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Assessment of Pollution of the Rustavi City's Atmosphere with Microaerosols

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***Abstract*—**According to observational data, experimental measurements and numerical modelling, the pollution of one of the industrial centers of Georgia, Rustavi City's atmosphere with micro aerosols are assessed. Monthly, daily and hourly changes of the concentrations of PM2.5 and PM10 in the city atmosphere are analyzed. It is accepted that PM2.5 concentrations are always lower than PM10 concentrations, but their change curve is the same. In addition, it has been noted that the maximum concentrations of particles in the atmosphere of Rustavi city will be reached at any part of the day, which is determined by the total impact of the traffic flow and industrial facilities. Through numerical modelling, the influence of background western light air, gentle and fresh breeze on the distribution of particulate matter in the atmosphere was calculated. Calculations showed that background light air and gentle breeze lead to an increase the concentrations of microaerosols in the city's atmosphere, while fresh breeze contributes to the dispersion of dusty clouds. As a result, the level of dust in the city is decreasing, but the distribution area is expanding.

***Keywords*—**Air pollution, numerical modeling, experimental measurement, PM2.5, PM10.

I. Introduction

RUSTAVI is the largest industrial center of Georgia and it is located at a distance of 27 km south-eastward of Tbilisi city. Its population exceeds 138 thousand. The city occupies 60.6 km^2 territory situated northward of the plain area of Kvemo Kartli [1]. It is surrounded by mountain groups from three sides, and by plain territory – from the east. Industrial facilities are mainly disposed in the eastern, southern and south-eastern parts of the city. Metallurgical, chemical, building material enterprises and objects for household purpose are basically located in the city.

Statement of the Problem

It is known that PM2.5 and PM10 are harmful for human health, that is why we have selected the analysis of their concentration change using experimental measurements and numerical modeling as the subject of our research in order to get the broad picture of city pollution, especially for such industrial city, as Rustavi is.

According to the National Environmental Agency data the microaerosol pollution level of Rustavi atmospheric air frequently surpasses the respective maximum allowable concentrations (MAC) [1], [2]. As an example, Fig. 1 shows the monthly data of 2022, from where one can clearly see that the values of maximal, average and minimal concentrations of PM2.5 and PM10 vary in the limits of 30-103, 15-40, 2-20 and 80-176 mkg/m^3, 33-82 and 5-40 mkg/m^3, respectively. At that, average values frequently, while maximal concentrations every month, exceed the values of respective MAC. The analysis of day-by-day and hour-by-hour changes of microaerosols concentrations showed that high concentrations are registered on frequent occasions, though without any regularity, in different time periods (intervals).

