

Analysis of Air Monitoring System in Megacity on the Example of St. Petersburg

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ABSTRACT

The paper considers the current problem of improving the quality of atmospheric monitoring. The paper aimed at conducting a monitoring section of the existing situation in the studied territories in St. Petersburg. The following study methods were described: gravimetric, electrochemical, and chromatographic. The analysis of samples was carried out on the following laboratory facilities of the mobile environmental laboratory: PU-3E aspirator, ECO-LAB portable gas analyser, DUSTTRAK 8533 dust analyser, portable gas chromatograph FGKh-1, professional weather station. The study consisted of two parts and was carried out in two districts of the city: Novosmolenskaya Embankment of the Smolenka River (Vasileostrovsky District) and the banks of the Volkovka River (Frunzensky District). As a result of the study, the concentrations of nitrogen dioxide, carbon oxide, suspended solids and volatile organic compounds in the air of the studied districts were measured. The obtained values were compared with the maximal single limiting concentration ($LMC_{m.s.}$) and assumptions were made about the possible sources of pollution. In the territory of Novosmolenskaya Embankment, the concentration of nitrogen dioxide varied from 0.211 mg/m³ to 0.472 mg/m³, which means the exceedance of $LMC_{m.s.}$. The maximum permissible concentration of the volatile organic compounds (VOC) content in air was exceeded by several orders of magnitude. No exceedance of $LMC_{m.s.}$ was detected for the content of carbon oxide and suspended solids in the air. The empirical data was used to build the air pollution content maps and to calculate the atmospheric pollution index in the studied territory.

Keywords: monitoring of atmospheric air quality, environmental safety, dust, PM2.5, PM10, volatile organic compounds, carbon oxide, nitrogen dioxide

INTRODUCTION

Saint Petersburg is the second largest city in Russia in terms of population (5 million people) and economic capacity. In Saint Petersburg, motor transport sources account for about 90% of pollutant emissions. According to the official report of the Committee for Environmental Protection, Nature Management and Ecological Safety of Saint Petersburg, the total volume of pollutant emissions in the city is growing every year.

This trend can be traced in large megacities around the world: in the works of researchers [Chen et al. 2017], the assessment of the contribution of regional transport to the PM_{2.5} air pollution in the North China Plain was made. This problem was also considered in the works of authors from the USA [Fann et al. 2013], India [Guo et

al. 2019], Italy [Padoan et al. 2020], some studies cover entire regions [Monforte et al. 2018]. In connection with the scale of the problem of air pollution in cities, it becomes urgent to study the main sources of pollutants, among which the main ones are construction [Shvartsburg et al. 2017, Zuo et al. 2017, Manzhilevskaya et al. 2021] and anthropogenic activities [Bespalov et al. 2016], including mining [Kokoulina et al. 2018, Danilov et al. 2015, Ivanov et al. 2018a].

An increase in concentrations is observed for such indicators as carbon oxide, volatile organic compounds (VOCs), becoming extremely relevant in the context of the study of the concentration of these components in the air, as well as the study of the principles of organizing environmental monitoring in the urban environment [Li et al. 2019, Volkodaeva et al. 2017].

1. The exceedance of the normal concentration of nitrogen dioxide in the air, which is contained in the vehicle exhaust gas, can reach 20 times through the city.
2. The solids content in urban air is one of the most significant indicators of the atmospheric air quality. According to the recommendations of the World Health Organization as well as the sanitary and hygienic standards adopted in our country, organization and monitoring of dust concentration in the air of settlements should pay special attention to fine particles PM_{10} and $PM_{2.5}$.

In connection with the need of forming a system of social and hygienic monitoring based on the analysis of health risks [Tikhonova et al. 2019] and competent planning of the urban environment [Sidorenko et al. 2020], it is important to study the complex of ecological problems of megacities [Blinov et al. 2013], their genesis [Jiang et al. 2021], the patterns of their impact on human health [Elansky et al. 2021, Ignatyev et al. 2020], the issues of catalytic processing of hydrocarbons [Kuzhaeva et al. 2019], removal of rare-earth elements by ion flotation [Lobacheva et al. 2016], and the problems of environmental responsibility of citizens [Goman et al. 2019a, Goman et al. 2019b].

The effect of dust on human health depends on its physical and chemical properties: chemical composition, concentration in the air, particle size (dispersion), their hardness, etc. Fine dust with a

particle size ranging from 2 to 5 microns is the most dangerous for human health.

It should be noted that the pollution of the urban airshed with fine dust depends not only on the volumes of emissions, but also on the climatic conditions that determine the transfer and dispersion of suspended solids.

With the help of specialized GIS systems, it is possible to assess of climatic parameters for environmental monitoring [Yakubailik et al. 2018, Pashkevich et al. 2017].

In this regard, it is of interest to analyze the peculiarities of climatic conditions in Saint Petersburg and it is required to record the meteorological parameters when conducting a study to determine the content of suspended solids. The climate of Saint Petersburg can be characterized as transitional from temperate continental to temperate marine.

