

Microscale Atmospheric Pollution in Some Small and Medium-sized Settlements of Primorsky Region (Russian Federation) –Results of Particle Size Analysis

A S Kholodov, S M Ugay, V A Drozd, K S Golokhvast

Far Eastern Federal University, 8, Sukhanova St., Vladivostok 690090 Russia

E-mail: alex.holodov@gmail.com

Abstract. The paper deals with the study of atmospheric particulate matter in medium and small settlements of Primorsky Region: Lesozavodsk town (Lesozavodsky urban district); settlements Gornye Kluchi and Ussurka (Kirovsky district); LDK settlement (Dalnerechensky urban district); villages Novopokrovka and Izmaylikha (Krasnoarmeysky district) by means of particle size analysis. It is shown that the atmosphere of each settlement contains microparticles sized under 10 μm (PM10) in significant proportions (over 20%). A conclusion is made that there is a need for continuous environmental and hygienic monitoring not only in big cities and heavily contaminated areas, but also areas that are considered environmentally safe.

1. Introduction

The contemporary scientific level of air pollution research allows the researchers to single out a new class of toxicants - nano- and micro-sized particles of atmospheric particulate matter. Atmospheric particulate matter in the air of settlements is polluted with ultrafine nano- and microparticles of both man-made and natural origin: components of vehicle exhaust, various smoke emissions, products of dusting from various industries, wind-blown volcanic ash, etc. [1-4]. The impact of such particles on humans and animals is associated with the development of so-called ecology-dependent pathology, increased risk of pathological changes in the respiratory system, cardiovascular diseases, etc. among the inhabitants of large cities and settlements with adverse environmental conditions [3, 5].

In Russia continuous environmental and hygienic monitoring of the composition of atmospheric particulate matter is carried out in major cities, industrial polluted areas, and in the reserves [6-8]. However, of certain interest are medium and small (in terms of population) settlements, as well as territories with a small number of people. Studies have shown that even the atmosphere of small towns and villages may contain dangerous to human health and biota microparticles (less than 10 μm) and potentially dangerous (10-50 μm) in significant parts, the causes of which are cars and boiler-houses fired with coal [9]. It should be noted that often in small towns there are township-forming enterprises which have significant impact on the environment, equating such settlements to mega-cities in terms of the ecological status, especially in cases of enterprises of mining and metals industries. In some cases, boilers and vehicles can have greater impact on the environment than the enterprises (on the basis of particle size analysis of particulate matter PM10 in the air).

One of the features of Primorsky Region is long distances between towns (about 100-150 km on average), small number of large industrial enterprises and low population density. Environmental



conditions in small settlements can differ dramatically depending on many factors, so it is important to carry out environmental and hygienic monitoring of the composition of atmospheric particulate matter. Previously the authors examined microscale atmospheric pollution in towns Bolshoi Kamen, Spassk-Dalniy, Pogranichniy settlement.

This paper deals with the study of atmospheric particulate matter in 6 medium and small settlements of Primorsky Region by laser granulometry methods with the aim to identify the content of nano- and microparticles in the atmospheric particulate matter, which have an impact on air quality, climate, people and animals.

2. Materials and methods

For this study the authors collected snow samples in 6 medium and small settlements located in two districts and two urban districts of Primorsky Region: 1) Lesozavodsk town (Lesozavodsky urban district, the total population of the district is 43,769 people); 2) settlements Gornye Kluchi ("Shmakovka" resort) and Ussurka (Kirovsky district, the total population of the district – 19,268 people); 3) LDK settlement (Dalnerechensky urban district, the total population of the district – 29,185 people). 4) villages Novopokrovka and Izmaylikha (Krasnoarmeysky district, the total population of the district – 17,075 people). The general map of settlements where the authors collected the snow samples for this research is presented in Figure 1.

