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# Study of Tbilisi City Atmosphere Pollution with PM2.5 and PM10-Microparticles During COVID-19 Pandemic Period

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***ABSTRACT***

*Temporal and spatial variations of PM2.5 and PM10 concentrations in Tbilisi city atmosphere during pandemic period (2020-2021) are studied through analysis of routine observations, experimental measurement data, and numerical modeling. Maximum, minimum and average monthly values of concentrations are determined. It is shown that hourly variation of concentration is characterized with two maximums in the intervals between 9-10 and 18-21 hours and by one minimum from 0 to 6 h. It is established that measures related to "Lockdown" cause significant reduction of microaerosols concentration in urban air. It is shown that a change of their concentrations varies near the average values peculiar for automobile roads. Sharp increase of concentration values is observed at some road sections that is caused by local ecological conditions. Kinematics of PM2.5 and PM10 concentration changes induced by motor transport at Tbilisi city territory is explored using 3D model of admixture transfer-diffusion in the atmosphere. Diurnal pattern of dust spatial distribution is studied. Concentration values obtained via modeling are within the limits of values received through routine observations. It is established that a disposition of heavily polluted areas depends on motor transport traffic intensity, highways location, and local circulation systems formed by the dynamic influence of terrain and diurnal change of thermal regime at the underlying surface.*

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***Key words:*** *atmosphere, pollution, numerical modeling, concentration, PM*

## Introduction

PM2.5 and PM10 microparticles are the main ingredients of environment pollution with high risk factor for human health. Prolonged presense of dust and microparticles in the atmosphere causes not only significant deterioration of human health, but also millions of deaths. Atmospheric air pollution with PM2.5 and PM10 particles is especially dangerous under conditions of COVID-19 pandemic. Scientific investigations show that microaerosols as COVID-19 virus carriers with great permeability into human organism are very hazardous for public health [1-7].

Negative impact of PM2.5 and PM10 is particularly strong in large cities and industrial centers, where a potential of atmosphere pollution with aerosols is very high. Though, Tbilisi is not ranked among the 500 most contaminated cities of the world [8], but according to data of National Environmental Agency of Georgia [9] PM2.5 and PM10 concentrations in Tbilisi city atmosphere reach and in some cases even exceed the values of maximum permissible concentrations (MPC). Presumably, a high mortality level caused by viral diseases in 2020-2021 in Georgia is partly resulted from this circumstance. Therefore, the study of temporal variation and spatial distribution of PM2.5 and PM10 in Tbilisi city atmosphere is of great importance for elaboration of practical measures aimed to human health and environment protection.

## Research method

Some issues of temporal and spatial variation of dust propagation in Tbilisi city atmosphere are discussed in the works [10-13]. The impact of restrictions on the movement of road transport on air pollution in Tbilisi in the spring of 2020 due to the COVID-19 coronavirus pandemic is discussed in [14]. Due to small size and very low precipitation rate (<1 mm/sec) of PM2.5 and PM10, atmospheric distribution of microparticles under complex terrain conditions differs from dust propagation. The current work deals with the problems of atmospheric pollution of Tbilisi city and adjacent territories with PM2.5 and PM10 under conditions of restrictions related to COVID-19 pandemic by means of analysis of routine observations, experimental measurements data, and numerical modeling.

**Research results**

In Fig. 1 there are shown monthly absolute maximum, minimum and average PM concentrations in Tbilisi city atmosphere in 2020, which are obtained according to data of operating supervision carried out by the National Environmental Agency of the Ministry of Environmental Protection and Agriculture of Georgia [9]. It is seen from Fig. 1, that as a rule, concentrations of PM2.5 particles in Tbilisi atmosphere are 2-4-times less than PM10 concentrations, and their change curve behaviour is similar (Fig. 1). In case of routine pace of everyday life, maximum values of concentration almost always exceed the corresponding MPCs, minimum concentrations are always less than MPC, while average values surpass the respective MPCs in winter period only.

