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The Association of High COVID-19 Cases and Mortality with Anomalous High Surface Ozone Concentration in Moscow City in Summer 2021

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Aim: to compare statistical data on the frequency of COVID-19 and deaths from it with the ozone content in the surface atmosphere of Moscow in the summer of 2021.
Materials and methods. We used data on the frequency of daily COVID-19 cases and mortality from COVID-19 in Moscow in 2020–2021 published by Rospotrebnadzor. Data on the ozone content in the surface layer of the atmosphere were obtained by an automatic monitoring station using a chemiluminescent analyzer.
Results. The waves of high frequency of COVID-19 cases and mortality from COVID-19 in Moscow in the summer of 2021 were compared with abnormally high concentrations of ozone in the surface atmosphere of the megalopolis. Variations of these parameters were found to be markedly correlated. The coefficients of correlation of the COVID-19 cases and mortality with the concentration of ground-level ozone were 0.59 ($p < 0.01$) and 0.60 ($p < 0.01$), respectively.
Conclusion. The observed noticeable relationship may be due to the combined pathological effect of high concentrations of ozone and the SARS-CoV-2 on the respiratory and circulatory organs, which can lead to both easier transmission of infection and a more severe course of the disease with increased mortality.
Keywords: surface ozone, pandemic COVID-19, SARS-CoV-2, mortality
Conflict of interest: the authors declare no conflict of interest.

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Корреляция частоты заражений и смертности от COVID-19 с аномально высоким содержанием озона в приземной атмосфере Москвы летом 2021 года

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Цель: провести сопоставление статистических данных о частоте заражений и смертности от COVID-19 с содержанием озона в приземной атмосфере Москвы летом 2021 года.
Материалы и методы. Использованы официальные данные по частоте ежедневной заражаемости и смертности от COVID-19 в Москве в 2020–2021 годах, публикуемые Роспотребнадзором. Данные по содержанию озона в приземном слое атмосферы получены автоматической станцией мониторинга с помощью хемолюминесцентного анализатора.
Результаты. Проведено сопоставление волн высокой частоты заражений SARS-CoV-2 и смертности от COVID-19 в Москве летом 2021 года с аномально высокими концентрациями озона в приземной атмосфере мегаполиса. Вариации этих параметров оказались заметно коррелированными. Коэффициенты корреляции частоты заражений и смертности с концентрацией приземного озона составили 0,59 ($p < 0,01$) и 0,60 ($p < 0,01$) соответственно. Выводы: наблюдаемая взаимосвязь может быть обусловлена сочетанным патологическим действием высоких концентраций озона и вируса SARS-CoV-2 на органы дыхания и кровообращения, что может приводить как к более легкой передаче инфекции (заражаемости), так и к более тяжелому течению заболевания и повышению смертности.

Ключевые слова: приземный озон, пандемия COVID-19, SARS-CoV-2, частота заражений, смертность
Конфликт интересов: авторы заявляют об отсутствии конфликта интересов.

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Introduction

The problem of atmospheric air quality influence on the development of the COVID-19 pandemic, virus transmission, rate of coronavirus cases, severity of the disease, and risk of death has received a lot of attention in recent scientific publications [1–7]. A number of special studies have been carried out in this area. Nitrogen oxides NO_2, NO, ozone O_3, CO, aerosols and dust particles of various sizes PM2.5 and PM10 [1, 3, 6] are considered as the main factors polluting the atmospheric air, which could affect the spread of infection as well as the severity of the COVID-19 disease. They are considered the most harmful and dangerous to humans and appear in the urban air mainly as a result of the operation of automobile transport. The results of these studies did not give an unambiguous answer to the question of possible dangerous relationships between the purity of the surrounding air and the COVID-19 cases [5], since the phenomena under consideration depend on many versatile and difficult to take into account factors (global, local, personal, external and internal). Therefore, this problem requires further study.

With this report, we want to once again draw attention to the possible impact of high concentrations of ozone in the surface atmosphere of a metropolis on the spread of SARS-CoV-2 infection, infection rates and mortality associated with COVID-19. It is known that ozone is a strong oxidizing agent and its high concentrations in the inhaled air increase the risk of diseases of the respiratory, cardiovascular and nervous systems [8, 9]. A strong relationship has been established between cases of pneumonia and overall mortality with the level of ozone in the environment [10–17]. At the very beginning of the pandemic, when all the features of the pathological effect of the SARS-CoV-2 virus on the body were not yet known exactly, we suggested that a combined pathological effect of the virus and high concentrations of ozone in the inhaled air is possible [18]. This hypothesis was based on the most general considerations taking into account the fact that both SARS-CoV-2 and ozone similarly adversely affect the respiratory system, blood vessels and the blood system. This article has listed the main pathogenetic properties of ozone. Moreover, an increase in the frequency of severe pneumonia and mortality caused by SARS-CoV-2 in Moscow in the summer period was predicted in case of a significant rise of ambient temperature and solar activity as these factors causes an increase in the ozone content in the surface atmosphere.

