Investigation of the dustiness of various zones of a metropolis and a set of measures to reduce the negative impact of dust on living organisms

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Abstract. One of the negative factors that affects human health is dust. Particularly high dust exposure in megacities. There are no unambiguous approaches to solving this problem. A lot depends on the geographical location of the metropolis. Therefore, for each city, it is necessary to conduct personal research on the situation with the formation of dust from various objects in the climatic conditions of the city. In addition, the composition of urban dust is complex, which depends on many factors. In the study, it is necessary to determine the main sources of dust and the possibility of reducing their activity. It is also necessary to establish the nature of the medium (e.g. dispersion system, etc.) in which dust is present. An important point is the chemical composition of the dust. It is especially important to know about the presence of dangerous chemical elements or radioactive particles in it. The paper shows that wind flows on the one hand contribute to reducing the level of dust, on the other hand, when it is polluted, they sharply worsen the environmental situation. In modern cities, a decrease in green spaces, especially trees, is planned. This fact also needs to be considered as one of the options for reducing dust load. Special attention should be paid to the methods of rapid monitoring of the air environment in real time. Their use will help in time to take the necessary measures to block dust sources.

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1 Introduction

One of the negative factors that have a great impact on the human condition is dust [1-3]. Moreover, the dust appears in various forms. Particularly sharp differences are present in megacities, which are filled with different infrastructure [4-10]. The diversity of infrastructure results in a combination of dust containing different particles. For example, abandoned construction sites, businesses, and freight transport in an industrial zone create the most dangerous dust composition for health. In dry weather, this dust is transported over long distances across the metropolis. From the metropolis, the dust can be transferred to agricultural fields. This will change their state [11-16]. With strong gusts of wind and the absence of trees, dust enters the premises through windows and doors and settles there. In such confined spaces, it becomes difficult for people to breathe [1-3].

The efficiency of workers is falling. Modern optical sensors allow registering changes in the state of the atmosphere and the presence of foreign particles in them [17-19]. In some cases, they can be classified. After the dust settles on various objects, it is removed with a vacuum cleaner (other methods are less effective). This process is quite laborious and requires the cost of consumables. Wet cleaning in corridors also removes dust.

It should be noted that the means used to remove dust must be disposed of in the future. They contain dangerous substances that are dangerous to people. This is an additional environmental problem. The same applies to people's living quarters, etc. Many scientists are currently working on this problem. Various models, techniques and methods are considered. Any new variation in this area is always welcome. Its results make it possible, by integrating them into existing methods, to improve the situation with dust formations.

2 Research methodology and instruments

Analysis of the results of various studies has shown that it is most advisable to use a complex technique. This technique includes a theoretical study of the presence of dust in a metropolis and experimental confirmation of the proposed hypotheses. Theoretical study and preliminary calculations allow us to propose a method of research and determine the necessary instruments for its implementation. Pay special attention to the use of express control methods [20-32]. A preliminary calculation based on previously obtained data showed that the process of studying the state of dustiness of a megacity must be divided into four stages:

1. Selection of a metropolitan area for the study of dustiness. The area should have businesses, transport interchanges, green areas and water formations (sea coast, rivers or ponds). In St. Petersburg, the Kirovsky district was selected for research. All marked objects are present in this area;
2. Measurement of dust and particle types using various instruments at various points in the area. Dust monitoring should be carried out at different times of the year, especially in unfavorable weather. When measuring, be sure to control temperature, wind speed and humidity;
3. Compile, based on control points, the dependence of the dust content of the Kirovsky district zones on various factors;
4. Control of the state of dustiness should be carried out at different times of the year, especially in adverse weather. When measuring, it is necessary to monitor the temperature, wind speed and humidity;
3 Results of experimental studies and their discussion

We used the Fluke 975 AirMeter to study the state of the atmosphere (the presence of carbon dioxide and carbon monoxide in it), as well as to measure temperature and humidity. It comes with an air flow sensor. This allows you to measure the air speed. Three devices were used to control the dustiness of the air and determine the particle size. Portable particle counter TSI AeroTrak 9303, dust particle counter in the air SU VE-9680, as well as the air optical density meter IDIP-01 (Fig. 1). A small-sized NMR spectrometer was used for rapid monitoring of the state of liquid media, such as reservoirs [33-40].