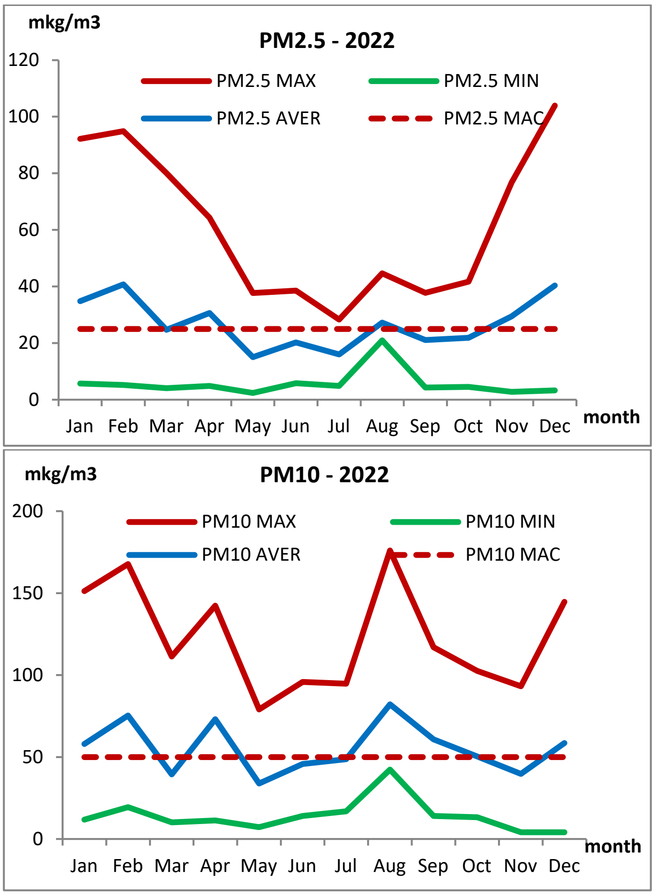

Fig. 1 Maximal, average and minimal concentrations of PM2.5 and PM10, 2022

II. Research Results

Experimental measurements included Tbilisi-Rustavi and Tbilisi-Gachiani main trunks, central areas of the city and territories adjacent to the industrial facilities. Expeditions have

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been conducted during different meteorological situations.

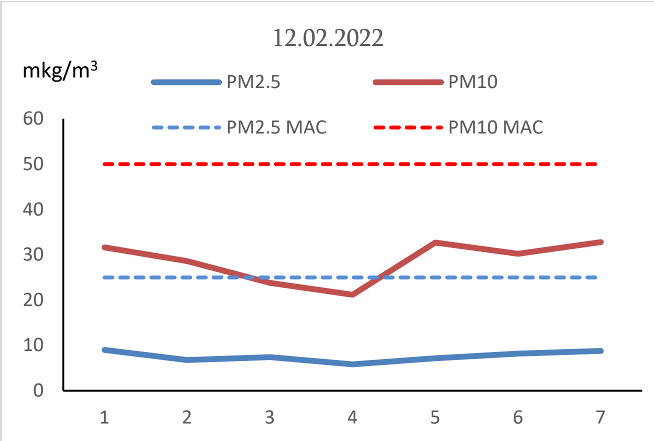

Fig. 2 PM2.5 and PM10 concentrations in the different observation points of Rustavi city, February 12, 2022

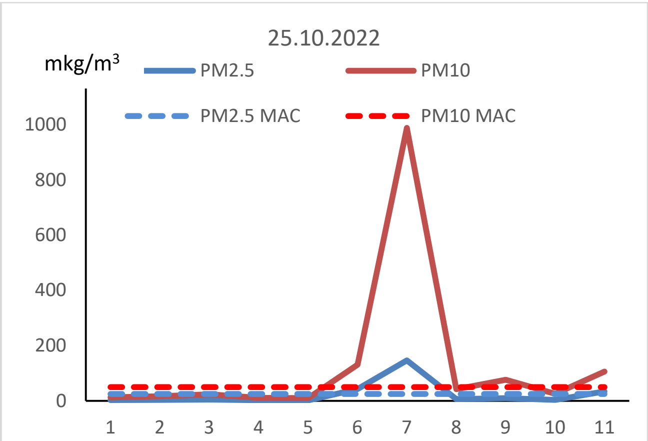

Fig. 3 PM2.5 and PM10 concentrations in the different observation points of Rustavi city, October 25, 2022

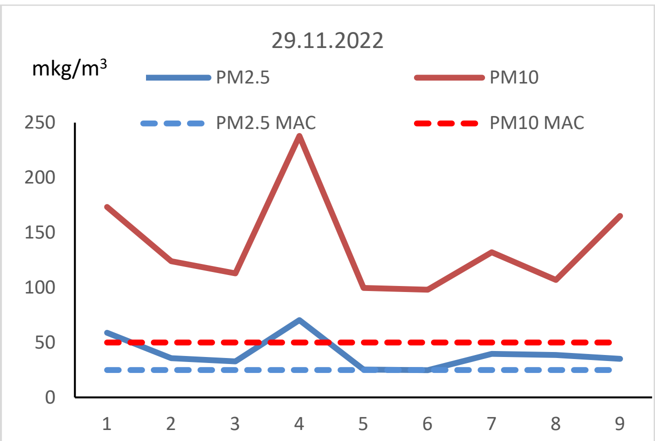

Fig. 4 PM2.5 and PM10 concentrations in the different observation points of Rustavi city, November 29, 2022

