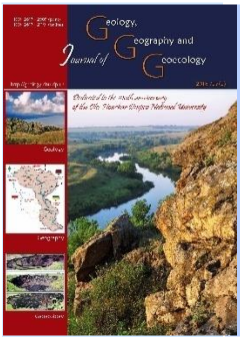


Journal of Geology, Geography and Geoecology

Journal home page: geology-dnu-dp.ua

ISSN 2617-2909 (print)
ISSN 2617-2119 (online)

Journ.Geol.Geograph. Geoecology, 28(1), 140-147
doi:10.15421/111915

Spatial Assessment of Seasonal Changes in Pollution of the Air Ground Layer with Aerosol Particles in School Yards of Tiaret city (Algeria)

Naceur Khadidja[1], Maatoug Mhamed[1], Benaichata Lazreg[1], S.A. Stankevich[2], O.V. Titarenko[1], M.M. Kharytonov[1]

[1]Ibn Khaldou. University Tiaret. BP 78, Zaaroura, Tiaret, (Algeria) , e-mail: khadidja366@gmail.com
[2]Scientific Centre for Aerospace Research of Earth, NAS Ukraine, Oles Honchar st. 55 b. Kiev, 01054, Ukraine, e-mail: st@casre.kiev.ua
[3]Dnipro State Agrarian and Economic University, Sergey Yefremova st.25, Dnipro 49600, Ukraine, e-mail: kharytonov.m.m@dsau.dp.ua

Received 29.12.2018;
Received in revised form 14.01.2019;
Accepted 03.03.2019

Abstract. According to the data obtained in the autumn-winter period, the excess of $PM_{2.5}$ in air during the schoolday after a short stay by pupils in the school yards was 1.5 – 2 times. The $PM_{2.5}$ concentration in the autumn - winter period was up to 1.5 times higher than that of the spring – summer time. High concentrations of dust particles are observed in areas close to heavy traffic in winter in the South-Eastern part of the city. Low concentrations were recorded in the autumn-winter time in areas adjacent to forests in the North –Western part of the city of Tiaret. However, the protective function of forest stands in the spring – summer period in the North-Western part of the city of Tiaret is less evident. The need for introduction of several nature protection measures in the city is obvious. Among them: fuel quality control and fines for the use of low-grade fuel, increasing the density of trees and shrubs in the city in the areas uncovered by vegetation.

Keywords: air pollution, technogenic dust, aerosol, mass concentration, remote sensing, cartography, health, Tiaret, Algeria.

Просторова оцінка сезонних змін забруднення приземного шару повітря аерозольними частинками пилу на шкільних майданчиках міста Тіарет (Алжир)

Насер К.[1], Маатуг М.[1] , Бен’ячата Л.[1], Станкевич С., Титаренко О.[2], ХаритоновМ.[3]

[1]Університет Ібн Халдун, BPP78 Задроура 14000, Тіарет, Алжир,, e-mail:maatoug.moh@gmail.com
[2]Науковий центр аерокосмічних досліджень Землі, НАН України, вул. Олеся Гончара 55б. Київ, 01054, Україна, e-mail: st@casre.kiev.ua
[3]Дніпровський державний аграрно – економічний університет, вул. Сергія Єфремова 25, Дніпро, 49600, Україна, e-mail: kharytonov.m.m@dsau.dp.ua

Аннотація. Згідно з отриманими даними перевищення забруднення повітря частками пилу 2,5мкм ($ЧП_{2.5}$) на шкільних майданчиках міста вже в ранкові години (з 7до 9 годину ранку) після короткочасного перебування там школярів доходить до 1,5 – 2 разів. Концентрація $ЧП_{2.5}$ в осінньо - зимовий період була майже у 1,5 рази вище, ніж у весняно – літній період. Високі концентрації спостерігаються на ділянках, розташованих неподалік від інтенсивного дорожнього руху в зимовий період. Низькі концентрації зафіксовані у районах, прилеглих до лісових масивів у північно –західній частині міста Тіарет. Однак влітку захисна функция лісових насаджень в північно-західній частині міста Тіарет проявляється в меншій мірі. Очевидним є впровадження декількох природо - охоронних заходів в місті. Серед них: контроль якості палива і штрафи за використання низькосортного палива, збільшення щільність деревно-чагарникових насаджень в місті на непокритих рослинністю територіях.

Ключові слова: забруднення повітря, техногенний пил, аерозоль, масова концентрація, дистанційне зондування, картографія, здоров’я, Тіарет, Алжир.

Introduction. Dusty atmosphere is currently the main problem of air quality management in cities. Fine dust particles come from a variety of sources, among which the main products are anthropogenic activities. Atmospheric particles can be divided into two categories according to their sources, namely primary and secondary sources. Particles of the primary sources are emitted directly into the air, while the particles of secondary sources $PM_{2.5}$ are formed in the process of chemical reactions of such gases as sulphur dioxide (SO_2), volatile organic hydrocarbons, oxides of nitrogen (NO_x) and ammonia (Dunea D. et al, 2016).

