Seasonal variability of PM concentration in Tashkent

Mansur Amonov¹,² and Bakhridin Nishonov²
¹Tashkent institute of irrigation and agricultural mechanization engineers, 39 Kari Niyazov Street, Tashkent 100000 Uzbekistan
²Hydro meteorological research institute, 72 1st Bodomzor Yuli Street, Tashkent 100052 Uzbekistan
E-mail: m.amonov@tiiame.uz

Abstract. Several hundred cities of the world, have announced goals to become “smart” cities that include environmental sustainability, health, climate-resiliency and livability. Tashkent is capital city of Uzbekistan can count a candidate to the list of “smart” environmentally-sustainable, healthy and livable cities. To investigate the ambient mass concentration, size-distribution and seasonal variability of atmospheric particulate matter (PM), a long-term monitoring campaign was undertaken at an urban background site of Tashkent city during 3 year period (December 1, 2011- November 30, 2014). Goal of the current paper is to analyze the seasonal variations of PM₁₀ and PM₂.₅ concentration in the ambient air of the city. Monitoring of PM was carried out according to requirements of European standards and during monitoring, a low-volume PNS 16T-3.1 sampler, as well as quartz and fiberglass filters with a diameter of 47 mm, were used. Diurnal concentration of particles in atmospheric air was determined by the gravimetric method. The PM concentration levels varied greatly, with higher mean mass concentrations during the heating season. For whole monitoring period average concentration of PM₂.₅ was 29.3±13.5 μg/m³ and PM₁₀ was 55.4±21.7 μg/m³ and that is under interim target values but higher than WHO recommended value (respectively equal to 10 μg/m³ and 20 μg/m³). Wintertime observed high concentration of PM compared to summer and spring (average PM₂.₅ = 42.0 μg/m³ and PM₁₀ = 63.7 μg/m³). Sprinertime observed lower concentration of PM (average PM₂.₅ = 22.3 μg/m³ and PM₁₀ = 45.9 μg/m³). Highest concentration of PM was observed in February (average PM₂.₅ = 45.0 μg/m³ and PM₁₀ = 67.8 μg/m³) and lowest in June (average PM₂.₅ = 19.6 μg/m³ and PM₁₀ = 41.7 μg/m³).

1. Introduction
The concept of a “smart” city was formed under the influence of a number of factors and projects on a “smart” city are being implemented in many cities of the world [1]. According to the UN, by 2030 more than 80% of the world's population will live in cities. This will entail a shortage of various resources, the amount of various kinds of waste and environmental pollution will increase, and other social and economic problems will aggravate [2]. By creating a “smart” city it will be possible to ensure the sustainable development of urban infrastructures, the premise of which is the integration of information and communication technologies in city management. Tashkent is capital city of Uzbekistan can count a candidate to the list of “smart” environmentally-sustainable, healthy and livable cities. In Uzbekistan adopted a program for 2020, there given special attention to development digital economy and in the public transportation system of Tashkent city already started introduction some elements of “smart” city.
One of the key elements in managing a “smart” city is ensuring environmental safety, which should be based on the implementation of effective monitoring of environmental pollution [3].

Scientists from developed countries began to pay attention to the problem of particulate matter (PM) air pollution in megacities from about the mid 80-90s of the twentieth century. By that time, the concentrations of the most common pollutants had decreased in the atmospheric air of cities in developed countries due to the prohibition of leaded gasoline in vehicles, switching to gas and other more environmentally friendly fuels. At the same time, a serious problem was identified with particulate air pollution and extensive studies of their impact on the health status and on the environment as a whole began [4]. To date, the World Health Organization (WHO) recommends that coarse particles PM$_{10}$ (particles smaller than 10 microns) and fine PM$_{2.5}$ (particles smaller than 2.5 microns) be classified as priority air pollutants [5]. In the Republic of Uzbekistan, the Center for Hydrometeorological Service (Uzhydromet) in monitoring sites regularly monitors the concentration of solid particles (dust) in the air without separation into coarse PM$_{10}$ and fine PM$_{2.5}$ particles [6].

It is known that PM$_{10}$ can penetrate the bronchial tree and accumulate in the tissues of the lungs; PM$_{2.5}$ can reach bronchioles and alveoli, and the smallest nanoparticles penetrate the bloodstream. The results of many studies conducted in different countries of the world indicate a relationship between increased levels of PM and an increase in cases of respiratory and cardiovascular diseases, as well as a decrease in life expectancy and an increase in premature mortality [7, 8, 9]. In addition to effects on human health, small particles also affect the radiation balance of the earth-atmosphere system and, therefore, affect the weather and climate, absorbing, reflecting and scattering radiation. Under certain conditions, particles suspended in the air can lead to a significant decrease in the visibility and crops yield [10, 11].

