Temperature Effect on Particulate Matter Concentrations PM 10 during the heating season in Burgas

F B Hasan¹, B N Midyurova¹ and T M Mihalev²
¹ Burgas “Asen Zlatarov” University, Faculty of Natural Sciences, Department of Ecology and Environment Protection
² Executive agency for the environment, Burgas, Bulgaria

e-mail: blagi77@abv.bg

Abstract. In the present paper, the dynamics of particulate matter (PM) concentration during the heating season was studied with respect to the seasonal dynamics of the temperature recorded at two measuring sites from the National system for monitoring of air quality in Burgas. The automated measuring stations (AMS) selected for the present study are located in Dolno Ezerovo (DE) and Meden Rudnik (MR) in the municipality of Burgas. This study looks at the impacts of Temperature on localised PM10 concentrations in an urban area of Burgas over the winter period. The levels of PM 10 pollution is an important characteristic for the quality of life in urban environment. The main source of PM 10 emissions is considered to be the domestic heating with wood which varies with the values of the temperature during the heating season.

1. Introduction
Environment protection on the whole is undoubtedly necessary and important but the main efforts of the world community should be focused on the protection and improvement of the quality of main components of the environment. One of them, moreover the most mobile one and for this reason exerting the strongest effect on the others is air [1]. Air pollution and particularly the concentration of particulate matter (PM) is harmful for human health [2]-[4] and results in increased mortality rate [5], [6]. The World Health Organization (WHO) recommends allowable limit of PM10 to be 20 μg/m3 (annual average) to reduce the harmful effects on human health [7]. The studies of Ostro and Hodas [8], [9] showed that PM2.5 is the more harmful part of PM10. The national ecologic standards (NES) for air quality comply with the limits set by WHO for PM10 (daily limit for PM10 of 50 μg/m3) [10]. The studies of Barmpadimos [11] and Giri [12] proved that the PM10 concentration is not just product of the concentrations of the different emissions but it is affected by the processes of diffusion. In turn, the diffusion of particulate matter depends on the geographical and meteorological conditions. The meteorological conditions which can affect PM10 concentration are wind, temperature, precipitation and relative humidity [13].

In the present paper, the influence of temperature on the PM10 concentarion in the town of Burgas is studied. The variations in the PM10 concentration were analysed for the period of the cold season which is from October until March for the years 2017, 2018, 2019 and 2020 [14]-[16]. The influence of the ecologic pressure exerted by PM 10 is estimated, as well as the atmospheric air pollution resulting from the temperature differences at the two sites where the samples were taken – Dolno ezerovo quarter (figure 1) and Meden Rudnik quarter (figure 2) during the heating seasons 2017-2020.
2. Materials and Methods
The data were collected during the 6-month period from October until March for the four years 2017-2020. The analysis of particulate matter was carried out by Thermo Scientific aiming to ensure continuous and simultaneous measurements of PM10 concentration. The equipment contained optical particle counter which converts from number to mass parts using patented algorithm. The range of the sensor unit was PM1 0-200 μg/ m³; PM2.5 0- 000 μg/ m³; PM10 0-5000 μg/ m³; TSP 0-5000 μg/ m³, with precision < ± 5 μg/ m³ + 15% from the measured values.

For the present measurement of PM10, the method of absorption of β-rays was used. This method describes measurement of the mass concentration of particulate matter present in the atmospheric air on the basis of the absorption of β-rays by these particles. The concentration of particles is calculated by the mass of the dust deposited on a filter band and the volume of sampled air passed through it. The aim of the method is to determine the dust concentration in the range from several μg/m³ to several mg/m³ in the atmosphere in the settlements. The profiles are fixed 3.3 m above the ground. The distance to the nearest building is approximately 15 m. The meteorological data are registered by meteorological station mounted 10 m above the ground.

The observations were carried out at two sites, as shown in Figs. 1 and 2.

![Figure 1](image1.png)  ![Figure 2](image2.png)

**Figure 1.** Locations of the analysis sites used for the study - Dolno ezerovo quarter.

**Figure 2.** Locations of the analysis sites used for the study - Meden Rudnik quarter.

The filter is measured before taking the samples. When taking samples, the β-ray absorption is registered. At the end of the period of sample taking, the filter is moved to a new part of the filter. Description of the main components of the system for separate sampling and analysis: the first part of the system is designated for taking particulate matter samples; the second part is the system for measuring the β-ray absorption. It is of crucial importance to record the average values of the temperature and atmospheric pressure during the sampling in order to make it possible to normalize the sample volume. The results obtained from the measurements are expressed in μg/m³ or mg/m³ by dividing the values of the mass measured by the β-ray absorption to the volume of the air sample adjusted to normal conditions during the sampling. The design of the meteorological station is presented in Figs. 3, 4 and 5.
3. Results and discussion