The size and composition of primary source particle emissions depends on the source of emission. Urban vehicles, as well as chimneys and incinerators in industrial areas, emit large amounts of soot. Complex chemical composition and small particle size of technogenic dust are prerequisites for increased impact on the environment, including the reduction in visibility, changes in the processes of formation of clouds, the damage to forest plantations and crops (Tang et al, 2006; Myhre, 2009). $PM_{2.5}$ contain many toxic compounds, such as acids, polycyclic aromatic hydrocarbons and heavy metals, which, as shown in epidemiological studies, directly impair human health, especially respiratory functions (Pope and Dockery, 2006; Franklin et al, 2008).

$PM_{2.5}$ remain in the atmosphere for days up to several weeks, depending on the particle size, the rate at which they are removed and possible precipitation (Chen et al, 2016).

It was found that unexpectedly high air pollution in cities and their surroundings is not a direct consequence of the sudden increase in emissions of pollutants. This is largely due to the prevailing adverse weather conditions (Han et al, 2015). First of all, this is due to the reduced ability of the atmosphere to disperse pollution and transport pollutants from other areas. It is established that the wind speed is the main meteorological factor determining the air quality in the city. Strong air pollution disappeared when wind speed exceeded 4 m / sec.

It is known that aerosol particles are mainly concentrated in the boundary layer of the earth's atmosphere. This is the first atmospheric layer, which is under the direct influence of the earth's surface. The composition of the surface layer varies during the day due to convection processes. Therefore, it is called a convective mixed layer (Stull, 1988).

The urban landscape is another factor that can affect the quality of the atmospheric boundary layer, as it exhibits different types of anthropogenic activities. Vegetation cover, presence of surface moisture radiation and surface temperature are microclimatic variables obtained by multispectral satellite images. A large proportion of emissions from vehicles into the environment are from paved roads. Features of the landscape affect the urban surface runoff. Most human activities occur on the urban impervious surface (Carlson and Arthur, 2000). Therefore, the share of the surface of an urban area occupied by the impenetrable surface, to some extent, may indicate the intensity of human activity.

Thus, it is possible thanks to use of remote sensing data to assess the impact of relief on the flushing of man-made dust in an area of urban agglomeration (Farah et al, 2018). Recent studies of the impact of fine-grained particles of soil contaminated with mycotoxins on the health of residents of an suburban area, found deterioration of lung function and chronic lung disease (Capasso et al., 2015). Over the past decade, many residential areas in cities around the world have been exposed to $PM_{2.5}$, resulting in poor air quality, and contributing to higher levels of respiratory morbidity and multiple clinical symptoms, especially in children (Henschel et al., 2012; Pope & Dockery, 2006; Ward and Ayres, 2004).

Living or attending schools near high-density roads exposes children to higher levels of vehicle air pollution, increases the frequency and prevalence of childhood asthma and shortness of breath (Gasana et al, 2012). Especially interesting is the assessment of seasonal changes in the concentration of $PM_{2.5}$ in the atmosphere of cities. In particular, particle quantities and mass concentrations were measured in Beijing in winter and summer 2003. The ratio of $PM_{2.5}$ / PM_{10} was higher in winter than in summer (Yu et al, 2005).

It is believed that frequent strong winds in winter increase the dispersion of pollutants and increase the average particle concentration by weight in winter compared to summer values (Glen et al., 1996).

Seasonal variability in the conditions of Morocco noted a decrease in the concentration of dust particles in the winter and rise in summer, testified to the manifestation of the processes of soil deflation in the region of Meknes (Ait Bouh et al, 2012). Studies of aerotechnogenic pollution in Katowice (Poland) have confirmed that meteorological conditions have a strong impact on the composition of aerosol particles, including wind speed and direction. It was found that compared to winter, the number of particles enriched with some heavy metals in the spring was less. (Wawroś et al, 2003).

The aim of this work was to conduct a geospatial assessment of seasonal changes of $PM_{2.5}$ in the open areas of schools in Tiaret (Algeria).

Material and methods. The study was conducted in Tiaret city, located to the North-West of Algiers city in the mountainous region of Tell Atlas, about 150 km from the Mediterranean coast. The population of Tiaret city is up to 160 000 people.

The climate is Mediterranean semiarid with average annual precipitation of 400 mm. The predominant sector of the local economy - agriculture. The relatively cool climate and the availability of water sources contribute to the cultivation of cereals and livestock. The Tiaret region is located in an isolated position on the slopes of the mountains with an average height of 990 m.

The study of the direction and speed of the prevailing winds revealed some patterns of their dominance in the region and around it. Wind speeds recorded within Tiaret city sometimes exceed 4 m / s. However, the wind speed in suburban areas often exceeds 5 m / s (Kasbadji Merzouk, 1999).

Tiaret city has more than 200 km of urban road network. The city's fleet consists of up to 157,000 cars of all types, about 70% of them run on gasoline, 30% - with the use of diesel fuel. It is still common to use anti - knock additives with lead in gasoline. Another method of increasing the octane number of fuel is associated with the addition of 500 g of naphthalene per 10 liters of gasoline , which increases the fuel octane number by 3-4 units: 92nd gasoline "turns" into 95th. Once in benzene, naphthalene leaves a significant amount of carbon, increases the number of harmful exhaust gases. In addition, it crystallizes, clogs the fuel system, from fuel pump, hoses, and ending with injectors. Thus, there is significant uncertainty associated with naphthalene emission factors of gasoline and diesel vehicles. Emissions tend to vary with season due to changes in temperature and relative humidity, fuel composition, and vehicle fleet composition (Cohan et al, 2013).

