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Evaluation of the Quality of Atmospheric Air in Novosibirsk on the Basis of the Mass Concentration of Solid Particles

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Abstract

Evaluation of the quality of atmospheric air in Novosibirsk was made on the basis of the examination of solid suspended particles (SSP) measured by the Rosgidromet system and by the Institute of Chemical Kinetics and Combustion of the SB RAS. It was established that the fraction of particles ≤10 μm (SP_{10}) in SSP is equal to 0.67. Evaluation of the quality of atmospheric air on the basis of SP_{10} did not reveal other pollutants in the urban air as established by Rosgidromet according to the existing procedure.

Key words: quality of atmospheric air, solid suspended particles (SSP), mass concentration of aerosol, particles of the fraction ≤10 μm (SP_{10}), maximum permissible concentration, quality standard, population health, life interval

INTRODUCTION

According to modern estimates of the European Section of the World Health Organization (WHO), aerosol particles along with ozone present in the atmospheric air pose the major danger for the health of population [1]. Coarse and fine particles have different effects on human health. Coarse aerosol particles penetrate only the upper air passages, while fine particles, as a rule, get into the lungs and deposit in the lower layers of the respiratory tract. So, the risk of diseases connected with the penetration of aerosol particles into human organism depends on size fraction. In Russia and in the countries of former USSR investigations of air pollution with dust are carried out without separating the particles into coarse and fine fractions. Suspended matter including the entire spectrum of solid particles is measured, while the countries of Europe and the USA follow another approach to the evaluation of air quality on the basis of its pollution with dust. Thus, to characterize air quality, PM_{10} term has been introduced. This term characterizes the entire fraction of suspended particles with the aerodynamic diameter of 10 μm, though larger suspended particles with larger diameters can also be present in PM_{10}.

Russia starting to actively join the European and world community is a member of WHO, so the problem of levelling the approaches to the evaluation of atmospheric air quality on the basis of the concentrations of a number of admixtures including dust is becoming urgent. Due to a combination of the efforts of the Siberian Regional Research Hydrometeorological Institute and the Institute of Chemical Kinetics and Combustion (ICKC) of the SB RAS, an evaluation of atmospheric air quality was carried out in Novosibirsk on the basis of the data on dust concentration measure using different techniques.

EXPERIMENTAL

The state control of atmospheric air quality in Novosibirsk is carried out by the West Siberian Centre for Environmental Monitoring of the Roskomgidromet. This centre performs observations of atmospheric air pollution with dust (suspended matter) at nine observation sites. Observations are carried out at 7.00, 13.00 and 19.00 (local time) every day except Sunday and holidays. The positions of observations sites are shown in Fig. 1. Sampling method is based on the determination of the mass of suspended dust particles held on AFA-KhA-20 filters from a definite air volume passing through the filter for 20 min. The relative error of the method is ±25 %, the absolute error of the measurement of dust mass on the filter is 0.2 mg, and the limiting relative error of the determination of air volume passing through the filter is 6 % [2].

Systematic works aimed at the investigation of aerosol are carried out at the ICKC during the recent decades within the Aerosols of Siberia programme. Measurements of the mass concentration of aerosol are carried out in a number of stationary observation stations of