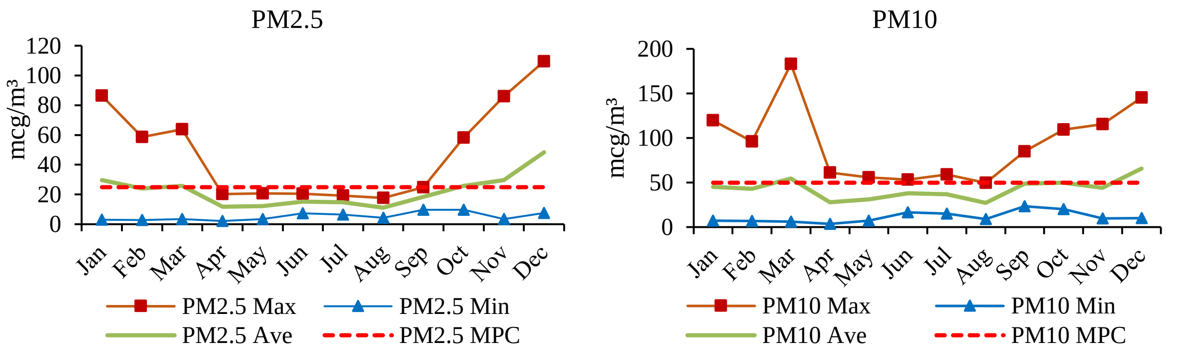


Fig. 1. Monthly absolute maximum, minimum and average PM2.5 and PM10 concentrations in Tbilisi city atmosphere in 2020.

Fig. 2 shows the diagram of hourly motion for last 5 days of November 2020. It is seen from Fig. 2 that from 26 to 28 day of the month inclusive, low concentrations are registered. Concentration drop is related to measures foreseen by the Lockdown (during the second pandemic wave) that were introduced starting from November 24: motor transport traffic restriction, closing of stores, shift to remote working for many public services etc. On November 29, so-called “Black Friday”, transport traffic was sharply increased that respectively caused the rise in microparticles concentrations. Maximum PM2.5 concentration reached 136.59 mcg/m$^3$ within 2 days, while PM10 concentration – 186.54 mcg/m$^3$, that 4- and 5-times exceeds their respective MPCs.

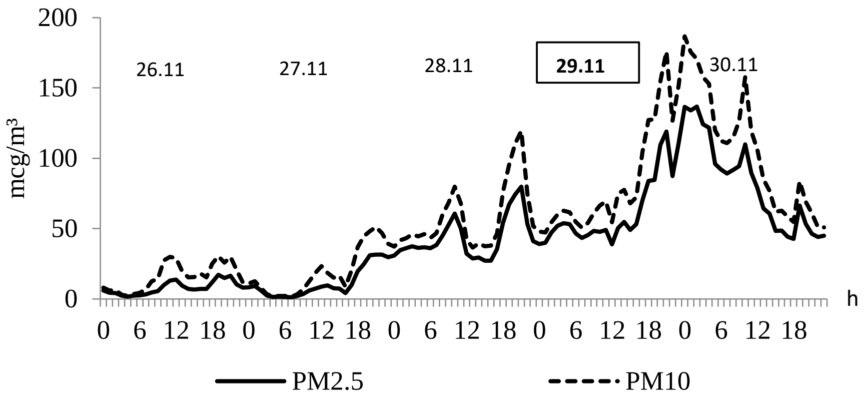


Fig. 2. Hourly motion of PM2.5 and PM10 concentrations on November 26-30, 2020 at observation point of monitoring situated at Tsereteli Avenue.

Experimental route measurement of PM2.5 and PM10 concentrations were conducted at main trunk roads of Tbilisi and its adjacent territories. Concentration values were determined using portable devices

„Aeroqual Series 500“ and „TROTEC PC220“ with 10 minute averaging. In Fig. 3 there are shown average values of concentrations obtained through measurements carried out in summer period of 2020 and 2021 from 9AM to 10PM.

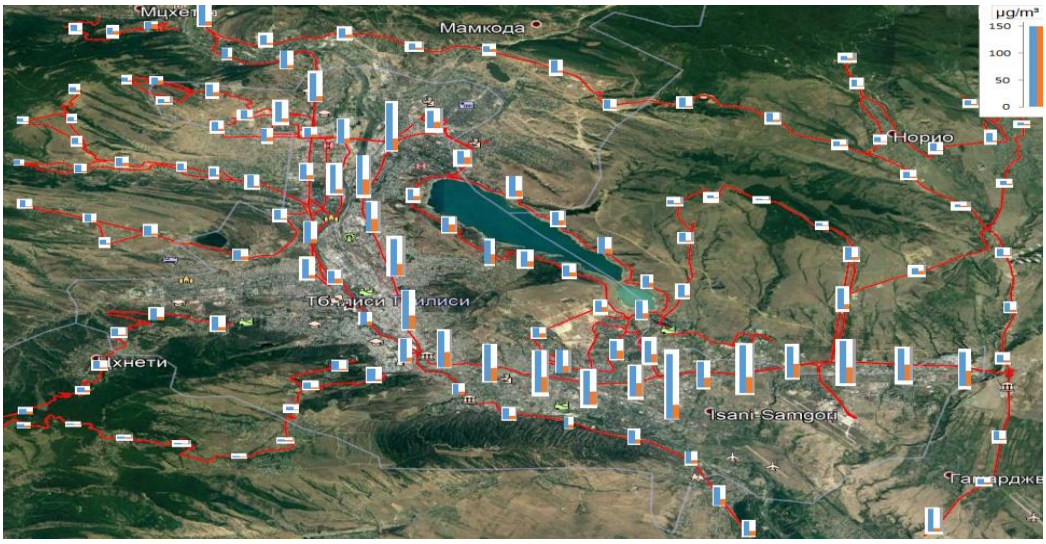


Fig. 3. Column-type diagram of PM2.5 and PM10 concentrations obtained via field measurements in Tbilisi city and adjacent territories (dark blue – PM10, red – PM2.5)

