AKV-2 mobile station and its use in Tomsk city as an example

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A new version of AKV-2 mobile station, designed and manufactured at the Institute of Atmospheric Optics SB RAS is described. The station is intended for measurements of air composition under urban and rural conditions. It differs from earlier versions by a possibility to conduct measurements not only at stationary sites, but also from a moving car. This significantly accelerates the process of surveying air state at urban territories. The results of surveying Tomsk city in June, 2004 are presented.

The quality of urban air on the territory of the former USSR remains unsatisfactory despite the economical depression (downswing) lasting from 90s until now. Such a conclusion follows from annual state-of-the-environment reports of conservation organizations.[1–4] This is caused by the fact that the industrial emission reduction is compensated for many-fold growth of automotive pollution.

Mathematical methods and models evolved by V.V. Penenko,[5–7] as well as measurements in particular regions show the urban area to be not only a “heat island” but also an “island of pollutants” due to specific local air circulation around a town.

The Penenko’s data not only change modern insight into urban aeration, but explain a number of factors deduced from experiments and cannot be interpreted on the base of existing concepts, in particular, fast (1–2 days) restoration of chemical equilibrium in air of industrial centers after passage of a decontaminating atmospheric front.

The local circulation zone depends on a size of a town, the number and capacity of its industrial enterprises; pollutants are accumulated here up to a certain limit. Since the air temperature in the formed column is higher, the air begins to ascend. First the column is vertical,[8] but under effect of the main flow it inclines and becomes horizontal at a considerable distance from a town, extending then near the top of the atmospheric boundary layer. The height of this layer is seasonally dependent; it separates from the free atmosphere by a trapping layer.[9]

All the foregoing calls for nontraditional techniques for measurements of pollutant distribution in the urban atmosphere. In the framework of this problem, an AKV-2 mobile station was designed and manufactured at the Institute of Atmospheric Optics SB RAS for monitoring the air composition under urban and rural conditions. This paper describes its specifications, as well as some results obtained.

To conduct measurements both at stationary sites and en-route, the station is provided for instrumentation and a self-contained power supply. A wide range of determinable air characteristics permits measurements both in background regions and in heavily polluted industrial zones. All measurements are computerized, if possible, and the measurement results are stored into electronic media.

In the beginning of 2004, the mobile station mounted on Gas-66 vehicle has undergone first *in situ* tests.

Measuring instrumentation, which included 6 gas analyzers and 2 aerosol analyzers, was installed inside a special-purpose van, equipped with operator’s working places as well (Fig. 1).

Outside the van, on its back wall, a telescopic mast of KhZh4.115.025Sp type[10] with a M-63 anemometer, a M-115m pyranometer, temperature and humidity sensors fixed on it was mounted. If necessary, air intakes for analyzers can be fixed on the mast at different heights. The outside air samples enter the measurement devices through the main intake mounted on the roof forepart. The appearances of the station and the telescopic mast are shown in Fig. 2.

The air mixture transportation to analyzers was of special attention in the station design. The air flow consumption required for operation of an AZ-6 aerosol counter, determining countable concentration of particles in the range $0.4 \le d \le 10.0$ μm, and a diffusion battery ($3 \le d \le 200$ nm), is 1.2 and 1 l/min, respectively. In this case, the average linear air flow rate in the air inlets is 52 cm/s. Total air consumption is set such that air flow speed in the air intake is equal to the speed of air outgoing through a pipe, that meets the isokinetic condition. Subject the above conditions, the air transportation is carried out without a noticeable distortion of the aerosol size distribution.[11,12]

