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The Study of Air Pollution with Coal Dust in Nakhodka City and Posyet Settlement (Primorsky Krai, Russian Federation)

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Abstract. In recent years, the export volumes of Russian coal to the Asia-Pacific countries have been continuously growing. Coal dust is among of the strongest air pollutants. The article describes the study of airborne particulate matter in large transport hubs of the Primorsky Krai (Russian Far East): Nakhodka city and Posyet urban-type settlement using the method of measuring the mass and quantitative concentrations of particulate matter. It is shown that the air of these areas is polluted with particulate matter with diameter below 10 microns (PM_{10}). The absolute dominance of 0.3 μm and 0.5 μm particles was revealed in the air of both areas. According to the Russian hygienic standard, the maximum permissible concentrations of PM were exceeded only at several sampling points. However, when compared to some international standards, the content of PM exceeded maximum permissible values at 42% of sampling points in Nakhodka city and at 43% of sampling points in Posyet settlement. It is advisable to install systems for continuous environmental monitoring of air pollution with coal dust particles near coal terminals.

1. Introduction

In recent years, the export volumes of Russian coal to the Asia-Pacific countries have been continuously growing. Far Eastern ports, initially not adapted for dusty cargo, switched to handling coal. The coal is handled and stored in outdoor terminals (there are no specialized closed facilities) causing pollution of air, water, and soil of the territories bordering on transport terminals. Large coal terminals are sources of dust significantly affecting the environment, and, first of all, the composition of airborne particulate matter. In the Far East there are several large coal terminals in terms of cargo turnover. Two of the largest ones in the Primorsky Krai are Vostochny Port located at the eastern suburb of Nakhodka city (cargo turnover in 2017 was to 69.2 million tons including 47 million tons of coal [1]) and the port of urban-type settlement Posyet (cargo turnover in 2017 was 7.7 million tons). The coal terminal of the Vostochny port is the largest coal handling complex in the Far East, where more than a dozen companies are engaged in outdoor coal handling. Continuously growing volumes of coal handling lead to increased emissions of coal dust into the atmosphere and degradation of the environment.

Coal dust is one of the strongest air pollutants. Coals can contain over 20 toxic and potentially toxic (for example, Hg, As, Sb, Cd, Pb, etc.) and radioactive (U, Pu) elements [2]. Prolonged inhalation of coal dust may cause a wide range of respiratory diseases, including pneumoconiosis, chronic obstructive pulmonary disease, diffuse fibrosis, chronic bronchitis and other chronic and incurable respiratory diseases [3-5].

The population of settlements located near coal terminals in Primorsky Krai is over 200 thousand people [6] and that determines the important social and ecological role of monitoring air pollution.

Taking into account the growing anthropogenic pressure and the negative trend on the degradation of the atmospheric air quality in large industrial centers, practical steps are needed to timely solve the environmental pollution issues, including pollution with coal dust. That is why the need for constant monitoring of air pollution and comprehensive study of the quantitative and qualitative composition of microparticles of coal dust in Nakhodka city and urban locality Posyet are important, followed by an assessment of the environmental impact of coal dust microparticles on marine biota and human health.

The goal of this work was to measure the mass (mg/m^3) and quantitative (pcs/m^3) concentration of particulate matter in the air of Nakhodka city and urban-type settlement Posyet.

2. Materials and methods

2.1. Quantitative composition of particulate matter

AeroTrak Handheld Particle Counter 9306 (TSI Incorporated, USA) was to measure the quantitative composition of particulate matter. This model meets all the requirements set out in ISO 21501-4.

Based on our earlier research of air pollution in the Nakhodka city and urban-type settlement Posyet [7, 8], we decided to expand the area of measurement. In the Nakhodka city, samples were taken along the marine coast from the Astafiev Bay to Kozmino port (table 1 and figure 1).

In the urban-type settlement Posyet we sampled the air at 7 points located from the Shelekh Cape in the west to the Novgorod Bay in the eastern part of the Posyet settlement, where freight trains loaded with coal are stationed (table 2 and figure 2).

Table 1. Sampling points of the quantity and mass concentration of particulate matter in Nakhodka city.