It is seen from Fig. 3 that microaerosols concentrations in daylight hours are high throughout the length of the central part of the city, in the surroundings of trunk roads, passing along Mtkvari River embankment, as well as Kakheti Highway, and Vake-Saburtalo, Gldani, TEMKA, Ortachala districts. Relatively fewer concentrations are obtained in the neighborhood of Tbilisi Sea. Concentration values in the high pollution area reach 1 MPC, while at less urbanized territories located out of the city, concentrations are less than 0.3 MPC.

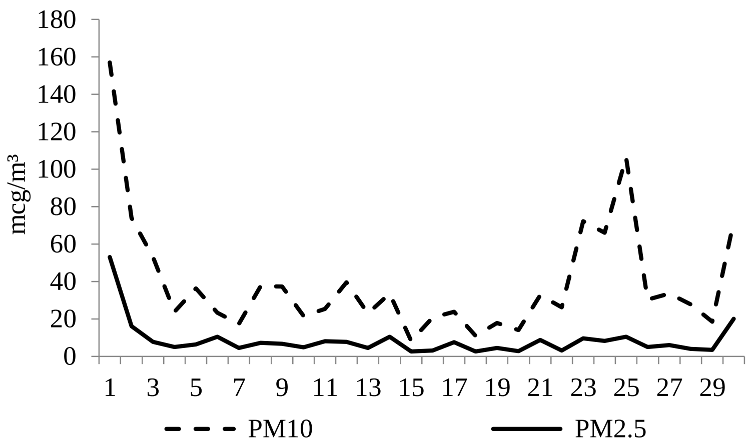


Fig. 4. PM2.5 and PM10 concentration values at the automobile road: Gldani bridges, Beliashvili Str., Vakhushti Bridge, Gagarin Str., Gelovani Ave., hospitals, Didi Digomi, on 21.10.2020 (N – sequential number of a measurement point)

Microaerosols concentration along some automobile roads depends on both motor transport traffic intensity and local peculiarities. Fig. 4 shows a concentration change at the road connecting Gldani bridges with Didi Digomi. It is seen from Fig. 4 that microaerosols concentration at major part of the road is less than MPC and varies within average values, and concentrations are especially high in the vicinity of Gldani bridges and Didi Digomi (Gelovani Highway). High concentration values at the mentioned sections are caused by “rush-hour”-like situation existing at the moment of observation, and by current repair and construction works.

Microaerosols concentrations change within the similar limits in the neighborhood of other main trunk road of Tbilisi, depending on respective local peculiarities.

In order to investigate the temporal and spatial evolution of microaerosols, PM2.5 and PM10 distribution in Tbilisi and adjacent territories is modeled by means of 3D numerical model [11]. Numerical grid of high resolution ability with 300 and 400 m horizontal steps along parallel and meridian is used. Vertical step varies from 0.5 to 15 m in the 100 m thick surface layer of the atmosphere, while in the atmospheric boundary layer and free atmosphere a vertical step is equal to 300 m. As far as there are no atmosphere-polluting large industrial enterprizes in Tbilisi city, it is assumed that a main source of atmosphere contamination is represented by microparticles generated and sprayed due to motor transport traffic. PM2.5 and PM10 concentrations change is modeled for 72 hours in cases of meteorological situations peculiar for the region.

Numerical modeling showed that in summer, during light background south air, a spatial distribution of PM2.5 in the atmosphere in 0-6 h time interval is not uniform. Its concentration at the major part of the city is within 0.001-0.1 mcg/m$^3$ at 2 m height from the Earth surface. In the city center, at the territories of Vake, Saburtalo districts, in the neighborhood of Tsereteli Avenue, Kakheti Highway and trunk roads connecting Tbilisi and Rustavi, PM2.5 concentrations vary from 1 to 5 mcg/m$^3$. Above 100 m, concentration reduction takes place and its value at 600 m altitude doesn't exceed 1 mcg/m$^3$.

