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The influence of meteorological factors on air pollution in Chechen Republic: results of measurements from a mobile environmental laboratory

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Abstract. The paper presents data from operational monitoring of atmospheric air in the city of Chechen Republic, obtained through a mobile environmental laboratory in 2023. An assessment of the quality of atmospheric air in the city was carried out and a comparison of the concentrations of pollutants obtained as a result of measurements with the maximum permissible maximum one-time concentrations was presented. 37 excesses were identified and priority (most frequently detected) pollutants were identified. The correlation between recorded excesses of indicators and unfavorable weather conditions has been analyzed, and the wind direction in which exceedances of maximum permissible concentrations are most often recorded has been established. The principles of operation of the model of distribution of aerodisperse systems taking into account meteorological data have been formed.

1 Introduction

Air pollution has significant negative impacts on human health and is considered one of the most serious and pressing health problems facing society. According to WHO experts, exposure to air pollution leads to more than 4 million cases of premature death, affecting both residents of cities and rural areas [1].

Exposure to pollutants such as particulate matter less than 10 and 2.5 microns in diameter (PM10 and PM2.5) and volatile organic compounds has been linked to a range of health effects, including respiratory and cardiovascular diseases, cancer lungs and asthma [2-3]. Acute respiratory diseases are also associated with the influence of pollutants such as nitrogen dioxide and sulfur oxide [3]. Cardiovascular diseases are also affected by carbon monoxide, making it difficult for the body's cells to bind oxygen [3]. Exposure to high levels of carbon monoxide can be fatal.

To manage air quality, air pollutant concentrations are monitored. To collect data on the concentrations and characteristics of air pollutants, stationary observation posts are installed, which are located in different areas of the city and are the basis for regular observations of air conditions. In addition to pollutants, observation posts also measure meteorological air parameters.

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Weather conditions, such as ambient temperature, wind, and air humidity, are important factors in the distribution of pollutants in the air. Above-normal high temperatures that persist for a long time create heat waves that can contribute to the outbreak of forest fires [4]. The smoke and emissions of PM2.5 particulate matter generated during the combustion process under the influence of wind currents can spread several kilometers from its source [5-6]. Additionally, adverse weather conditions may occur during the winter, especially if the region is prone to temperature inversions, which can occur when warm air forms above cooler air on the ground. Temperature inversions trap pollution in a certain area, preventing it from spreading to other places, thereby creating a cumulative effect [7]. According to studies, temperature inversions correlate with the concentration of pollutants in the air and the number of diseases associated with air pollution [8].

2 Materials and methods

In order to cover a larger territory and quickly ensure control over the state of atmospheric air in the city of Tolyatti, the work of a mobile environmental laboratory (MEL) has been organized. The mobile environmental laboratory regularly measures emissions of an approved list of air pollutants. Upon the occurrence of unfavorable meteorological conditions (UMC) and/or complaints from the population received by the Unified Duty Dispatch Service (UDDS), the Tolyatti city administration sends a mobile environmental laboratory to the established addresses to carry out measurements of atmospheric air, after which the results of each measurement are transmitted to the interactive platform – Ecological Atlas (Figure 1).

Fig. 1. Organization of mobile environmental laboratory visits.

The obtained measurement data from the mobile environmental laboratory is used for:

- Creating an archive of data on monitoring the air condition of the urban environment in the Ecological Atlas.
- Informing the city administration and city residents about the state of the environment.
- Assessment of air pollution in the event of an emergency.

The equipment of the mobile environmental laboratory includes several chromatographs and gas analyzers, a dust analyzer and an automatic weather station (Figure 2).

The list of atmospheric air monitoring includes pollutants characteristic of industrial cities and the road transport complex: suspended substances (PM1; PM2.5; PM4; PM10), ammonia (NH_3), nitrogen oxide (NO), nitrogen dioxide (NO_2), hydrogen sulfide (H_2S), sulfur dioxide (SO_2), carbon monoxide (CO). At the same time, chromatographs located in a mobile environmental laboratory make it possible to measure the concentrations of organic substances: a mixture of saturated hydrocarbons CH_4-$C5H_{12}$ and C_6H_{14}-$C_{10}H_{22}$, phenol, benzene, toluene, xylenes, α-methylstyrene, styrene, ethylbenzene, acetone, methanol, propanol -2, butanol. Also, laboratory staff can carry out sampling for formaldehyde with subsequent analysis in an accredited laboratory and use the portable device GANK-4 to analyze a wide range of substances: gasoline, butan-1-ol, butyl acetate, methanol, acetone, solvent naphtha, white spirit, saturated hydrocarbons C_{12}-C_{19}, ethanol,

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ethyl acetate, hydrogen fluoride, methyl mercaptan, lead and its inorganic compounds, chlorine, trichlorethylene, acetic acid. In addition to measuring pollutants using the Nasal Ranger, laboratory staff can measure odor intensity in ambient air.