![IDIP-01](image)

Fig 1. The optical density measurement of IDIP-01.

The use of these devices allowed us to determine the fractional composition of dust for different seasons (the distribution of dust by particle size). As an example, tables 1 and 2 show the results of such studies in several locations in the Kirovsky district of Saint Petersburg. There were more than 300 such points during the research.

| N  | Characteristic of the measurement point | Time interval | Particle size, μm | Number of particles | Air humidity, % | T, K | u, m/s |
|----|----------------------------------------|---------------|------------------|---------------------|-----------------|------|-------|
| 1  | Kirovsky Zavod metro station. Nearby is the Kirov factory and a large street with heavy traffic. | October       | 0.25             | 118516              | 57.3            | 279.3| 0.6   |
|    |                                        |               | 0.4              | 46092               |                 |      |       |
|    |                                        |               | 0.6              | 37187               |                 |      |       |
|    |                                        |               | 1.0              | 6782                |                 |      |       |
|    |                                        |               | 2.5              | 897                 |                 |      |       |
|    |                                        |               | 5.0              | 207                 |                 |      |       |
|    |                                        |               | 8.0              | 114                 |                 |      |       |
|    |                                        |               | 10.0             | 39                  |                 |      |       |
Table 2. Dispersion analysis of the dust state in several points of the Kirovsky district of Saint Petersburg in the spring.

| N  | Characteristic of the measurement point | Time interval | Particle size, μm | Number of particles | Air humidity, % | T, K | υ, m/s |
|----|---------------------------------------|---------------|------------------|---------------------|----------------|------|-------|
| 1  | Kirovsky Zavod metro station. Nearby is the Kirov factory and a large street with heavy traffic. | May           | 0.25              | 126712              | 63.4           | 283.4 | 1.2   |
|    |                                        |               | 0.4               | 57042               |                |      |       |
|    |                                        |               | 0.6               | 57042               |                |      |       |
|    |                                        |               | 1.0               | 43117               |                |      |       |
|    |                                        |               | 2.5               | 27116               |                |      |       |
|    |                                        |               | 5.0               | 41146               |                |      |       |
|    |                                        |               | 8.0               | 10172               |                |      |       |
|    |                                        |               | 10.0              | 10172               |                |      |       |
|    |                                        |               | 0.25              | 126712              | 63.4           | 283.4 | 1.2   |
|    |                                        |               | 0.4               | 57042               |                |      |       |
|    |                                        |               | 0.6               | 57042               |                |      |       |
|    |                                        |               | 1.0               | 43117               |                |      |       |
|    |                                        |               | 2.5               | 27116               |                |      |       |
|    |                                        |               | 5.0               | 41146               |                |      |       |
|    |                                        |               | 8.0               | 10172               |                |      |       |
|    |                                        |               | 10.0              | 10172               |                |      |       |

2 Avtovo metro station. October 0.25 102117 56.4 280.2 0.47
0.4 42253
0.6 24714
1.0 4103
2.5 456
5.0 317
8.0 83
10.0 26

3 Viaduct at Avtovo metro station. Territory under the bridge, near the railway. October 0.25 124547 49.3 280.9 0.36
0.4 59386
0.6 41146
1.0 7248
2.5 1144
5.0 282
8.0 167
10.0 59

4 Coast of the Krasnenkaya river near the fishing port. October 0.25 73523 68.4 277.2 4.7
0.4 27116
0.6 12256
1.0 1016
2.5 207
5.0 101
8.0 17
10.0 9

5 Park on Stachek Avenue. October 0.25 22783 59.3 280.4 0.41
0.4 10172
0.6 4113
1.0 937
2.5 261
5.0 143
8.0 23
10.0 12

6 Residential area between Kirovsky Zavod and Avtovo metro stations. October 0.25 103726 58.7 281.0 0.53
0.4 32117
0.6 22544
1.0 4252
2.5 611
5.0 171
8.0 62
10.0 15
Analysis of the results obtained showed the following. In areas where there are few green spaces and there is no strong wind in dry weather there is a very high concentration of dust particles with sizes of about 2.5 μm. Particles of this size pose the greatest danger to humans. They do not stay in the airways and sink deep into the lungs, damaging tissues. The presence of green spaces significantly reduces the concentration of dust in the air.