The effect of the higher temperatures on the PM10 concentrations can be explained with the process of thermally induced convection. During the warm months, the wind gusts are more frequent which results in increased diffusion of particulate matter [17]. In the cold months, the lower temperature often creates temperature inversion which acts as surface layer which inhibits the particulate matter. The condensation of volatile compounds and the increased wood burning are other possible reasons for the increased concentration of PM10. The data about the annual average values of the main pollutants in the atmospheric air in µg/m³ measured in Meden Rudnik quarter are summarized in Tables 1 and these for Dolno Ezerovo – in Table 2. The mean annual rainfall 1.240 mm and mean annual wind speed 3.9 m/s.
A steadfast tendency was observed for the whole week and the highest ratio was observed in January, February (average of 89% and 91%, respectively) and the lowest values were registered in October and November for the four years studied (average values of 23% and 30%).

Table 1. Minimal and maximal annual average values of the min pollutants of the atmospheric air in µg/m³ measured in Meden Rudnik.

|       | NO₂ | O₃  | SO₂ₖ | PM10 | CO     | benzol |
|-------|-----|-----|------|------|--------|--------|
| 2020  | 8.5-12.4 | 3.1-3.6 | 19.4-21.3 | 18-27 | 0.2-0.3 | 0.2-0.5 |
| 2019  | 9.3-10.7 | 28-63  | 10.8-15 | 18. -19 | 0.2-0.3 | 0.7-0.8 |
| 2018  | 12-17   | 36-54  | 8.7-10.5 | 15-22 | 0.2-0.5 | 0.7-1.9 |

Table 2. Minimal and maximal annual average values of the min pollutants of the atmospheric air in µg/m³ measured in Dolno Ezerovo.

|       | NO₂ | O₃  | SO₂ₖ | PM10 | CO     | benzol |
|-------|-----|-----|------|------|--------|--------|
| 2020  | 17.2-19.1 | 43-59  | 11-11.5 | 31-53 | 0.2-0.3 | 0.3-0.4 |
| 2019  | 12.9-14.5 | 44-55  | 8.6-12.2 | 34-40 | 0.2-0.3 | 0.4-0.7 |
| 2018  | 13.4-16.8 | 55-73  | 6.7-11.3 | 38-55 | 0.2-0.3 | 0.3-0.8 |

The anthropogenic sources of sulfur compounds are from the energy and thermal power industries and the pollution is caused mainly by the burning of coal and petroleum products. There are no such factors at the sites of sampling; the sulfur dioxide as a gas classified as industrial pollutants is present in the air throughout the year and its values are affected by factors different from these for PM10. The nitrogen oxides emissions came mainly from the road transport traffic – internal combustion engines. The carbon monoxide emissions in the atmosphere come mainly from the incomplete combustion of wood, coal and liquid fuels with transport vehicle being the main source and smaller portion from the household heating. The data analysis periods cover mathematical averaged data for previous years – 2017, 2018, 2019 and 2020. On their basis, graphical plot was drawn showing the distribution of PM 10 pollution levels and temperatures during the months studied – figure 6 (DE) and figure 7 (MR).

Figure 6. In this case simply justify the caption so that it is as the same width as the graphic.
As a result from the studies carried out and the estimation for 2019m the following facts were established: AMS D.E. In October, the difference PM\textsubscript{10}/T was 2 times, in November there was no difference PM\textsubscript{10}/T, in December the difference PM\textsubscript{10}/T was 25 times which means that the PM\textsubscript{10} emissions was not only formed by the domestic heating, in January PM\textsubscript{10} was 34,2%↑, i.e. 89,39%↑, which indicates that the domestic heating is not the only source of PM\textsubscript{10}, in February there was no difference PM\textsubscript{10}/T, in March PM\textsubscript{10} was 8,8%↓ while at the same time T was 9,14%↓ which indicates that the PM\textsubscript{10} emissions was not generated only by the domestic heating. It can be summarized that only in November and February the PM\textsubscript{10} was generated by the domestic heating. Obviously, there is another source of PM\textsubscript{10} in October, December, January and March which forms the pollution levels measured.

![Annual averaged data for PM\textsubscript{10} at MR](image)

**Figure 7.** In this case simply justify the caption so that it is as the same width as the graphic.

AMS MR October PM\textsubscript{10} was 1,48%↓, T was 6,77%↓, which indicates that the PM\textsubscript{10} emissions were not formed only by the domestic heating, in November PM\textsubscript{10} was 11,6%↓, T was 23,75%↑, which also indicates that the domestic heating is not the only source of PM\textsubscript{10}. The same tendency was observed for December PM\textsubscript{10} was 2,87%↓, T was 23,8%↑, January PM\textsubscript{10} was 17,48%↓, T was 29,82%↑, in February PM\textsubscript{10} was 27,06%↑, T was 10,11%↑ and in March PM\textsubscript{10} was 73,66%↑, T was 5,27%↓.