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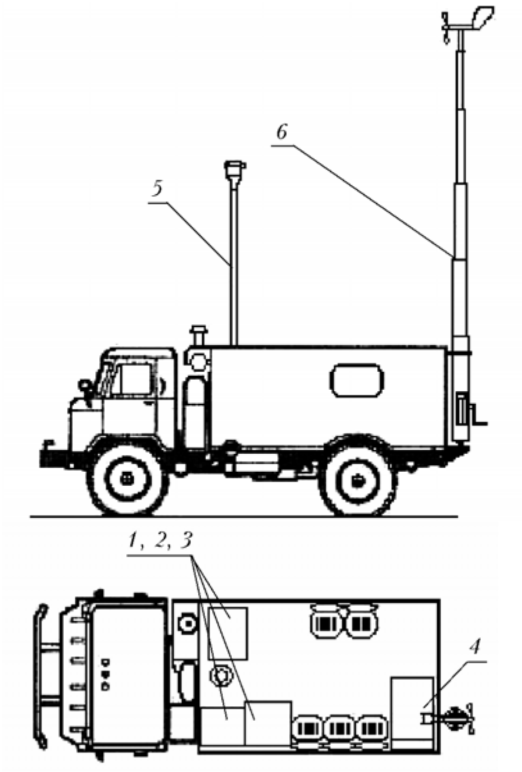

Fig. 1. The appearance of the AKV-2 station: posts with the measuring instrumentation (*1*, *2*, and *3*); power module (*4*); aerosol-gas intake (*5*); meteorological station based on the telescopic mast of KhZh4.115.025Sp type (*6*).

The AKV-2 station is equipped with a computer to record measurement data incoming from sensors through interface.[13] Simultaneously, protocols of data from gas analyzers and a GPS-receiver are recorded through standard serial ports. The computer software allows one to choose the operation mode. The measurements can be conducted at stationary sites or en-route. In the latter case, synchronously with the measured data, the station coordinates, fixed by the GPS-receiver, are recorded into the database at a reading frequency of 1/s. However, such a large amount of data is not always necessary; during long-term stationary measurements, we used the operation mode similar to that used at the TOR-station[14]: blowing of inlets and measurements alternated every ten minutes. The measured parameters and instrument specifications are given in Table 1.

The station is equipped with a self-contained power supply based on 24 V accumulators and ~220 V single-phase voltage converters. This allows a fast start of measurements, since the station instrumentation is ready to work just upon its arrival to a measurement site, i.e., there is no need for preheating, calibrating, and waiting for the full operation mode.

Thus, the time required for the station activation reduces to a few minutes. Completely charged batteries of 210 A/h capacities permit the station to operate during 3 hours or longer consuming up to 2 kW/h at ~ 220 V voltage. The station is equipped with a small frame electro-petrol generator (~ 220 V) and has a possibility of external power supply. Therefore, it can serve as a temporary station of air quality control both in some urban zone with a lot of energy sources and in points distant from the power supplies. In this case, it is possible to simultaneously recharge the accumulators.

Fig. 2.

From the beginning of February, 2004, within the framework of the SB RAS project No. 130 "Ecology of Siberian industrial centers," the station took part in several expeditions: Tomsk–Irkutsk, Tomsk–Novosibirsk (twice). It operated in industrial zones of Tomsk and Novosibirsk and their outskirts. Some obtained results are generalized in Ref. 15. The results obtained in Tomsk on June 23, 2004, are described below.

The scheme of the experiment is shown in Fig. 3. First, stationary measurements were conducted on Tomsk leeward, near Chernaya Rechka village; then they were continued in motion through the Tomsk territory. The route ended on the city windward with surveying a sanitary zone of the petroleum chemical plant.

Table 1. Specifications of the AKV-2 station instrumentation

Parameter	Instrument	Detection limit	Measurement range	Error
Temperature and humidity of air	HYCAL Sensor Products Honeywell Inc., Model: IH-3602C	0.1°C; 1%	T –70 to +70°C Rel. humidity 15–100%	±0.5°C; ±7%
Wind speed	Wind meter M-63	10° 0.5 m/s	0...360 0.5...40	±10% ±10%
Total solar radiation	Pyranometer M-115m	10 W/m^2	10–1368 W/m^2	±10%
Particle number concentration and size distribution	Photoelectric particle counter AZ-6 (12-channel)	$0.4 \le d \le 10.0$ μm	0–300 cm^{-3}	±20%
	Diffusion aerosol spectrometer (8-channel diffusion grid battery)	$3 \le d \le 200$ nm	0–10^5 cm^{-3}	±10%
NO	Chemoluminescent gas analyzer	0.1 μg/m^3	0.1–1000 μg/m^3	± 25%
NO_2		1 μg/m^3	1–1000 μg/m^3	± 25%
O_3		1 μg/m^3	1–1000 μg/m^3	± 15%
SO_2		1 μg/m^3	1–2000 μg/m^3	± 25%
CO_2	Optical IR gas analyzer	100 ppm	100–2000 ppm	±20%
CO	Electrochemical gas analyzer	0.1 mg/m^3	0.1–400 mg/m^3	±20%
Air aerosol chemistry	Filter-aspirated system (up to 10 m^3/h per filter)	Up to 10 ions, 25 elements	Determined by analysis for each chemical component	