Fig. 2 shows the data of expedition made on 12th of February, from where one can see that PM2.5 and PM10 concentrations are within normal limits. Fig. 3 shows the results of expedition carried out on the 25th of October, and it is seen that PM particles concentration values taken from the 7th observation point are 9-times and more times higher than data of other points. This measurement has been taken in the vicinity of the cement plant, in the windy weather (roughly 9-10 m/sec) and one can see a dust storm even with the unaided eye that is reflected in the graph. As for Fig. 4, it is seen that data taken from each point exceed MAC that can be explained by the fact that there was a low cloud on 29th of November and at such times dust particles are unable to dissipate in the atmosphere and remain in the lower layer [3].

In order to assess the Rustavi city impact on the pollution of atmospheric air of adjacent territories, PM2.5 diffusion in the Rustavi atmosphere during background western light air, gentle and fresh breeze (light, mean and strong winds) has been numerically modeled by means of a 3D model of atmospheric process development and admixture distribution [4], [5]. Modeling has been made at the $118 \times 91 \times 31$ numerical grid with 100 m horizontal steps and 1/31 dimensionless vertical steps. In the boundary layer and free atmosphere, a vertical step roughly corresponds to 300 m; 17 vertical grid points are selected in the lower 100 m thick surface layer of the atmosphere, and a step varies from 0.5 to 15 m. It has been accepted during modeling that PM2.5 concentration at the territory of Rustavi city is constant in time, maximal and equals to 50 mkg/m^3. Numerical calculations have been made for a 3-day interval. Calculations showed that polluting ingredients are distributed on a quasiperiodic basis, with 24 h period.

A. Light Air

In Fig. 5 there are shown wind velocity and PM 2.5 concentration fields in the surface and boundary layers of the atmosphere, obtained during western background light air. Background wind velocity varies from 1 m/sec (at 100 m height from the earth ground) to 20 m/sec (in the tropopause). It is seen from Fig. 5 that change in the diurnal behavior of terrain and temperature at midday (t = 12 h) induces change in the surface wind velocity value. In the surroundings of Trialeti Range eastern slope it forms a narrow convergence zone of wind velocity directed from south to north. Western air flow available above the Trialeti range and eastern flow formed on the eastern slope of this range meet each other in this zone. At the plain territory of Kvemo Kartli the north-western and northern winds prevail, which transforms into western wind in the southern part of the region. Above the surface layer of atmospheric air (600 m), in the western, central and eastern parts of the region the wind changes from a south-western to western and north-western one. Wind change is accompanied with change in PM2.5 microparticles transfer direction. In the surface layer of the atmosphere at 2 m height from the earth ground it propagates towards south and south-east, while at 100 m height and above – in the south-eastern and eastern direction. Concentration spatial distribution shape shows that advective transfer is predominant in the surface layer of the atmosphere, while in the atmospheric boundary layer, advective and diffusive transfers contribute equally in the contamination propagation process. By t = 24 h, the pattern of wind spatial

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distribution undergoes changes resulting from atmosphere thermal regime change. Wind convergence zone disappears in the eastern part of the region, and a meso-scale anticyclone swirl is formed, which gradually weakens with height increase, and at 600 m height, a western light air with a weak wave disturbance is formed.

Wind change induces respective changes of PM2.5 transfer direction. In the surface layer of the atmosphere, it is propagated in the form of an arc-like zone to the south-eastern part of the anticyclone. Above, in the boundary layer, the concentration field is localized in the form of broad zone in the south-eastern periphery of the region. During the transfer of microparticles, the area of their distribution in the surface layer of the atmosphere is approximately 50 km, and in the boundary layer - approximately 70 km.