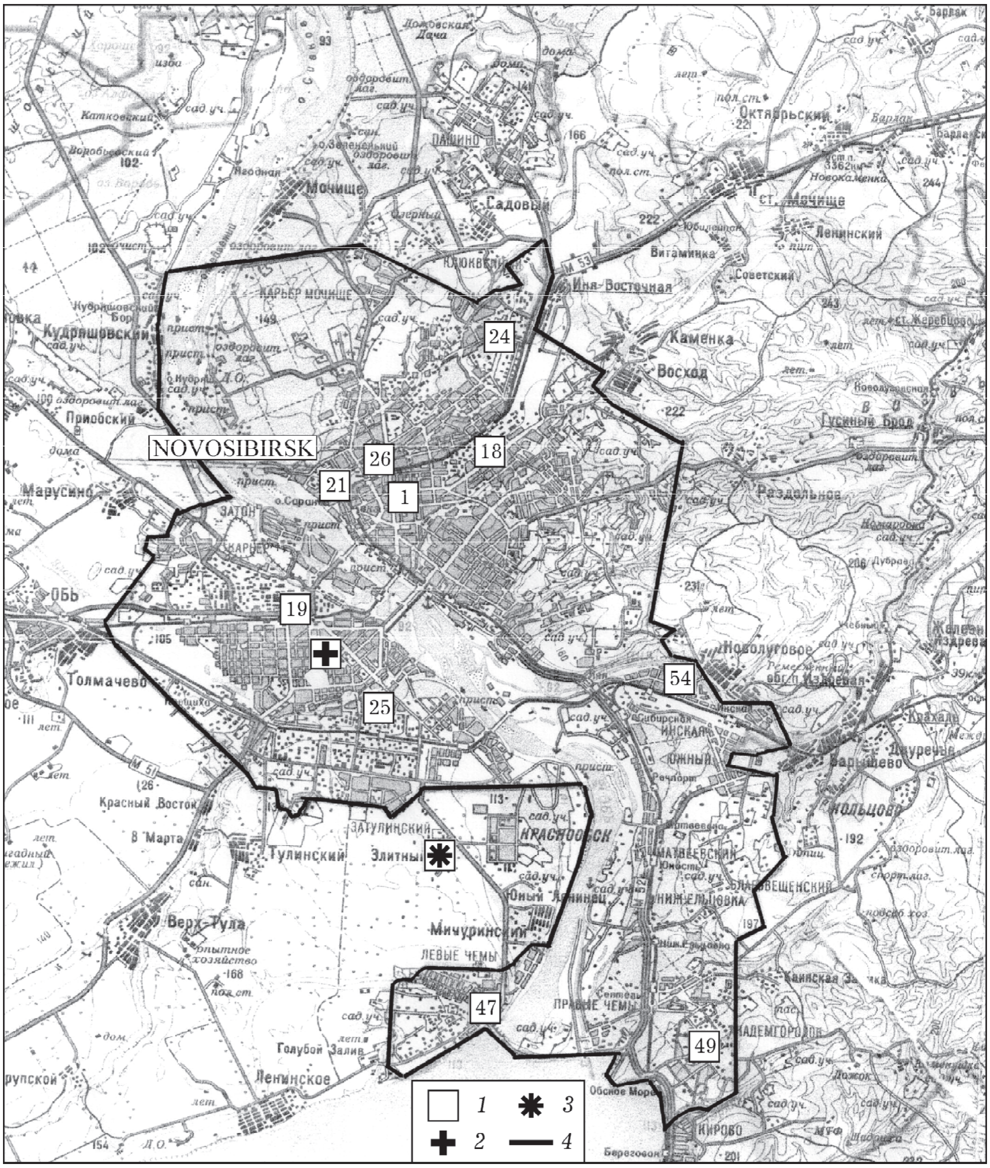

Fig. 1. Positions of the sites of observation of atmospheric air pollution in Novosibirsk: *1* – observation station and its number; *2* – the site of observations of the mass aerosol concentration; *3* – meteorological station in Ogurtsovo settlement; *4* – the boundary of the city territory.

the institute. One of these stations is situated in Novosibirsk, at the territory of the municipal hospital No. 34 (the left bank of the Ob River), where the mass concentration of aerosol was measured during the years 2005–2007. Samples were collected on the fine-fibrous aerosol filters AFA-KhA-20 with the help of filtering ventilation set-up pumping the air at a rate of 13 m^3/h during 24 h. The error of the method is ±1 %. Observations were carried out in series, 30 days each, over the seasons (winter, spring, summer, autumn). The values of the mass concentration of aerosol were obtained by averaging over 24 h not during the natural day but with a shift by 8–12 h, which later on affected the results of comparative analysis.

So, the measured solid suspended matter (SSM) characterizing all the fractions of particles in atmospheric dust are called in Roskomgidromet "suspended matter" (q), and in the ICKC the same value is called mass concentration of aerosol (C). These are similar characteristics of atmospheric air quality on the basis of its dust content and should be closely related to each other.