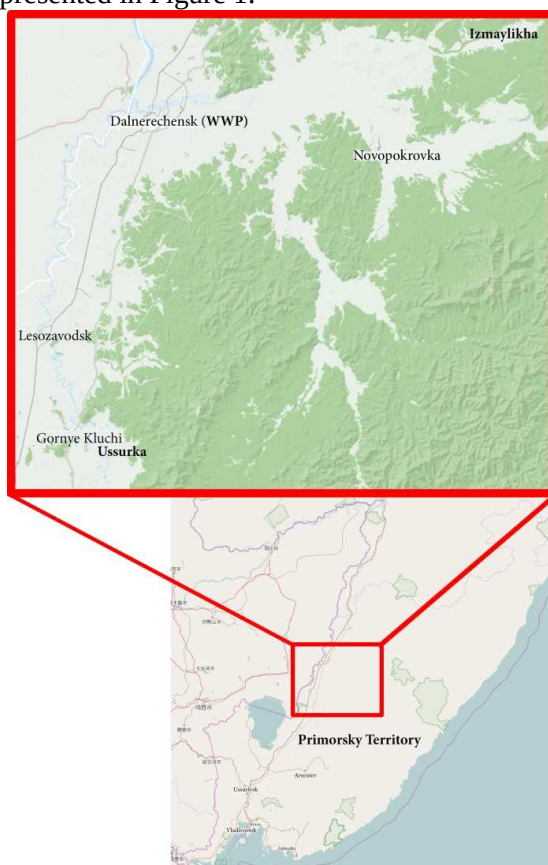


Figure 1. General map of settlements where snow samples were collected. © OpenStreetMap contributors

Sampling stations were selected near highways, near boiler houses (if available), in residential neighborhoods. Samples were taken in winter 2015-2016 in the course of three snowfalls. In order to avoid secondary pollution, only the top layer of fresh snow (5-10 cm) was collected. The snow was placed in sterile 3.2-3.5 liter containers. After melting, the fluid in the containers was stirred, then 60 ml of liquid were taken from each sample, and the liquid was analyzed on a laser particle analyzer

Fritsch Analysette 22 NanoTech (Germany), which allows us to determine the particle size distribution and the shape of particles in a single set of measurements.

3. Results and discussion

Lesozavodsky urban district, Lesozavodsk town

Lesozavodsk is the administrative center of Lesozavodsky urban district of Primorsky Region. Ussuri River runs through the town, there is a railway and a motorway. In the past the town was the center of wood processing industry, currently there is a woodworking plant, biochemical factory, clothes factory, and a number of food enterprises. One of the major employers is Ruzhino railway station, located in the town. The climate is temperate monsoon dominated by southern and south-western winds. As of 2016 the town's population is 36 027 people (Russian Federal State Statistics Service 2016).

In Lesozavodsk snow samples were collected at three sampling stations during three snowfalls in December 2015 - January 2016. The sizes of particles and percentage ratio of fractions in samples of particulate matter at all sampling stations are presented in Table 1.

Table 1. Distribution of particle fractions in snow samples in Lesozavodsk town

Fraction, μm	Percentage of particles in sample, % (^a Lesozavodsk)		
	1	2	3
Under 1	4.6	6.7	1.9
1 - 10	26.2	38.4	25.4
10 - 50	9	13.6	15.6
50 – 400	22.7	11.4	12.9
400-700	33.9	12.3	34.3
Over 700	3.6	17.6	9.9
Arithmetic mean	278.59	485.99	311.04
Mode	460.85	597.61	524.80

^a 1 - the road at the entrance to the town (Dzerzhinskogo Str.); 2 - near the boiler house and the railway station (Oktyabrskaya Str.); 3 - residential district (Lenina Str.).

As shown in the data presented in Table 1, the particles of the first two size classes (10 μm) were found at all sampling points in Lesozavodsk in significant quantities (from 25.4 to 38.4%). In other size classes the particles are distributed more evenly. According to the table the author can conclude that hazardous and potentially hazardous to the health particle of sizes up to 50 μm constitute on average a half of the particle size spectrum detected in the samples in the settlement (from 39.8 to 58.7% on average, see Figure 2).

The data show that the atmosphere of Lesozavodsk contains microparticles hazardous (under 10 μm) and potentially hazardous to human health (10-50 μm) in significant proportions. Judging from the geographical location of sampling points and their proximity to certain objects it can be concluded that the sources of PM_{10} microparticles are motor vehicles, as well as the proximity to the boiler house and railway station. It is worth noting, however, that according to authors' observations, in some cases, the proximity to a railway station does not lead to the increase in the content of fine particles [10].