Fig. 5 shows the fields of wind velocity and PM2.5 concentration obtained through numerical integration at 2, 100 and 600 m height above ground level at t = 9, 12, and 15h in case of light background south air. It was obtained that after 6AM, PM2.5 concentration increases at the entire territory of the city with increase of motor transport traffic intensity. Concentration growth is not uniform. It is especially high in the city center, in Vake and Saburtalo districts. At these territories, at 9AM, concentration value at 2 m height in the surface layer of the atmosphere varies within the limits of 25-35 mcg/m$^3$. After 9AM, concentration reduces in the main pollution areas and quazi-stationary distribution of microaerosols establishes. A slight positive vertical gradient is characteristic for obtained distribution at 100 m thick boundary layer, and a slight negative gradient – above 100 m altitude.

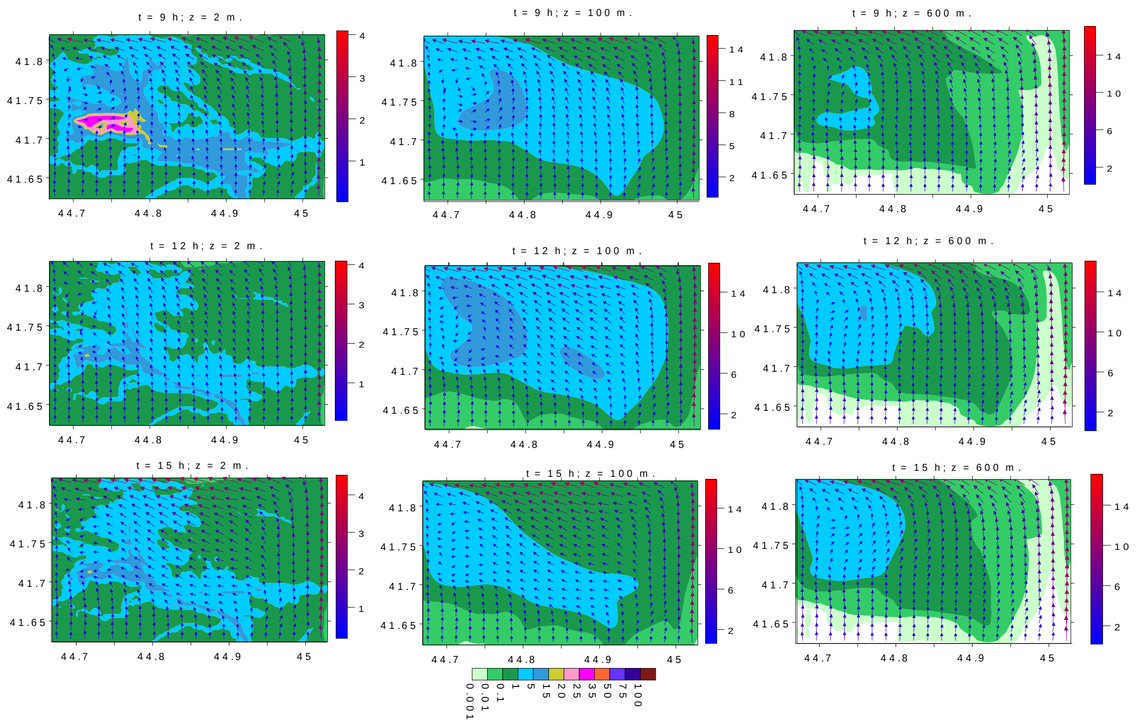


Fig. 5. Wind velocity (m/sec) and PM2.5 concentration (mcg/m$^3$) fields in summer, in the surface and boundary layers of the atmosphere, when t = 9, 12, and 15 h.

In the time interval from t = 15h to 21 h, takes place a sharp increase of PM2.5 concentration, which is caused by the second "rush-hour"-like situation of motor transport traffic (Fig. 6). Concentration increase at

2 m height from the Earth surface at t = 18h is obtained in Vake and Saburtalo districts. Concentration changes within the limits of 25-35 mcg/m$^3$. Concentration rise is relatively lesser at some small-size areas of Rustaveli and Gorgasali Avenues, Kakheti and Rustavi Highways, Ortachala and Ponichala. From t = 18h to 21 h, PM2.5 concentration is getting smaller at relatively highly polluted areas. Vertical turbulent and convective diffusion of aerosol particles occurs with ground-level concentration increase and, as a result, PM2.5 content increases at 100 and 600 m heights. At these levels, maximum concentration values by t = 18h become equal to 20 and 15 mcg/m$^3$. After t = 18 h, at 2 m height a slow reduction of concentration begins and at 100 m height its rise lasts. When t = 24h, such a vertical distribution of microaerosols establishes, during which PM2.5 concentration at 100 m height is higher than those obtained at 2 and 600 m altitude. As for time variation of pollution, the process repeats on a quasi-periodic basis after t = 24h.

