IOP Conference Series: Earth and Environmental Science

PAPER • **OPEN ACCESS**

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To cite this article: T V Solovyova *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **272** 022148

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On the Pollution of the Atmosphere of the City of Kabul with Fine Dust

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Abstract. The article presents new results of many years of research conducted by the national agency of Afghanistan on ecology and environmental protection as well as studies by Russian authors on the assessment of atmospheric air pollution in Kabul. The paper presents data for the spring months (March, April, and May) of 2016. The analysis of information on the quality of atmospheric air in the city of Kabul examining its street-road network and the mining industry located near the city as a source of chemical pollution of the air was performed. A mathematical model of the dependence of the concentration of fine dust (PM_{10}) on three factors: wind speed, humidity, and temperature for each month has been obtained. For the maximum daily concentration (PM_{10}), a density function and an integrated distribution function are obtained. A comparative analysis of atmospheric air pollution in the spring months of 2015 and 2016 was performed. It was not possible to obtain a general mathematical model for all three months.

1. Introduction

According to recent scientific data, one of the factors that significantly affect people's health is air pollution by chemical substances and fine solid PM_{10} particles. Fine particles PM_{10} can enter the atmosphere in the form of emissions from industrial enterprises, as well as dust emissions from transportation infrastructure. In addition, air quality is affected by individual meteorological conditions that are unique to each locality and have significant temporal variability [1-9].

To study the emission of PM_{10} particles into the atmosphere, Kabul was chosen because it is one of the cities with a high level of environmental pollution. The city of Kabul is characterized by rather dry weather with wind, so the transportation and road complex is a "supplier" of fine dust to the urban air environment and there is a mining industry near the city [10-14].

During 2015-2016 in the spring months (March, April, May) in Kabul, PM_{10} fine dust concentrations were measured as part of monitoring air pollution. The measurements of PM_{10} (mg/m^3) were carried out using the Air pointe instrument; three other factors were simultaneously measured: V - wind speed (m/s), φ - humidity (%) and T – air temperature (degrees C). According to the air quality standards for Afghanistan, the PM_{10} solid particle concentration should not exceed 150 mg/m^3 per day. The results of the measurements showed that the number of exceedances of the PM_{10} particulate matter concentration at 150 mg/m^3 in the spring months of 2015 occurred 38 days out of 64

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and in 2016 - 40 days out of 60. At the same time, the PM_{10} concentration reached 877 mg/m^3 on some days, especially high values were observed at low wind speeds.

2. The dependence of PM_{10} on three factors

Let's take a look at the assessment of the dependence of PM_{10} on three factors (wind speed, humidity, and air temperature) for the spring months of 2016, as for the year 2015 it was obtained earlier [10]. All the initial data were reduced to the normalized form by the formulas (1).

$$y_j = \frac{Y_j - Y_0}{\Delta y}; \quad x_i = \frac{X_{ij} - X_{i0}}{\Delta x_i}; \quad X_{i0} = \frac{\max\limits_j\{X_{ij}\} + \min\limits_j\{X_{ij}\}}{2}; \quad \Delta x_i = \frac{\max\limits_j\{X_{ij}\} - \min\limits_j\{X_{ij}\}}{2}, \quad (1)$$

$i = 1, 2, 3; \quad j = 1 \div n$, where Y_j is a concentration of suspended particles PM_{10}; X_{1j} - wind speed; X_{2j} - humidity; X_{3j} - the air temperature in the j-th day, and n is the sample size in the corresponding month.

For each month a linear (2) and a quadratic (3) function of regression were obtained i.e. the regression equation was calculated in two forms:

$$y = c_0 + c_1x_1 + c_2x_2 + c_3x_3 \quad \text{and} \quad (2)$$

$$y = a_0 + a_1x_1 + a_2x_2 + a_3x_3 + a_4x_1^2 + a_5x_2^2 + a_6x_3^2 + a_7x_1x_2 + a_8x_1x_3 + a_9x_2x_3. \quad (3)$$

The regression equations were obtained with the following initial data (table 1).

Table 1. The values of the variables for normalizing.

Notation of mean	Mean values	Intervals of change Δy, Δx_i
Y_0	499,5	377,5
X_{10}	3	3
X_{20}	46,5	37,5
X_{30}	19	13

As shown by the research and testing by the Fisher criterion, quadratic regression is significant for March and April months, and linear regression is for May. The universal form of the PM_{10} dependence on three factors: wind, humidity and air temperature cannot be obtained for all three months since no model gives a good correlation coefficient. The sample size for each month was collected for 20 days.

Using Student's t-test, only significant coefficients were selected in the regression equations. The resulting regression equations are listed in table 2.

Table 2. Regression equations for PM_{10} with normalized variables.

