Study of air pollution in the area of compact accommodation of students (campuses) of three universities in Vladivostok city

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Abstract. The article presents the results of the study of airborne particulate matter in Vladivostok city in three areas of compact residence of students (university campuses) using the methods of laser particle size analysis and atomic emission spectrometry. It is shown that the atmospheric air in these areas of the city is polluted with airborne particulate matter with diameter less than 10 μm (PM_{10}). In 5 out of 13 points, we found PM_{10} microparticles hazardous to health in significant proportions – from 39.9% to 99.5%. The maximum content of particles of the smallest fraction was detected in the Maritime State University campus (railway dead end near the Vladivostok commercial port). The content of particles of heavy metals (I and II hazard class) in the air was identified as well.

1 Introduction

Air pollution remains a major threat to global health. According to a WHO assessment of the burden of disease associated with air pollution, more than two million premature deaths are attributed to the effects of urban air pollution each year. More than half of this disease burden is carried by people in developing countries [1].

The peculiarity of air pollution is that it is not caused by the absolute influence of a single substance, but by a mixture of substances, which in their totality affect the human body [2]. The most dangerous of them are fine particulate matter (PM). According to studies [3-4], the chemical composition of particles is no less important than their concentration in assessing the impact of PM on human health.

As a continuation of previous studies on air pollution [5-6], freshly fallen snow was sampled in December 2017 at 13 locations in Vladivostok, including Russky Island. According to the results of previous studies, Vladivostok was classified as a city with average environmental pollution, mostly caused by motor traffic. Negative dynamics of air

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pollution is associated with an increase in anthropogenic load since the first observations in 2011.

Vladivostok is the largest city and the administrative center of Primorsky Krai. The population is 633,144 (as of 2019) [7]. Vladivostok is the educational center of the entire Russian Far East and an outpost in the Asia-Pacific region. The number of students studying at the three largest higher education institutions in Vladivostok (Far Eastern Federal University, Vladivostok State University (formerly Vladivostok State University of Economics and Service), and Maritime State University named after Admiral G.I. Nevelskoy) is 44,166 people [8-10].

The main sources of air pollution are large enterprises, which daily release into the atmosphere solid particles of industrial aerosols such as electroplating, welding, etc. (Vladivostok Commercial Seaport, Dalzavod, Vostochnaya Verf, Izumrud, Dalpribor, Varyag), as well as motor transport. In many Russian cities, the standards of housing construction have been violated, which is why industrial enterprises are often located in residential areas [11-12].

2 Materials and methods

This work is focused on the study of air pollution in three places of compact residence of students (campuses) in Vladivostok: Far Eastern Federal University, Maritime State University named after Admiral G.I. Nevelskoy and Vladivostok State University. This fact justifies the choice of sampling sites. The snow sampling sites are listed in Table 1.

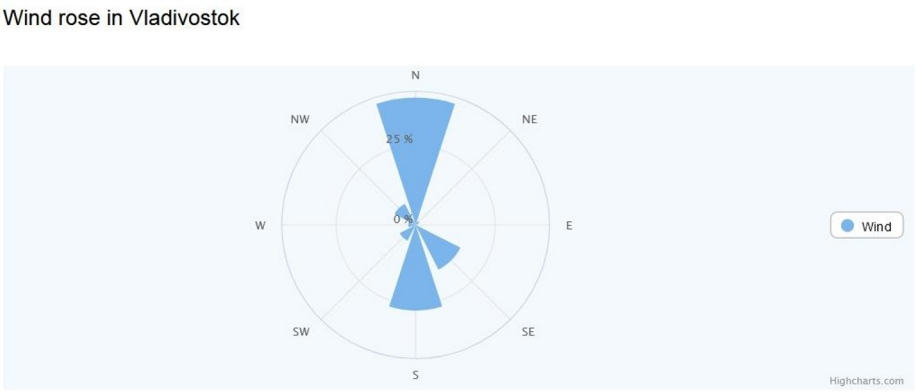
Table 1. Snow cover sampling sites in Vladivostok.

Sampling site No.	Description of sampling site
1	The beach of Maritime State University named after Admiral G.I. Nevelskoy
2	Far Eastern Federal University Campus, main entrance
3	Voroshilovskaya Battery, Russky Island
4	Primorsky Aquarium, Russky Island
5	Instrumentalny Zavod bus stop, Vladivostok State University
6	Vladivostok State University, driving school
7	Transport junction in the Gogol district (near apartment building on Nekrasovskaya St., 74)
8	Vladivostok State University, sports complex
9	Roundabout, Russky Island
10	Canal settlement, Russky Island
11	Strelnikova St., 3a
12	Railroad dead end near the Vladivostok Commercial Seaport
13	Maritime State University named after Admiral G.I. Nevelskoy, main entrance

The choice of sampling sites was based on the location of the above-mentioned educational institutions in Vladivostok (Figure 1). For comparison, samples were also collected at points in the recreational area of Russky Island, which are presumably less exposed to anthropogenic pollution and major traffic hubs. These sampling sites are traditional for the environmental monitoring organized since 2011 [5-6].