No.	Sampling point	Coordinates
1	Astafiev Cape	42°47'47.4"N 132°53'50.9"E Height above sea level – 17 m
2	Crossroads of Pirogova and Musatova streets	42°47'12.8"N 132°52'43.4"E Height above sea level – 52.2 m
3	FEFU branch in Nakhodka city, Sportivnaya St. 6	42°46'37.1"N 132°51'20.7"E Height above sea level – 25 m
4	Primorsky plant, Nakhodkinsky prospect 90	42°47'12.0"N 132°51'40.3"E Height above sea level – 14 m
5	Pogranichnaya St. 36	42°49'20.1"N 132°52'39.5"E Height above sea level – 17 m
6	Malinovsky Street, Xiyuan Hotel	42°50'17.3"N 132°54'19.4"E Height above sea level – 7 m
7	Shosseynaya St. 151	42°50'50.8"N 132°57'02.4"E Height above sea level – 7 m
8	Krasny cape (recreation camp)	42°46'57.7"N 133°01'55.8"E Height above sea level – 38 m
9	Vrangel settlement (road junction to	42°45'37.6"N 133°05'00.6"E

	Khmylovka), entrance to Vostochny port	Height above sea level – 13 m
10	Fire department at the Vrangel settlement	42°43'54.5"N 133°05'23.1"E Height above sea level – 10 m
11	Vostochny port (viewing platform)	42°43'47.3"N 133°04'18.0"E Height above sea level – 33 m
12	Kozmino settlement (recreation camp)	42°43'39.7"N 133°01'38.9"E Height above sea level – 30 m

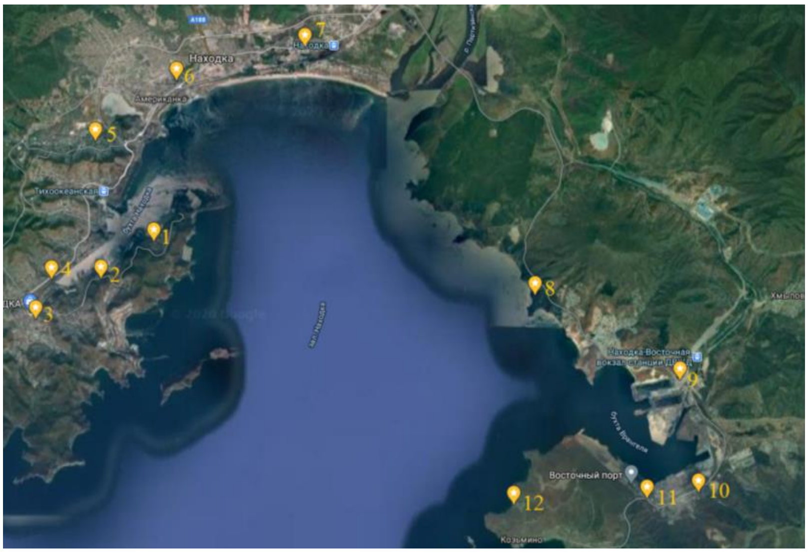

Figure 1. Location of sampling points in Nakhodka city.

Table 2. Sampling points of the quantity and mass concentration of particulate matter in Posyet settlement.

No.	Sampling point	Coordinates
1	Shelekh Cape, small house suburbs	42°38'38.8"N 130°47'44.0"E, Height above sea level – 8 m
2	Beach	42°38'59.2"N 130°47'45.9"E, Height above sea level – 7 m
3	Unsurfaced road	42°39'14.8"N 130°47'56.4"E, Height above sea level – 56 m
4	Coal terminal	42°39'00.7"N 130°48'20.0"E, Height above sea level – 14 m
5	School	42°39'24.8"N 130°48'22.6"E, Height above sea level – 54 m
6	Portoviy tupik 2	42°39'13.4"N 130°48'29.8"E, Height above sea level – 28 m
7	Novgorodskaya Bay, recreation area, railway parking of freight trains	42°39'39.8"N 130°49'07.3"E, Height above sea level – 3 m

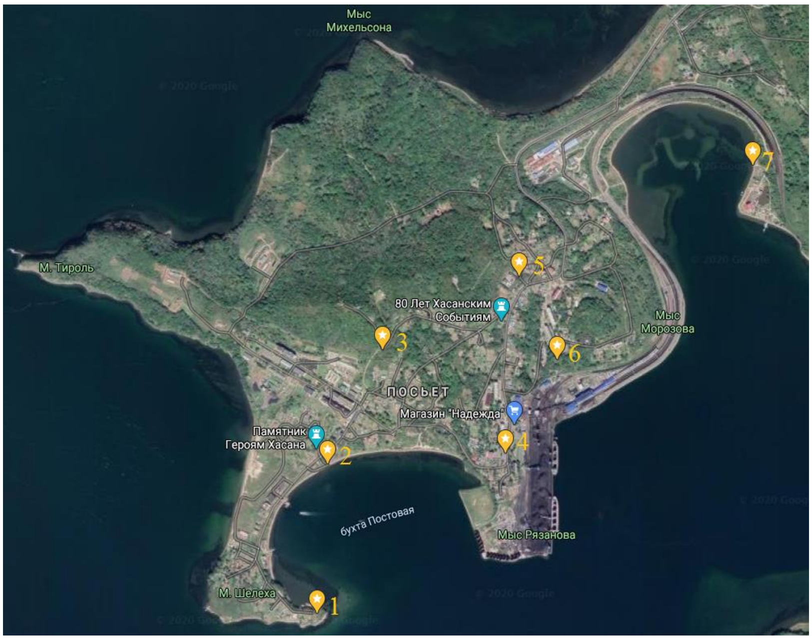

Figure 2. Location of sampling points in Posyet settlement.