The climatic features of Saint Petersburg compare the city favourably with other large cities, both in Russia and abroad, in terms of the conditions for dispersion of pollutant emissions in the atmosphere [Solomakhina et al. 2018]. In particular, the high relative humidity of air, characteristic of Saint Petersburg during all climatic periods of the year, contributes, as is known, to the coagulation of solid particles, which, in turn, causes their faster settling and, consequently, a decrease in the concentration in the urban air environment [Sergina et al. 2019]. However, a large number of vehicles, active development of

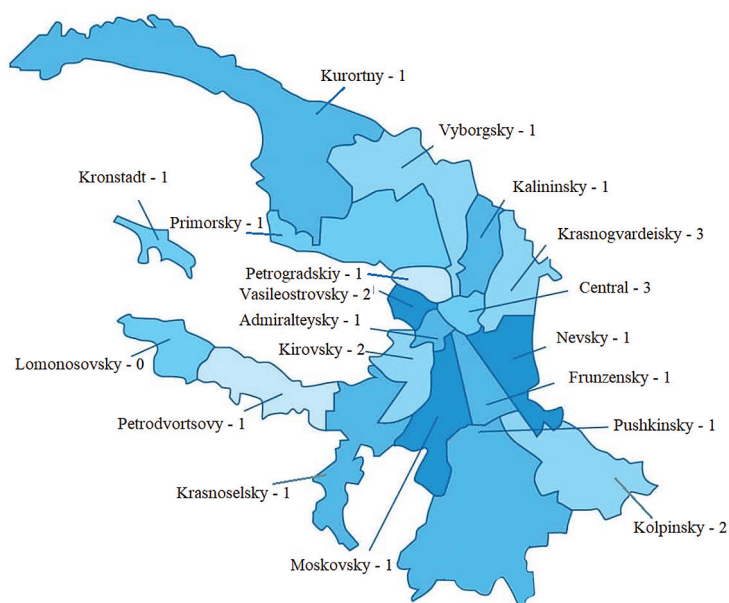


Figure 1. Number of air quality monitoring stations in the districts of Saint Petersburg

territories [Strizhenok et al. 2016], a reduction in the number of green spaces and a large number of industrial enterprises affect the state of atmospheric air, necessitating constant monitoring of the air quality in the city.

Environmental monitoring can be carried out using the equipment of mobile laboratories, at stationary posts, as well as using automatic monitoring stations, the work of which can be observed online [Ivanov et al. 2018b].

Currently, there are only 24 automatic atmospheric air monitoring stations in Saint Petersburg (Fig. 1):

On the basis of the analysis of the map above, it can be concluded that such a small number of air quality monitoring stations, which covers the vast territories of districts (Kurortny, Pushkinsky, Vyborgsky, etc.), or their complete absence (Lomonosovsky District), is unable to provide representative information on the quality of atmospheric air in the city districts.

In addition to the meteorological stations of the State Hydrometeorological Service, there are airport meteorological stations [Dmitrieva 2019]. Airplanes equipped with sensors provide the information on the state of the atmosphere at different altitudes and in different territories. However, due to the coronavirus pandemic, air communication with a number of countries has been limited since February 2020. According to TASS, 700 flights a week have been cancelled. Thus, during the pandemic, only 10% of flights remained in Russia. It is quite obvious that such a situation led to a decrease in the quality of data reflecting the meteorological parameters of the atmosphere, which, in turn, affected the information on the state of the atmospheric air, because, as mentioned above, the content of pollutants in the air is inextricably linked with the meteorological parameters of the atmosphere.

MATERIAL AND METHODS

The following equipment provided by the mobile environmental monitoring laboratory was used to take the samples and carry out the measurements in order to establish the quality of atmospheric air:

1. PU-3E aspirator

A PU-3E aspirator [Aspirator PU-ZE] was used to determine the concentration of dust in the surface layer of the atmosphere by using the

gravimetric method. This tool is also designed to provide air sampling for determination of the aerosol content.

Upon completion of air pumping, the filter was removed from the conical funnel and packed in a case. In the laboratory, the filter was weighed, after which the mass of the settled dust was determined.

2. ECOLAB portable gas analyzer [Gas analyzer EKOLAB]

It was used to determine the content of such pollutants in the air as carbon oxide (CO) and nitrogen dioxide (NO₂).

The principle of operation consists in aspiration of air for a specified time using fans through installed sensors, which are selected individually depending on the purpose of the study. In order to determine the concentrations of carbon oxide and nitrogen dioxide, electrochemical sensors were used [Principles of operation of sensors in a gas analyzer]: these sensors operate on the basis of the electrolysis process. The sensor consists of three electrodes (working, reference and integrating) which are placed in a plastic case with electrolyte.

3. DUSTTRAK 8533 dust analyzer

When studying the state of atmospheric air, a DUSTTRAK 8533 dust analyzer was also used. It is designed to measure the mass concentration of aerosol particles of various origins in the atmospheric air and the air of the working area.

All measurements were carried out within 5 minutes, with the device fixed at a height of 1.5–2 meters, and the analyzer directed to the windward side for the most accurate analysis.

4. Gas chromatograph

A portable gas chromatograph FGKh-1 was used to determine the content of VOCs in the atmospheric air. It is a device for analyzing complex gaseous substances by differentiating them into monocomponents.

Differentiation occurs according to the general principles of chromatography: the elements of the mixture supplied for analysis are distributed between two phases: mobile (eluent) and stationary (sorber). A moving medium in a gas chromatograph is represented by nitrogen that serves as a carrier gas.

5. Professional weather station

In addition to air sampling, the meteorological parameters were measured with the help of a DAVIS VANTAGE PRO2 PLUS 6163EU professional weather station.

RESULTS

The first field where we conducted our research was the Novosmolenskaya embankment. The studied territory is located along the road, which is the main source of pollution of the surface layer of the atmosphere with such substances as: benzo(a)pyrene; gasoline vapors, diesel fuel and its components: benzene, xylene, ethylbenzene, saturated hydrocarbons, hydrogen sulfide, carbon monoxide, nitrogen dioxides. River transport can also be identified as a potential source of pollution. The atmosphere is polluted mainly by exhaust gases from the power unit of ships.