23 primary schools were selected for local and spatial assessment of air pollution by $PM_{2.5}$ (Fig.1).

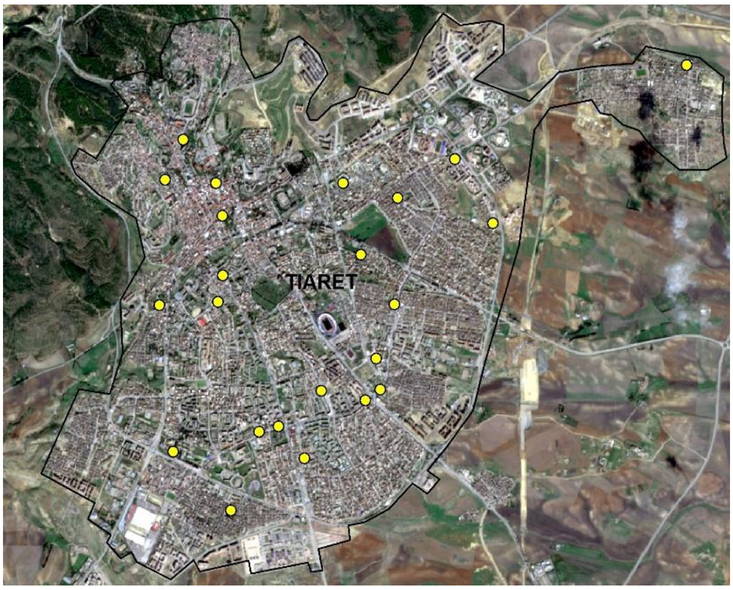


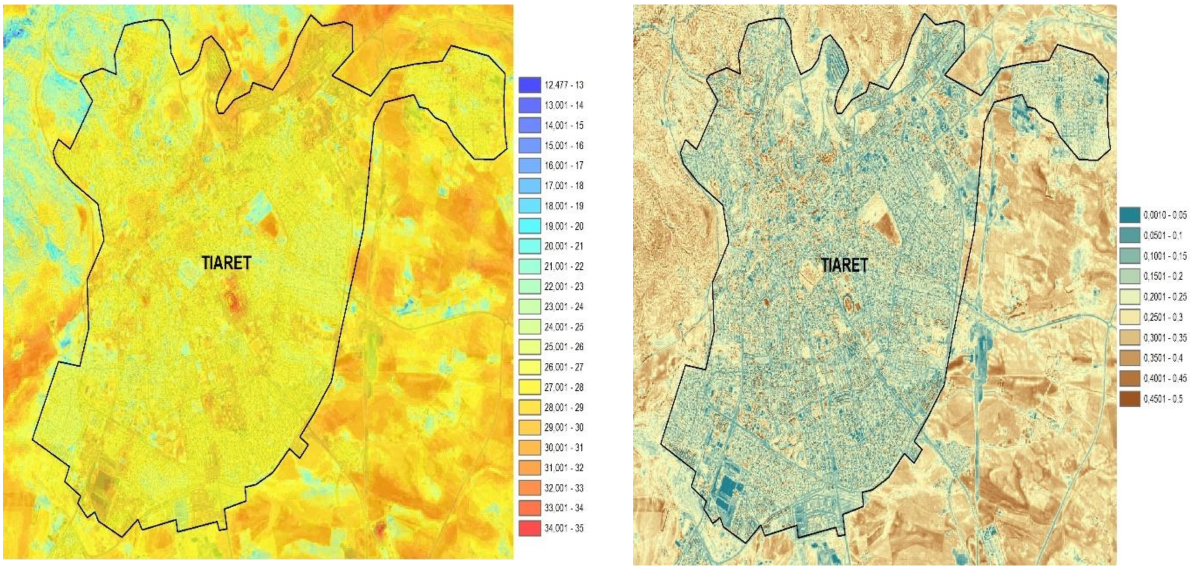
Fig. 1. The map plots in the city of Tiaret (SENTINEL-2, 04/11/2018)

Sampling of $PM_{2.5}$ was associated with the use of the installation DEKATI PM10 (ISO23210, www.dekati.com, 2017) in the center of the school yard at a height of one meter. Three samples were taken daily in each school: in the morning (from 7 to 9 am), at noon (from 11am to 1 pm) and at the end of afternoon (from 3:30pm to 5:30 pm). $PM_{2.5}$ sampling was carried out in the presence and absence of pupils in the school yard. The duration of collection was given as 30 minutes. A total of six samples per day were collected for each school sample. The study sites were selected either at the intersection of the grids or in the middle of each grid (grid size 0.5 km × 0.5 km). 138 samples were collected in just eight months from November 2016 to June 2017.