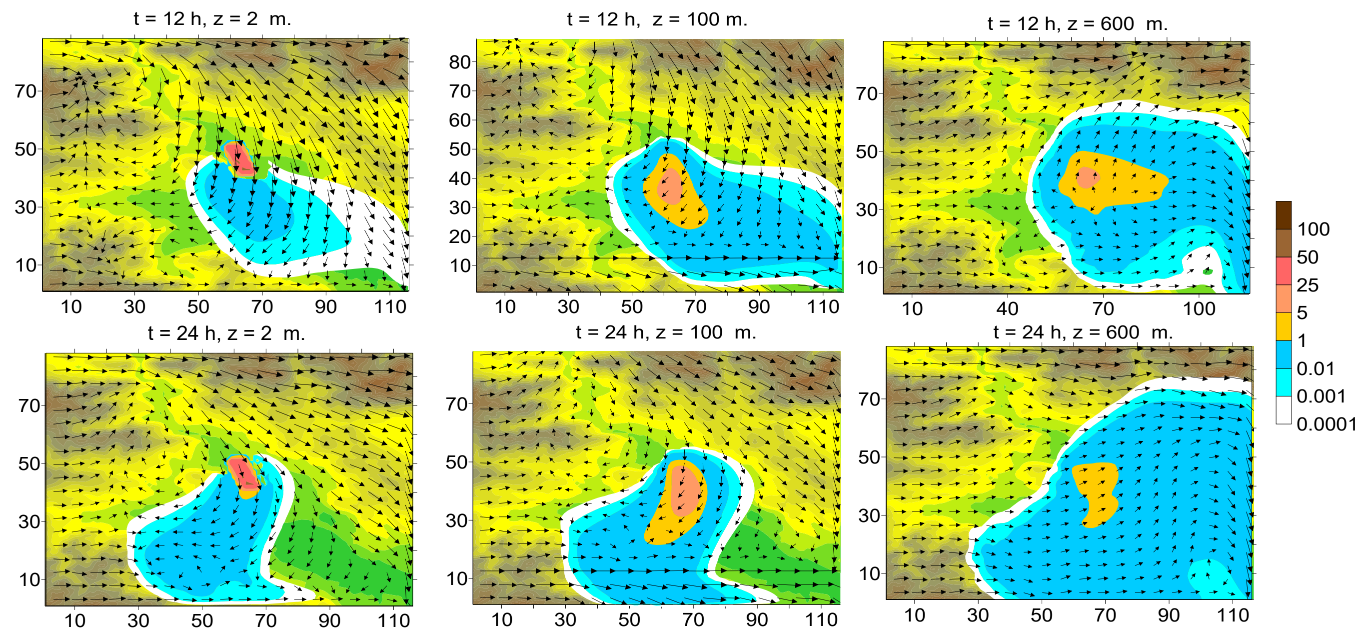

Fig. 5 Wind velocity and PM2.5 concentration distribution at z = 2, 100 and 600 m height in case of western background light wind, when t = 12 and 24 h

B. Gentle Breeze

In case of background gentle breeze, a local field of formed wind velocity is significantly changed (Fig. 6). At t = 12 h, there is a western wind in the surface layer of the atmosphere, and north-western wind – in the western part of modeling area. In the wind velocity field, a convergence zone of a wind directed from north-west to south-east is formed in the surface layer, which moves to the surroundings of Rustavi city. This convergence zone above the surface layer disappears and wind is mainly a western one. According to wind spatial distribution, Rustavi city atmosphere pollution is transferred in the form of a narrow and elongated arc zone, which follows the convergence band. This band is 20 km width. In the atmospheric boundary level, an atmosphere pollution area substantially expands from the city outskirts to its eastern border, where a pollution zone width becomes roughly 80 km.

By t = 24 h, the wind velocity field becomes substantially uniform and in the surface layer of the atmosphere it is directed south-eastward, while in the boundary layer – eastward. Respectively, the spatial field of concentration has an elongated ellipse-like shape, which is peculiar for admixture transfer in the constant velocity field. In the atmospheric boundary layer pollution is maximal. A width of spatial field is less by roughly 75 km than a width obtained in the surface layer.