The quality of atmospheric air in the studied territory was measured using devices operating in accordance with aspiration methods: passing a known volume of air through an absorbing medium [Ottosen et al. 2016].

The location of the test sites for the measurements was predetermined and was made as points located in a straight line at a distance of 50 meters from each other.

1. The dust concentration in the air was determined using a PU-3E aspirator with the gravimetric method by pumping a given volume of air for 20 minutes with a fixed position of the filter.

As a result of measurements, an increase in the filter mass by 0.0008 g was observed. In accordance with the data obtained, the content of dust particles in the surface layer of the atmosphere was calculated:

With an average flow rate of 12.5 l/min, a set measurement time of 20 minutes and a dust mass of 0.0008 g, the dust concentration was calculated and amounted to 3.2 mg/m³, which exceeds LMC_{m.s.} (0.15 mg/m³). Such indicators can be associated with the sandy road surface in the alley along the embankment, as well as the proximity of the road.

2. The content of carbon oxide and nitrogen dioxide in the air was determined using a portable gas analyzer EKOLAB. The content of various fractions of dust ($PM_{10} - PM_{10}$) was determined using a DUSTTRAK 8533 dust analyzer. The measurements were carried out for 5 minutes at the established sampling points, followed by recording the measurement results. The measurements revealed the exceedance of LMC_{m.s.} in terms of NO₂ (0.2 mg/m³) at 9 sampling points.

On the basis of the pollution content data obtained, maps of the concentrations of nitrogen dioxide (Fig. 2), carbon oxide (Fig. 3), the total dust content (Fig. 4) in the studied area were constructed, and the atmospheric pollution index (API) was calculated (Fig. 5), which included the concentrations of the above-mentioned chemical compounds and the concentration of dust.

Novosmolenskaya Embankment has three areas with elevated concentrations of nitrogen dioxide, which are clearly visible on the map. The most polluted is the right bank of the Smolenka River, where the exceedance of

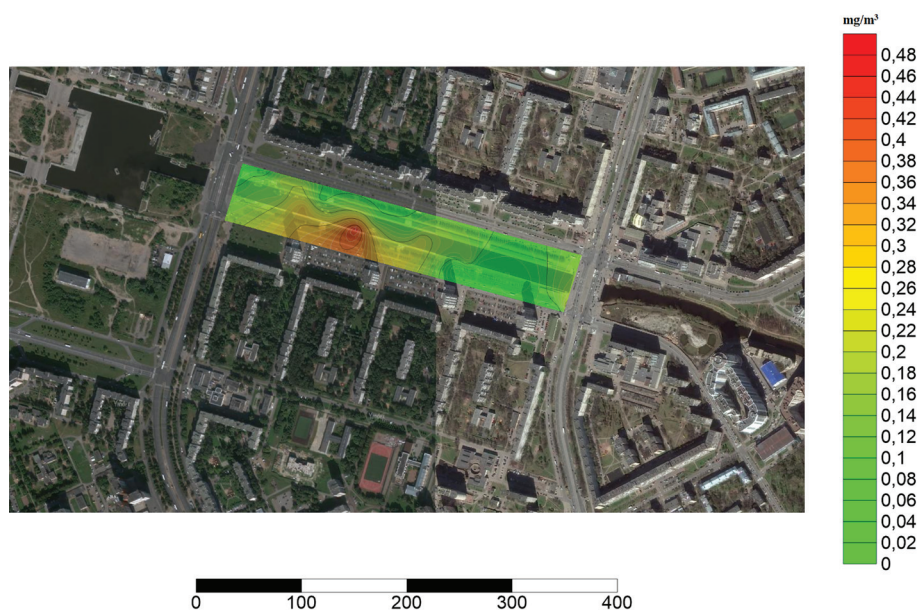


Figure 2. NO₂ concentration at Novosmolenskaya Embankment

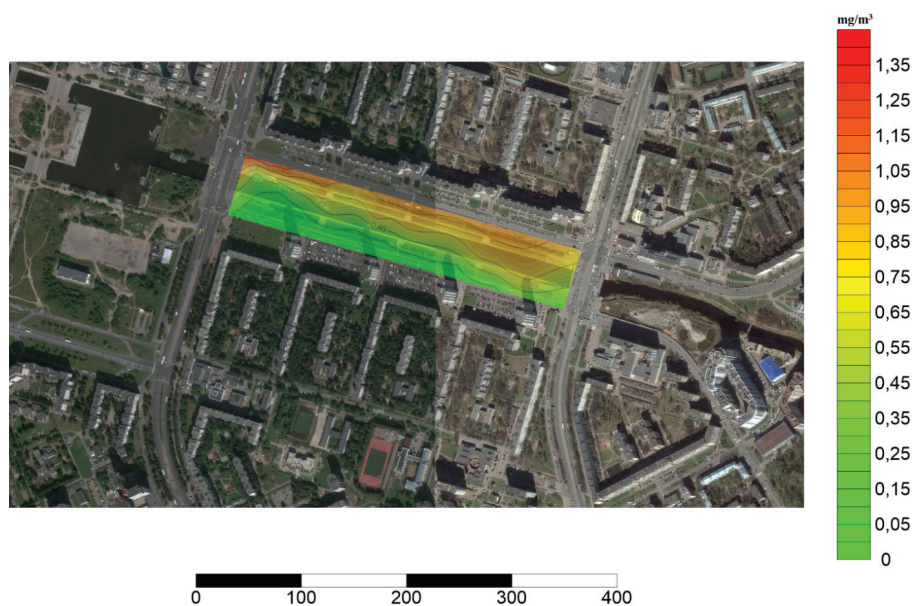


Figure 3. CO concentration at Novosmolenskaya Embankment

$LMC_{m.s.}$ (0.2 mg/m^3) was recorded at 5 consecutive observation points; there, the concentrations of the pollutant amounting from 0.211 mg/m^3 to 0.472 mg/m^3 were observed. On the left bank of the river, the exceedance of $LMC_{m.s.}$ was recorded at 3 air sampling points. Hotbeds of elevated NO_2 concentrations were identified in the area of public transport stops, which is one of the main sources of anthropogenic air pollution with nitrogen compounds.

