INFORMATION FLOWS IN THE SYSTEM OF ROUTINE MONITORING OF AIR POLLUTION IN THE AIR BASIN OVER INDUSTRIAL CENTERS

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When constructing a system for routine monitoring of the ecological state of the environment, one faces the problem on transmitting the data acquired, besides the problem of obtaining reliable information that is not redundant. Besides, the use of different, by types of measurements and the information acquired, information sources requires different channels to be used for data transmission, formats of transmitted data and methods of data transmission under regular and emergency conditions. In this paper we evaluate the information streams circulating in one of the systems developed at the Institute of Atmospheric Optics SB RAS (the routine monitoring system "Gorod"). This system combines two principles of constructing such systems, that is, the spatially representative one and that oriented toward data sources. This is achieved by employing the network of observation stations available and by introducing lidars to that system structure. In addition to the lidar measurements, a wide-aperture photometer is used for reconstruction of the pollution pattern over the region surveyed.

The data formats and the order of data transmission under regular and emergency conditions are determined for various data sources. Recommendations are given on how to deploy the information sources and on the arrangement of communication with these sources.

1. INTRODUCTION

Permanent development of industries has led to their concentration. As a result, the ecological conditions of the environment within the industrial centers and in the nearby territories worsen. The anthropogenic impact on the environment has already reached such a power that the environment is almost incapable of self-purifying. To elaborate the effective and timely measures to rehabilitate the environment, it is necessary to have objective information, both qualitative and quantitative, on the current state of the environment as well as on the dynamics of its change.

To obtain this information, the systems are being developed for ecological monitoring of the environment that are intended for solving the following problems:

1. Acquisition of data on the composition of the contaminating species and on the distribution of these over the medium under surveillance.
2. Identification of pollution sources.
3. Study of mechanisms and kinetics of reactions of transformation of different compounds in natural media under the effect of photolysis, hydrolysis, biological decomposition and so on.
4. Mathematical simulation of all the processes of inflow, transformation, and migration of the contaminants for the purpose of predicting the state of the environment and giving recommendations on necessary protective measures to be undertaken, as well as for making assessments of the efficiency of measures in use.

At present there are known more than 5 million chemical compounds, of which more than 60 thousand are being produced on a commercial scale. Moreover, the total volume of production of chemical compounds all over the world increases, every ten-year period by a factor of 2.5 (Ref. 1). Besides, when constructing the prediction subsystem, one needs for data on distribution of meteorological quantities over the area under study and height. It is natural that such a great number of quantities can hardly be controlled and it is impossible to organize routine monitoring of that kind. Therefore, when developing the systems for monitoring of the atmosphere, normally some reference compounds are considered that characterize certain groups of substances. The height distribution of meteorological quantities is monitored not over the entire area but at a single point or at several points only. Ultimately, the structure of the monitoring system is obtained as a compromise between the purpose to measure as many

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characteristics as possible and the costs of such measurements.

Besides the problem of acquiring necessary data, there exist certain problems on data transmission, storage and processing. Modern detectors are capable of measuring at a rate of tens of hertz thus producing a large bulk of data. On the one hand, it is desirable to have a detailed information about the state and dynamics of the environmental changes while on the other hand, if the bulk of data is too large, the rate of data acquisition decreases due to a limited transmission capability of the communication channels and, hence, the usefulness of the data obtained becomes doubtful. The problems may also arise on storage of large bulks of data as well as on their timely processing. In the majority of cases, that is, under regular conditions (no sudden emissions and/or sharp changes in the meteorological quantities) large bulk of data acquired is redundant, while being necessary under the emergency conditions.

At present a large number of systems have been developed for monitoring of the air quality. According to Ref. 2 there exist two conceptions of constructing such systems. The first one comprises the systems, which enable one to reconstruct the concentration fields (based on the data obtained from a network of measurement posts) closely approximating the actual ones. Such systems are known as spatially representative ones. The systems of the second kind, are those oriented to acquire information on the pollution sources, that is, allowing one to estimate the contribution from individual sources to the total field of the atmospheric pollution. At the Institute of Atmospheric Optics SB RAS the routine monitoring system "Gorod",[3] integrating both principles, has been developed.

The primary goal of this paper was to assess the streams of information, the order of transmitting the data, and types of data transmitted under regular and emergency conditions.

2. STRUCTURE OF DATA ACQUISITION SUBSYSTEM

The integration of both principles in the system "Gorod" is achieved by use of a network of distributed, over the area under surveillance, posts (see *7* in the Figure 1) of the "Post"[4] type and by the adding into the system of lidars *1* of "LOZA" type (see figure).[5] The integration of both principles into one system makes it possible to obtain the objective pattern of the pollution distribution over the area controlled from the data of the ground-based network of posts. At the same time lidar sounding enables one to identify the sources of industrial emissions, to evaluate the emission intensity, to follow up the directions of the emission spread, and to map the dispersal of the contaminants over the air basin surveyed.