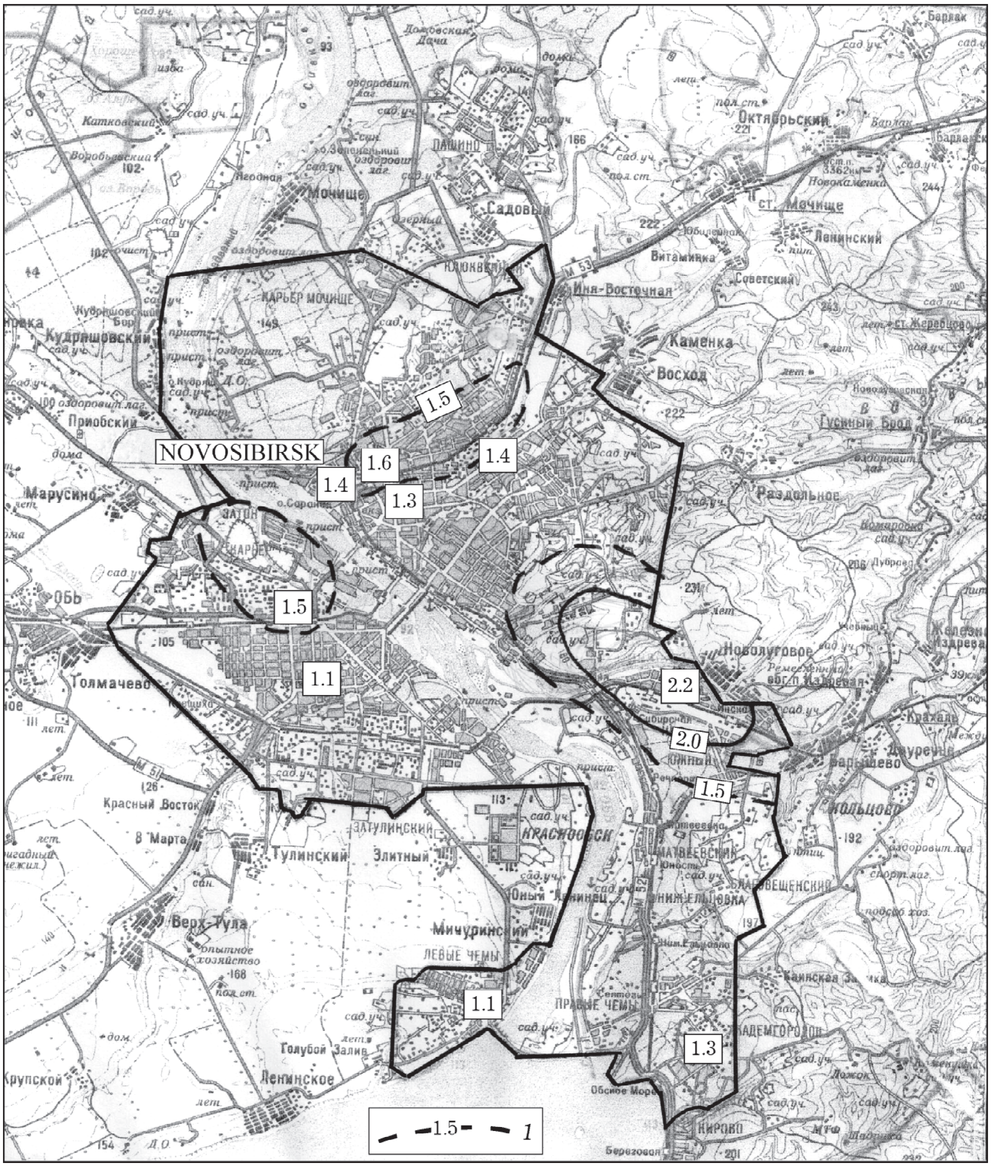

Fig. 2. Distribution of yearly averaged concentrations of suspended matter over Novosibirsk (2005–2007): *1* – isolines of the concentrations of suspended matter, fractions of MPC_{24}.