On the basis of the map analysis, we can conclude that the CO concentration increases from the right bank to the left. The maximum

concentrations (1.415 mg/m^3) are geographically confined to the intersection of two streets with more active traffic. The carbon oxide concentrations also increase smoothly to the southeast of the studied area, which may be a consequence of the denser development of the area with residential buildings and the presence of a metro station. However, the measurements did not reveal any exceedance of $LMC_{m.s.}$ (5.0 mg/m^3).

On the basis of the measurements of the dust concentration in the surface layer of the atmosphere, carried out using a DUSTTRAK 8533 gas analyzer, a map was built in relation to the

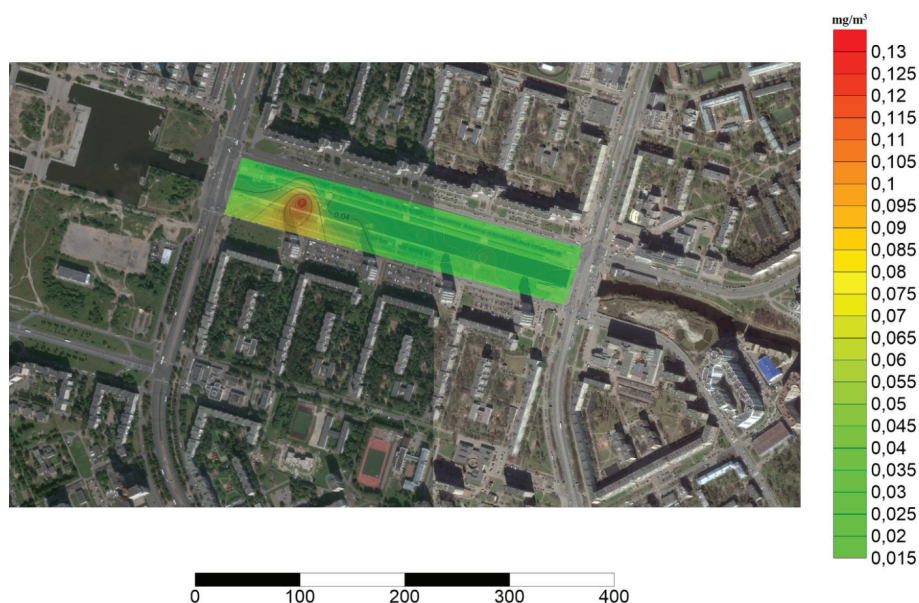


Figure 4. Total concentration of dust at Novosmolenskaya Embankment

Table 1. Air pollution degree evaluation

Level	Air pollution degree	API value
I	Low	from 0 to 4
II	Elevated	from 5 to 6
III	High	from 7 to 13
IV	Very high	≥ 14

total concentration of various dust fractions ($PM_1 - PM_{10}$) in the studied territory. Despite the nature of the underlying surface of the sample areas (sandy paths), no exceedance of $LMC_{m.s.}$ (0.15 mg/m^3) was recorded. However, the right bank of the Smolenka River can be identified as the most dusty area (0.128 mg/m^3), which may be associated with meteorological conditions in the process of air sampling (increased wind, etc.).

Integrated Air Pollution Index (API) takes into account the contribution of individual impurities to the total level of pollution. According to the API values, it is customary to distinguish between the degrees of air pollution (Table 1):

The Air Pollution Index was calculated based on the data obtained on the concentrations of the main pollutants studied at Novosmolenskaya Embankment (see Table 2).

On the basis of the data presented in the Table, it can be concluded that there is a relatively low level of air pollution on the left bank of the Smolenka River and an elevated level of pollution with test substances on the right bank of the river. Nitrogen dioxide is the main pollutant, the concentration of which exceeded the maximum

permissible values. This is especially relevant for the Vasileostrovsky District where air polluting industrial enterprises operate. On average, on the island, the concentration of nitric acid in the air is exceeded by almost 2–3 times.

The second field was the territory of the Volkovka River which is located near a road and characterized by inactive traffic. Along the road there are car service centers and metal sales enterprises (with operating construction equipment), which can be potential sources of air pollution with gasoline vapors, diesel fuel and their combustion products.

VOCs were measured in the studied territory using a portable gas chromatograph. For further analysis, the samples were taken in a special container (without concentration), namely a polymer bag. This sampling method was chosen due to the simplicity and rapidity of the method, as well as taking into account the direction of study, as the presence of high concentrations of organic and inorganic gases was expected at the sampling points. After filling the plastic bag with the required volume of air, the sample was analyzed with a portable gas chromatograph for 20 minutes to achieve the most accurate VOC readings.

As a result of the measurements, 4 chromatograms (Fig. 6–9) of the VOC content in the atmospheric air were obtained; vehicle/generator exhaust gas and gasoline vapors.