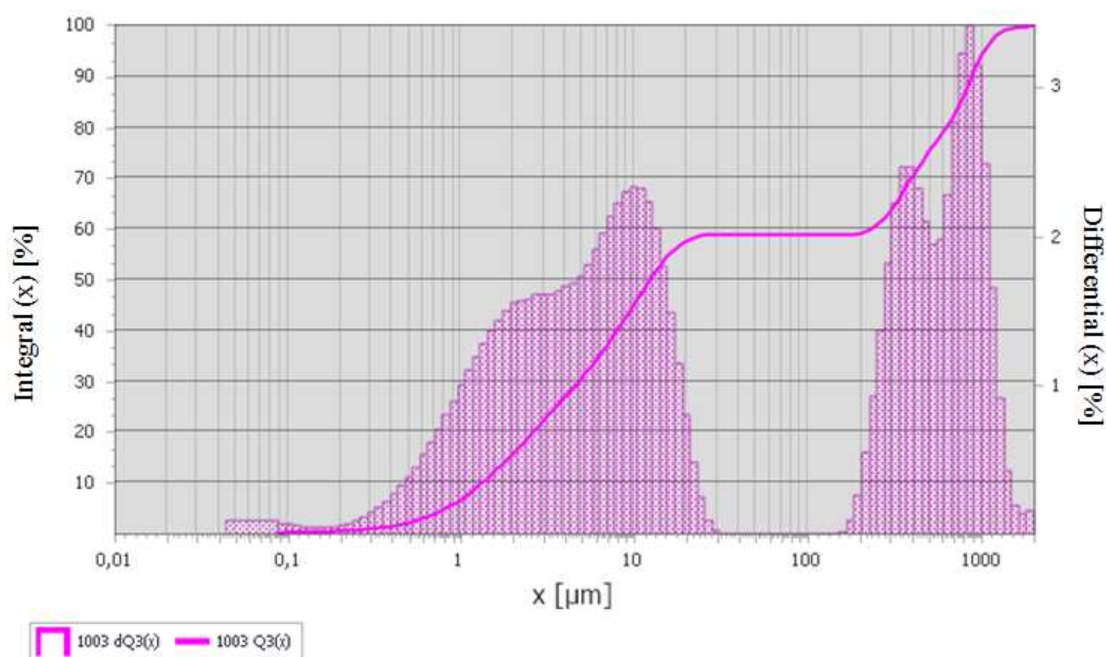


Figure 2. A typical bar graph of particulate matter distribution in the snow water sample collected in Lesozavodsk town at sampling point No.2 (Oktyabrskaya Str., close to the boiler house and the railway station)

Kirovsky district, settlements Gornye Kluchi (“Shmakovka” resort) and Ussurka

Kirovsky district is located on the bank of the Ussuri River, bordering on the north-east with Lesozavodsk urban district. One of the most important items in the district’s budget is health-improvement and recreational services, the sources of calcium-magnesium mineral waters are located here. The climate is temperate monsoon with prevailing southern winds. Two small settlements were selected for sampling in the district: Gornye Kluchi and Ussurka.

Gornye Kluchi is a resort settlement in which 4 health resorts are located. As of 2016 the population is 4249 people. Federal highway A-370 “Ussuri” runs through the settlement. Ussurka settlement is located 10 km to the south of Gornye Kluchi. Its population is 630 people. There are no industrial enterprises; the residents are mostly engaged in agriculture.

According to the data collected, particles of sizes up to 10 μm hazardous to the health of humans and animals were found in significant quantities at one sampling point in Gornye Kluchi settlement and at three sampling points in Ussurka settlement. With the absence of industry in these settlements one can conclude that the sources of micro-dusting, probably, are boilers fired with coal, as well as the products of combustion at house stoves. It is necessary to continue research in this area to identify the sources of micro-sized air pollution.

Dalnerechensky urban district, LDK settlement

LDK is a settlement situated in the immediate vicinity of a woodworking plant, 8 km from the city of Dalnerechensk. Snow samples were collected at three sampling points in three steps during snowfalls of winter 2015-2016. As seen in the data collected, the distribution of particulate matter in snow water samples is relatively uniform at all sampling points. Only at one snow sampling point the content of PM10 fraction exceeded a significant percentage (26.7%). Most likely, this distribution of particles is due to the remoteness of the sampling points from the woodworking plant, and that should be taken into account in subsequent monitoring of the atmosphere of the settlement.

Krasnoarmeysky district, villages Novopokrovka and Izmaylikha

Krasnoarmeysky district is one of the largest in the north of Primorsky Region; its area is over 20,660 square kilometers, covering a significant part of the taiga on the western slope of the Sikhote-Alin. The area has distinctly continental climate. In the Krasnoarmeysky district the content of micro particles in the atmosphere was studied in two small villages: Novopokrovka and Izmaylikha.

Novopokrovka village is located on the bank of the Bolshaya Ussurka River. The population in 2010 was 3,646 people. There is no industry in the village, but there is food production (dairy plant, bakery). Izmaylikha village is located in the basin of Izmaylikha River, tributary of Bolshaya Ussurka River, and it is equated to the regions of Far North. The population in 2010 was 287 people. The landmarks of the place are meteor craters, located 5 km from the village.