Calculation of $PM_{2.5}$ concentrations, in μg / m^3, was performed according to a calculation model, on an Excel program (PM_{10} 30LPM calculation sheet ver1.51), delivered with the impactor, taking into account the values of the meteorological conditions outside the harvesting area (Marjamaki et al, 2000).

The data were processed using GIS mapping. Remote sensing mapping was performed using the satellite images of the satellite Sentinel-1, multispectral instrument (MSI) and thermal infrared sensor (TICHS) optical multispectral data in order to assess the features of the spatial distribution of temperature fields and soil moisture (Sakhatsky et al. 2007).

Results and Discussion. The data of scanning the heterogeneity of the temperature field distribution, as well as the humidity of the earth's surface in the Tiaret region was performed using the infrared radar of the Sentinel-2A/MSI Image satellite from November 4, 2018 are shown in Figure 2.



a b

Fig. 2. Maps of temperature fields (a) and soil moisture (b) spatial distribution

The analysis of the temperature fields and humidity data of the Tiaret region shows a rather uniform spatial distribution of these parameters. It was necessary to assess the possible risks associated with dry or wet deposition of dust particles suspended in the surface layer, as well as to determine the places of formation of surface runoff of the analyzed area, taking into account the fact that the surface of the city of Tiaret is covered with both asphalt and stone blocks (Fig. 3).

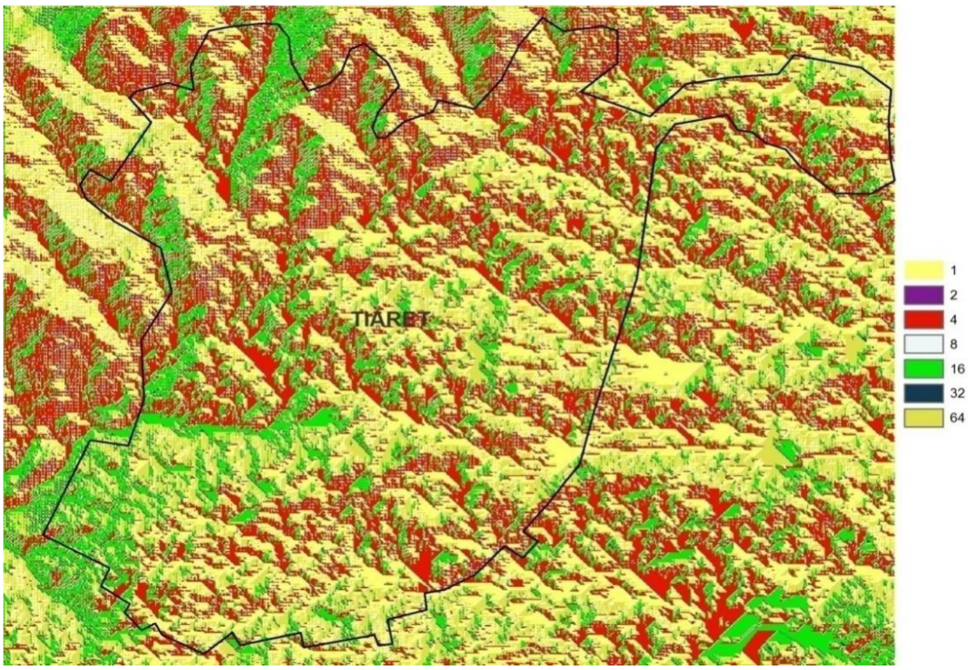
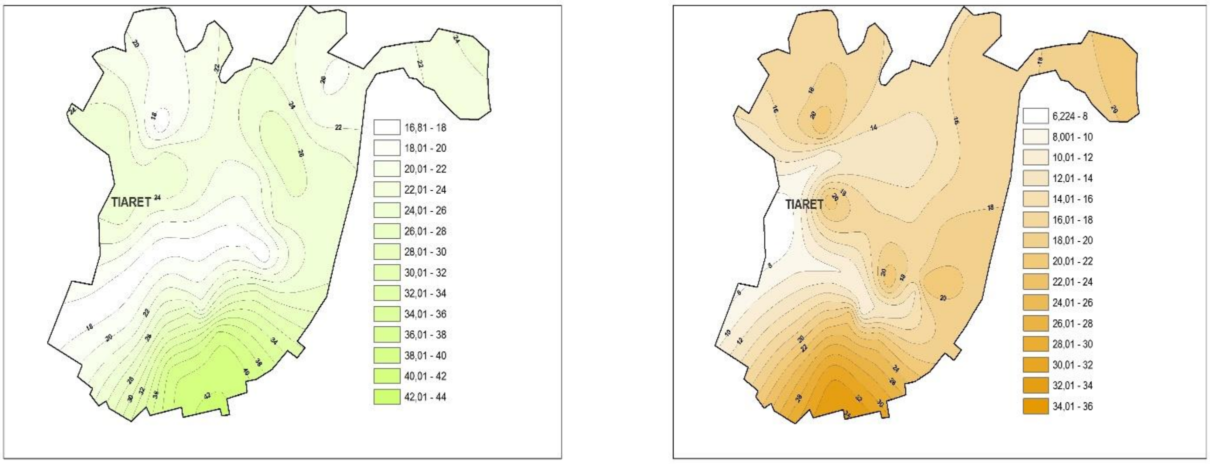


Fig. 3. Map of surface runoff, relative to the height above sea level in the city of Tiaret, m

It is necessary to take into account that the map of surface runoff was built taking into account the digital map of the terrain and the situation of the hydrographic network in the Tiaret region. Elevation changes in the area relative to sea level range from 1 to 16 meters. Comparison of the data allows us to note a sufficiently large dissection of the terrain in the city. This means that depending on the seasonal precipitation, the surface will be cleaned, creating additional risks of contamination by toxicants after they enter open water bodies.