A vertical distribution of PM2.5 concentration in the surface layer of the atmosphere, in three vertical cross-sections made along the parallel, is shown in Fig. 7, from where is seen that in the period from t = 3h to 6 h, PM2.5 concentration in the surface layer of the atmosphere is less than 5 mcg/m$^3$ and is characterized by slight reduction trend. After t = 6 h, aerosol concentration in the surface layer is getting higher with motor transport traffic intensity growth and by t = 9 h, average and high pollution zones form. They have quite large vertical and horizontal sizes and include almost entire surface layer. From t = 9h to 15 h time period, despite a fixed amount (9-12 h) and small reduction (12-15 h) of aerosols, entering into the atmosphere, takes place substantial reduction of concentration and air quality improvement. Sharp increase of ground-level concentration is registered in t = 16-21 h time interval. In this timespan, maximum value of concentration near the earth ground reaches 50 mcg/m$^3$ at small area. Through analysis of vertical distribution of PM2.5 concentration at various points of time one can conclude that in case of light background air the prevailing mechanism of aerosol propagation is represented by vertical and horizontal diffusion into the surface layer of the atmosphere. Turbulent flows take aerosols away from the surface layer to the boundary layer, where an advective transfer causes pollution dispersing at large areas and air self-purification. In high pollution zone, in the second half of a day, an important role is played by convective transfer, during which a heated air mass starts an intensive ordered relocation upward vertically from the earth ground and takes along available microparticles.

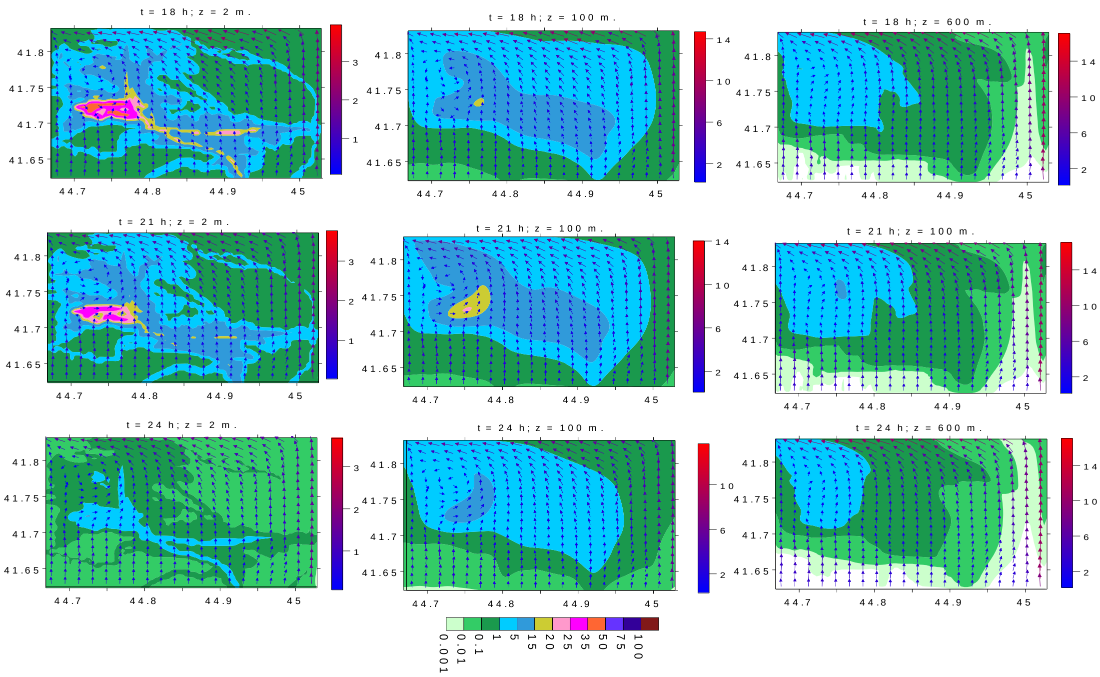


Fig. 6. Wind velocity (m/sec) and PM2.5 concentration (mkg/m$^3$) fields in summer, in the surface and boundary layers of the atmosphere, when t = 18, 21, and 24 h.