In 2007-2010, as part of research projects, researchers conducted pioneering short-term monitoring of PM$_{10}$ and PM$_{2.5}$ in the air of Tashkent [12,13]. On August 1, 2011 Uzhydromet began a longer monitoring of the concentration of PM$_{10}$ and PM$_{2.5}$ in a single site in Tashkent, using a sampler with an automatic filter replacement system [14]. The purpose of this article is to analyze the seasonal variations of PM$_{10}$ and PM$_{2.5}$ concentration in Tashkent during 3 year period (December 1, 2011-November 30, 2014).

2. Methods
A set of samplers (1 pc for PM$_{2.5}$ and 1 pc for PM$_{10}$) was installed at one of oldest meteorological site of Uzbekistan “M1 Tashkent-Observatory”. This site is located close to geographical center of Tashkent on the territory of Uzhydromet and nearby the site, in addition to the buildings of Uzhydromet, is the buildings of the Institute of Astronomy, the International Institute of Solar Energy, as well as apartment buildings and houses where the population lives. In the northeast, approximately 1.5 km away is located a Paint factory.

Monitoring of PM$_{10}$ and PM$_{2.5}$ was carried out according to requirements of European standard [15] and during monitoring a low-volume PNS 16T-3.1 sampler (Derenda GmbH, Germany) as well as quartz and fiberglass filters with 47 mm diameter, were used. The concentration of coarse and fine particles in atmospheric air was determined by the gravimetric method. The sampler is equipped with a rotary vane vacuum pump with a capacity of up to 4 m$^3$/h. When sampling air, in order to determine the concentration of PM$_{10}$ and PM$_{2.5}$, the pump was operated at air speed of 2.3 m$^3$/h. Before sampling begins, the desired settings are entered in the control unit, and the filter magazine is placed in the filter changer. Once the operating cycle is activated, sampling takes place automatically according to the set parameters. During operation the vacuum pump draws in air laden with fine particulate matter through the sampling inlet. The dust particles are fractionated by size in the sampling inlet with impactor. The particles of desired fraction are then deposited on the sampling filter in the sampling position. At the end of the sampling period, the loaded filter is automatically placed in the store, and the new filter is transferred to the sampling position for next cycle.

The volumetric flow rate is measured with an orifice plate and electronically adjusted with an accuracy of $\leq$ 2%. The ambient climatic conditions are continuously monitored by temperature and
humidity sensors. The optional Peltier cooler ensures that the laden filter storage temperature in the unit does not exceed 23°C.

During operation, the filter number, the initial and final sampling times, air flow, pressure, temperature and humidity are recorded and stored in the internal memory. Data additionally copied to an SD card.

The weight of the filters used during monitoring before and after sampling was measured on an analytical balance with high accuracy (10^-6 g) XP-26DR (Mettler-Toledo GmbH, Switzerland).

3. Results and discussion

Table below shows average annual mean concentration of the particles in ambient air in Tashkent over the monitoring period. As can be seen from the table, average annual concentration of fine PM$_{2.5}$ particles exceeds the WHO recommended value, and it is on the border between interim target value 1 and 2. The concentration of PM$_{10}$ shows also an excess of the WHO recommended value. Maximum exceeds of PM$_{2.5}$ annual mean concentration was equal to 34.9 μg/m$^3$ and it is observed in the first year, for PM$_{10}$ almost the same excess was observed in the first (57.0 μg/m$^3$) and third year (57.3 μg/m$^3$). The PM$_{2.5}$/PM$_{10}$ ratio, respectively, was equal to 0.61 in the first year, 0.51 in the second year, 0.47 in the third year and average value for three years equal to 0.53. For comparison in Tehran annual PM$_{2.5}$ mean concentration in 2012 was equal to 36.0 μg/m$^3$, annual mean concentration of PM$_{10}$ in 2013 was equal to 90.0 μg/m$^3$ [16]. The annual average PM$_{2.5}$ concentration in Bagdad in 2013 was 50.0 μg/m$^3$ [17].

| PM | Monitoring period | Measured days | Annual mean (μg/m$^3$) | Max (μg/m$^3$) |
|----|------------------|---------------|------------------------|---------------|
| PM$_{2.5}$ | 1.12.2011-30.11.2012 | 364 | 34.9±14.3 | 132.4 |
|  | 1.12.2012-30.11.2013 | 365 | 26.7±11.9 | 109.8 |
|  | 1.12.2013-30.11.2014 | 360 | 26.6±13.3 | 126.3 |
|  | For 3 year | 1089 | 29.3±13.5 | 132.4 |
| PM$_{10}$ | 1.12.2011-30.11.2012 | 360 | 57.0±19.6 | 225.9 |
|  | 1.12.2012-30.11.2013 | 365 | 52.0±21.2 | 164.6 |
|  | 1.12.2013-30.11.2014 | 357 | 57.3±24.0 | 235.4 |
|  | For 3 year | 1082 | 55.4±21.7 | 235.4 |

To better reveal the most polluted seasons and months in Tashkent, seasonal and monthly concentrations of particulate air pollutants were investigated. Four seasonal periods were examined as following: winter (December 1 to February 28/29), spring (March 1 to May 31), summer (June 1 to August 31), autumn (September 1 to November 30).