C. Fresh Breeze

In case of fresh breeze, a terrain effect on wind spatial distribution is weak (Fig. 7). The effect is qualitatively similar to the impact obtained in case of gentle breeze and is manifested in wind direction change from the western wind to the north-eastern wind in the central and eastern modeling parts. PM 2.5 concentration spatial distribution is slightly differed from that obtained in case of gentle breeze, as well. The particle propagation area is reduced a little. This effect is caused by the fact that a strong air flow draws the major part of particles toward moving and does not afford them to dissipate widthway.

III. Conclusion

Through the analysis of routine observations and experimental measurements data, the values of PM2.5 and PM10 concentrations in the Rustavi city atmosphere and their change features were determined. PM concentrations frequently exceed MACs, though the maximums are registered in the different periods of a day that is caused by the fact that industrial facilities also make substantial contribution to the Rustavi city atmosphere pollution along with motor transport.

Experimental measurements showed that in the industrial areas of the city, PM2.5 and PM10 concentrations significantly depend on meteorological conditions. In the case of a moderate wind under low cloud conditions, PM concentrations may reach 3-5 MACs.

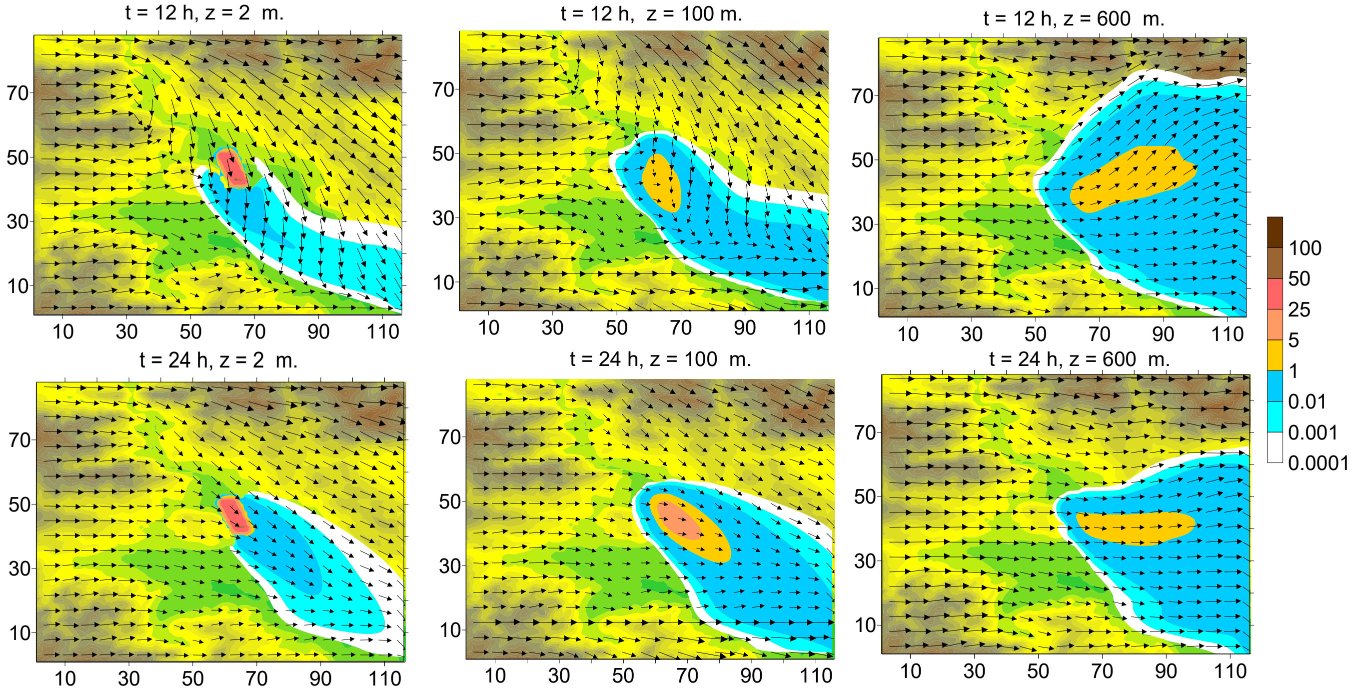

Fig. 6 Wind velocity and PM2.5 concentration distribution at z = 2, 100 and 600 m height in case of western background gentle breeze (mean wind), when t = 12 and 24 h

