Bull. Nov. Comp. Center, Num. Model. in Atmosph., etc., 14 (2014), 105–111

Monitoring of snow cover dust pollution near a cement plant*

T.V. Yaroslavtseva, V.F. Raputa, V.V. Turbinsky, A.F. Shcherbatov

Abstract. The results of field studies of the snow cover pollution by inorganic dust around an industrial enterprise for the cement production in the winter season of 2012–2013 are discussed. Based on the field fallout, the numerical reconstruction has shown the existence of stable quantitative regularities of dust content in the snow cover in the radial direction relative to the mein source. The total field of dust deposition was restored, and the evaluation of emissions in the above winter season was carried out.

Keywords: pollution, snow cover, cement dust, numerical modeling, reconstruction.

Introduction

The socio-economic development of the Novosibirsk region is directly associated with increasing the environmental load. Currently, the environment of the industrial areas is characterized by problematic situations [1], which require the governmental regulation of the air pollution. The introduction of modern technologies, the use of high-performance gas treatment systems are of primary interest in the system of the atmospheric air protection in the Novosibirsk region.

The cement production is accompanied by the atmospheric emissions both of solid and gaseous pollutants having a significant public health risk [2]. As part of such an emission there are present mainly inorganic dust, oxides of nitrogen, sulfur, carbon, benzo[a]pyrene.

The town of Iskitim is situated in the south-eastern part of the Novosibirsk region at a distance of 55 km from the regional center: the city of Novosibirsk. The Iskitim cement plant is located in the northern part of the town. On the north and the east sides, the industrial area is adjacent to the river Berd. On the southern and the western sides of the industrial site there is a residential area. Distance to the nearest residential areas is 30–50 m.

*Supported by the Program of RAS 4.9, Rospotrebnadzor sectoral programs on hygienic assessment and minimize the risk to public health.

1. Objects, materials and methods

The object of this study was pollutant emissions from stationary sources of "Iskitimcement" snow cover on the territory of the town of Iskitim and its suburbs. The research materials were reports of "Iskitimcement" on emissions of pollutants from stationary sources in the period of 2012, 2013, the results of visual examination and physical and chemical analysis of samples of the snow water.

Sampling routes were located on the main eight rhumbs inorganic dust emission sources — two closely spaced 80-meter pipes. The sampling scheme is shown in Figure 1. The observation points are in the range of distances from 0.4 km to 3 km. Given the winter wind rose [3], the main attention was paid to routes of the northern areas.

Sampling with the use of a plastic tube of a diameter of 10 cm was carried out. At each sampling point, from 2 up to 10 snow cores were taken. Snow samples were thawed at room temperature, melt water was filtered through a filter (a blue ribbon), the value pH was measured. The interpolated (in

Figure 1. A scheme of snow samples selection in the vicinity of Iskitim cement plant. Black square marks the position of the main source of dust emission