In the fig 1 is possible to see seasonal variations of ambient PM$_{2.5}$ and PM$_{10}$ concentrations in Tashkent during whole study period (1.12.2011–30.11.2014).

Because of heating, unfavorable meteorological conditions, including stagnant weather, reduced sunshine time, temperature inversion and lower the boundary layer during the coldest seasons and months observed high concentration of PM compared to summer and spring months (winter time average PM$_{2.5}$ = 42.0 μg/m$^3$ and PM$_{10}$ = 63.7 μg/m$^3$). During the spring months observed lower
concentration of PM and it is connected to high level of precipitation during spring in Uzbekistan (spring time average $PM_{2.5} = 22.3 \, \mu g/m^3$ and $PM_{10} = 45.9 \, \mu g/m^3$). Similar conclusion was made by other researchers [18, 19, 20].

![Monthly variations of ambient PM$_{2.5}$ and PM$_{10}$ concentrations in Tashkent during the study period (1.12.2011–30.11.2014)](image)

**Figure 1.** Seasonal variations of ambient PM$_{2.5}$ and PM$_{10}$ concentrations in Tashkent during the study period (1.12.2011–30.11.2014)

Highest concentration of PM was observed in February (average $PM_{2.5} = 45.0 \, \mu g/m^3$ and $PM_{10} = 67.8 \, \mu g/m^3$) and lowest in June (average $PM_{2.5} = 19.6 \, \mu g/m^3$ and $PM_{10} = 41.7 \, \mu g/m^3$) (see fig 2).

![Temporal variations of ambient PM$_{10}$ (in left) and PM$_{2.5}$ (in right) concentrations in Tashkent during the study period (1.12.2011–30.11.2014), $\mu g/m^3$)](image)

**Figure 2.** Temporal variations of ambient PM$_{10}$ (in left) and PM$_{2.5}$ (in right) concentrations in Tashkent during the study period (1.12.2011–30.11.2014), $\mu g/m^3$

From the fig 3 and 4 can be seen that just about 5% of monitored days particulate air pollution was lower than WHO recommended value. Around 80% of monitored days PM$_{10}$ level was between 20...80 $\mu g/m^3$, and around 75% of monitored days PM$_{2.5}$ level was between 10...40 $\mu g/m^3$. 
Figure 3. Repeatability of the average daily concentration of PM$_{10}$ in Tashkent during the study period (1.12.2011–30.11.2014)

Figure 4. Repeatability of the average daily concentration of PM$_{2.5}$ in Tashkent during the study period (1.12.2011–30.11.2014)

4. Conclusion
The present study has provided an assessment of PM concentrations in Tashkent city, for whole monitoring period average concentration of PM$_{2.5}$ = 29.3 ± 13.5 μg/m$^3$ and PM$_{10}$ = 55.4 ± 21.7 μg/m$^3$
and that is under interim target values but higher than WHO recommended value (respectively equal to 10 µg/m³ and 20 µg/m³). The average PM₂.₅/PM₁₀ ratio for three years were equal to 0.53.

The seasonal concentrations of PM₂.₅ for whole monitoring period showed some variation and were relatively higher in winter (average PM₂.₅ = 42.0 µg/m³) and lower in summer (average PM₂.₅ = 22.1 µg/m³) and spring (average PM₂.₅ = 22.3 µg/m³) time. PM₁₀ concentrations were relatively higher in winter (average PM₁₀ = 63.7 µg/m³) and autumn (average PM₁₀ = 61.4 µg/m³) and lower in spring (PM₁₀ = 45.9 µg/m³) time.

Highest concentration of PM was observed in February (average PM₂.₅ = 45.0 µg/m³ and PM₁₀ = 67.8 µg/m³) and lowest in June (average PM₂.₅ = 19.6 µg/m³ and PM₁₀ = 41.7 µg/m³).