RESULTS AND DISCUSSION

Before we pass to the comparative analysis of the concentrations of suspended matter (q_{m}, C) averaged over 24 h, it is necessary to clear up the situation with atmospheric air pollution with suspended matter (dust) in Novosibirsk over the period under consideration. For this purpose, using the data reported in [3], we treated the data of observations of suspended matter concentrations separately over each observation site and in general over the city. On the basis of these results, we plotted the schematic maps of the distribution of year-averaged and maximal concentrations of suspended matter over the territory of Novosibirsk (Figs. 2, 3).

One can see (see Fig. 2) that the pollution of atmospheric air with dust over the whole territory of Novosibirsk exceeds the sanitary and hygienic standards by a factor of 1.1–2.2. At this background, three foci with the heaviest air pollution with dust are distinguished: Pervomayskiy District (q_{m} = 2.2MPC$_{24}$, where MPC$_{24}$ is maximal permissible concentration averaged over 24 h); Zaeltsovskiy District, along the overpass (q_{m} = 1.6MPC$_{24}$); Leninskiy Dis-

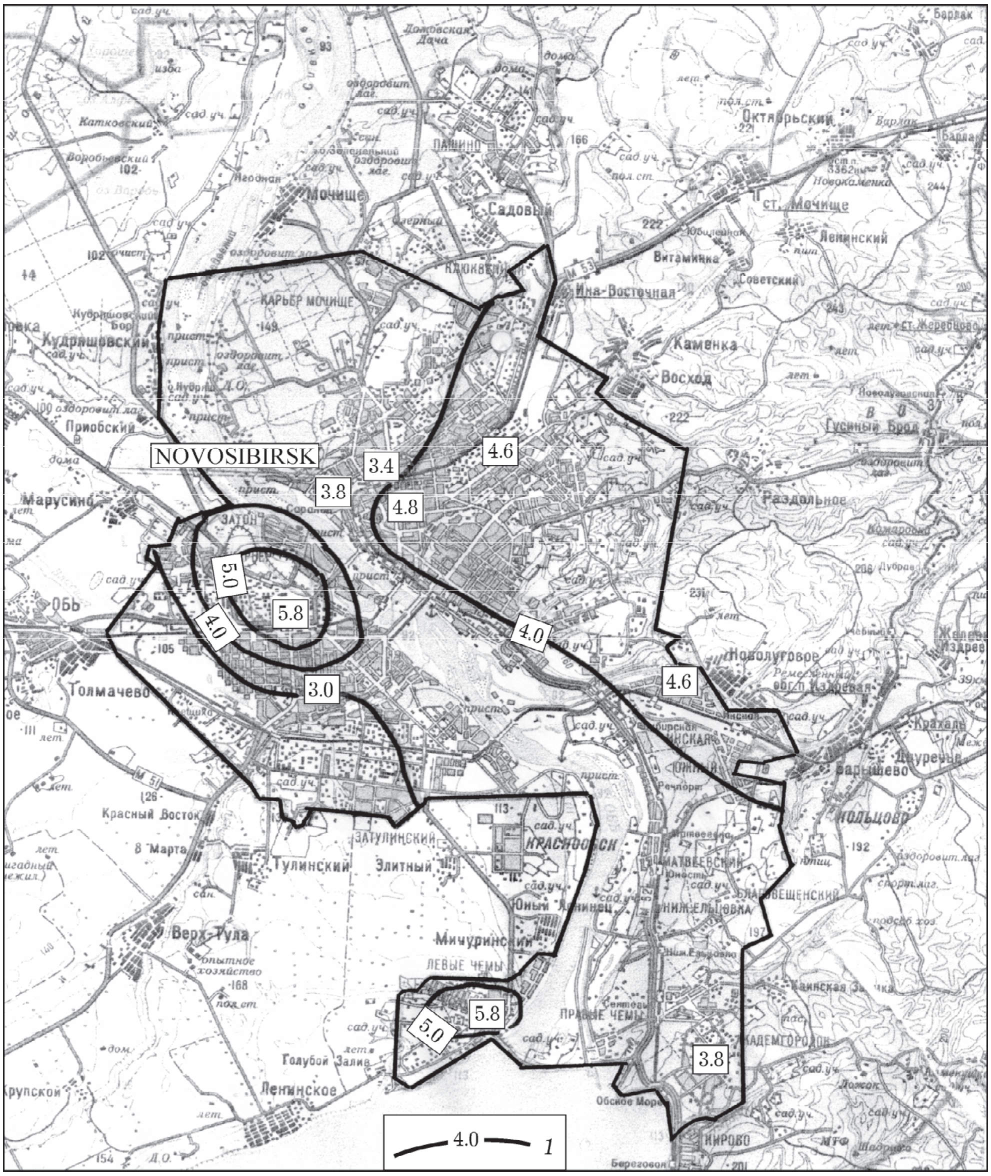

Fig. 3. Distribution of the maximal concentrations of suspended matter over Novosibirsk (2005–2007): *1* – isolines of the concentrations of suspended matter, fraction of MPC$_{\mathrm{s}}$.

trict, near power plants Nos. 2 and 3, as well as other industrial objects (q_m = 1.5MPC$_{24}$).

In the Pervomayskiy District, atmospheric air pollution with suspended matter is caused by a large number of small boiler plants, private sector, and insufficient land improvement. The site of dust concentration observations in Zaeltsovskiy District (Station No. 26) is situated at the road with heavy traffic along which numerous garages, vehicle repair works *etc.* are situated. In Leninskiy District, increased pollution of atmospheric air with dust is connected with emissions from power plants Nos. 2 and 3 as well as other industrial objects. Relatively clean region is the south-western territory of the city (Zatulinka, Chyomy) where q_m = 1.1MPC$_{24}$.

Maximal single concentrations of suspended matter (see Fig. 3) in different regions of the city during the period under consideration exceeded the maximal permissible single concentrations (C_s) by a factor of 3.0–5.8. The highest concentrations were detected near power plants Nos. 2 and 3 (Station No. 19) at a level of 5.8MPC$_s$. Similarly high dust concentrations were detected also at the territory of ObGES (Station No. 47) but that was a short-term episode in April only.