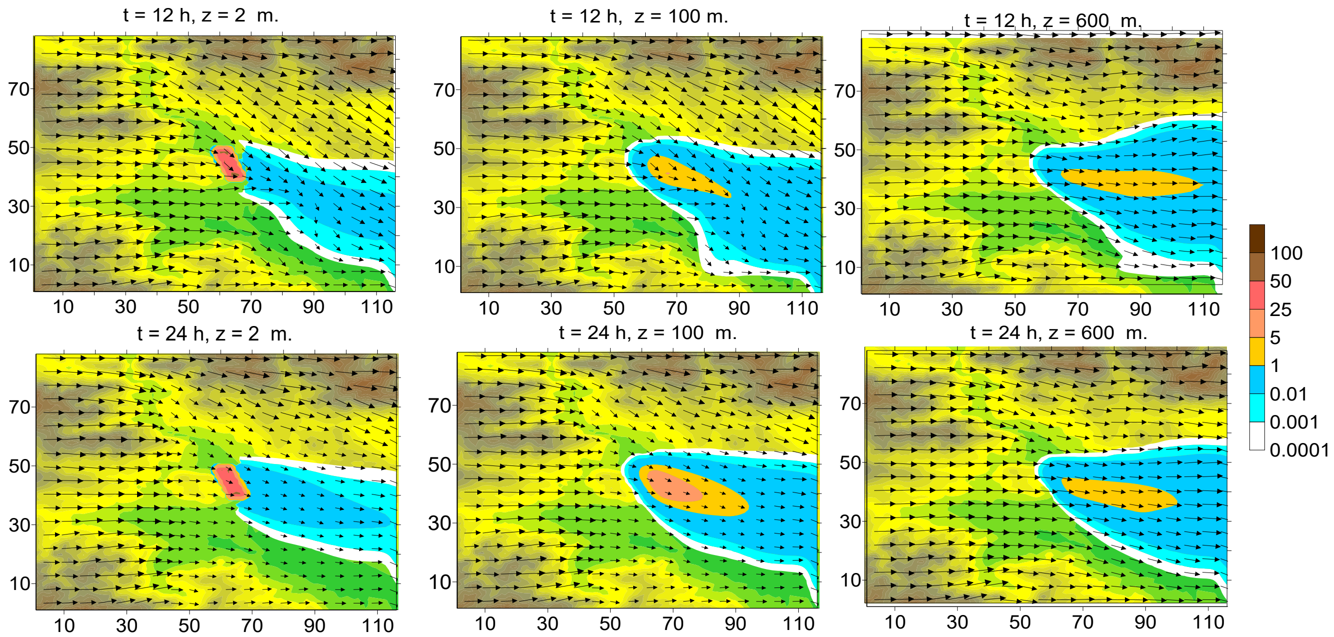

Fig. 7 Wind velocity and PM2.5 concentration distribution at z = 2, 100 and 600 m height in case of western background fresh breeze (strong wind), when t = 12 and 24 h

Propagation of PM2.5 in the Rustavi city atmosphere to the adjacent territories of the city in cases of light air, gentle breeze and fresh breeze is studied using a 3D model of atmospheric process development and admixture distribution. A dust-filled cloud spreads at larger territories in the case of light air, while during gentle and fresh breeze due to strong air flow it mainly shifts toward moving from west to east in the form of a band. In case of fresh breeze, a city terrain effect is weaker, as well.

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