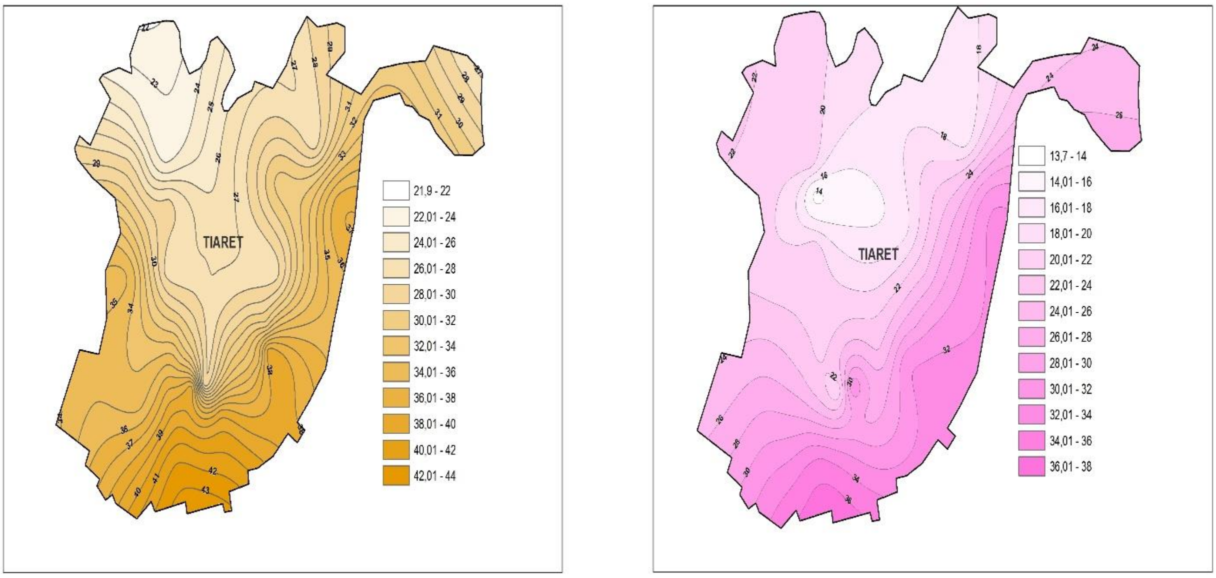
The results of determining the concentration of $PM_{2.5}$ suspended in the surface atmosphere layer of the city of Tiaret, performed during the school day in the autumn – winter period are shown in Fig.4-6.



a b

Fig. 4. Isolines of $PM_{2.5}$ from 7 to 9 am (μg/m^3) in the autumn – winter period
(a) in the presence of pupils (b) in the absence of pupils

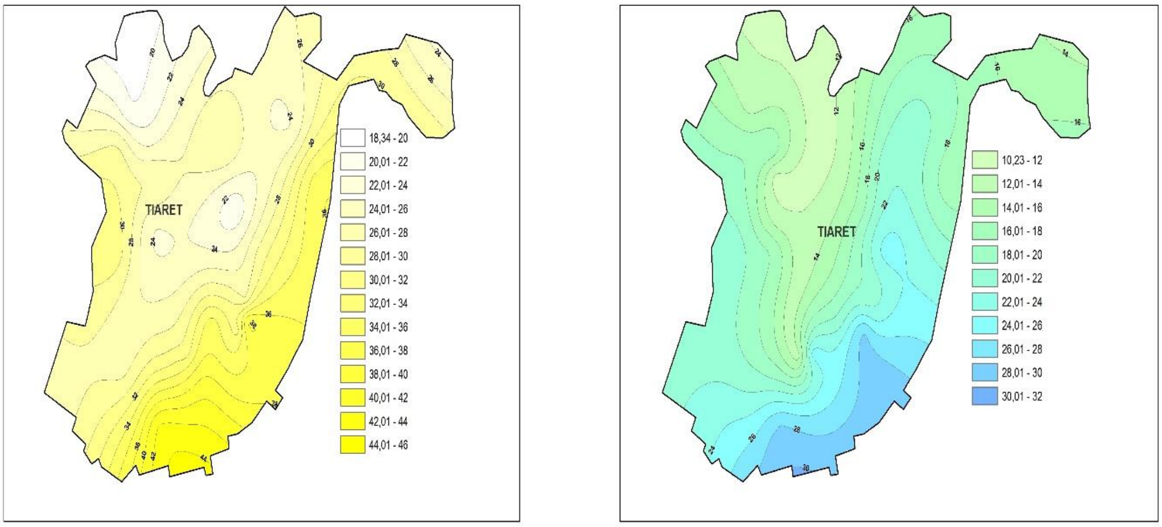
According to the data obtained, the excess of air pollution in the school yards of the city in the morning (from 7am to 9 am) after a short stay by pupils equals 1.5 – 2 times.