So, the pollution of atmospheric air with suspended matter in Novosibirsk is different in different city districts and is determined by the distance from industrial objects, roads with heavy traffic, transport of air flows *etc.*

The question arises: what concentrations of suspended matter are to be used for comparison with the mass concentration of aerosol? Observation sites situated at the right bank of the Ob River are excluded because they are too remote from the site of C value observations and are included into their own circulation process the boundary of which is the Ob River as a natural separating factor. It draws polluted air flows into the channel and carries them downstream [4]. Two left-bank observation stations are left for comparison: stations Nos. 19 and 25. The nearest station (No. 19) is situated at a distance of 1.75 km to the north from the hospital No. 34, where observations of the mass concentration of aerosol were carried out by the ICKC. Station No. 25 is situated at a distance of 4 km to the south-east from the hospital. To avoid erroneous conclusions, comparative analysis of q_m and C values was carried out with the data from the above-indicated observation stations.

The annual variations of monthly averaged concentrations of suspended matter at stations Nos. 19 and 25 and the mass concentration of aerosol are shown in Fig. 4. One can see that the annual variations of monthly averaged concentrations of suspended matter measured at station No. 19 and monthly averaged C values measured at the territory of the Municipal Hospital No. 34 have the same maximum appearing during the same period (April). The maximum of monthly averaged dust concentrations at station No. 25 is shifted to May. The curves of the annual variation have specific features for each observation site and are not quite identical but they conserve the general trend to increased monthly averaged concentrations in spring months and decreased values in winter months.

It follows from the analysis of data shown in Fig. 4 that monthly averaged concentrations of suspended matter (q_m) exceed C values by a factor of 1.5–5.0. On the one hand, this excess is explained by the absence of nighttime observations in the Rosgidromet system, which results in the incomplete coverage of the 24-h period. On the other hand, the major difference is in the method of concentration measurements. The Rosgidromet stations perform sampling three times a day for 20 min each, and the daily averaged concentrations are calculated from these data; while at the ICKC air

