Dust pollution of snow cover in the industrial areas of Tomsk city (Western Siberia, Russia)

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Abstract This article describes the results of long-term monitoring (2007-2014) of snow cover pollution in the territory of Tomsk city. Snow samples were collected in the territory of Tomsk. Determination of dust load level was carried out by comparing with the background and reference values. It has been determined that the north-east and central parts of Tomsk are the most contaminated areas, where brickworks, coal and gas-fired thermal power plant are located. The analysis of long-term dynamics showed a dust load decrease in the vicinity of coal and gas-fired thermal power plant due to upgrading of the existing dust collecting systems. During the monitoring period the high dust load in the vicinity of brickworks did not change. The lowest value of the dust load on snow cover was detected in the vicinity of the petrochemical plant and concrete product plants. The near and far zones of dust load on snow cover were determined with the reference to the location of the studied plants.

1. Introduction

Today, the study of the snow cover is one of the most affordable and reliable methods to obtain information about the intake of pollutants from the atmosphere. Snow cover is successfully used by many researchers from different regions and countries to indicate air pollution because snow is an excellent natural absorber for many substances from the air [1-9].

The chemical composition of snow is determined by several processes: formation of snowflakes around condensation nuclei (dust, drops, etc.) in the cloud, sorption of impurities during the passage of snowflakes through the atmosphere; inflow of pollutants from the air (aerosols, dust, ash, smoke, exhaust fumes and other).

Air pollution assessment in Tomsk region is of special interest as there are specific industries within the area. Volumes of solid pollutants emitted into the ambient air from stationary sources of Tomsk region increased more than 2.5 times for the period from 2005 to 2011. South-Eastern part of Tomsk region is the most urbanized because Tomsk city and Seversk town are located there, with the population more than half of the region's population. Also the northern areas, where oil and gas complexes are located, make a significant contribution to the pollution of the region [10].

The study of snow cover as an indicator of anthropogenic air pollution was conducted in the territory of Tomsk city and its surroundings [11-13].

The present study of snow cover was carried out in the industrial areas, with brickworks, coal and gas-fired thermal power plant, petrochemical plant and concrete product plants. The industrial enterprises emit annually between 35.5 and 37.1 thousand tons of pollutants into the ambient air in

Tomsk [10]. The main sources of emission of solid pollutants in Tomsk are coal and gas-fired thermal power plant and brickworks. A petrochemical plant operates in the northern part of Tomsk as well; it is the largest Russian enterprises for the production of polyethylene and polypropylene.

The main objectives of the present study were to (a) determine dust load value on snow cover in the territory of Tomsk-city, (b) identify the most snow polluted areas in the city and (c) reveal the changes of dust load between 2007 and 2014 in the vicinity of brickworks, coal and gas-fired thermal power plant, petrochemical plant and concrete product plants.

2. Methods

Snow sampling was conducted on a regular survey grid with a step of 500-600 m in the entire territory of Tomsk in March 2007. Just in the city 69 samples were collected. From 2009 to 2014 we collected snow samples annually in the zone affected by some large industrial enterprises of the city, such as coal and gas-fired thermal power plant, petrochemical plant, brickworks, and concrete product plant. In addition, private housing development and local boilers are found in the zone. Five samples were collected at the distance of 200 to 1500 m north-eastwards from the boundaries of the plants. The total number of samples during 6 years was 120.

Snow samples were collected at the sites with undisturbed snow cover for all its depth except 5 cm above the ground, the mass of each sample was 15-18 kg. While sampling, the pit area from which the samples were taken and the time from the formation of a stable snow cover till snow sampling time moment were checked and fixed.

Snow samples were melted at 20-22º C, and the snow water was filtered through a pre-weighed filter paper. The precipitated insoluble snow residual on the filter were passed through a sieve with a mesh size of 1×1 mm and then it was weighed with the error of 0.01%. Insoluble snow precipitate contains insoluble aerosol particles.

The calculations of a daily dust load (L_{dust} , $mg/m^2 \times day$) were made using equation:

$$L_{dust} = M / (S \times t),$$

where M is the mass of insoluble residue in the snow sample (mg), S is the pit area (m^2), t is the time from the moment of stable snow cover formation till the snow sampling (day) [14].

3. Results and discussion

According to the results of areal snow geochemical survey in the territory of Tomsk in 2007, sites of increased dust load were determined.The first site was revealed in the north-eastern part of the city and it was related to the brickworks location, the second one is located in the city center and is caused by emissions from coal and gas-fired power and heating supply plant. In addition, we also detected the contamination in the residential areas with private low-rise buildings and local boiler houses. The average value of the dust load in the territory of the city was 63 $mg/m^2 \times day$, it conforms to a low level of contamination (less than 250 $mg/m^2 \times day$ according to [14]), by the background of 7 $mg/m^2 \times day$.

The average value of the dust load in the territory of Tomsk is 2 times lower than for the territory of the South of West Siberia (135 $mg/m^2 \times day$), Seversk (153 $mg/m^2 \times day$), Omsk (132 $mg/m^2 \times day$) and Rubtsovsk (106 $mg/m^2 \times day$); it is 5 times lower than for the territory of Mezhdurechensk (316 $mg/m^2 \times day$).

