DYNAMICS OF PHYSICOCHEMICAL PARAMETERS OF THE URBAN AEROSOL UNDER CONDITIONS OF COLD FRONT PASSAGE

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Received May 4, 1994

In this study we measured diurnal behavior of the number density of aerosol particles and mass density of some chemical elements in the aerosol substance in the atmosphere over Gorno–Altaisk city. The features of the dependences observed are explained from the standpoint of the behavior of aerosol sources and meteorological parameters during measurements. We have revealed certain correlation between the number and mass densities of the elements under study.

Gorno–Altaisk is one of the cities with unfavorable ecological state. It is because the city is situated in the depression between mountains where the air stagnation is observed and then there is an accumulation of the toxic pollutants from the emissions of numerous boiler–houses, houses with the stove heating, industrial enterprises, and cars.

A round–the–clock cycle of measurements of atmospheric aerosol parameters was performed in Gorno–Altaisk in November, 1992 during an expedition to the Altai Republic. Aerosol particles number density was measured at the center of the city each 2 hours. Measurements were carried out in 7 size ranges. Simultaneously aerosol samples were collected for subsequent element analysis. The beginning of the daily cycle (November 2, 1992, 11 p.m.) occurred in the calm meteorological situation characterized by a pronounced temperature inversion in the atmospheric boundary layer and absence of the snow cover. The cold atmospheric front passed in the second half of the cycle. It was accompanied by a snowfall and strong wind.

The study of aerosol particle size–spectra was carried out using PKZV–906 photoelectric counters that are capable of recording the number of particles in 1 dm^3 of air in 7 size ranges: 0.3–0.4, 0.4–0.5, 0.5–1, 1–2, 2–5, 5–10, and 10–100 μm. The results were presented in the form of plots of daily behavior of the number density in every range and the total number density of all particles.

Aerosol samples were collected on the analytic filters AFA–HA–20 and AFA–VP–20 according to the technique described in Ref. 1. The volume of the air pumped through was 4 m^3 taking into account the correction for viscosity. Time of pumping through was 30 min. The chemico–analytical studies of the exposed filters on determining the mass density of 12 base metals (BMs) were carried out under laboratory conditions. The mass density of Hg and As was determined by voltamperometry technique, and the other elements were determined by the atomic–emission method. The quality of the filters (content of the element to be determined in their material as an admixture) allowed us to determine the mass density of BMs lower than background level quite reliably. The error of analysis did not exceed 20% with the confidence level of 0.95. The results are given in Table I.

TABLE I. Mass density of some metals in the near ground aerosol in the city of Gorno–Altaisk on November 3, 1992 (μg/m³).

No. of a sample	Time	Ba	Be	B	Mn	Cr	Pb	Zn	Cu	Cd	Hg	T°C	Notes
1	0.00–0.30	0.3	0.00009	0.003	0.19	0.05	0.06	0.04	0.012	0.02	0.08	0	wind of 2–4 m/s
2	2.00–2.30	0.08	0.00009	0.0025	0.015	0.022	0.042	0.05	0.015	0.022	0.02	0	calm
3	4.00–4.30	0.06	–	0.002	0.010	0.013	0.025	0.032	0.005	0.015	–	– 1	calm
4	6.00–6.30	0.01	–	–	0.012	0.007	0.0018	0.020	0.005	0.010	–	– 1	wind
5	8.00–8.30	0.06	–	0.0042	0.010	0.038	0.048	0.038	0.006	0.030	–	– 1	wind
6	10.00–10.30	0.07	–	0.0051	0.020	0.05	0.25	0.09	0.048	0.062	–	0	wind
7	12.00–12.30	0.22	0.0012	0.007	0.012	0.082	0.23	0.11	0.022	0.070	–	2	wind
8	14.00–14.30	0.17	0.002	0.0048	0.017	0.080	0.31	0.093	0.034	0.058	–	5	wind
9	16.00–16.30	0.28	0.0017	0.0012	0.010	0.035	0.12	0.04	0.009	0.030	–	3	snow
10	18.00–18.30	0.05	–	0.0010	0.008	0.009	0.09	0.02	0.005	0.007	–	2	snow
11	20.00–20.30	–	–	0.0008	0.062	–	0.03	–	0.004	–	–	0	wind
12	22.00–22.30	–	0.00002	0.0005	0.050	–	0.025	0.015	0.004	–	0.02	– 2	wind
MPC		4	0.1	50	1	1.5	0.3	50	2	1	0.3		
Sensitivity of the analysis. Thresh-old concentration (μg/m³)		0.01	0.00001	0.0005	0.002	0.0005	0.0005	0.001	0.001	0.002	0.01		

Note: – denotes the content that is less than a threshold concentration.