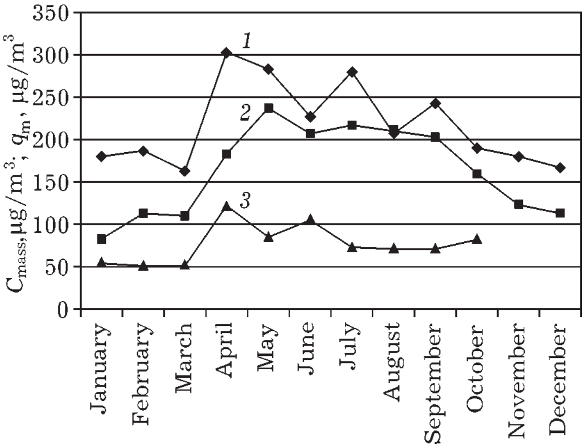

Fig. 4. Annual variations of q_m (*1, 2*) and C_{mass} (*3*): *1, 2* – stations Nos. 19 and 25, respectively; *3* – Municipal Hospital No. 34.

samples are collected on filters for 24 h, and the results are averaged over the 24 h interval. For this reason, different results were obtained for the same material (in the first case it is aerosol, in the second case it is suspended matter) sampled on the same filters but with different amounts of polluted air pumped, different sampling times and averaging periods.

A comparative analysis of C and q_m averaged over 24 h near the Hospital No. 34 over the synchronous series of observations, both for station No. 19 and for station No. 25, showed large discrepancies. Correlation coefficients (r) between C and q_m separately over seasons and in general for stations Nos. 19 and 25 are given below:

	Winter	Spring	Summer	Autumn	Annual
No. 19	0.10	0.53	0.08	0.02	0.35
No. 25	0.01	0.23	0.04	0.10	0.29

One can see that the correlation coefficient for station No. 19 is relatively significant only in spring (during the maximal dust content) and is equal to 0.53. During other seasons, any correlations between the values under consideration are almost completely absent, which could be expected because the series under comparison are not correct. The fact is that the distance between observation sites is large, and the levels of pollution are formed under different meteorological and emission factors.

As we have mentioned above, in European countries and the USA in order to evaluate the quality of atmospheric air they measure not the whole fractional composition of solid suspended matter but only definite fractions. For this purpose, the term PM_{10} was introduced. It characterizes the fraction of suspended matter with the aerodynamic diameter 10 mm and smaller, though larger suspended particles can also be present [1].

Different methods to measure atmospheric air pollution with dust in Russian Federation and in the countries of European Community and the USA define also different standards accepted for air quality assessment. In Russia, the measured concentrations of suspended particles are compared with the maximum permissible concentration (MPC). Single (measured during 20 min) concentrations are compared with the maximal single permissible concentration (MPC_s) which must not exceed 500 mg/m^3. Daily, monthly and yearly averaged concentrations are compared with the maximal permissible concentration averaged over 24 h (MPC_{24}) which is equal to 150 μg/m^3 [5]. The standard of atmospheric air quality for PM_{10} in 15 European countries for the daily averaged dust concentration is 50 μg/m^3, for year-averaged concentration it is 20 μg/m^3 [4].

If we accept that the mass concentration of aerosol C_{mass} corresponds to the concentration of solid suspended particles (SSP) in the terms of WHO, it is necessary to establish the fraction of PM_{10} particles in C_{mass}. For the conditions of Siberian cities, calculations were carried out at the ICKC of the SB RAS to distinguish the ratios of spectra of different size fractions within C_{mass}. It was established that for Siberian cities C_{10} (PM_{10}) = $0.67C_{mass}$. This value is close to the data reported in [6, 7] where the coefficients of transition from SSP to PM_{10} values are reported for a number of European cities. For them, the concentration ratio PM_{10}/SSP varies within 0.5–0.7.

On the basis of the data on the coefficient of transition from SSP to PM_{10} equal to 0.7 (the worst conditions), a number of observations of the mass concentration of aerosol near the hospital No. 34 was transferred to the series of PM_{10} concentrations. Then the quality of atmospheric air in Novosibirsk near Hospital No. 34 was assessed using the standards of WHO (days with the concentrations ≥50 μg/m^3 were chosen). In parallel, estimation of air quality in relation to pollution with suspended matter was carried out for data from stations Nos. 19 and 25 with respect to MPC_{24} = 150 μ/m^3. This analysis showed that the existing evaluations of the atmospheric air quality at the stations of Rosgidromet reveal much more cases of air pollution than the method based on the use of PM_{10} (Fig. 5).