On the basis of the constructed chromatogram, it can be concluded that there are no volatile organic compounds in the atmospheric air at

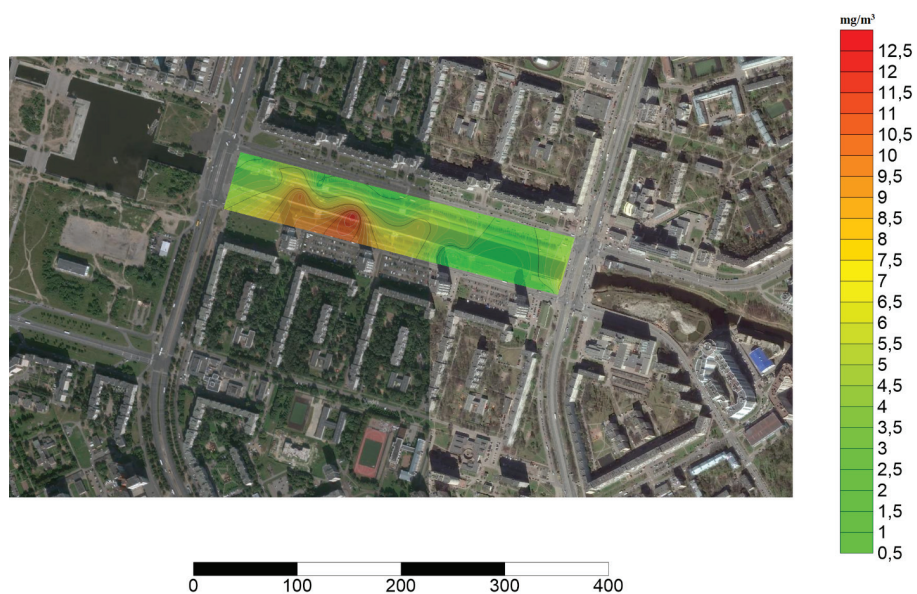


Figure 5. Air Pollution Index

Table 2. Air Pollution Index

Sampling point No.	API value	Pollution level
Left bank of the Smolenka River		
1	2.76092	Low
2	5.57185	Elevated
3	6.14048	Elevated
4	2.51067	Low
5	4.00635	Low
6	4.75625	Low
7	4.04970	Low
8	4.08503	Low
9	3.64942	Low
10	6.64342	Elevated
11	4.55603	Low
12	4.58992	Low
13	2.24155	Low
14	1.58135	Low
15	1.96835	Low
Right bank of the Smolenka River		
1	2.65418	Low
2	3.83153	Low
3	4.41113	Low
4	9.85577	High
5	6.06245	Elevated
6	12.7371	High
7	6.54357	Elevated
8	6.65772	Elevated
9	0.72808	Low
10	2.26800	Low
11	2.80330	Low
12	1.87395	Low
13	6.06810	Elevated

the sampling point (the sampling point was located far from the road): after passing the “dead” time, the chromatograph did not isolate a single organic chemical compound for 20 minutes.

Due to the fact that no permissible concentrations were presented for most substances determined during the chromatographic analysis, the VOC concentrations in a sample taken at a

considerable distance from the road (as the main source of pollution) were taken as conditionally background concentrations equal to zero.

The results of the study of the qualitative and quantitative composition of gasoline vapors demonstrate the presence of all the main components of gasoline in the sample, thereby giving the most complete picture of its composition.

As a result of the analysis of the data obtained, we compiled a table of the VOCs exceedance, which included 10 substances, with the highest frequency of exceedance (relative to the LMC or background, conditionally zero, concentrations) (Table 3).

Thus, the studies of the VOC content in the atmospheric air using a portable gas chromatograph have detected the component composition of the toxic vapors of the fuel and its combustion products. The highest concentrations of hazardous substances were detected in the immediate vicinity of the pollution sources; however, when moving away from the sources, the VOC concentrations decreased due to the lack of active traffic. For this reason, it can be concluded that it is necessary to conduct systemic monitoring of the content of VOCs in the atmospheric air due to their danger to the human health.

DISCUSSION

The following areas of possible use and practical application of the results of a scientific project have been identified:

1. The data obtained as part of the study should be used to keep records of the existing facilities and sources of negative impact on the atmospheric air in accordance with the requirements of the current legislation, as well as to inventory territories with unfavourable environmental conditions in Saint Petersburg.

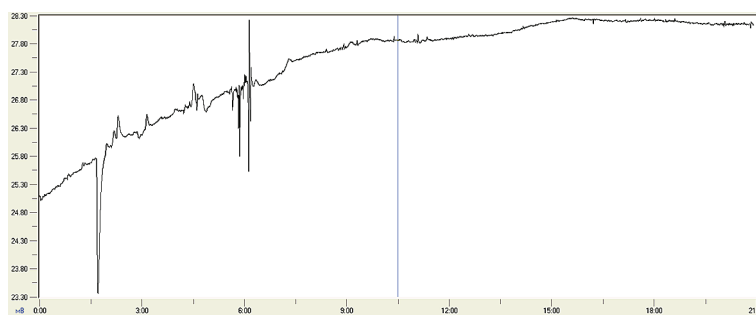


Figure 6. Chromatogram No. 1 “VOC content in the air”

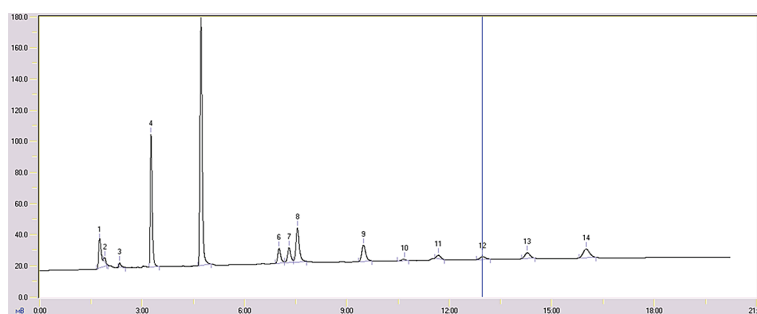


Figure 7. Chromatogram No. 2 “VOC content in the samples taken near the road”

As a result of the analysis of an air sample taken near the road, 11 organic chemical compounds were found, most of which were components of gasoline.