a b

Fig. 5. Isolines of $PM_{2.5}$ at noon from 11am – to 1 pm) (μg/m^3) in the autumn – winter period
(a) in the presence of pupils (b) in the absence of pupils

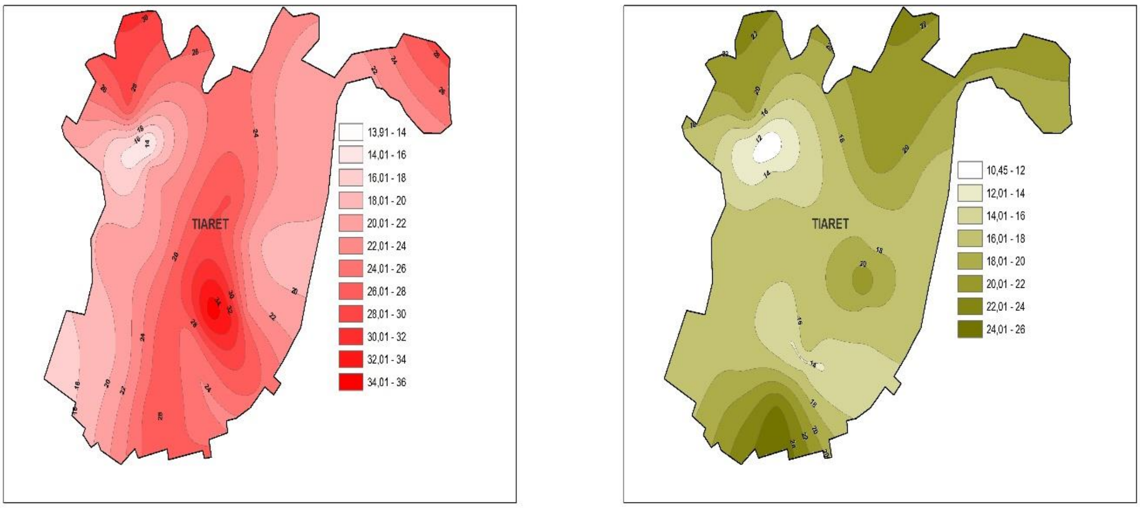
At noon, the above pattern is maintained. Comparison of the data of spatial air pollution from 3:30pm – 5:30 pm reveals a large differentiation in the distribution of $PM_{2.5}$ in the South - Eastern part of the city during the absence of schoolchildren from the school yards (Fig.6).



a b

Fig. 6. Isolines of $PM_{2.5}$ afternoon from 3:30pm – 5:30 pm) ($\mu g/m^3$) in the autumn – winter period
(a) in the presence of pupils (b) in the absence of pupils

The results of determining the concentration of $PM_{2.5}$ suspended in the surface layer of the atmosphere of the city of Tiaret, performed during the school day in spring – summer period are shown in Fig.7-9.



a b

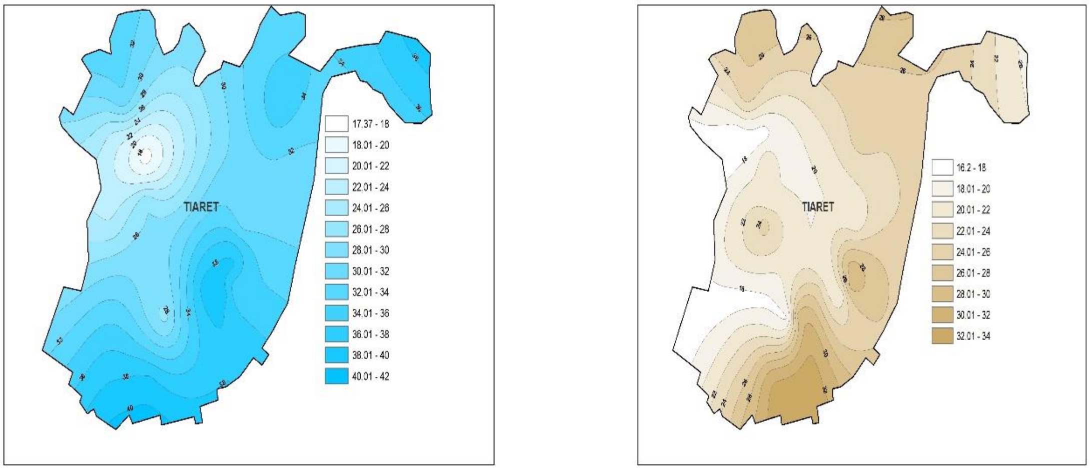
Fig. 7. Isolines of $PM_{2.5}$ from 7 to 9 am ($\mu g/m^3$) in the spring –summer period
(a) in the presence of pupils (b) in the absence of pupils

It is interesting to note that in the spring and summer the situation with the spatial distribution of $PM_{2.5}$ in the morning (from 7 to 9 o'clock in the morning) remained, but the overall level of pollution decreased in comparison with this in the autumn by up to 1.5 times.