The plots of the obtained diurnal behavior of particle number density are shown in Fig. 1*a* for one of the size ranges (0.5–1 μm) as well as for the total concentration. Since the start of measurements the total number density decreased during the night, then increased in the morning and reached the maximum value (~10^6 dm^{-3}) at 11 a.m. on November 3, 1992. Evidently, only the aerosol sources connected with boiler–houses operating continuously worked during the night, but the stove heating was practically absent. During this time aerosol admixtures had time to spread.

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In the morning stove heating and motor transport gave essential contribution to the number density that led to its sharp increase. Further, in the daytime, the increase of wind and snowfall connected with the passage of cold front led to the spreading and partial washing out of aerosol from the atmosphere. It resulted in the decrease of the particle number density by two orders of magnitude. Then the particle size distribution function varied a little because even a strong wind could not clear the atmosphere of the city effectively enough, but only caused equalizing of aerosol number density over the city area under the conditions of continuous work of aerosol sources. It follows from the measurement data, that 70–80% of particles had the size less than 0.5 μm that is typical for aerosols emitted by a heating system.

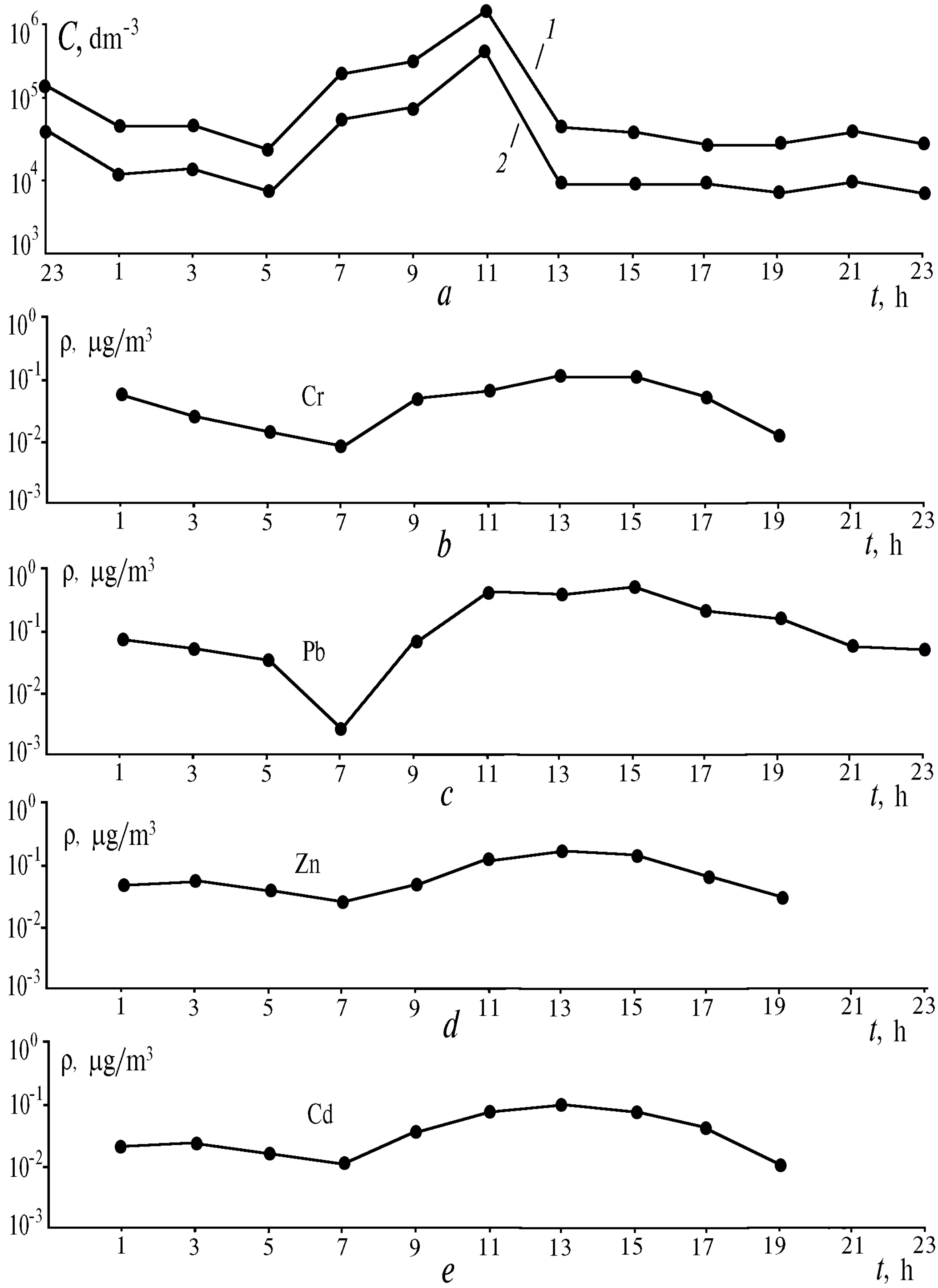

Fig. 1. Diurnal behavior of the total number density (curve 1) and the number density of particles with the size of 0.5–1 μm *(curve 2) (a); and, the mass density of Cr, Pb, Zn, and Cd (b, c, d, and e, respectively).*

The results of chemical analysis of aerosol samples show that the mass density of a number of elements analyzed decreased, on the average, from the beginning of the cycle during the nighttime due to partial spreading of aerosol in the atmosphere under the weak wind conditions, then increased during the daytime that corresponded to "switching on" of different aerosol sources, and in the evening the mass density decreased with the cold front passing. The mass density of such elements as Cr, Be, and Ba increased during the daytime by 10–30 times in comparison with the morning one, and decreased by one order of magnitude (Cr and Ba) by the end of the cycle. The mass density of Be decreased by two orders of