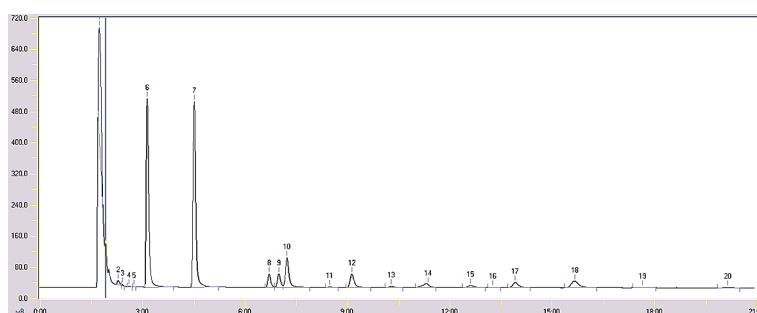


Figure 8. Chromatogram No. 3 “VOC content in the air of an operating generator”

As a result of the analysis of an air sample taken near the operating generator set of the industrial premises, 17 organic chemical compounds were found, including the components of gasoline, as well as the products of its combustion.

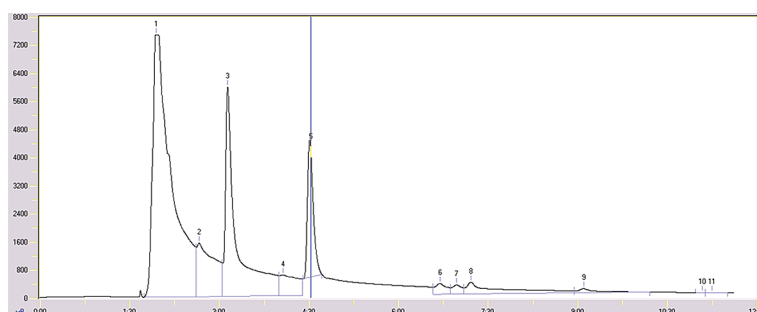


Figure 9. Chromatogram No. 4 “VOC content in gasoline vapors”

2. The results of the study make it possible to form an idea of the state of atmospheric air on the territory of certain districts of Saint Petersburg, which, in turn, will provide a more effective solution to the problems in the development of environmental protection measures, urban planning and planning for the development of transport systems.
3. The data obtained in the course of the study can be used to assess the effectiveness of environmental protection measures in certain districts of Saint Petersburg, as well as to substantiate the clinical studies of the impact of air pollution on the human health.

The results obtained while studying have significance for Saint Petersburg. Taking into account the territorial features of the administrative districts of the city and their significant areas, the studied districts do not have enough stations of automatic monitoring of the state of atmospheric air to obtain the data that fully reflect air pollution (see Fig. 1).

The results obtained in the course of the independent study make it possible to substantiate the need to expand the network of monitoring stations in order to form the most complete and objective “picture” of the degree of anthropogenic impact on the urban airshed. In turn, the formed

Table 3. Excessive VOC content in the air

Substance	Exceedance frequency	Substance	Exceedance frequency
Acetic aldehyde*	1,770,000 (LMC)	Isobutanol	17.3 (background)
Ethyl acetate*	20,600 (LMC)	Carbon sulphur	6.6 (LMC)
Benzene*	56–4,233 (LMC)	Methyl acetate	6 (LMC)
Ethyl benzene*	89–2,525 (LMC)	Ethyl glycol	4–8 (background)
Toluene	31 (background)	Methanol	3 (background)

* Value obtained by measuring a sample taken in gasoline vapors.

database will serve as the basis for the timely response of the legislative, executive and regulatory authorities. This will make it possible to more effectively implement environmental programs in Saint Petersburg.

Due to the peculiarities of this study, characterized by a selective coverage of the territory, the topic of systematic environmental monitoring needs further development in order to increase the area of the studied territories, conduct a comparative, retrospective analysis and subsequent objective substantiation of the economic, practical and scientific feasibility of expanding the network of automated monitoring stations.

According to the implemented environmental policy of Saint Petersburg until 2030 [Telichenko et al. 2016], in order to ensure the possibility of obtaining complete and reliable information on the state of atmospheric air on the territory of Saint Petersburg, we propose a list of recommended measures:

1. Taking into account the existing rating of the ecological situation of the city districts, draw up a schedule of screening monitoring of the existing sources of negative impact on the atmospheric air by means of using the mobile hardware complex of control means (the schedule should take into account the formed landscape of the building and the meteorological parameters of the atmosphere).
2. Ensure a sufficient density of monitoring stations in the districts of Saint Petersburg to obtain an objective situation of air pollution.
3. Taking into account the recommendations of the World Health Organization, prescribing the control of the content of 21 pollutants in the air, expand the list of the measured pollutants recorded at automatic monitoring stations (from 6 to the recommended number).