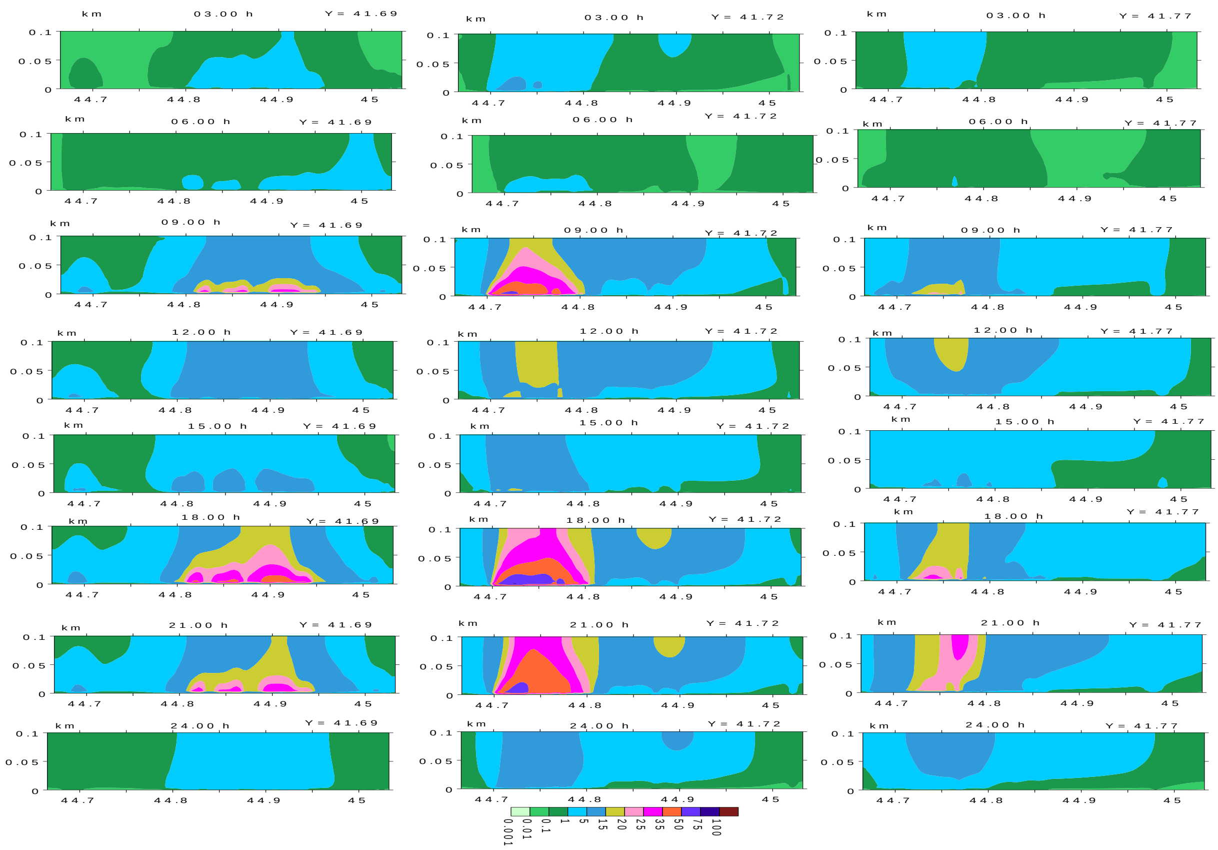

Fig. 7. PM2.5 concentration isolines in three vertical cross-sections made along the parallel in the lower 100 m thick atmospheric layer.

The picture similar from the viewpoint of temporal change and significantly different according to spatial distribution was obtained in winter, during numerical modeling of PM10 distribution in case of light background south air. The similarity lies in the pattern of concentration's temporal variation. In particular, it was established that a pollution level is minimal in time interval from t = 0 h to 6 h and maximal – during rush-hour situations (t = 9-10 h and 18-21 h).

When t = 9h, concentration is relatively high at 2 m height above ground level, both at main trunk road and urbanized territories, and in the suburbs. 25-40 mcg/$m^3$ concentration is obtained in the neighborhood of Vake, Saburtalo, Gldani, TEMKA districts and near Guramishvili Avenue, Kakheti and other highways. Pollution level increase takes place at 100 m altitude from the earth surface, as well, and in relatively small amount at 600 m height. Concentration values at 100 and 600 m heights are within the limits of 20-30 mcg/$m^3$ and 10-15 mcg/$m^3$.

In time interval from t = 9 h to 15 h a slight reduction of concentration is obtained. It is related to reduction of transport traffic intensity and to approach of formed local anticyclonic whirl center to the sources of pollution. The same situation occurs at 100 and 600 m height above ground level. Calculations showed that maximum values of PM10 concentration are equal to 20-25, 10-15 and 5-10 mcg/$m^3$ at 2, 100 and 600 m altitudes from earth surface, respectively. At 100 m height from earth surface, the difference between concentration distributions at t = 9h and 12 h is very small.