A series of observations of suspended matter during the period under consideration gave excess over the MPC_{24} in 185 cases at station No. 19 and 150 cases at station No. 25. As a result of the observations of the mass aerosol concentrations transferred into PM_{10}, only 135 cases of the excess over the standard of atmospheric air quality for dust were revealed. Higher concentrations (>2MPC) are almost not fixed by the evaluation basis of WHO, while using the standard approach of

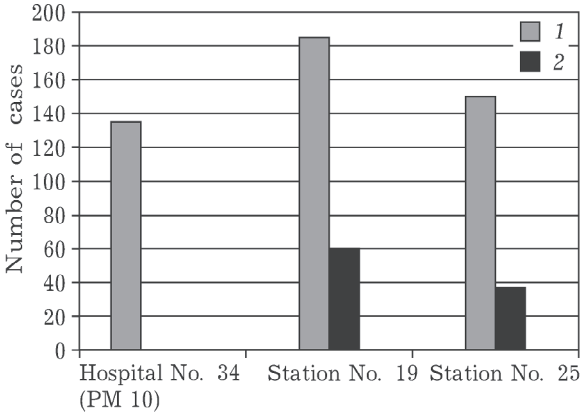

Fig. 5. Evaluation of atmospheric air quality in Novosibirsk with respect to solid suspended matter according to PM_{10} standards (Hospital No. 34) and MPC_{24} (stations Nos. 19 and 25): *1* – >1MPC, *2* – >2MPC.

Rosgidromet they were revealed in 60 cases at station No. 19 and in 37 cases at station No. 25.

CONCLUSION

Investigations confirm the conclusions of the authors of [6] that the transition to the procedure of dust observation according to WHO standards will not change our notions of air pollution with dust but will require substantial material expenses for the creation of additional network of measurements of PM_{10} concentrations. This problem appears difficultly implementable during the period of economic difficulties. However, in future the approaches to air quality evaluation on the basis of solid suspended matter content should be unified in all WHO member countries.

Attention to PM_{10} is connected with the hazardous action of aerosol of this size fraction on human health, which is confirmed by numerous results of epidemiological and toxicological studies. Evaluations over 25 countries of the European Community showed that the action of the air containing PM_{10} causes a decrease in lifetime by 8.6 months for the population [8].

REFERENCES

1 Monitoring Ambient Air Quality for Health Impact Assessment. WHO Regional Publications, European Series, No. 85, Copenhagen, 1999.
2 Rukovodstvo po Kontrolyu Zagryazneniya Atmosfery, RD 52.04.186–89, Moscow, 1992, pp.181–183.
3 Ezhegodnik Sostoyaniya Zagryazneniya Atmosfernogo Vozdukha v Gorodakh i Promyshlennykh Tsentrakh, Raspolozhennykh na Territorii Deyatelnosti Zapadno-Sibirskogo Mezhregionalnogo Territorialnogo Upravleniya po Gidrometeorologii i Monitoringu Okruzhayushchey Sredy za 2005–2008 gg., Novosibirsk, 2006–2009.
4 Selegey T. S., Formirovaniye Urovnya Zagryazneniya Atmosfernogo Vozdukha v Gorodakh Sibiri, Nauka, Novosibirsk, 2005.
5 Perechen' i Kody Veshchestv, Zagryaznyayushchikh Atmosferny Vozdukh, Integral, St. Petersburg, 2005.
6 Bezuglaya E. Yu., Smirnova I. V., Vozdukh Gorodov i Yego Izmeneniya, TsNIT "Asterion", St. Petersburg, 2008.
7 Kachestvo Atmosfernogo Vozdukha v Krupneyshikh Gorodakh Sibiri za Desyat' Let, 1998–2007gg. (Anal. Review), TsNIT "Asterion", St. Petersburg, 2009.
8 Tsyro S. G., *Meteorol. and Gidrol.*, 2 (2008)34.