Figure 2 shows the rose of the prevailing winds, according to the Primorsky Hydrometeorological Center.

Figure 1. Sampling area in Vladivostok. VVSU – Vladivostok State University (formerly Vladivostok State University of Economics and Service); MSU – Maritime State University named after Admiral G.I. Nevelskoy; FEFU – Far Eastern Federal University.



Wind direction graph in Vladivostok using average values according to our data.

N ▼ Northern	NE ▲ Northeastern	E ◄ Eeastern	SE ► Southeastern	S ▲ Southern	SW ◄ Southwestern	W ► Western	NW ▲ Northwestern
40.1%	**1.3%**	**0.3%**	**15.8%**	**27%**	**5.6%**	**2.3%**	**7.5%**

Figure 2. Wind rose in Vladivostok (according to Primgidromet data).

Airborne particulate matter was studied in fallen snow collected at the time of snowfall in December 2017 and January 2018. To exclude secondary contamination by anthropogenic aerosols, only the top 5-10 cm of freshly fallen snow was collected. It was placed in sterile 2.7 liter containers. When the snow reached the liquid aggregate state, the liquid was shaken and 60 ml of each sample was taken for measurement on a Fritsch

Analysette 22 NanoTech laser particle analyzer (Germany) according to previously approbated technique [13].

Chemical analysis of atmospheric suspensions sampled in Vladivostok was carried out on an atomic emission spectrometer with inductively coupled plasma ICPE-9000 (Shimadzu). Quantitative determination of elemental contents was carried out by the calibration curve method using the MERCK MES-IV multi-element standard.

3 Results

The results of particle size analysis are presented in Table 2.

Table 2. Distribution of particles by fractions in snow in Vladivostok.

Fraction, µm	**Size distribution of particles in samples, %**												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Under 1	8.4	4.4	1.5	6.8	1.8	3.8	3.5	3.1	3.5	2.4	2.8	0	2.5
1.0-10	40.4	39.9	10.2	52	41.6	31	33.8	34.6	34.9	23.6	29.9	99.5	40.1
10.0-50	47	37.7	26	41.2	25.3	57.1	37.1	39.9	55.3	61.5	43.1	0.5	25.1
50 - 100	4.2	0	15.4	0	0	0	0.1	0	6.3	3.6	4.6	0	0
100 – 400	0	0	42	0	0	8	0.1	0	0	7.2	0.6	0	0
400-700	0	0.3	4.9	0	2.2	0.1	0.5	0.8	0	1.3	0.7	0	1.1
Over 700	0	17.7	0	0	29.1	0	24.9	21.6	0	0.4	18.3	0	31.1

At all 13 sampling sites the content of particles of the smallest fraction PM10 (one of the most dangerous fractions for human health) was determined. Their quantity is regulated by the Decision of the Chief State Sanitary Doctor of the Russian Federation from 22.12.2017 No. 165 "On Approval of Hygienic Standards GN 2.1.6.3492-17 "Maximum Permissible Concentrations (MPC) of Pollutants in the Air of Urban and Rural Settlements", as well as WHO Recommendations on Air Quality, 2005.

Concentrations of chemical elements, including Hazard class I and II heavy metals, are shown in Table 3.

Table 3. Chemical composition of airborne particulate matter.

Sampling site No.	**Element**							
	Al	Ba	Ca	Cd	Co	Cu	Fe	K
1	1100	37.5	11500	<5	<5	398	1240	806
2	140	11.5	1590	<5	<5	340	394	236
3	195	10.0	1110	<5	<5	290	327	145
4	263	34.5	156000	214	<5	559	461	6990
5	200	10.5	1430	<5	<5	235	296	107
6	322	16.9	4870	<5	<5	280	475	280
7	59.4	8.9	2680	<5	<5	243	145	249
8	248	15.2	1940	<5	<5	234	409	367
9	652	40.5	18000	<5	<5	385	726	3490
10	287	31.3	353000	56.8	<5	197	269	2440
11	180	15.7	2320	<5	<5	231	1040	329
12	325	17.4	5670	<5	<5	212	483	424
13	89.3	5.9	952	<5	<5	154	130	269
Hazard class		III		I	II	II		

Sampling site No.	Element							
	Li	Mg	Mn	Na	Ni	Pb	Sr	Zn
1	<5	778	107	2370	<5	14.7	24.2	44.8
2	<5	280	19.1	1950	<5	<10	6.6	29.7
3	<5	392	14.8	834	<5	<10	13.1	4.43
4	<5	2670	238	493000	<5	83.8	127	224
5	<5	147	22.1	924	<5	<10	6.0	22.8
6	<5	364	63.9	2640	<5	<10	14.2	44.7
7	<5	151	10.3	2440	<5	<10	5.7	9.15
8	<5	177	17.4	972	<5	14.1	6.6	32.7
9	<5	748	52.4	16700	<5	18.8	21.8	36.9
10	5.4	2170	100	26800	<5	36.0	151	35.2
11	<5	501	23.0	2730	<5	<10	9.4	54.9
12	<5	404	27.2	7470	<5	<10	12.4	46.5
13	<5	236	11.3	1030	<5	<10	4.6	69.5
Hazard class			III		II	I	III	I

Data are expressed as μg/L of melted snow (sample was acidified with HCl and filtered with 0.22 μm pore size syringe filters).