Fig. 3. Scheme of the experiment (June 23, 2004).

The weather conditions on June 23, 2004 were not standard for that season. It is seen in Fig. 4 that the northeast transfer was observed down at the inner mixing layer (before its decomposition).[16] To determine the pollutant vertical distribution, a pilot balloon tracked by the basic method was flown.

Figure 5 shows the distribution of number concentration of aerosol (NS), carbon monoxide, nitric oxide, and nitric dioxide along the station route (leeward part (*1*), town part (*2*), and windward part (*3*)). As a majority of Siberian cities, Tomsk is an island of pollutants. Pollutant concentration inside Tomsk is several times higher than at its leeward and windward.

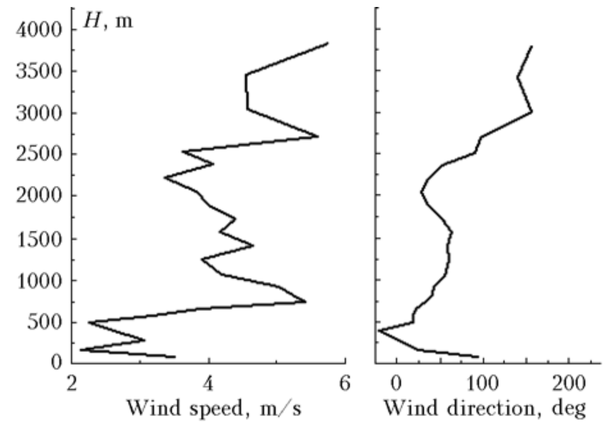

Fig. 4. Vertical distribution of wind speed (*a*) and direction (*b*) leeward of Tomsk on June 23, 2004.

On the contrary, the ozone concentration in Tomsk is lower (Fig. 6). It is a standard situation, because ozone is not emitted by enterprises and motor transport, but is formed of impurities directly in atmosphere.[17] At a high aerosol concentration, ozone begins to interact with particles, which results in destruction of O_3 molecule. At the same time, Fig. 6 shows an intensive ozone generation leeward. Evidently, in the plume above, ozone is formed of compounds emitted from the city territory. As Fig. 5 shows, these compounds are not nitric oxides; they presumably were not controlled in the experiment.

Data on the air temperature show it to be 2.5°C lower at the eastern and western outskirts of the city than in its center (Fig. 7).

Relative humidity is of special interest. Until now, there is no consensus in literature, whether it is higher in town or not. According to Ref. 18, there can be additional sources of water vapor in town, e.g. enterprises, leaky water pipe-lines, motor transport. At the same time, snow is removed in winter, the most part of the urban territory is covered with asphalt, that makes surface evaporation (natural source) to be less effective. Hence, if the ratio between specific and relative humidity at a fixed temperature is known,[9] we can conclude the following. If the relative humidity decreases proportionally in the town center at a temperature rise, then additional sources of water vapor are absent there. If the change is disproportional, there are some water vapor sources. Returning to Fig. 7, we can see a proportional decrease of the relative humidity in Tomsk, which indicates the absence of additional moisture sources. The data on specific humidity confirm this fact.

