact on the state of residential areas of northern cities of Russia on the example of Magadan Regional ecology 1(2) pp 136-141
[4] Boguslavskaya N V 2008 Assessment of arable soils in the Magadan Region in terms of contamination by toxic microelements Environmental safety in the agricultural complex 3 p 630
[5] Tsyplakova E G and Potapov A I 2010 Estimation of environmental danger of stationary and non-stationary power plants and their effect on the state of atmospheric air in northern cities of Russia on the example of Magadan Problems of regional ecology 4 pp 11-16
[6] Lagudu U R K, Raja S, Hopke P K, Chalupa D C, Utell M J, Casuccio G, Lersch T L and West R R 2011 Heterogeneity of Coarse Particles in an Urban Area Environmental Science & Technology 45(8) pp 3288-3296
[7] Kumar P, Hopke P K, Raja S, Casuccio G, Lersch T L and West R R 2012 Characterization and heterogeneity of coarse particles across an urban area Atmospheric Environment 46 pp 449-459
[8] Kholodov A, Ugay S, Drozd V, Maiss N and Golokhvast K 2017 Data on microscale atmospheric pollution of Bolshoy Kamen town (Primorsky region, Russia) IOP Conference Series: Earth and Environmental Science 90 012023
[9] Pant P and Harrison R M 2013 Estimation of the contribution of road traffic emissions to particulate matter concentrations from field measurements: A review Atmospheric Environment 77 pp 78-97
[10] Shi Z, Shao L, Jones T P, Whittaker A G, Lu S, Bérubé K A, He T and Richards R J 2003 Characterization of airborne individual particles collected in an urban area, a satellite city and a clean air area in Beijing, 2001 Atmospheric Environment 37(29) pp 4097-4108
[11] Hong K Y, King G H, Saraswat A and Henderson S B 2017 Seasonal ambient particulate matter and population health outcomes among communities impacted by road dust in British Columbia, Canada Journal of the Air & Waste Management Association 67(9) pp 986-999
[12] Vu T V, Delgado-Saborit J M and Harrison R M 2015 Review: Particle number size distributions from seven major sources and implications for source apportionment studies Atmospheric Environment 122 pp 114-132
[13] Lugovaya E A and Stepanova E M 2016 Features of the composition of drinking water in Magadan and public health Hygiene and Sanitation 95(3) pp 241-246
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[14] Petukhov V I, Gidarakos E, Erekhinsky A N, Zinkov A V, Litvinets O I, Salhofer S, Tarasenko I A, Kholodov A S and Chernysh O G 2016 Integrated sustainable waste management. Mining (Moscow: The Russian Academy of Natural History Publ.) p 638

[15] Kholodov A, Ugay S, Drozd V, Agoshkov A and Golokhvast K 2017 Microscale atmospheric pollution of Pogranichny settlement (Primorsky region, Russia) IOP Conference Series: Earth and Environmental Science 90 012024