4. Provide an informational Internet resource accessible to the population of Saint Petersburg (under the control of a single operational centre, which ensures the timely and complete solution of monitoring tasks), containing the data from monitoring studies, in order to carry out environmental education, inform the population about the environmental situation in the districts, thereby contributing to the formation of the environmental awareness of citizens and ensuring an integrated approach (both from the outside administration of the city, and on the part of the population) in ensuring environmental protection and ecological safety.

CONCLUSIONS

The measurements detected the exceedance of $LMC_{m.s.}$ of the content of nitrogen dioxide in the territory of Novosmolenskaya Embankment (the concentration of the pollutant varied from 0.211 mg/m^3 to 0.472 mg/m^3), which may be a consequence of active traffic. No exceedance of $LMC_{m.s.}$ of the content of nitric oxide at Smolenka River Embankment was detected, as well no exceedance of $LMC_{m.s.}$, despite the nature of the underlying surface of the sample areas (sandy paths) was detected.

As a result of the measurements carried out using a gas chromatograph, in the samples taken, the content of hydrocarbons of a number of alkanes, salts and esters of acetic acid, aromatic hydrocarbons, etc., which are extremely toxic to living organisms, was detected. The maximum permissible concentration was exceeded by several orders of magnitude.

On the basis of the empirical data, we built maps of the content of pollutants in the air and calculated the Atmospheric Pollution Index in the territory of Novosmolenskaya Embankment, which made it possible not only to visualize the distribution of concentrations of pollutants, but also to draw the decisions about the main sources of pollution.

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REFERENCES

1. Aspirator PU-ZE. Instruments and equipment for ecology, medicine, gas stations and oil depots URL: <https://www.ximko.ru/catalog/aspirators/PU-3T/>
2. Bepalov V.I., Gurova O.S., Samarskaya N.S. 2016. Main Principles of the Atmospheric Air Ecological Monitoring Organization for Urban Environment Mobile Pollution Sources. *Procedia Engineering*, 150, 2019–2024. DOI: 10.1016/j.proeng.2016.07.286
3. Blinov L.N., Perfilova I.L., Yumasheva L.V., Sokolova T.V. 2013. Ecological problems of megacities. Health is the basis of human potential: problems and solutions, 2(8), 837–845.
4. Chen D., Liu X., Lang J., Zhou Y., Wei L., Wang X., Guo X. 2017. Estimating the contribution of regional transport to PM_{2.5} air pollution in a rural area on the North China Plain. *Science of the Total Environment*, 583, 280–291. DOI: 10.1016/j.scitotenv.2017.01.066
5. Danilov A.S., Smirnov Y.D., Pashkevich M.A. 2015. Use of biological adhesive for effective dust suppression in mining operations. *Journal of Ecological Engineering*, 16(5), 9–14. DOI: 10.12911/22998993/60448
6. Dmitrieva T.V. 2019. Weather forecasts in aviation and the use of modern methods of transmission of weather forecasts in airports and airfields. METAR, Internet and other types of weather forecast transmission methods. *Vector of Geosciences*, 2(1), P. 47–53. DOI: 10.24411/2619–0761–2019–10007
7. Elansky N.F., Shilkin A.V., Ponomarev N.A., Semutnikova E.G., Zakharova P.V. 2020. Weekly patterns and weekend effects of air pollution in the Moscow megacity. *Atmospheric Environment*, 224, 117303. DOI: 10.1016/j.atmosenv.2020.117303
8. Fann N., Fulcher C.M., Baker K. 2013. The recent and future health burden of air pollution apportioned across U.S. sectors. *Environmental Science & Technology*, 47(8), 3580–3589. DOI: 10.1021/es304831q
9. Gas analyzer EKOLAB. EKOBIOCHIM URL: <http://ekolab.su/index.php/katalog-priborov/gazoanalizatory/gazoanalizator-ekolab-detail#tehnicheskieskharakteristiki>
10. Goman I.V. 2019a. Development of the dialogue skills in a foreign language in comparing of oil benchmarks. *Journal of Physics: Conference Series*, 1384(1). DOI:10.1088/1742–6596/1384/1/012013
11. Goman I.V., Varlakova E.A. 2019b. Teaching communication skills in a foreign language to students of oil and gas specialisation. *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management*, 19(5.4), 295–300. DOI:10.5593/sgem2019/5.4/S22.040
12. Guo H., Kota S.H., Sahu S.K., Zhang H. 2019. Contributions of local and regional sources to PM_{2.5} and its health effects in north India. *Atmospheric Environment*, 214, 116867. DOI: 10.1016/j.atmosenv.2019.116867
13. Ignatyev A.V. 2020. Methodology for comprehensive assessment of atmospheric air state in populated areas. *Materials Science and Engineering*, 962(4). DOI:10.1088/1757–899X/962/4/042048
14. Ivanov A.V., Platov A.Y., Stepanov D.V., Ostanina I.M. 2018b. Online monitoring of urban environment. *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management*, 18(2.2), 339–346. DOI: 10.5593/sgem2018/2.2/S08.043
15. Ivanov A.V., Strizhenok A.V. 2018a. Monitoring and reducing the negative impact of halite dumps on the environment. *Pollution Research*, 37(1), 51–55.
16. Jiang Y., Xing J., Wang S., Chang X., Liu S., Shi A., Sahu S.K. 2021. Understand the local and regional contributions on air pollution from the view of human health impacts. *Frontiers of Environmental Science and Engineering*, 15(5). DOI:10.1007/s11783–020–1382–2
17. Kokoulina A., May I. 2018. Health risk assessment in development the air quality monitoring programs for the areas affected by production, preparation and primary oil refining. *International Multidisciplinary Scientific GeoConference Surveying Geology and Mining Ecology Management*, 18(4.2), 467–474. DOI: 10.5593/sgem2018/4.2/S19.061
18. Kuzhaeva A.A., Dzhevaga N.V., Berlinskii I.V. 2019. The processes of hydrocarbon conversion using catalytic systems. *Journal of Physics: Conference Series*, 1399(2). DOI:10.1088/1742–6596/1399/2/022057
19. Li C.Z., Zhao Y., Xu X. 2019. Investigation of dust exposure and control practices in the construction industry: Implications for cleaner production. *Journal of Cleaner Production*, 227, 810–824. DOI: 10.1016/j.jclepro.2019.04.174
20. Lobacheva O.L., Dzhevaga N.V., Danilov A.S. 2016. The method of removal yttrium (III) and ytterbium (III) from dilute aqueous solutions. *Journal of Ecological Engineering*, 17(2), 38–42. DOI:10.12911/22998993/62284
21. Manzhilevskaya S., Petrenko L., Azarov V. 2021. Monitoring methods for fine dust pollution during construction operations. *International Scientific Conference Energy Management of Municipal Facilities and Sustainable Energy Technologies. Advances in Intelligent Systems and Computing*, 1259. DOI:10.1007/978–3–030–57453–6_29
22. Monforte P., Ragusa M.A. 2018. Evaluation of the air pollution in a Mediterranean region by the air quality index. *Environmental Monitoring*