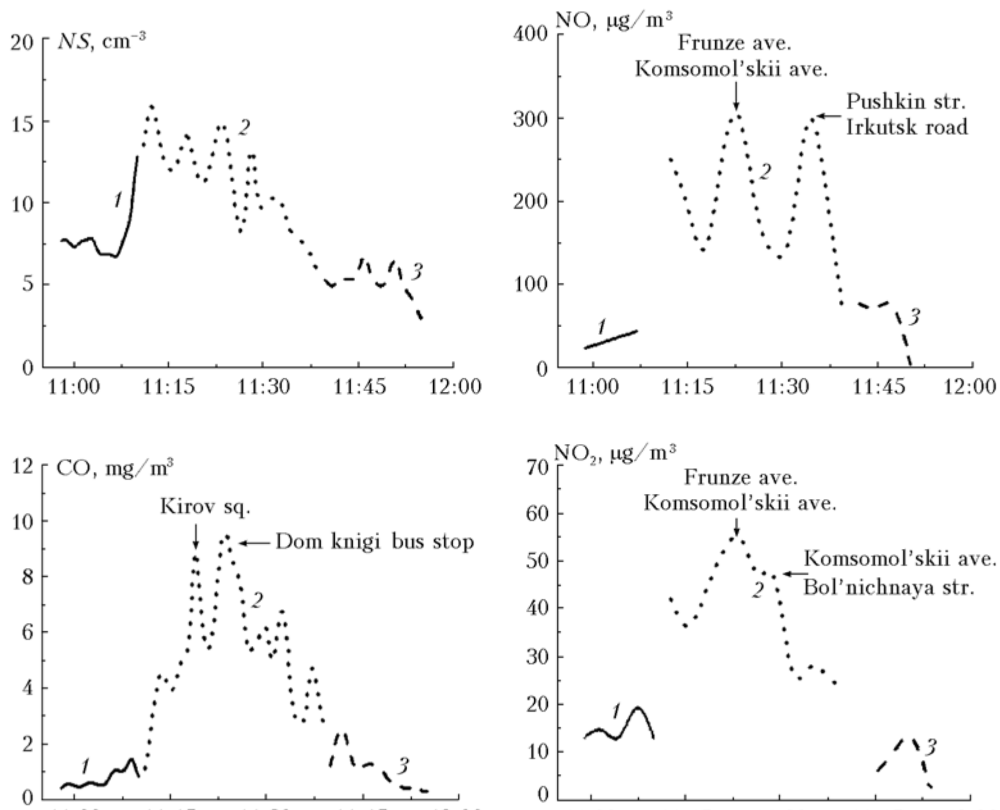

Fig. 5. The distribution of aerosol, carbon monoxide, and nitric oxides along the route.

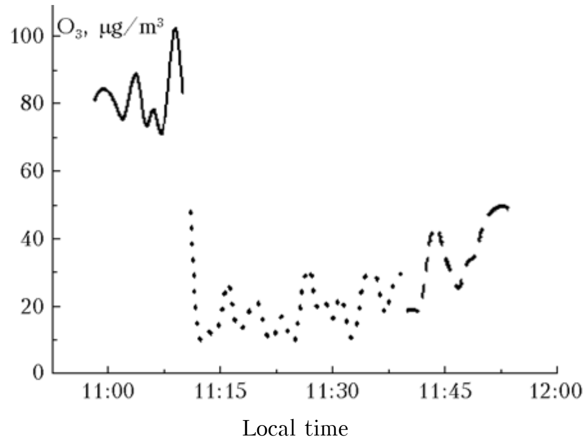

Fig. 6. Ozone concentration along the route.