The Table presents the results of the dust load calculations. The analysis of long-term monitoring data shows that high values of dust load in the vicinity of brickworks remain. During the monitoring period, the dust load exceeds the background from 12 to 103 times. There is a decrease tendency of dust load amount by 35% from 2009 to 2012, which is caused by modernization of new dust collecting systems. Our data confirm the data of these plants about emission decrease. This decrease is determined by measures of the Department of natural resources and environmental protection of Tomsk region in response to the complaints of citizens in April 2009 about «red» snow in residential areas, in the territory of schools and kindergartens, located near the plants. In 2013, the dust load dramatically increased.

The contamination level is medium and high according to the reference and the dust load for the city exceeds 5.3 – 11.0 times in the near-field impacted area of brickworks. In the far-field impacted area of brickworks, the amount of dust contamination corresponds to low level of the air contamination after the normative scale and 3 times higher than the average dust contamination for the city. Such variation dynamics of the dust load value with distance from the plants can be explained by the fact that the material composition of the dust is mainly represented by various types of mineral particles with a heavy specific weight (quartz, feldspars, carbonates, clay minerals), which deposit with atmospheric fall-outs in the territory near the emitters. On the other hand, while loading and transporting dust is transported to the residential areas located near the plants.

Table. Dust load on snow cover in the industrial areas of Tomsk region, mg/m^2×day.

Industry	Distance from plant, m	2009	2010	2011	2012	2013	2014
coal and gas-fired thermal power plant	300	152	99	100	87	46	105
	600	219	162	131	38	63	42
	900	84	53	66	21	31	44
	1200	70	70	65	98	38	28
	1500	52	65	48	41	44	35
	mean value	115±31	90±20	82±15	57±15	44±5	51±14
brickworks	200	571	275	215	693	450	216
	400	584	720	455	100	526	405
	600	292	300	255	191	217	246
	800	256	259	134	96	221	106
	1000	122	123	162	86	249	95
	mean value	365±91	335±101	244±57	233±116	333±65	213±56
petrochemical plant	300	45	51	50	44	28	51
	600	54	45	63	33	54	52
	900	73	112	80	52	29	48
	1200	69	74	76	62	58	48
	1500	85	55	90	37	28	62
	mean value	65±7	67±12	72±7	46±5	39±7	52±3
Concrete plant	200	127	149	120	67	36	45
	400	139	212	145	54	84	89
	600	108	56	95	34	54	80
	800	82	81	85	71	34	78
	1000	94	n.d.	80	57	96	142
	mean value	110±10	125±35	105±12	57±6	61±13	87±16

Note: n.d. – no data; the average dust load for Tomsk-city is 63 mg/(m^2×day), the background is 7 mg/(m^2×day).

The similar tendency to the change of dust load volume with distance from the plants and dynamics in the impacted area of brickworks is presented in the vicinity of the construction industry enterprises, specializing in the production of reinforced concrete constructions. In general, all recorded data of the dust load in this territory exceed the regional background 15 - 18 times, and double the average amount for the city. It should be noted that formation of dust contamination in the vicinity of these plants is caused by the emissions from local boiler-houses, private houses and small private enterprises, located near the plants.

According to the study in the vicinity of coal and gas-fired thermal power plant, the dust load level reduced about by 45 % from 2009 to 2013. This reduction occurs despite the fact that the volume of burning coal at the station increased during these 5 years and the main part of coal (up to 80 – 90 %) is burnt from November to March. The decrease in dust load can be explained by the fact that, according to the official data, in 2010 ash collector of boiler was reconstructed and two additional ash collectors were installed. Moreover, ash collectors are annually repaired and tuned to improve the quality of dust emission cleaning; it provides complete large-sized particle trapping.

Dust load in the near-field impacted area exceeds the background from 17 to 27 times, and the excess of the average value for the city is 2-3 times. The increased values of the dust load in the near-field area can be connected with influx of dust by wind from coal storages, located in the power plant area, or during coal unloading. In the far-field impacted area dust load complies with the average value for the city.

The most significant dust precipitations in the area of 2 km from 100 m chimneys of coal and gas-fired thermal power plant are in the form of large-sized particles, despite permanent cleaning system for ash emissions to the atmosphere. The velocity of these particle precipitation develops several tens centimeters per second. An approximate assessment of such high precipitation rate is caused by simple kinematic features. For example, if average wind speed is 10 m/s, a particle must travel for a distance of 1 km in just 100 seconds and reach the earth's surface from the height of 100 meters. It points to the strong dependence of dust particles washing-out processes in the composition of ice grains, formed by freezing of water vapour in the smoke stream of power plants in winter. This effect was investigated and confirmed at the coal-fired power station in Kyzyl [15].

The dust load volume does not significantly change by years in the vicinity of a petrochemical plant. It is worth noting that this dust load level could be caused by transport of dust emissions from the plans located nearby.

4. Conclusion

As a result, we identified the most contaminated areas of snow cover in the territory of Tomsk and Tomsk region. According to the data of our snow survey in the territory of Tomsk in 2007, areas with high dust load accords to the position of the brickworks and coal and gas-fired thermal power plant. In addition, the results of long-term observations (2009-2014) of dust load from surrounding plants of Tomsk are ranked as follows: brickworks - 304 mg/m^2×day, plants for the production of concrete products - 88 mg/m^2×day, coal and gas-fired power and heating supply plant - 78 mg/m^2×day and petrochemical plant - 58 mg/m^2×day. We discovered that most part of dust deposited on the snow cover at the distance of 300-600 m, there is a tendency of distance decrease from 600 to 1500 m from the borders of the studied plants. The obtained results can be used for air monitoring scheme optimization and undertaking detailed assessment of long-term atmospheric pollution in winter.

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