magnitude. The most increase of the mass density was recorded for Pb (by more than 150 times), but further the mass density of this element also decreased by one order of magnitude. Analogous variations of the mass density of Zn, Cu, and Cd were less sharp, but their mass density also decreased by order of magnitude when the coldfront passed. Diurnal behavior of the mass density of some elements is shown in Figs. 1*b*–*e*. Let us note, that these variations qualitatively correlate with the variations of the number density of particles.

The fact that the points of minimum of mass and number densities do not coincide in time can be explained by the duration of collecting aerosol samples. In this connection the results of the analysis were referred to the closest integer hour.

The mass density of Cr, Zn, and Cd decreased after 7 p.m. lower than the threshold of detection by atomic–emission method.

Absolute values of the mass density of all determined elements did not exceed the maximum permissible concentration (MPC) for residential area. At the same time, the mass density of such elements as Pb, Cd, Mn, and Zn was 4–6 times greater that the maximum value of the background accepted for the European part of Russia.[2] The mass density of aerosol particles was up to two times greater than the maximum permissible concentration (0.5 mg/m^3).

As it was already noted, the main reasons for higher pollution of the atmosphere over the city of Gorno–Altaisk are the depression location of the city, that leads to the low degree of its ventilation; appearance of frequent and long inversions in the near ground layer; large number (> 100) of small boiler–houses that have no systems for cleaning the smoke emission; the use of low–quality brown coal of Kansk–Achinsk deposit for heating. All these reasons lead to the higher smoke content, especially in the morning and in the evening, and to appearance of the smog conditions. It is characteristic that the mass density of a number of BMs in the atmosphere of Gorno–Altaisk city before winter exceeds the analogous parameters in another city of Altai region, Zmeinogorsk, although the latter has much more developed industry.

REFERENCES

1. *State Standard 17.23.01–81. Preservation of Nature. Atmosphere. Rules of Air Quality Monitoring in Cities.*
2. *Handbook on the Atmosphere* (Gidrometeoizdat, Leningrad, 1991), 510 pp.

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