- and Assessment, 190(11), 625. DOI: 10.1007/s10661-018-7006-7
23. Ottosen T.B, Ketzler M., Skov H., Hertel O., Brandt J., Kakosimos K.E. 2016. A parameter estimation and identifiability analysis methodology applied to a street canyon air pollution model. *Environmental Modelling & Software*, 84 165–176, DOI: 10.1016/j.envsoft.2016.06.022
 24. Padoan S., Zappi A., Adam T., Melucci D., Gambaro A., Formenton G., Popovicheva O., Nguyen D.L., Schnelle-Kreis J., Zimmermann R. 2020. Organic molecular markers and source contributions in a polluted municipality of north-east Italy: Extended PCA-PMF statistical approach. *Environmental Research*, 186, 109587. DOI: 10.1016/j.envres.2020.109587
 25. Pashkevich M.A., Petrova T.A. 2017. Assessment of Widespread air Pollution in the Megacity Using Geographic Information Systems. *Zapiski Gornogo instituta*, 228, 738–742. DOI:10.25515/PMI.2017.6.738
 26. Principles of operation of sensors in a gas analyzer. REIKEN KEIKI URL: <http://rikenkeiki.ru/for-clients/useful/printsip-raboty-datchikov-v-gazoanalizatore/>
 27. Sergina N.M., Solomakhina L.Ya., Lazurenko K.I., Solomakhin M.S. 2019. On air pollution in St. Petersburg with suspended substances. *Engineering Bulletin of the Don*, 1(52). 157.
 28. Shvartsburg L.E., Butrimova E.V., Yagolnitser O.V. 2017. Energy Efficiency and Ecological Safety of Shaping Technological Processes. *Procedia Engineering*, 206, 1009–1014. DOI: 10.1016/j.proeng.2017.10.586
 29. Sidorenko V.F., Ignatyev A.V., Abroskin A.A. 2020. Application of results of atmospheric air monitoring for safe location of construction sites. *Innovacii i Investicii*, 3, 273–276.
 30. Solomakhina L.Ya., Lazurenko K.I., Solomakhin M.S. 2018. Climatic features of St. Petersburg in assessing the content of suspended solids in atmospheric air. *Engineering Bulletin of the Don*, 4(51). 257.
 31. Strizhenok A.V., Ivanov A.V. 2016. An advanced technology for stabilizing dust producing surfaces of built-up technogenic massifs during their operation. *Power Technology and Engineering*, 50(3), 240–243. DOI:10.1007/s10749-016-0690-y
 32. Telichenko V.I., Slesarev M.U., Kuzovkina T.V. 2016. The Analysis of Methodology of the Assessment and Expected Indicators of Ecological Safety of Atmospheric air in the Russian Federation for 2010–2020. *Years Procedia Engineering*, 153, 736–740. DOI: 10.1016/j.proeng.2016.08.235
 33. Tikhonova I.V., Zemlyanova M.A. 2019. Social-hygienic monitoring system updating based on health risk analysis (at the municipal level). *Health Risk Analysis*, 4, 60–69. DOI: 10.21668/HEALTH.RISK/2019.4.06.ENG
 34. Volkodaeva M.V., Kiselev A.V. 2017. On development of System for Environmental Monitoring of Atmospheric Air Quality. *Zapiski Gornogo instituta*. 227, 589–596. DOI: 10.25515/PMI.2017.5.589
 35. Yakubailik O.E., Kadochnikov A.A., Tokarev A.V. 2018. WEB Geographic Information System and the Hardware and Software Ensuring Rapid Assessment of Air Pollution. *Optoelectronics, Instrumentation and Data Processing*, 54(3), 243–249. DOI: 10.3103/S8756699018030056
 36. Zuo J., Rameezdeen R., Hagger M., Zhou Z., Ding Z. 2017. Dust pollution control on construction sites: Awareness and self-responsibility of managers. *Journal of Cleaner Production*, 166, 312–320. DOI: 10.1016/j.jclepro.2017.08.027