The obtained results are showed necessity the using for particles size control of different devices. The most effective of them, as research have shown, are devices whose operating principle is based on the use of optical methods [41-46].

Low temperature and humid weather also reduce dust concentration in the air. Therefore, in megalopolises located on the coast, it is important to ensure that the territory of the megalopolis is blown through the sea air through the highways.

| No. | Location Description                                                                 | Month | Size (μm) | PM2.5 | PM10 | PM15 |
|-----|--------------------------------------------------------------------------------------|-------|-----------|-------|------|------|
| 2   | Avtovo metro station. May 0.25                                                        |       | 1.118940  | 62.3  | 283.2| 1.1  |
|     |                                                                                       |       | 0.4 54296 |       |      |      |
|     |                                                                                       |       | 0.6 42752 |       |      |      |
|     |                                                                                       |       | 1.0 7034  |       |      |      |
|     |                                                                                       |       | 2.5 1014  |       |      |      |
|     |                                                                                       |       | 5.0 303   |       |      |      |
|     |                                                                                       |       | 8.0 202   |       |      |      |
|     |                                                                                       |       | 10.0 87   |       |      |      |
| 3   | Viaduct at Avtovo metro station. Territory under the bridge, near the railway. May 0.25|       | 1.143543  | 57.8  | 284.1| 0.9  |
|     |                                                                                       |       | 0.4 69494 |       |      |      |
|     |                                                                                       |       | 0.6 52947 |       |      |      |
|     |                                                                                       |       | 1.0 11756 |       |      |      |
|     |                                                                                       |       | 2.5 4943  |       |      |      |
|     |                                                                                       |       | 5.0 1713  |       |      |      |
|     |                                                                                       |       | 8.0 552   |       |      |      |
|     |                                                                                       |       | 10.0 214  |       |      |      |
| 4   | Coast of the Krasnenkaya river near the fishing port. May 0.25                         |       | 1.64727   | 67.8  | 281.1| 7.9  |
|     |                                                                                       |       | 0.4 41119 |       |      |      |
|     |                                                                                       |       | 0.6 11017 |       |      |      |
|     |                                                                                       |       | 1.0 9172  |       |      |      |
|     |                                                                                       |       | 2.5 286   |       |      |      |
|     |                                                                                       |       | 5.0 93    |       |      |      |
|     |                                                                                       |       | 8.0 12    |       |      |      |
|     |                                                                                       |       | 10.0 7    |       |      |      |
| 5   | Park on Stachek Avenue. May 0.25                                                       |       | 1.23214   | 64.3  | 282.3| 0.7  |
|     |                                                                                       |       | 0.4 9152  |       |      |      |
|     |                                                                                       |       | 0.6 3117  |       |      |      |
|     |                                                                                       |       | 1.0 811   |       |      |      |
|     |                                                                                       |       | 2.5 214   |       |      |      |
|     |                                                                                       |       | 5.0 123   |       |      |      |
|     |                                                                                       |       | 8.0 17    |       |      |      |
|     |                                                                                       |       | 10.0 6    |       |      |      |
| 6   | Residential area between Kirovsky Zavod and Avtovo metro stations. May 0.25           |       | 1.94176   | 62.4  | 281.8| 0.4  |
|     |                                                                                       |       | 0.4 33119 |       |      |      |
|     |                                                                                       |       | 0.6 20172 |       |      |      |
|     |                                                                                       |       | 1.0 5426  |       |      |      |
|     |                                                                                       |       | 2.5 517   |       |      |      |
|     |                                                                                       |       | 5.0 176   |       |      |      |
|     |                                                                                       |       | 8.0 94    |       |      |      |
|     |                                                                                       |       | 10.0 17   |       |      |      |
4 Conclusion

The results obtained show the prospects of applying this methodology for assessing the dustiness of the territory from various factors. Its use makes it possible to establish the presence of permanent dust sources and the direction of the main streams of its distribution.

Analysis of the state of dustiness of the territory after various measures for cleaning dust showed that the most effective way is to clean the territory using a vacuum cleaner-based technique. All small particles are successfully removed from the territory to the bunker. Large, heavy particles can be washed off with water. Green spaces are the most effective way to reduce dust formation, especially 2-3 meters high with dense vegetation.

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