Snow samples in villages Novopokrovka and Izmaylikha were collected at three sampling points in each village in three steps during snowfalls of winter 2015-2016. All samples were collected near the roads passing through the center of villages (Sovetskaya Str. in Novopokrovka village and Centralnaya Str. in Izmaylikha village). The sizes of particles and percentage ratio of fractions in samples of particulate matter at all sampling stations are presented in Table 2.

Table 2. Distribution of particle fractions in snow samples in Novopokrovka and Izmaylikha villages

Fraction, μm	Percentage of particles in sample, %					
	Novopokrovka village, Sovetskaya Str. (house number in brackets)			Izmaylikha village, Centralnaya Str. (house number in brackets)		
	1 (7)	2 (74)	3 (128)	1 (1)	2 (23)	3 (56)
Under 1	1.4	1	3.1	1.6	0	2.2
1 - 10	6.4	10.3	26.7	19.8	0	22.7
10 - 50	4.4	7.1	15.4	15.3	1.4	1
50 – 400	10.1	8.7	8	0.7	27.8	15.6
400-700	29.9	26.7	13.8	9.5	44	39.9
Over 700	47.8	46.2	33	53.1	26.8	18.6
Arithmetic mean	644.03	610.68	425.61	584.39	557.18	422.99
Mode	800.52	800.52	882.46	882.46	578.51	597.61

Krasnoarmeysky district is considered environmentally safe, and there are no industrial enterprises in villages selected for sampling. As seen from the data in Table 2, the fractions of bigger sizes (400 μm and above) constitute a major part in the atmosphere of these villages: from 46.8 to 77.7%). However, particulate matter PM₁₀ was detected in significant quantities (from 19.8 to 26.7%) in three of six sampling points in two villages in Krasnoarmeysky district. Therefore, the results of laser particle size analysis allow us to make the preliminary conclusion that the increased content of the microparticles of the second size class may be due to the proximity to the highway which is the source of dusting, or smoke emissions. Detailed conclusions on the sources of micro-sized pollution will be possible after the analysis of samples using a scanning microscope.

4. Conclusion

It is shown in the results obtained that the atmosphere of small and medium-sized settlements contains dangerous (under 10 μm) and potentially dangerous to human health microparticles (10-50 μm) in significant parts, and it is observed both in settlements under anthropogenic pressure (Lesozavodsk town) and areas considered environmentally safe (Ussurka village). The sources of this particulate matter may be small boiler houses fired with coal, automobiles and other sources of dusting and smoke. Obviously, it is necessary to carry out periodical environmental and hygienic monitoring not only in big cities and heavily contaminated areas, but also in the areas that are considered environmentally safe. Prolonged exposure to microparticles has an impact on human and animal

health, so periodical monitoring will allow determining whether the background of microparticles is “accidental” or it is caused by a permanent source of dusting.

5. Acknowledgements

The research was conducted using the equipment of the Interdepartmental Center of Analytical Control of the State of Environment FEFU and Nanocenter FEFU.

References

- [1] Brines M *et al* 2015 *Atmospheric Chemistry and Physics* **15** 5929–5945
- [2] Golokhvast K S, Chernyshev V V, Nikiforov P A, Avtomonov E G, Glushchenko D A, Panichev A M and Gulkov A N 2012 *Proc. Samara Scientific Center of the Russian Academy of Sciences* **14**(1) 2405–2408
- [3] Simonova I N, Antonyuk M V and Vitkina T I 2013 *Bulletin Physiology and Pathology of Respiration* **49** 115–120
- [4] Vu T V, Delgado-Saborit J M and Harrison R M 2015 *Atmospheric Environment* **122** 114–132
- [5] Brook R D *et al* 2004 *Circulation* **109** 2655–2671
- [6] 2009 *Analytical Review The air quality in major cities of Russia for ten years* (St. Petersburg: Asterion) 133 p.
- [7] Avdeeva E L, Revutskaya I L, Lonkina E S and Polyakov V Yu 2016 *Proc. The architecture of multipolar world in the XXI century: ecology, economy, geopolitics, culture and education* p. 4–7
- [8] Artamonova S Yu 2012 *Chemistry for Sustainable Development* **4** 405–418
- [9] Golokhvast K S 2013 *Urban atmospheric suspensions of the Russian Far East* (Vladivostok: Publishing House of the Far Eastern Federal University)
- [10] Kholodov A S, Ugay S M, Drozd V A and Golokhvast K S 2016 *Bulletin Physiology and Pathology of Respiration* **61** 42–45