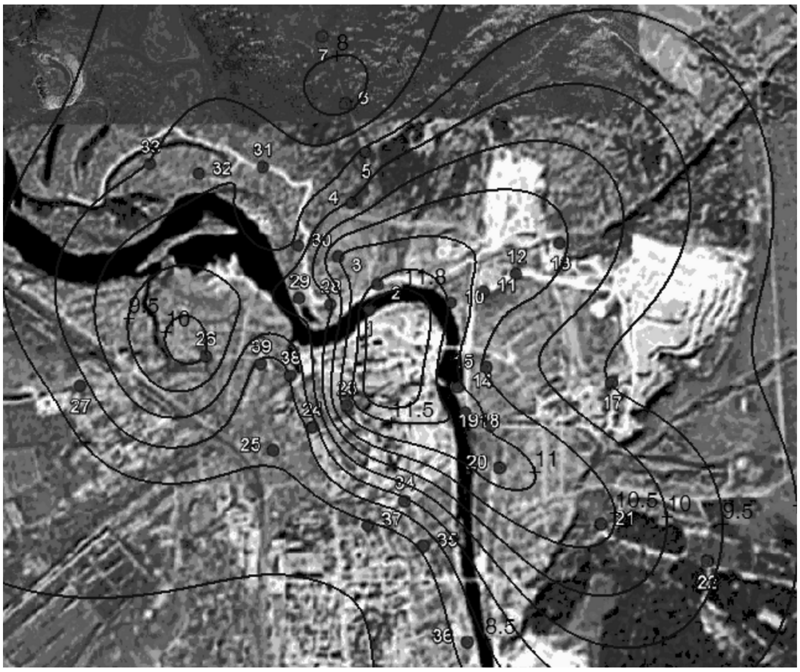

Figure 2. Interpolated field of pH values

terms of sampling point) field of pH values is shown in Figure 2. The analysis of Figure 2 implies that within 1.5 km from the main sources of the atmospheric dust emissions, the value pH ranges from 9 to 12, thus indicating a high level of alkalinity of the areasadjacent to the industrial area of the plant.

The study of the chemical composition of snow water and isolated precipitation was carried out in accredited laboratories of the Novosibirsk Institute of Hygiene, SSC "Vector" Rospotrebnadzora, the Institute of Inorganic Chemistry, SB RAS. Statistical processing and mathematical modeling were carried out at the Institute of Computational Mathematics and Mathematical Geophysics, SB RAS.

2. A model of estimation of the dust fallout of duration field

When calculating the average concentration in the surface layer of the atmosphere, of primary importance are common weather conditions. These include the so-called normal weather conditions, which applies power approximation of the wind speed and the vertical turbulent exchange coefficient [4]. Using these approximations, the asymptotics of the semi-empirical equation of turbulent diffusion and the statistical characteristics of the distribution of wind speed and vertical turbulent exchange in the atmospheric surface layer allows us to express the fallout density polydispersed particles over a long period of time in the form of the following regression dependence [5]:

$$\overline{q}(r,\varphi) = \frac{\theta_1}{r^{1.5}} P(\varphi + 180^\circ) \exp\Big(-\frac{c}{r}\Big) \int_0^\infty \frac{\omega^{\theta_2} \exp(-\theta_3 \omega)}{\Gamma(1+\omega)} \Big(\frac{c}{r}\Big)^\omega d\omega, \qquad (1)$$

where r, φ are the polar coordinates, $P(\varphi)$ is the surface wind rose; $\Gamma(m)$ is the Euler gamma-function, θ_1, θ_2, θ_3 are unknown parameters to be determined from the observational data.

Remark 1. For dust, essentially inhomogeneous in its dispersion composition, its main loss in the near field of the source will be presented to larger particles, particles with settling velocity in the atmosphere, a few tens of cm/s. In this case, using the kinematic scheme of the transport of particles in the atmosphere, the dust loss in the near field can be described by a simple dependence:

$$\overline{\sigma}(r,\varphi,\vec{s}) = s_1 r^{s_2} \exp\Big(-\frac{s_3}{r}\Big) P(\varphi + 180^\circ), \qquad (2)$$

where the unknown parameters s_1, s_2, s_3 are also estimated from the observational data.

The parameter s_1 linearly depends on the intensity of the source and the parameters s_2 and s_3 depend on characteristics of a particulate dust.

Repeatability of wind directions $P(\varphi)$ is usually given in the tabular form at 8 or 16 points off. To describe it, it is convenient to use the continuous between rhumbs linear interpolation on the corner φ:

$$P_i(\varphi) = p_i + \frac{p_{i+1} - p_i}{\pi/N} \Big(\varphi - \frac{\pi i}{N}\Big), \quad \varphi \in \Big[\frac{\pi i}{N}, \frac{\pi(i+1)}{N}\Big], \qquad (3)$$

where p_i is repeatability of the i-th wind direction, $i = 1, \dots, N$.

Remark 2. In the absence of reliable information about the wind rose for the area point or a variable source of dust emission intensity the recovery of a sediment density field can be done by stages. For a fixed φ_0, i.e., the one located on the radially sampling route the values $\overline{\theta}_1(\varphi_0) \equiv \theta_1 P(\varphi_0 + 180^\circ)$, θ_2 and θ_3 are assessed. Then, provided that the parameters θ_2 and θ_3 do not essentially depend on φ, the estimation of the values $\overline{\theta}_1(\varphi)$ for the other angles φ should be made.