In the middle of the day, the overall level of pollution in the school yards of the city increased and became comparable to that in the autumn winter time. However, the character of the spatial distribution of dust particles in the spring - summer period was different.

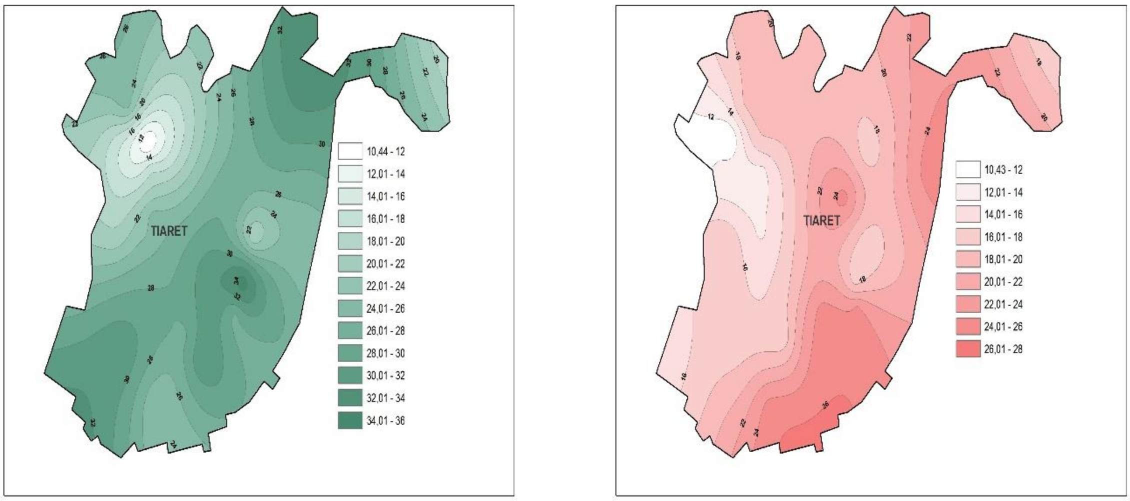
The data obtained are consistent with the results of other researchers about the increased risk of contamination of the ground layer of air and associated health problems in particular with the manifestation of asthma, allergies and shortness of breath (Gasana et al., 2012) in high traffic areas (Henschel et al, 2012; Cohan et al, 2013) and near industrial areas (Dunea et al, 2016, Wawroś, 2003). Analysis of maps of air pollution in the autumn - winter period makes it possible to assert that lower concentrations are recorded in the areas adjacent to forest plantations in the

North - Western part of the city. However, in summer, the protective function of the forest stands in the North-Western part of the city of Tiaret is less evident. According to Chinese scientists (Chen et al, 2016), obtained in the conditions of the Beijing metropolis, forest stands have many protective functions, including purification of the atmosphere due to adsorption of $PM_{2.5}$, providing better air quality than in uncovered areas.



a b

Fig. 8. Isolines of $PM_{2.5}$ at noon from 11am – to 1 pm) ($\mu g/m^3$) in the spring –summer period (a) in the presence of pupils (b) in the absence of pupils



a b

Fig. 9. Isolines of $PM_{2.5}$ afternoon from 3:30 – 5:30 pm) ($\mu g/m^3$) in the spring –summer period (a) in the presence of pupils (b) in the absence of pupils

Conclusions. The trend of exceeding the acceptable level of air pollution by $PM_{2.5}$ up to 1.5-2 times was observed in the open areas of schools during the presence of schoolchildren in both seasons. The $PM_{2.5}$ concentration in the autumn - winter period was up to 1.5 times higher than that of the spring – summer time. High concentrations were observed in areas close to heavy traffic in the autumn-winter period. Meantime, low $PM_{2.5}$ concentrations were recorded in areas adjacent to forests in the North – Western part of the city of Tiaret.

The need for introduction of several nature protection measures in the city is obvious. Among them: fuel quality control and fines for use of low-grade fuel , increasing the density of trees and shrubs in the city in the areas uncovered by vegetation.

References

Ait Bouh H, Benyaich F, Bounakhla M, Noack Y, Tahri M, Zahry F.. 2012. Seasonal variations of the atmospheric particles and its chemical components in Meknes city - Morocco:2028-2508 (in French)

Chen B., Lu S., Zhao Y., Li s., Yang X., Wang B., Zhang H.. 2016. Pollution Remediation by Urban Forests: $PM_{2.5}$ Reduction in Beijing, ChinaPol. J. Environ. Stud. Vol. 25, No. 5: 1873-1881. DOI: 10.15244/pjoes/63208

Capasso, L., Longhin, E., Caloni, F., Camatini, M. and Gualtieri, M. 2015. Synergistic inflammatory effect of PM10 with mycotoxin deoxynivalenol on human lung epithelial cells. Toxicon 104: 65–72. https://doi.org/10.1016/j.toxicon.2015.08.008

Carlson, T., Arthur S.. 2000. The impact of land use - Land cover changes due to urbanization on surface microclimate and hydrology: A satellite perspective. Global Planet. Change 25:49–65. doi:10.1016/S0921-8181(00)00021-7