2.2. *Mass concentration of particulate matter*

To determine the content of fine particles of industrial aerosol in the air of settlements, we sampled particulate matter at various points: major traffic intersections, near industrial buildings, coal terminals, residential areas and recreational areas. We chose the gravimetric method for assessing the concentration of particles using an aspirator-type sampler "Aspirator PU" (OOO Khimko, Russia). Aerosol filters used were based on a Petryanov filtering cloth made of fibrous perchlorovinyl fabric (filter type AFA-VP-20-1 according to TU 95 1892-89) without binders, with a working surface area of 20 cm^2 (Gorky Kimry Factory, Russia). These filters are characterized by a high particles collection efficiency due to the electrostatic attraction of aerosol particles to the charged fibers; the penetration coefficient for 0.1 μm particles in AFA filter is only 0.1%.

During the experiment, this sampler was equipped with an additional attachment for sampling particles of the PM_{10} fraction, taken from a similar aspirator LVS 3.1 (Ingeniero Nobert Derenda, Germany). The range of particles for the filters in this attachment is from 0.45 μm to 10 μm. The upper limit (PM_{10}) was chosen because it poses the greatest danger to human health, being the cause of respiratory diseases [9, 10]. This reflects the current trend in the field of control of substances suspended in the atmospheric air [11].

Before the sampling, the filters were pre-dried in a TC-1/20 thermostat (Russia) for 24 hours at 40 °C, then each filter was weighed five times on electronic balance (Sartorius, Germany). Arithmetic mean weight was determined for each filter.

Samples were taken at locations shown in Tables 1 and 2. The statistical sampling consisted of 3 measurements for each point. The installation height of the sampler corresponded to the level of human respiration – 1.5 m. The sampling time at each point was 24 hours. The air temperature during the sampling period was 8-14 °C, the wind speed was 1-3 mps. The volume of air passing through the sampler corresponded to 2.8 m^3/h. After 24 hours, the sampling site was changed and the filter was replaced, then the cycle was repeated. Filters with samples of particulate matter were transported to the laboratory of REC "Nanotechnology" of the Polytechnic Institute FEFU for further determination of the concentration of PM_{10} particles.

Dust content in the air was measured by weighing the filters on analytical balance before and after sampling. Each filter was weighed five times on an electronic balance. The resulting difference in the

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weight of the filters before and after the air sampling procedure corresponded to the settled mass of particles of atmospheric suspensions, including the PM_{10} fraction.

3. Results and discussion

The results obtained indicate the absolute predominance of particles of the smallest fraction (0.3 μm; tables 3 and 4). Technogenic particles of this fraction can penetrate deep into the respiratory system and then spread throughout the human body [12], causing the development of chronic diseases and a general decrease of the quality of life. The number of particles in the fraction less than 0.3 μm is more than 10,000 times the number of PM_{10} particles.

Table 3. The quantity and mass concentration of particulate matter in Nakhodka city (thousand/L).

Sampling point No.	$PM_{0.3}$	$PM_{0.5}$	PM_1	PM_3	PM_5	PM_{10}	Mg/m^3	PM_{10} Mg/m^3
1	111.10	16.14	1.55	0.17	0.13	0.03	0.03	0.03
2	74.04	9.83	1.79	0.28	0.23	0.07	0.02	0.02
3	108.05	14.21	1.53	0.20	0.16	0.04	0.03	0.03
4	164.36	23.54	2.67	0.23	0.11	0.02	0.04	0.05
5	227.57	38.80	4.33	0.58	0.54	0.14	0.04	0.05
6	370.70	96.72	8.60	0.77	0.57	0.11	0.06	0.06
7	205.67	32.19	3.78	0.42	0.31	0.08	0.05	0.05
8	96.78	10.29	1.41	0.15	0.09	0.02	0.03	0.03
9	120.23	16.58	4.35	0.78	0.64	0.14	0.03	0.03
10	163.24	32.33	4.73	0.63	0.47	0.09	0.04	0.05
11	101.22	12.75	5.24	1.15	0.73	0.09	0.03	0.03
12	92.26	9.80	1.20	0.15	0.11	0.03	0.03	0.03
Russian health standard GN 2.1.6.3492-17 [13]								0.06
Belarus health standard GN-2 No. 113. [14]								0.05
US EPA NAAQS (USA) [15]								0.05