Obviously, the laboratory study of a combined effect of the SARS-CoV-2 and ozone molecules on a subject is not possible for ethical reasons. However, it is possible to compare statistical data on the frequency of SARS-CoV-2 cases and deaths from COVID-19, accumulated over the years of the pandemic, with data of air quality monitoring. We used this approach to study the problem for Moscow case.

The purpose of the study: to compare statistical data on the frequency of COVID-19 and deaths from it with the ozone content in the surface atmosphere of Moscow in the summer of 2021.

Materials and methods

For the analysis, we used data on the frequency of daily COVID-19 cases and mortality from COVID-19 in Moscow in 2020–2021 published by Rospotrebnadzor [19]. Data on the ozone content in the surface layer of the atmosphere of Moscow were obtained in our laboratory for monitoring the quality of the atmosphere at the Peoples' Friendship University of Russia [20, 21]. The monitoring station is located in the center of Moscow, within the third transport ring, at Ordzhonikidze str., 3. The measurement of ozone concentration in the surface atmosphere was carried out at the station using a commercially available 3.02П-А chemiluminescent analyzer manufactured by the instrument-making company OPTEK LLC, St. Petersburg, Russia. The sensitivity of the analysis is 1 mg/m^3, the frequency of data output is 1 time per minute. This analyzer is certified in the Russian Federation as a measuring instrument.

The time series of daily cases on infection and mortality as well as the data on ozone concentration used for the comparison were not subjected to any preliminary statistical processing. Daily data on infection and mortality are compared with the maximum daily surface concentrations of ozone. The correlation coefficient between data series is calculated using standard methods.

Results and discussion

The results of comparing the frequency of daily COVID-19 cases and mortality from it with the ozone content in the surface atmosphere of Moscow in the summer of 2021 are shown in Figures 1 and 2.

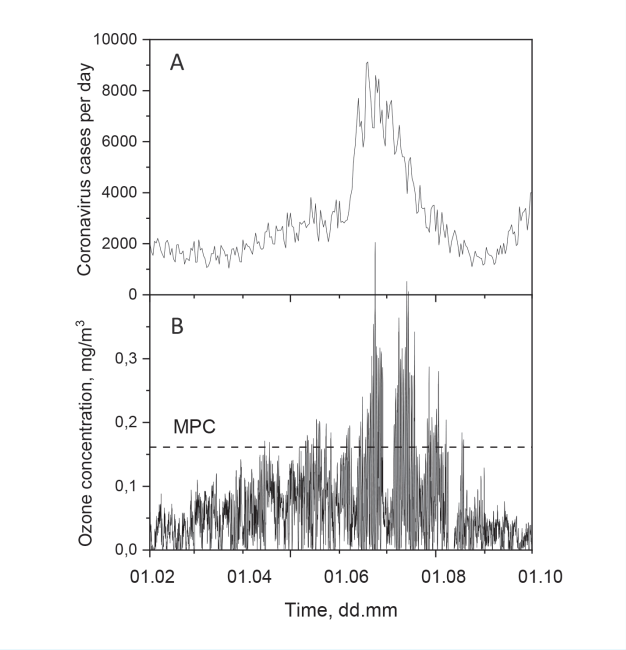

Fig. 1. A — the frequency of daily COVID-19 cases in Moscow in the summer of 2021 according to Rospotrebnadzor [19]; B — current surface ozone concentration in the central district of Moscow, Ordzhonikidze str., 3

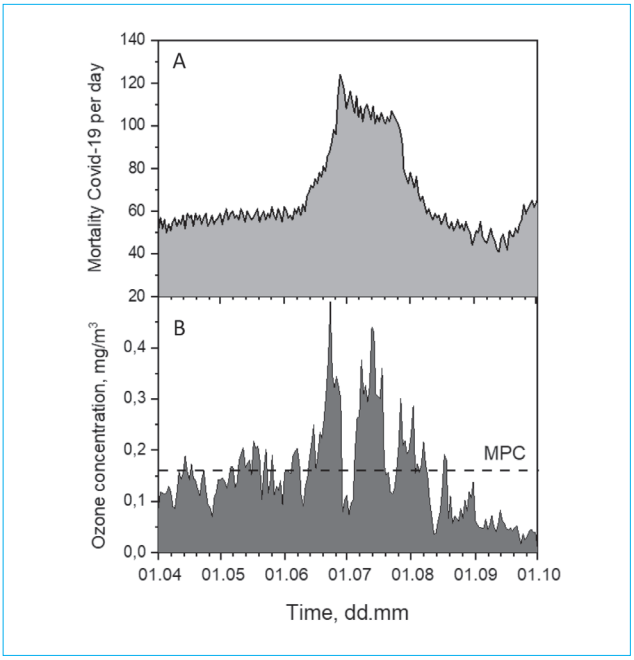

Fig. 2. A — mortality associated with SARS-CoV-2 infection in Moscow in the summer of 2021 according to Rospotrebnadzor data [19]; B — maximum daily surface ozone concentration in the central district of Moscow, Ordzhonikidze str., 3