As a supplement to lidar measurements, a wide-frame photometer *4* of the "All Sky Chamber" type is used (see the figure)[6] for reconstructing the pollution pattern.

To provide for surveillance of the areas that are not equipped with the stationary posts as well as for a more detailed surveillance of the polluted areas, mobile stations of two types are assumed to be used. The stations of the first type are equipped only with analytical instrumentation *2*, the stations of the second type are equipped with a Raman-lidar *3* (see the figure).[7]

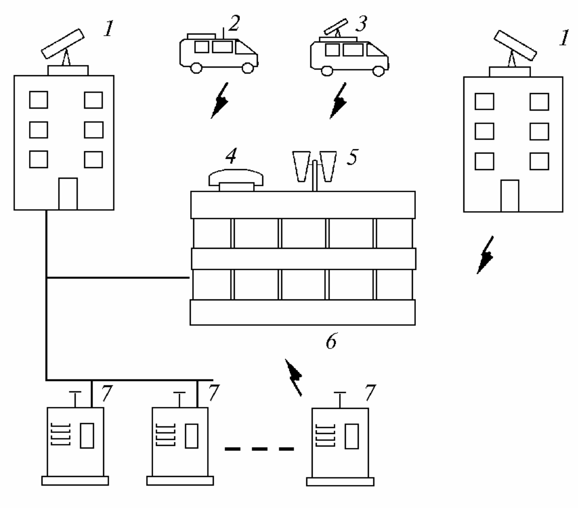

FIG. 1. The diagram of the data acquisition.

Use of a sodar (acoustic radar) of "MAL" type *5* (see the figure)[8] or of a mast equipped with the meteorological instruments are recommended for use to monitor altitude distributions of the meteorological quantities.

The information is accumulated at the data storage center *6* (see the figure) being transmitted via the commutated lines, separated lines or via radio channel. The "All Sky" photometer and the sodar should be located on roof of the building of the data storage center. In this case high-speed lines of a local network can be used for transferring the data.

3. OPERATION MODES

3.1. Routine mode

Ground-based post. Table I gives the list of parameters that are normally measured at the ground-based posts. The number of ground-based posts depends on the size and specific features of the areas to be surveyed. The post is intended for conducting the measurements continuously. Since the dynamics of changes in the air basin state is weak, under regular conditions, the data acquired are transmitted to the central station every hour. The period of data averaging is 0.5 hour. In case a quantity under control changes by a preset value an extra transmission of data is to be performed. A local storage device acquires data every minute.

Sodar. The instrument is intended for measuring the altitude distribution of wind speed and direction.

The measurements are carried out continuously. The data are transmitted to the central station every hour. The period of data averaging is 10-minute long. Extra transmission of the data is made when any parameter under control changes by a preset value. A local storage device acquires data every minute.

TABLE I. The data storage obtained from the ground-based post.

Parameter	Data storage, byte
Wind velocity	2
Wind direction	2
Temperature of air	2
Humidity of air	2
CO	4
NO	4
NO_2	4
NO_x	4
CH	4
O_3	4
SO_2	4
Dust	4
Total	40

TABLE II. Data storage obtained using sodar.

Parameter	Value
Distance	1000 m
Space resolution	8 m
Capacity	6 bytes
Total	750 bytes

The wide-frame "All-Sky" photometer. It is intended for recording the evolution and dynamics of the events, phenomena, and processes taking place in the atmosphere and accompanied by absorption, scattering or emission of optical radiation in the UV, visible and IR spectral regions. The field of view of the photometer objective is 180° wide. As a result, the image of the entire celestial sphere is formed in its image plane. The photometer can be used only during day-time since in this case we have a passive measurement technique. The instrument is mounted on the roof of building where the data storage center is located, and a local computer-network is employed for data transmission. Every minute a photograph taken in the visible region and a photograph of color temperature are saved in the local memory and transmitted to the central station for visual control by an operator. Under regular conditions the photographs are being saved at the central station once an hour.

Lidar. In this system "LOZA" aerosol lidars are assumed to be used. For cities with the population of 500–600 thousand people three or four lidars with a 5-km operation range are necessary to provide for reconstruction of the pollution field over the whole territory surveyed. Under regular conditions the lidar scans the atmosphere with the spatial resolution of 30 m and angular resolution over azimuth of 0.5°. During one measurement cycle 20 readings are taken over the elevation angle. Thus obtained data are reduced to several parallel square regions on horizontal planes with the grid cells of 30-m size. One plane is formed based on the results of measurements at zero elevation angle. The remaining planes are formed based on the measurements at different elevation angles. Thus processed data are then transmitted to the central station once an hour.

TABLE III. Data storage obtained using the photometer.