After t = 16h the ground-level concentration starts to rise. This increase is primarily noticeable at 2 m height. At 100 and 600 m altitudes concentration growth virtually has no place. By t = 18h PM10 concentration at 2 m height from earth surface equals to 35-40 mcg/$m^3$ in the vicinity of Vazha-Pshavela, Chavchavadze, Rustaveli avenues, Liberty and Erekle squares. Near other central avenues, concentration reaches 30 mcg/$m^3$ (Fig. 8).

Especially rapid growth of atmosphere pollution with PM10 takes place after t = 18h. Intensive growth of pollution occurs not only in the central part of the city, but also on the periphery: Gldani and TEMKA districts, surroundings of Ortachala and Ponichala, Rustavi and Kakheti highways etc. When t = 21 h, maximum concentration values are high at some small-size areas of polluted territory and they vary within 80-100 mkg/m$^3$, while at other heavily polluted territories – in the range of 50-70 mcg/m$^3$.

Ground-level concentration rise is accompanied with its growth in the upper surface layer and lower boundary layer of the atmosphere. When t = 21h, concentration values equal to 20-25 mcg/m$^3$ and 5-10 mcg/m$^3$ at 100 and 600 m height above ground level, respectively. The area of increased pollution is of horseshoe-shaped (U-shaped) form and covers large territory of the central and northern parts of the city. At 600 m height, the area of increased pollution occupies an eastern part of modeling area. After t = 21 h, a rapid decrease of ground-level pollution begins, due to which the ground-level concentration value drops to 5 mcg/m$^3$. The similar process takes place at 100 and 600 m altitudes, as well.

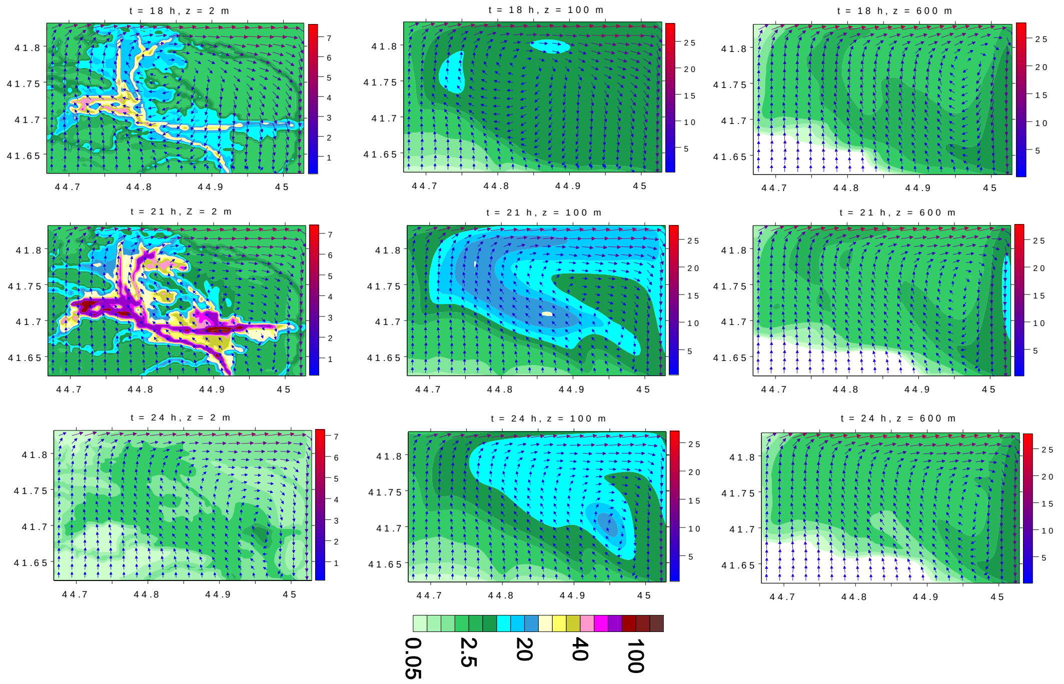


Fig. 8. Wind velocity (m/sec) and PM10 concentration (mcg/m$^3$) fields in winter, in the surface and boundary layers of the atmosphere, when t = 18, 21, and 24 h

## Conclusion

Temporal and spatial variation of PM2.5 and PM10 concentrations in the surface and boundary layers of atmospheric air at main trunk roads of Tbilisi city and adjacent territories in 2020 and 2021 is studied through analysis of routine observations and experimental measurement data. Monthly values of maximum, minimum and average concentration are determined. It is shown that hourly variation of concentration is characterized by two maximums in t = 9-10 h and 18-21 h time intervals. It is established that measures related to Lockdown cause significant reduction of microaerosols concentration in urban air. The pattern of concentration change along the main automobile roads of the city is determined. It is shown that concentration values oscillate near the average magnitudes peculiar for the automobile road. Sharp increase of concentration values is registered in some places that is associated with particular local conditions created at the time of measurement (traffic jam, repair and construction works etc.).