Figure 1 compares the frequency of daily SARS-CoV-2 cases and the current ozone content in the surface layer of the atmosphere in Moscow in the spring and summer of 2021, during the passage of the third wave of the pandemic caused by the delta strain of the virus. Note that the content of surface ozone in the summer of 2021 in Moscow was abnormally high. This was due to the peculiarities of the meteorological situation, which led to a warm, dry spring and a hot summer. These conditions were optimal for the formation of ozone in the surface atmosphere of the metropolis, polluted during the lockdown mainly by car emissions. There is a noticeable relationship between the frequency of daily COVID-19 cases and ozone concentration, the correlation coefficient was ~0.59 ($p < 0.01$). A possible causal relationship between the frequency of SARS-CoV-2 infections and the ozone content in the ambient air is not obvious due to the large number of factors that can influence the processes under study. The observation of the same positive relationship between these parameters was reported in [5]. At the same time, the authors of [5] initially assumed that the increased content of ozone in the air would, on the contrary, help to reduce the frequency of infections, since ozone has a detrimental effect on the viruses themselves.

Figure 2 compares mortality associated with SARS-CoV-2 infection and maximum daily surface ozone concentrations in the center of Moscow from April to September 2021. A sharp jump in mortality associated with COVID-19 is visible in the second half of June, which coincides in time with the passage of two heat waves through Moscow. At this time, the maximum daily temperatures reached 35 °C and the maximum daily ozone concentrations increased to 0,48 mg/m^3). It should be noted that before the passage of summer waves of especially high ozone concentrations, the ozone content in the Moscow air was also abnormally high. This could have an additional chronic effect on the health of the population, increasing oxidative stress, reducing the level of immune defense, and contributing to the development of systemic inflammation. A possible causal relationship between mortality from COVID-19 and the ozone content in the ambient air seems more obvious and can be attributed to the effect of the combined influence of the two factors acting on the body, which was discussed earlier [18].

Our study has several limitations. The official data on infection and mortality cases from COVID-19 in Moscow in 2020–2021 published by Rospotrebnadzor and used for comparison have a certain conventionality and reliability. The ozone content in the surface atmosphere of Moscow was estimated on the basis of local data obtained in one of the city areas. At the same time, it should be taken into account that the field of ozone distribution in the surface layer of the megalopolis atmosphere is non-uniform and the dose of the studied toxic effects on Moscow residents could depend on the area of their residence.

Conclusion

Thus, in the summer of 2021, during the COVID -19 pandemic in Moscow, a rare combination of the spread of a new wave of SARS-CoV-2 infection (the delta strain) and meteorological conditions conducive to the formation of abnormally high surface ozone concentrations was observed. In addition to the high frequency of Coronavirus cases at that time, Moscow also recorded the highest mortality due to this virus during the pandemic. Time variations of surface ozone concentrations, cases frequency and mortality from COVID-19 having wave-like pattern were found to be markedly correlated. The correlation coefficients of coronavirus case and mortality rates with surface ozone concentration were ~0.59 ($p < 0.01$) and ~0.60 ($p < 0.01$), respectively, while the correlation between case rates and mortality in this period was 0.72 ($p < 0.01$). The observed correlation may be due to the combined pathological effects on the respiratory and circulatory organs of high concentrations of ozone and SARS-CoV-2, which can lead to both easier transmission of the infection (and to a higher rate of cases) and a more severe course of the disease and increased mortality. Establishing the exact causal relationships of the observed effect requires a more special study including the analysis of multiparametric long-term statistical data.