Fig. 2. Equipment for a mobile environmental laboratory.

3 Results

In 2023, the Mobile Environmental Laboratory carried out 140 testing visits for a range of controlled substances: 34 based on complaints and 106 during periods of adverse weather conditions. To assess the quality of atmospheric air, the obtained concentrations of pollutants were compared with the maximum permissible maximum single concentrations (MPCm.r.). Thus, 37 exceedances of maximum permissible concentrations were identified (Figure 3). Some of the most frequently detected substances were α-methylstyrene and carbon monoxide.

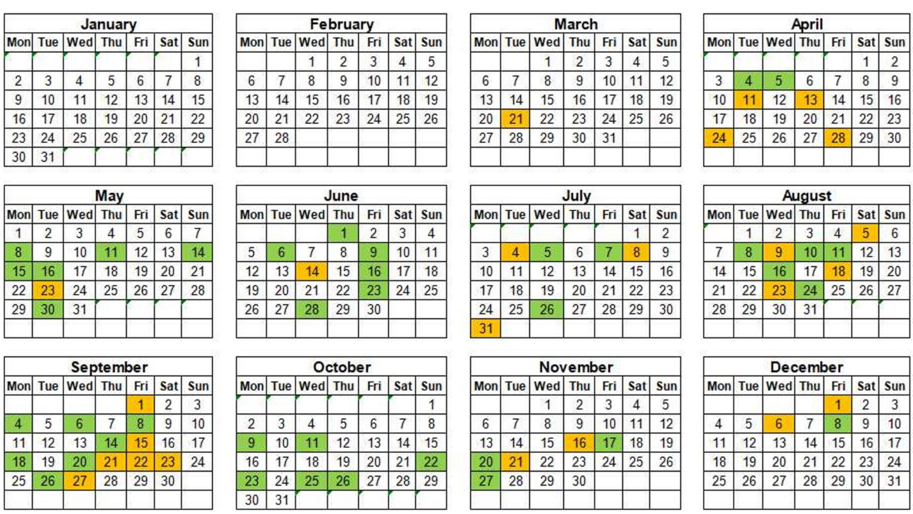

Fig. 3. Calendar of visits of the mobile environmental laboratory indicating the days when excesses were recorded.

Excesses of the maximum permissible concentration were mainly recorded in the Central and Komsomolsky districts of the city in the summer and autumn (Table 1).

Table 1. Substances for which excesses were detected.

Substance	Number of exceedances	Exceeding range	Excess recording area
Carbon monoxide	12	from 1.1 to 4.0 MPC	Central, Avtozavodskoy, Komsomolsky district
Suspended solids	3	from 1.7 to 5.0 MPC	central District
Isopropanol	2	2.4 MPC	Avtozavodskoy district
Hydrogen sulfide	1	1.1 MPC	Komsomolsky district
α-methylstyrene	15	from 1.1 to 2.4 MPC	Central, Avtozavodskoy, Komsomolsky district
Ammonia	1	2.5 MPC	central District
Butanol	3	from 1.1 to 3.6 MPC	Central, Komsomolsky district

4 Discussion

Comparing the data with the frequency of warnings about adverse meteorological conditions (Figure 4), it can be argued that the main number of established exceedances is associated with certain adverse meteorological conditions.