3. Method of estimating the total deposition of dust in the vicinity of a source

One of the main characteristics of a source is the release of impurities from it for a certain period of time. If the dust deposition field is quantitatively recovered according to the observations, for example, using relation (1), it becomes possible to evaluate the total emission of dust on based on the following relation:

$$Q_{\mathrm{sum}} = \iint_S \overline{\sigma}(\xi, \eta)\, d\xi\, d\eta, \tag{4}$$

where S is the area around the source on which the deposition of dust occurs, $\overline{\sigma}(\xi, \eta)$ is the dust fallout density represented in the Cartesian coordinates.

If the area S is relatively annular source, then, taking into account (1) and Remark 2, relation (4) is presented in a more convenient form:

$$Q_{\mathrm{sum}} = \int_0^{2\pi} \overline{\theta}_1(\varphi)\, d\varphi \cdot \int_{R_1}^{R_2} G(r, \theta_2, \theta_3)\, r\, dr. \tag{5}$$

Equation (5) can greatly simplify the calculation of the total deposition of dust in various fields and to optimize the number of sampling points. For example, taking into account interpolation formula (3) in the case of 8-rhumb setting the parts of the world without the wind rose, the value of Q can be estimated from 10 observational reference points.

4. Results of the research

Snow sampling was conducted on radial routes in more than 40 locations in the area. This allowed a detailed numerical analysis of the dust deposition processes from the main sources of the enterprise, to establish the quantitative relationships of sediments content in snow various fronts directions. Figures 3–5 present the results of the numerical reconstruction of the sediment density field of inorganic dust with the use of observational data.

The analysis of Figure 3 implies that the agreement between calculations and observations at the control points is quite satisfactory. A maximum

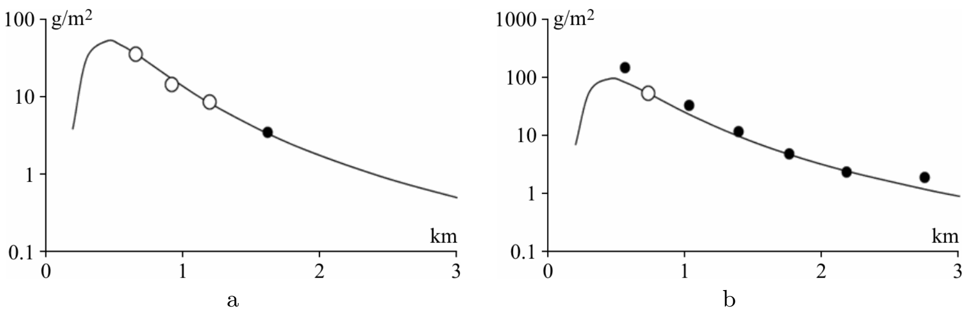

Figure 3. Recovered from the dependence of (1) loss of inorganic dust in the north-east (a) and north (b) of the cement plant: ○ and • are the reference measurement and control points, respectively

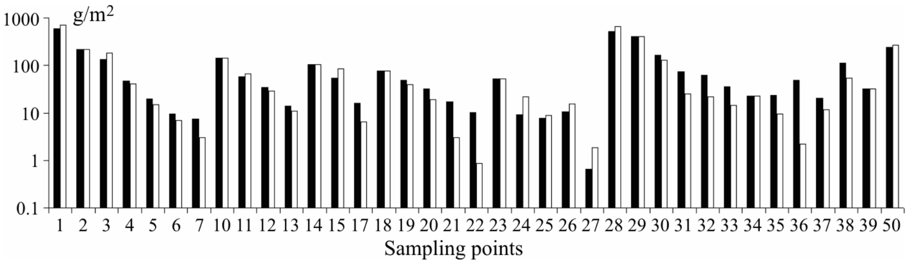

Figure 4. Measured (black) and restored (white) inorganic dust fallouts (g/m^2) based on relationship (1) at the snow sampling points