Kinematics of PM2.5 and PM10 concentration change generated by motor transport at the territory of Tbilisi city under summer and winter conditions, in case of light background south air is explored through numerical modeling. Diurnal pattern of dust spatial distribution is studied. Concentration values are determined via modeling, and they are within the limits of values obtained through routine observations. It is established that a spatial distribution of heavily polluted areas depends on motor transport traffic intensity, trunk roads location, on one hand, and on dynamic impact of terrain and on local circulation systems formed by diurnal change of thermal regime at the underlying surface.

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# ქ. თბილისის ატმოსფეროს PM2.5 და PM10 -მიკრონაწილაკებით დაბინძურების გამოკვლევა COVID-19-ის პანდემიის პერიოდში


ვ. კუხალაშვილი, მ. ფიფია, ნ. გიგაური,
ა. სურმავა, ლ. ინწკირველი


### რეზიუმე


რეგულარული დაკვირვებების და ექსპერიმენტული გაზომვების მონაცემების ანალიზით შესწავლილია 2020 და 2021 წლებში ქ. თბილისის ძირითადი ტრასებზე და მიმდებარე ტერიტორიებზე ატმოსფერული ჰაერის მიწისპირა და სასაზღვრო ფენაში PM2.5 და PM10-ის

კონცენტრაციების დროსა და სივრცეში ცვლილება. ნაჩვენებია, რომ კონცენტრაციის საათობრივ ცვლილებას ახასიათებს ორი მაქსიმუმი დღის 9-10 სთ და 18-21 სთ-ის ინტერვალში. მიღებულია , რომ ,,Lockdown“-თან დაკავშირებული ღონისძიებები იწვევს ქალაქის ჰაერში მიკროაეროზოლების კონცენტრაციის მნიშვნელოვან შემცირებას. ნაჩვენებია, რომ კონცენტრაციების სიდიდეები ირხევიან ტრასისათვის მახასიათებელი საშუალო მნიშვნელობების მახლობლობაში.
რიცხვითი მოდელირებით შესწავლილია მტვრის სივრცული განაწილების დღეღამური სურათი ზაფხულის და ზამთრის პირობებში, სამხრეთის სუსტი ქარის დროს. მიღებულია კონცენტრაციების მნიშვნელობები, რომლებიც რეგულარული დაკვირვებებით მიღებული სიდიდეების ფარგლებშია. დადგენილია, რომ ძლიერად დამტვერიანებული არეების სივრცული განაწილება დამოკიდებულია: ავტოტრანსპორტის მოძრაობის ინტენსივობაზე, ავტომაგისტრალების მდებარეობაზე, რელიეფის დინამიკური ზემოქმედებით და ქვეფენილ ზედაპირზე თერმული რეჟიმის დღეღამური ცვლილებით ფორმირებულ ლოკალურ ცირკულაციურ სისტემებზე.

**საკვანძო სიტყვები:** ატმოსფერო, დაბინძურება, რიცხვითი მოდელირება, კონცენტრაცია, PM

# Исследование загрязнения атмосферы г.Тбилиси микрочастицами РМ2.5 и РМ10 в период пандемии COVID-19

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## Резюме

На основе анализа данных регулярных наблюдений и экспериментальных измерений в 2020-21 годах изучено изменение во времени и пространстве концентраций РМ2.5 и РМ10 в приземном слое атмосферного воздуха на основных автомагистралях г. Тбилиси и прилегающих территориях. Показано, что почасовое изменение концентрации характеризуется двумя максимумамы в интервале 9-10 и 18-21 часов. Получено, что мероприятия, связанные с ,,Lockdown“-ом, приводят к значительному снижению концентрации микроаэрозолей в воздухе города. Показано, что уровни их концентраций колеблются в районе средних значений, характерных для автомагистралей.
Методом численного моделирования изучена суточная картина пространственного распределения пыли в летних и зимних условиях, при слабых южных ветрах. Полученые значения концентраций находятся в пределах значений, полученных при регулярных наблюдениях. Определено, что пространственное распределение сильно запыленных участков зависит от интенсивности движения автотранспорта, расположения автомобильных дорог, динамического воздействия рельефа и суточной смены термического режима на подстилающей поверхности.

**Ключевые слова:** атмосфера, загрязнение, численное моделирование, концентрация, РМ.