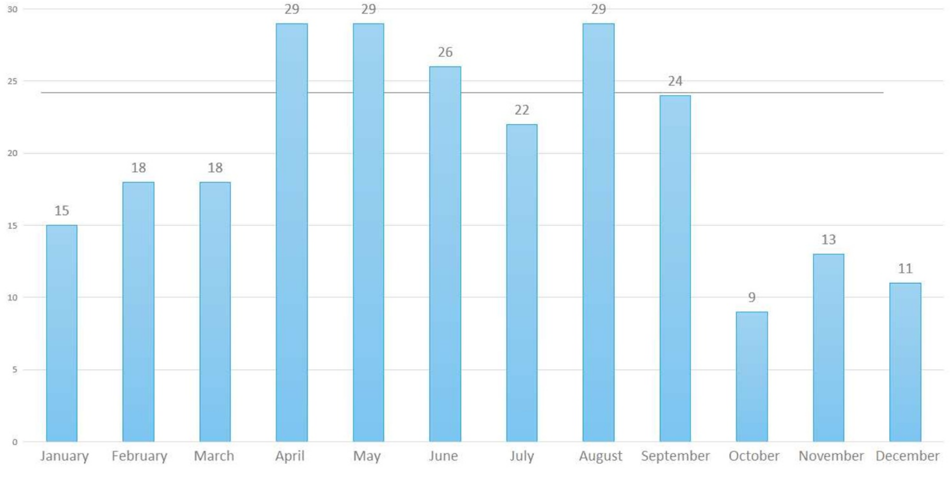

Fig. 4. Number of severe weather warnings issued in 2023.

This is also confirmed by a large number of excesses recorded in northeastern and northern wind directions, the speed of which did not exceed 1 m/s. During calm conditions, excesses of the maximum permissible concentration were recorded at five measurement points.

During the measurements, it was revealed that southern and northern winds are characteristic of Tolyatti (Table 2). Based on the averaged values obtained, a diagram of the city's wind rose was compiled (Figure 5).

Table 2. Wind direction graph in Tolyatti, with average values according to our data.

Northern (N)	Northeast (N-E)	Eastern (E)	Southeast (SE)	Southern (South)	Southwestern (SW)	Western (W)	Northwestern (NW)
22.7%	9.6%	4.3%	4.6%	33.5%	17.3%	4%	4.2%

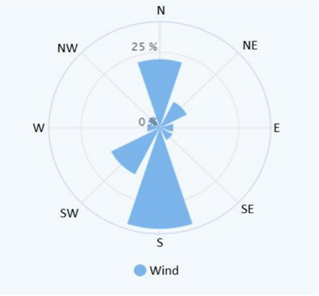

Fig. 5. Wind rose showing the city's characteristic wind directions.

5 Conclusion

The available statistical data will be used to train the neural network. This will make it possible to draw up a map of the city’s pollution and predict possible concentrations and distribution of pollutants, taking into account meteorological data, as well as determine the summation effect.

The operating principle of the airborne systems propagation model is as follows:

- The data obtained from measurements of pollutant concentrations by the mobile environmental laboratory, as well as data on meteorological conditions, are sent to the server for processing.
- The server block receives data, processes, stores and displays it in an application or website.
- The app and website displays data through mapping and provides users with real-time air quality information (Figure 6).

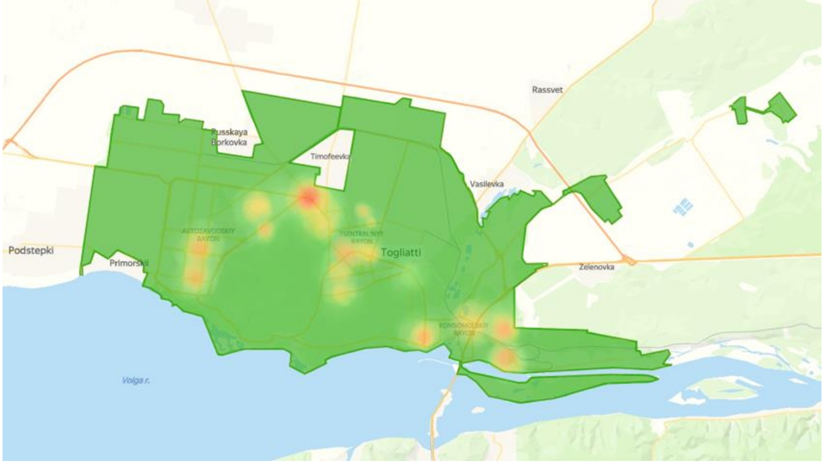

Fig. 6. An example of displaying a map of air pollution in Tolyatti.

It is also worth noting that as it develops, such a model will be able to take into account the urban density of the city, include air quality data from sensors installed in the city, and traffic data to provide a holistic picture of the air condition of the urban environment [9-10].

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