Cohan, A., Eiguren-Fernandez, A., Miguel, A.H., Dabdub, D. 2013. Secondary organic aerosol formation from naphthalene roadway emissions in the South Coast Air Basin of California, International Journal Environment and Pollution, 52, (3/4), 206-224. DOI: 10.1504/IJEP.2013.058461

Dunea D., Iordache S., Liu H.Y., Bøhler T., Pohoata A., Radulescu C. 2016. Quantifying the impact of $PM_{2.5}$ and associated heavy metals on respiratory health of children near metallurgical facilities. Environ Sci Pollut Res. 23:15395–15406. doi: 10.1007/s11356-016-6734-x

Farah A., Freney E., Chauvigné A., Baray J.L., Rose C., Picard D., Colomb A., Hadad D. , Abboud M. , Farah W., Sellegri K. 2018. Seasonal Variation of Aerosol Size Distribution Data at the Puy de Dôme Station with Emphasis on the Boundary Layer/Free Troposphere Segregation Atmosphere 9, 244. p.1-25. doi:10.3390/atmos9070244

Franklin M., Koutrakis P., Schwartz P. 2008. The role of particle composition on the association between $PM_{2.5}$ and mortality. Am J Epidemiol. 19, 680-689 https://www.jstor.org/stable/25662615

Gasana J., Dillikar D., Mendy A., Forno E., Ramos Vieira E. Motor vehicle air pollution and asthma in children: a meta-analysis. Environ Res. 2012. Aug;117:36-45. doi: 10.1016/j.envres.2012.05.001

Glen, W. G., M. P. Zelenka, and R. C. Graham, 1996. Relating meteorological variables and trends in motor vehicle emissions to monthly urban carbon monoxide concentrations. Atmos. Environ., 30(24), 4225 – 4232. https://doi.org/10.1016/1352-2310(96)00130-6

Han L, Zhou W., Li W., Li D.T. Zheng M.. 2015..Meteorological and urban landscape factors on severe air pollution in Beijing, Journal of the Air & Waste Management Association, 65:7, 782-787. DOI: 10.1080/10962247.2015.1007220

Henschel S, Atkinson R,, Zeka A, Le Tertre A,, Analitis A., Katsouyanni K. Chanel O., Pascal M., Forsberg B., Medina S., Goodman P.G.. 2012. Air pollution interventions and their impact on public health. Int J Public Health 57:757–768. DOI:10.1007/s00038-012-0369-6

Kasbadji Merzouk N. 1999. Carte des Vents de l'Algérie - Résultats Préliminaires. Rev. Energ. Ren. : Valorisation p.209-214

Marjamäki M, Keskinen M, Chen D-R, Pui D.Y. H. .2000. Performance evaluation of the electrical low - pressure impactor (ELPI) Journal of Aerosol Science, 31, p. 249-26. https://doi.org/10.1016/S0021-8502(99)00052-X

Myhre G. 2009. Consistency between satellite-derived and modeled estimates of the direct aerosol effect. Science. 325, 187-190. DOI: 10.1126/science.1174461

Pope C.A., Dockery D.W. 2006. Health effects of fine particulate air pollution: Lines that connect. J Air Waste Manag Assoc. 56, 709-742, Health effects of fine particulate air pollution: Lines that connect. https://doi.org/10.1080/10473289.2006.10464485

Sakhatsky O. I., StankevichS. A., 2007. Do mozhlyvostei otsiniuvannia zvolozhenosti zemnoho pokryttia za bahatospektralnymy kosmichnymy zobrazhenniamy optychnoho diapazonu na prykladi terytorii Ukrainy [On the possibilities of land cover moisture parameters determination using multispectral optical satellite images data on the example of Ukraine]. Reports of the National Academy of Sciences of Ukraine 11, 122-128 (in Ukrainian) http://dopovidi-nanu.org.ua/uk/archive

Tang X.Y., Zhang Y.H., Shao M. 2006. Atmosphere Environmental Chemistry. Book, Higher Education Press, Beijing, China, 268p.

Yu J., Guinot B. ,, Yu T., Wang X., Liu W. 2005. Seasonal Variations of Number Size Distributions and Mass Concentrations of Atmospheric Particles in Beijing. Advances in Atmospheric Sciences, Vol. 22, № 3. 401–407. DOI: 10.1007/BF02918753

Wawroś A., Talik E. , Żelechower M. , Pastuszka J. S. , Skrzypek D., Ujma Z. 2003. Seasonal Variation in the Chemical Composition and Morphology of Aerosol Particles in the Centre of Katowice, Poland. Polish Journal of Environmental Studies Vol. 12, No. 5: 619-627

Ward D.J., Ayres J.G. 2004. Particulate air pollution and panel studies in children: a systematic review. Occup Environ Med 61:13. http://dx.doi.org/10.1136/oem.2003.007088

Zerrouki D., Maatoug M , Mokhtar A., Chaker I., Kharytonov M. 2017. Pollution of agricultural land by naphthalene of roadside origin. Scientific Study & Research Chemistry & Chemical Engineering, Biotechnology, Food Industry. 18 (2), p. 181 – 190.