References
[1] Joss S, Sengers F, Schraven D, Caprotti F and Dayot Y 2019 The smart city as global discourse: story lines and critical junctures across 27 Cities Journal of Urban technologies 26 (1) p 3-34 doi.org/10.1080/10630732.2018.1558387
[2] Строев П и Решетников С 2017 «Умный город» как новый этап городского развития Экология в промышленности 10 (3) 207-14 doi.org/10.17073/2072-1633-2017-3-207-214 (in Russian)
[3] Ковалев Д и Кулик Е 2019 Решение задач мониторинга окружающей среды на основе интеграции ГИС-технологий в систему управления “умным городом” СГУГиТ p 231 (in Russian)
[4] Ревич Б 2018 Мелкодисперсные взвешенные частицы в атмосферном воздухе и их воздействие на здоровье жителей мегаполисов Проблемы экологического мониторинга и моделирование экосистем, 29 (3), p 53-76 (in Russian)
[5] WHO 2006 Air Quality Guidelines. Global Update 2005. Particulate matter, ozone, nitrogen dioxide and sulfur dioxide 484 p
[6] Amonov M, Claiborn C and Narbayev N 2010 Air quality monitoring and PM study results in Tashkent city, Uzbekistan Proceedings of the AWMA International Specialty Conference: “Leapfrogging Opportunities for Air Quality Improvement” (May 10-14, 2010 Xi’an, China) Xi’an, China p181-86
[7] Brook R, Rajagopalan S, Pope C, Brook J, Bhatnagar A, Diez-Roux A et all 2010 Particulate matter air pollution and cardiovascular disease. Circulation, 121 (21), 2331–78. doi.org/10.1161/cir.0b013e3181dbece1
[8] WHO 2013 Health effects of particulate matter. Policy implications for countries in Eastern Europe, Caucasus and Central Asia 15 p
[9] WHO 2014 Expert Meeting: Methods and tools for assessing the health risks of air pollution at local, national and international level Bonn, Germany, 12-13 May 2014 109 p
[10] Bergin M, Ghoroi C, Dixit D, Schauer J and Shindell D 2017 Large Reductions in Solar Energy Production Due to Dust and Particulate Air Pollution Environmental Science and Technology Letters 4 (8) p 339-344 DOI 10.1021/acs.estlett.7b00197
[11] Chameides W, Yu H, Liu S, Bergin M, Zhou X, Mearns L, et all 1999 Case study of the effects of atmospheric aerosols and regional haze on agriculture: An opportunity to enhance crop yields in China through emission controls? Proceedings of the National Academy of Sciences 96 (24) p 13626-33 DOI: 10.1073/PNAS.96.24.13626
[12] Амонов М, Клейборн К, Шалтанис Ж и Гриффин Р 2007 Тошкент шахрида атмосфер аҳоисидаги майдан учувчан заррачалар микдорини ўрганиш бўйича пилиот таджикотлар натижалари Экология хабарномаси 8, 24-26 б (in Uzbek)
[13] Амонов М, Клейборн К, Нарбаев Н и Нишонов Б 2009 Тошкент шахри атмосфер аҳоисидаги майдан заррачалар PM₁₀ ва PM₂.₅ микдори, 2008 йилги таджикотлар натижалари Экология хабарномаси 9, 36-39 б (in Uzbek)
[14] Нишонов Б, Амонов М 2018 Загрязнение атмосферного воздуха г.Ташкента мелкодисперсными взвешенными частицами Экологический вестник 9, с 40-44 (in Russian)

[15] EN 12341:2014 Ambient air. Standard gravimetric measurement method for the determination of the PM$_{10}$ or PM$_{2.5}$ mass concentration of suspended particulate matter 2014 58 p

[16] Yousefian F, Faridi S, Azimi F et al. 2020 Temporal variations of ambient air pollutants and meteorological influences on their concentrations in Tehran during 2012–2017. *Scientific Report* **10**, 292 doi.org/10.1038/s41598-019-56578-6

[17] Hamad S, Shafer M, Kadhim A, Al-Omran S, & Schauer J 2015 Seasonal trends in the composition and ROS activity of fine particulate matter in Baghdad, Iraq. *Atmospheric Environment*, 100, 102-10 doi.org/10.1016/j.atmosenv.2014.10.043

[18] Rovelli S, Cattaneo A, Borghi F, Spinazzè A, Campagnolo D, Limbeck A et al. 2017 Mass concentration and size-distribution of atmospheric particulate matter in an urban environment. *Aerosol Air Qual Res*, **17** (5) p 1142-55.

[19] Zhao X, Zhang X, Xu X, Xu J, Meng W, Pu W 2009 Seasonal and diurnal variations of ambient PM$_{2.5}$ concentration in urban and rural environments in Beijing. *Atmos Environ* **43** (18) p 2893-900

[20] Кузнецова И, Глазкова А, Шалыгина И, Нахаев М, Архангельская А, Звягинцев А и др 2014 Сезонная и суточная изменчивость взвешенных частиц в приземном воздухе жилых районов Москвы *Оптика атмосферы и океана* **27** (6) с 473-82 (in Russian)