Parameter	Value
Horizontal distribution	576 points
Vertical profile	544 points
Byte per point	1
Data compaction	3 times
Photograph of color temperature	104448 bytes
Photograph	120000 bytes
Total	224 448 bytes

TABLE IV. Data storage obtained using a lidar.

Parameter	Value
Transmission range	5000 m
Space resolution	30 m
Azimuth	360°
Number of readings at angle of elevation	10
Azimuth resolution	0.5°
Reading	1 byte
For one cycle of measurements	1 200 000 bytes
Time of measurement cycle	1.00 h
Side of a square	5000 m
Array pitch	30 m
Number of layers	4
Byte per point	1
Data compaction	1 time
Total	111 111 bytes

The mobile posts without a Raman-lidar are equipped with the same set of measuring instruments as the ground-based posts. The measurement data are averaged over 20-minute intervals.

TABLE V. Data bulk obtained from the mobile station with SRS-lidar.

Parameter	Data bulk, byte
Concentration of weighted particles	4
CO	4
NO	4
NO_2	4
SO_2	4
Rate of jet out flow	4
Gas temperature	4
Total	28

The data are transmitted to the central station via a radio channel.

Mobile stations with a Raman-lidar are capable of measuring concentration of gases and particulate matter at the mouths of plant stacks. The measurement time characteristic of a Raman-lidar assumed for use is about 15 minutes. The data transmission to the central station is assumed to be performed using a radio channel.

The total bulk of data collected at the center of data storage per day and year is given in Table VI.

TABLE VI. Total data bulk obtained by the central station under regular conditions.

System	Byte (data bulk per unit)	Number	Operation time, h	Transmission time, h	Total data bulk for a day, byte
Ground station	40	24	24	1	23040
Lidar	111111	4	12	1	5333333
Sodar	750	1	24	1	18000
All Sky	224448	1	12	1	2693376
Mobile station	40	2	12	0.5	1920
Mobile station with a Raman lidar	28	1	12	0.5	672
Mean data body per 1 min, byte					8069669
Mean data body per 1 s, byte					2945429307

3.2. Operation mode under emergency conditions

Emergency mode of operation is switched on when the rate of a change in any quantity under control exceeds a preset value (delta-threshold) or when the quantity itself exceeds a certain level. In this case the following actions are assumed: 1) the delta-threshold for the data sources within an emergency area decreases; 2) lidars start a new scanning over the emergency area, over the azimuth and elevation angle, immediately after completing the preceding cycle (every 6 minutes); the bulk of data storage depends on the size of the emergency area; 3) a demand to the data source may be sent from the central station for an extra transmission of data.

Now we assess the stream of information obtained at the central station from remote sources of data (which are not located at the central station) under most unfavorable conditions, that is, when all the data sources transmit data at a maximum possible rate. The minimum period of lidar data renewal, obtained at elevation angle 0°, is 12 minutes, and one from the mobile station with a Raman-lidar is 15 minutes. The minimum period of lidar data renewal obtained from other data sources is 1 minute. Thus, the mean rate of data acquisition under emergency conditions, excluding local lines of data transmission, is 700 bytes per second (Table VII).

TABLE VII. Maximum data bulk obtained at central station under emergency conditions.

System	Data bulk per unit, bytes	Period, min	Mean data body, byte/s	Quantity, pieces	Data body, bytes
Ground station	40	1	0.66667	20	12000
Lidar	111111	12	154.321	4	555556
Sodar	750	1	12.5	1	11250
Mobile station	40	1	0.66667	1	600
Mobile station with a Raman lidar	28	15	0.03111	1	28
Mean data body per 1 min, byte					38628.9
Mean data body per 1 s, byte					673.403

4. CONCLUSION

As is seen from Table VI, the most dense stream of information comes from the photometer and lidars, therefore the photometer and one lidar are proposed to be deployed on the roof of a building of the data processing center. In this case it is possible to connect those via high-transmission-rate channels of a local computer-network. It is desirable to connect other lidars using the special transmission lines that could provide for a high reliability of connection and the necessary transmission capacity. When using radio channels, the communication line is less noise proof. The employment of commuted lines (state Telephone System Lines) is not recommended, although these lines have sufficient transmission capacity. The matter is that these lines cannot provide high-quality connection at all times, thus causing a delay in communication or transmission of the control commands.

To transmit the data from ground stations, the commuted lines or Internet channels should be used.

In this case the operation reliability is higher due to the presence of data routing using some alternative routes for the data transmission. In certain specific cases the use of the radio channel is justified, namely, low quality of commuted lines or their overloading, the lack of transfer or if the use of Internet is inexpedient, and so on.

To transmit the data from a mobile station, we recommend to use the radio channel (low-density of the information stream, the necessity in establishing a link with different stations throughout a city). It is possible to use specially equipped stations for data transmission (for example, the channels of data transmission from the ground stations) or data delivery to the central station using a physical carrier (diskette). However, in this case the data exchange rate decreases.

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