In Nakhodka city, the content of airborne particulate matter with the diameter of 0.3 μm to 10 μm was approximately at the same level at sampling points 1, 3, 4, 9, 10, and 11. The maximum number of 0.3 μm and 0.5 μm particles was recorded in a residential neighborhood at Malinovsky St (point 6). This fact should be associated with a large road junction at 50 m distance and a railway at 200 m distance, where wagons are transported for subsequent reloading at coal terminals. Quantitative values higher than the average readings were observed in a residential area at Pogranichnaya St. (point 5) and in private sector at Shosseinaya St. (point 7). The distance from the nearest coal terminal to point 5 is less than 1 km. At a distance of 350 m from point 7, there is a large railway dead end for wagons which are mainly loaded with coal.

The smallest number of 0.3 μm and 0.5 μm particles was recorded at point 2, which is located at the intersection of Pirogova and Musatova streets. We associate this fact with the location of this point in a sparsely populated wooded area, which contributes to the deposition of airborne particulate matter due to the sorption of dust particles on the surface of leaves of local flora, mainly deciduous trees and shrubs. The quantity of particulate matter is a little below average at points 9 (road junction at the entrance to Vostochny port) and 12 (recreation camp in nearby settlement Kozmino). In the first case (point 9), we associate this fact with the installation of protective screens in Vostochny port, an operating system of water dust suppression and a northeastern wind, which contributed to the transfer of coal dust particles into the water area of Vrangel Bay. In the second case (point 12), the sampling point was located in the recreational coastal zone on the opposite side from the Vostochny Port, separated by the natural barrier of hilly terrain.

Table 4. The quantity and mass concentration of particulate matter in Posyet settlement (thousand/L).

Sampling point No.	$PM_{0.3}$	$PM_{0.5}$	PM_1	PM_3	PM_5	PM_{10}	Mg/m^3	PM_{10} Mg/m^3
1	82.31	12.54	0.91	0.05	0.02	0.01	0.04	0.05
2	48.74	6.82	0.74	0.05	0.02	0.01	0.02	0.02
3	73.81	10.35	0.86	0.05	0.03	0.01	0.03	0.03
4	88.31	12.37	1.18	0.09	0.05	0.01	0.04	0.05
5	55.07	7.92	1.19	0.13	0.06	0.01	0.03	0.03
6	133.16	18.50	1.31	0.12	0.07	0.02	0.05	0.05
7	81.90	11.19	0.99	0.07	0.03	0.01	0.03	0.04
Russian health standard GN 2.1.6.3492-17 [13]								0.06
Belarus health standard GN-2 No. 113. [14]								0.05
US EPA NAAQS (USA) [15]								0.05

In the Posyet settlement the quantitative content of airborne particulate matter at points 1, 3, 4, and 7 was at a similar level. The maximum number of 0.3 µm and 0.5 µm particles was recorded at point 6 located in the immediate vicinity (distance less than 100 m) from the coal terminal and railway tracks. This fact indicates that it is the coal terminal that is the main source of air pollution by coal dust particles. The smallest number of airborne particulate matter in Posyet urban settlement was observed at points 2 and 5 located near recreational areas. Point 2 is located on the coastal strip of the beach near a park, and point 5 – on the outskirts of the settlement near a forest, at a maximum distance from the coal terminal.

A comparison of the results of measurements of the mass concentration of airborne PM_{10} with Russian and some foreign standards is presented in tables 3 and 4. The USA standard and the standard of the Republic of Belarus put forward more stringent requirements for PM_{10} content. According to the Russian hygienic standard, the maximum permissible concentrations (MPC) of PM were exceeded only at several sampling points. However, when compared to the international standards, the content of PM exceeds MPC at 42% of sampling points in Nakhodka city and at 43% of sampling points in Posyet urban settlement.

4. Conclusions

The highest levels of airborne particulate matter content were observed at locations in the immediate vicinity of coal terminals or adjacent transport infrastructure, which are the sources of air pollution with coal dust. Forests and recreational areas have a positive effect on reducing the quantitative content of particulate matter in the air and can be an instrument to alleviate the level of air pollution with coal dust.

The quantity and mass concentration of airborne particulate matter in Nakhodka city is on average 1.5 ... 3 times higher than the values obtained in Posyet urban settlement, which is a consequence of smaller volumes of coal transported, lower population density and less traffic flow. However, compared to the international environmental standards, the content of particulate matter exceeded MPC at 42% of sampling points in Nakhodka and at 43% of sampling points in Posyet.

In the particulate matter samples, we found the dominance of 0.3 and 0.5 µm particles. This fact indicates the need to install systems for continuous environmental monitoring of air pollution with coal dust particles near coal terminals.

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