It can be summarized that no unequivocal numerical evidence were found that the PM\textsubscript{10} emissions are formed only by the domestic heating. The annual tendency for the two sites is related to the decrease of PM\textsubscript{10} levels with the increase of the temperature differences.

4. Conclusions

The meteorological conditions and particularly the temperature and the levels of PM\textsubscript{10} concentration in Burgas were monitored during the 6-month period of household heating. The results obtained were analyzed to find the relationship between the temperature and PM\textsubscript{10} concentration. The average values of PM\textsubscript{10} remained within the allowable limits of 20 μg/m\textsuperscript{3} during the heating season. It was found that the decrease of temperature has negative effect on PM\textsubscript{10} levels within the period of January and February.
It was realized during the present study that the future studies should be focused on the analysis of the meteorological variables which form a part of a complex system. The further studies should be focused on the involvement of other factors, e.g. wind direction and strength, precipitation and others which are characteristic for each region and their influence on the PM10 concentration for longer periods.

References

[1] Smith S K The global burden of disease due to outdoor air pollution 2005 *J. Toxicol. Environ. Health* **68** 1-7

[2] Donaldson K, Stone V, Seaton A, Mac Nee W Ambient particle inhalation and the cardiovascular system: potential mechanisms 2001 *Environ. Health Persp* **109** 523-527

[3] Pope C, Bates D, Raizenne M Health effects of particulate air pollution: time for reassessment? 1995 *Environ. Health Persp* **103** 472–480

[4] Puett R, Hart J, Yanosky J, Spiegelman D, Wang M, Fisher J, Hong B, Laden F Particulate Matter Air Pollution Exposure, Distance to Road, and Incident Lung Cancer in the Nurses’ Health Study Cohort 2014 *Environ. Health Persp* **122** 926-932

[5] Dockery D, Pope C, Xu X, Spengler J, Ware J, Fay M, Ferris B, Speizer F An association between air pollution and mortality in six U.S. cities. 1993 *N. Engl. J. Med* **329** 1753-1759

[6] Hales S, Blakely T, Woodward A. Air Pollution and mortality in New Zealand: cohort study. 2010 *J Epidemiol Community Health* **66** 468-473.

[7] World Health Organization. WHO Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide 2006 *Global update* pp 8

[8] Ostro B, Hu J, Goldberg D, Reynolds P, Hertz A, Bernstein A, Kleeman M Associations of mortality with long-term exposures to fine and ultrafine particles, species and sources: Results from the California teachers study cohort 2015 *Environ. Health Persp* **123** 549-556

[9] Hodas N, Meng Q, Lunden M, Rich D, Özkaynak H, Baxter L, Turpin B Variability in the fraction of ambient fine particulate matter found indoors and observed heterogeneity in health effect estimates 2012 *J. Expo. Sci. Environ. Epidemiol.*, **22** 448-454

[10] Ministry for the Environment (New Zealand). Ambient Air Quality Guidelines, 2002 Update. 2012. Available: http://www.mfe.govt.nz/sites/default/files/ambient-guide-may02.pdf

[11] Barmpadimos I, Hueglin C, Keller J, Henee S, Précôt A Influence of meteorology on PM10 trends and variability in Switzerland from 1991 to 2008 2011 *Atmo. Chem. Phys* **11** 1813-1835

[12] Giri D, Krishna V, Adhikary P.R The influence of meteorological conditions on PM10 concentrations in Kathmandu Valley. 2008 *Int. J. Environ. Res.* **2** (1) 49-60

[13] Hien P, Bac V, Tham H, Nhan D, Vinh L Influence of meteorological conditions on PM2.5 and PM2.5-10 concentrations during the monsoon season in Hanoi, Vietnam 2002 *Atmos. Environ* **36** 3473-3484

[14] Clean Air Act: Ministry of Environment and Water and Ministry of Health 2012 *State Gazette* p 356

[15] Ljubojev N, Veselinovic J, Mijatovic M Protection of the Quality of Air in the Legislation of the Republic of Serbia as a Process of Harmonisation with the EU Legislation 2013 *Oxid Commun*, **36** 4 p 1217

[16] Air Quality in Burgas, Burgas Municipality, http://air.burgas.bg

[17] Pepper I, Gerba C, Brusseau M. Environmental and pollution science, second ed. *Academic Press*, Canada, 2006