References / Литература

1. *Gujral H., Sinha A.* Association between exposure to airborne pollutants and COVID-19 in Los Angeles, United States with ensemble-based dynamic emission model. *Environ Res.* 2021;194:110704. DOI: 10.1016/j.envres.2020.110704
2. *Han Y., Zhao W., Pereira P.* Global COVID-19 pandemic trends and their relationship with meteorological variables, air pollutants and socioeconomic aspects. *Environ Res.* 2022; 204:112249 DOI: 10.1016/j.envres.2021.112249
3. *Conticini E., Frediani B., Caro D.* Can atmospheric pollution be considered a co-factor in extremely high level of SARS-CoV-2 lethality in Northern Italy? *Environ Pollut.* 2020;261:114465. DOI: 10.1016/j.envpol.2020.114465
4. *Marquès M., Domingo J.L.* Positive association between outdoor air pollution and the incidence and severity of COVID-19. A review of the recent scientific evidences. *Environ Res.* 2022;203:111930. DOI: 10.1016/j.envres.2021.111930
5. *To T., Zhang K., Maguire B., Terebessy E., Fong I., Parikh S., et al.* UV, ozone, and COVID-19 transmission in Ontario, Canada using generalized linear models. *Environ Res.* 2021;194:110645.
6. *Gough W.A., Anderson V.* Changing Air Quality and the Ozone Weekend Effect during the COVID-19 Pandemic in Toronto, Ontario, Canada. *Climate.* 2022;10(3):41. DOI: 10.3390/cli10030041
7. *Kolluru S.S.R., Patra A.K., Nazneen S.M., Nagendra S.* Association of air pollution and meteorological variables with COVID-19 incidence: evidence from five megacities in India. *Environ Res.* 2021;195:110854. DOI: 10.1016/j.envres.2021.110854
8. *Amann M., Derwent D., Forsberg B., Hänninen O., Hurley F., Krzyzanowski M., et al.* Health risks of ozone from long-range transboundary air pollution. WHO. Regional Office for Europe. 2008. URL: www.euro. who.int/__data/assets/pdf_file/0005/78647/E91843.pdf
9. *Bates D.V.* Ambient ozone and mortality. Epidemiology. 2005;16:4:427–9. DOI: 10.1097/01.ede.0000165793.71278.ec
10. *Al-Hegelan M., Tighe R.M., Castillo C., Hollingsworth J.W.* Ambient ozone and pulmonary innate immunity. Immunol Res. 2011;49:173–91. DOI: 10.1007/s12026-010-8180-z
11. *Chuang G.C., Yang Z., Westbrook DG, Pompilius M, Ballinger CA, et al.* Pulmonary ozone exposure induces vascular dysfunction, mitochondrial damage, and atherogenesis. Am J Physiol Lung Cell Mol Physiol. 2009;297(2):209–16. DOI: 10.1152/ajplung.00102.2009
12. *Bell M., Dominici F.* Effect Modification by Community Characteristics on the Short-term Effects of Ozone Exposure and Mortality in 98 US Communities. *Amer J Epidemiol.* 2008;167(8):986–97. DOI: 10.1093/aje/kwm396
13. *Peng R.D., Samoli E., Pham L., Dominici F., Touloumi G., Ramsay T., et al.* Acute effects of ambient ozone on mortality in Europe and North America: results from the APHENA study. *Air Qual Atmos Health.* 2013;6:445–53. DOI: 10.1007/s11869-012-0180-9
14. *Hollingsworth J., Kleeberger S.R., Foster W.M.* Ozone and pulmonary innate immunity. *Proc Am Thorac Soc.* 2007;4:240–6. DOI: 10.1513/pats.200701-023AW
15. *Srebot V., Gianicolo E.A., Rainaldi G., Trivella M.G., Sicari R.* Ozone and cardiovascular injury Cardiovasc Ultrasound. 2009;7:30. DOI: 10.1186/1476-7120-7-30
16. *Kotelnikov S.N., Stepanov E.V., Ivashkin V.T.* Ozone Concentration in the Ground Atmosphere and Morbidity during Extreme Heat in the Summer of 2010. *Doklady Biological Sciences.* 2017;473:1–5. DOI: 10.1134/S001249661702010
17. *Kotelnikov S.N., Stepanov E.V., Ivashkin V.T.* Aboveground Ozone Concentration and the Health Status in Various Age Groups of Muscovites in Summer 2010. Izvestiya. *Atmospheric and Oceanic Physics.* 2019;55(11):1602–13. DOI: 10.1134/S0001433819110070
18. *Ivashkin V.T., Kotelnikov S.N., Stepanov E.V.* Possible increase in the severity of COVID-19 due to the combined action of the Sars-CoV2 virus and ozone with a seasonal increase in ozone content in the surface atmosphere, *Ecology and Life.* 2020 (In Russ.). URL: http://www.ecolife.ru/zhurnal/articles/51434/
19. URL: https://www.rospotrebnadzor.ru/region/korono_virus/epid.php
20. *Andreev V.V., Arshinov M.Yu., Belan B.D., Davydov D.K., Elansky N.F., Stepanov E.V., et al.* Surface Ozone Concentration over Russian Territory in the First Half of 2020. *Atmos Oceanic Opt.* 2020;33(6):671–81. DOI: 10.1134/S1024856020060184

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