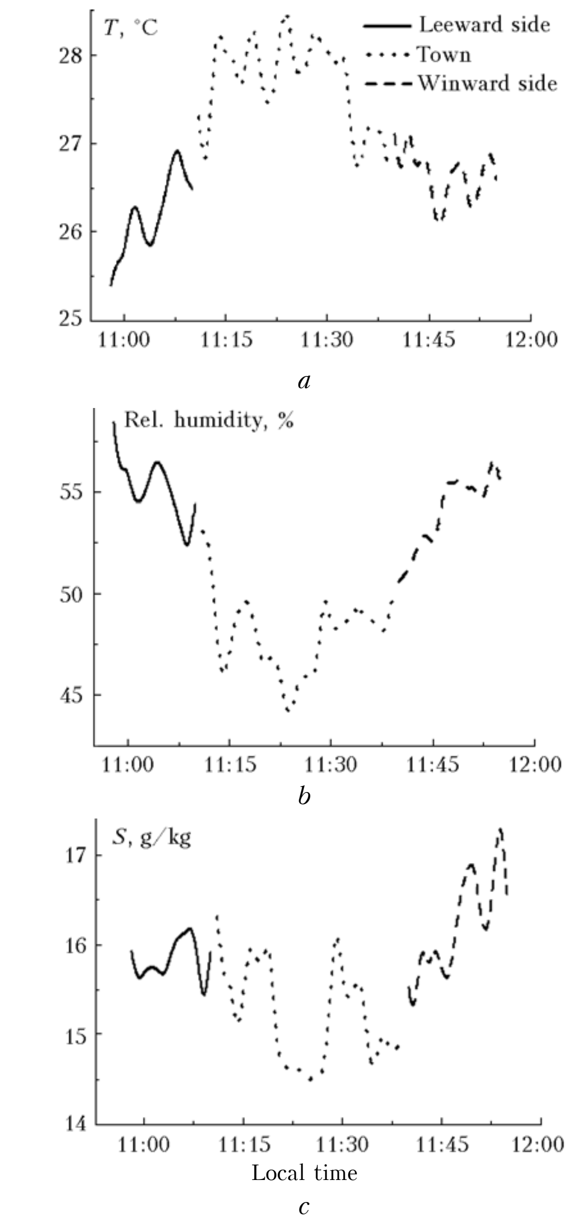

Fig. 7. Temperature (*a*), relative (*b*) and specific (*c*) air humidity along the route.

Let us dwell on one more aspect. Until now, there is no some conventional opinion on reasons of formation of heat islands. Such an island is in Tomsk as well. On the one hand, according to many researches, the albedo of the urban territory is 30% lower than the rural one, hence, the solar energy absorption is ditto more.[18] Recently, we checked this inference in Novosibirsk city and found[19] the albedo difference to be 34%. On the other hand, another measurement data[18] advocate that insolation in the urban zone is 30–40% lower due to some impurity cap above it. Therefore, it was interesting to measure the solar radiation change along the station route (see Fig. 8).

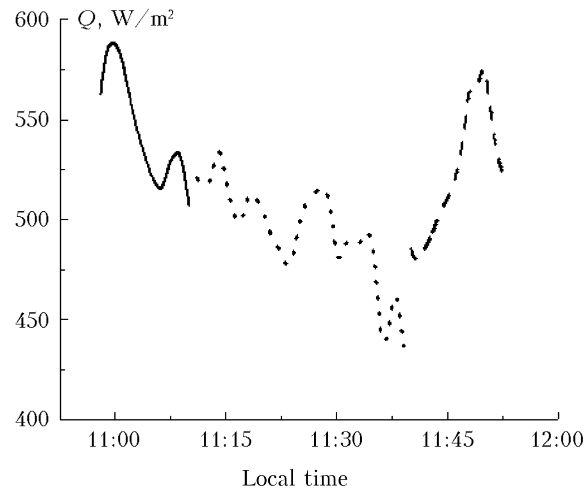

Fig. 8. Solar radiation along the route.

As is seen, the solar intensity is 550–580 W/m^2 outside the town, while inside it is 400–450 W/m^2, decreasing sometimes to 425 W/m^2, that is somewhat less than in Ref. 18. Possibly, this is due to the urban vertical building-up structure, which affects the surface atmosphere heating via heat accumulation in the urban canyons and buildings.[20]

Thus, the mobile station has shown itself as the effective instrument to investigate the urban atmosphere with the use of methodology accelerating data acquisition.

The conducted experiment allowed us to reveal some peculiar fields of impurity distribution in Tomsk (as in majority of Siberian towns), which are formed due to specific local air circulation. Their concentration is higher in central parts and decreases closer to outskirts. The same is true for thermodynamic air parameters.

Acknowledgments

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