4 Discussion

At 5 out of 13 sampling sites, PM_{10} fraction is predominant, ranging from 39.9% to 99.5% at one site. These points are located at the FEFU campus on Russky Island, near the Aquarium, at the bus stop Instrumentalny Zavod, at 3a Strelnikova St., and at the railroad dead end near the Vladivostok Commercial Seaport.

At sampling point No. 12 the PM_{10} content is the highest among the samples taken (99.5%). We attribute this value to the growing volume of cargo transported through the Vladivostok Commercial Port and the presence of trains carrying coal in the railroad dead end. There are only two ports in Vladivostok through which coal is transported: the commercial port and the fishing port. Vladivostok Commercial Sea Port, in 2019, handled 1.3 million tons of coal [14]. The port still uses the open method of coal handling, using rather outdated and inefficient environmental protection technologies.

The minimum level of microparticulate pollution was recorded at site No. 3, which is due to its location in the forest area of Russky Island and the minimum level of anthropogenic pollution.

It should be noted that large particles over 100 microns in diameter are an insignificant percentage in the collected samples.

The results of the chemical analysis showed the predominance of the following elements: Ca and Na. One should note the presence of heavy metals of hazard class I (highly hazardous) in particulate matter:

- Cd – significant levels were found at two sites: near the canal on Russky Island (56.8 μg/l) and near the Aquarium (214 μg/l).
- Pb – significant content was found at two sites: near the Canal on Russky Island (36.0 μg/L) and near the Aquarium (83.8 μg/L).
- Zn was detected everywhere, with levels ranging from 4.43 μg/L near the Voroshilovskaya Battery to 224 μg/L near the Aquarium.

Maximum content of metals of hazard class II (moderate):

- Cu was detected everywhere, with concentrations ranging from 154 μg/l near the main building of the Maritime State University named after Admiral G.I. Nevelskoy to 559 μg/l near the Primorsky Aquarium.

- Co and Ni content in the samples is negligible – less than 5 μg/L.

Hazard class III (low-hazard):

- Ba was detected everywhere, with levels ranging from 5.9 μg/l near the main building of the Maritime State University named after Admiral G.I. Nevelskoy to 40.5 μg/l near the Roundabout on Russky Island.
- Mn was detected everywhere, with levels ranging from 10.3 μg/L at 74 Nekrasovskaya St. to 238 μg/L near the Primorsky Aquarium.
- Significant levels of Sr were found at two sites: from 127 μg/L near the Aquarium to 151 μg/L near the Canal on Russky Island. At other sites, the Sr content ranged from 4.6 to 24.2 μg/l.

Hence, heavy metal particles were detected at all the sample sites studied, including those located in the recreational area of Russky Island. This fact confirms the possibility of distribution of technogenic suspended particles far beyond the sanitary protection zones of industrial enterprises and other sources of pollution.

The wind rose, obtained on the basis of long-term observations of the Vladivostok Center of Hydrometeorology [15], contributes to the transfer of man-made particles from the mainland part of Vladivostok to Russky Island (Figure 2).

5 Conclusions

It should be noted that site No. 12 (railroad dead end) has the highest level of particles of PM_{10} fraction among the samples taken, 99.5%. We associate this fact with the growing volume of cargo transportation through the Vladivostok Commercial Port and the presence of trains with coal in the railway dead end. A minimal level of microparticulate pollution was detected at site No. 3, which is determined by the location of the Voroshilovskaya Battery in the recreational forest area. Particles of heavy metal Zn (hazard class I) were detected everywhere, their content varies from 4.43 μg/l near the Voroshilovskaya Battery to 224 μg/l near the Aquarium. This fact confirms the detected air pollution not only in places of compact residence of students and in areas of dense urban development, but also in recreational areas of Russky Island, where the level of vehicle traffic is minimal, there are no industrial facilities and the population density is low.

According to the results obtained, the environmental background in Vladivostok has deteriorated in comparison with the data of 2011-2013, namely, the percentage of particles in the PM_{10} fraction has increased from 10.2 to 99.5%. Ambient air is a dynamic environment in which transboundary transport of suspended particles takes place. Among the most common pollutants are combustion products from forest fires in the territory of Siberia and the Far East, coal dust in conditions of growing volumes of coal transhipment to Asia-Pacific countries, etc. In today's conditions, continuous environmental monitoring of the air pollution level is particularly important.

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