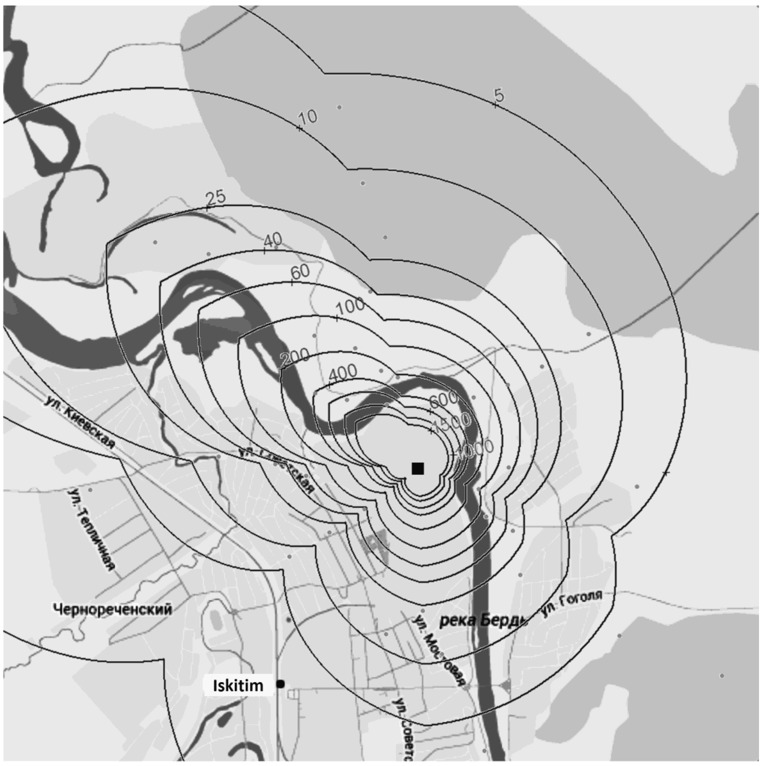

Figure 5. Refurbished density field of inorganic dust deposition (g/m^2) in the vicinity of Iskitim cement plant at the end of the winter season 2012/2013

deposition of inorganic dust is about 450 meters from the main sources, which indicates to quite a heterogeneous composition of particular settling particles. Removal of dust in the winter period in the north-west direction is dominant and is caused, apparently, by orographic terrain features.

Regularities obtained have allowed us to determine the value of the total fallout of the inorganic dust from winter emissions to the atmosphere at different distances from the cement production. The total content of inorganic dust in the snow on the territory within 1 km from the main source of emission from Iskitim cement plant is 626 tons, within 2 km — 875 tons, within 3 km — 942 tons, and within 4 km — 969 tons. The resulting estimates of the total deposition substantially differ from the total emissions inventory data dust of the cement plant obtained in 2012. According to these data, the total dust emission should be in the 2012/2013 winter season about of 100 tons.

Thus, the resulting divergence of calculated inventory data with the actual results of field studies indicates the need for an external pollution monitoring and establishing specific values of inorganic dust emissions for each cement production.

References

[1] Novikova I.I., Ogleznev G.A. Tissue environmental and public health major industrial center // Hygiene and Sanitation. — 2003. — No 3. — P. 66–68.

[2] Turbinsky V.V., Kriga A.A., Erofeev Yu.V., et al. Methodological approaches to development management decisions to reduce the risk to human health from environmental pollution // Public Health and the Eenvironment. — 2010. — No 7. — P. 18–21.

[3] Climate of Novosibirsk / S.D. Koshinsky, C.A. Schwer, eds. — Gidrometeoizdat, 1979.

[4] Berlyand M.E. Modern problems of atmospheric diffusion and air pollution. — Gidrometeoizdat, 1975.

[5] Raputa V.F. Reconstruction models fields long aerosol deposition // Atmospheric and Ocean Optics. — 2007. — Vol. 20, No. 6. — P. 506–511.