Month	Regression equations	Multiple correlation coefficient R
March	$y = -0{,}5535 - 2{,}9026\,x_1x_2 - 1{,}2357\,x_1x_3$	0,62
April	$y = -0{,}802 + 0{,}186\,x_1^2 - 0{,}144\,x_2^2.$	0,52
May	$Y = -0{,}4788 - 0{,}1337\,x_1 + 0{,}3212\,x_2 - 0{,}0619\,x_3$	0,77

Using the inverse transformation, i.e. transition of variables from the normalized form to the non-normalized form, the regression equations were obtained (table 3). Also in table 3 the regression equations that were obtained earlier for the spring months of 2015 are presented for comparison [10]. The values of V, φ and T are dimensionless, referred respectively to 1 m/s, 1% and 10°C.

Table 3. Calculated regression equations for PM_{10}.

Year	Month	Regression equation	Multiple correlation coefficient *R*
2016	March	$PM_{10} = 716,5V + 29,4\varphi + 36,2T - 9,8V\varphi - 12,1VT - 360,5$	0,62
	April	$PM_{10} = 7,928V^2 - 47,565V - 0,038\varphi^2 + 3,511\varphi + 186,5$.	0,52
	May	$PM_{10} = 247,265 - 17V + 3,4\varphi - 1,9T$	0,77
2015	March	$PM_{10} = -0,2007 + 0,0127\,V - 0,1892\,\varphi + 0,1031\,T$	0,87
	April	$PM_{10} = -0,2873 + 0,603T^2 + 0,4997\varphi T$.	0,65
	May	$PM_{10} = -0,0698 - 0,1078\,V + 0,7852\,\varphi + 0,6204\,T$	0,62

The wind speed *V* varied from 0 m/s to 7 m/s in 2015 and from 0 m/s to 6 m/s in 2016. Humidity φ varied from 5% to 86% in 2015 and from 9% to 84% in 2016. The air temperature *T* varied from -3^{0}C to 31^{0}C in 2015 and from 6^{0}C to 32^{0}C in 2016.

3. The law of distribution of the maximum daily dust concentration of PM_{10}

It is known that the maximum daily concentration of dust can be considered as a random function of a normal stationary process [14-22]. To obtain the distribution law of the maximum daily dust concentration of PM_{10} in the spring months of 2016 in the city of Kabul, its type and parameters were determined. Calculated for a sample size of 60, the values of the distribution parameters are presented in table 4.

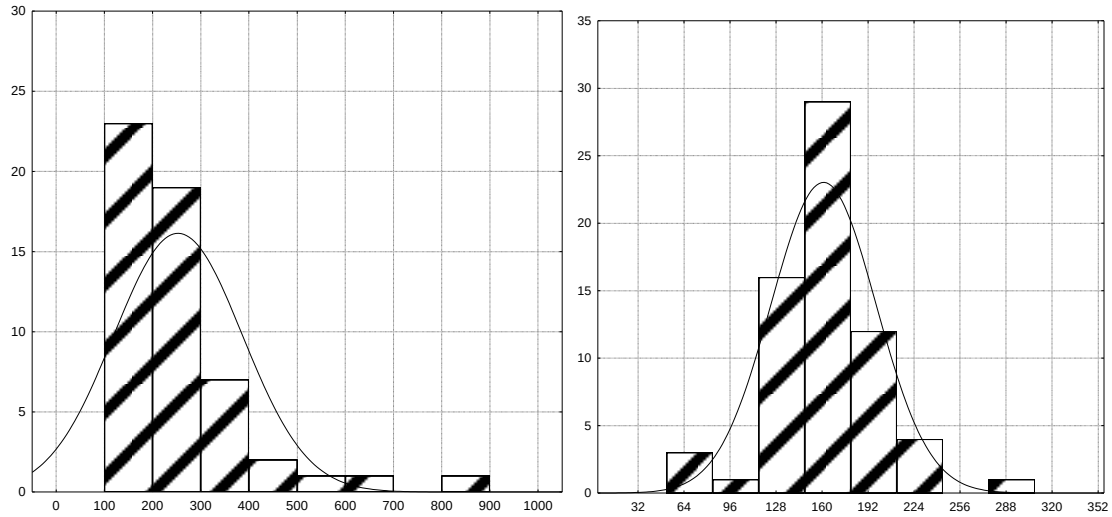
Table 4. Values of the parameters of distribution function PM_{10}.

Function parameters for distribution of dust concentration	Values of parameters	
	Year 2016	Year 2015
Mean	252	161
Dispersion	17810	1338,94
Mean square deviation	133,45	36,59
Mode	234	156
Median	221,5	156

By the type of distribution histograms (figure 1), based on the analysis of sample data and values of the distribution parameters, it seemed that there may be a normal or a log-normal law for the maximum daily dust concentration. Verification of assumptions about the normal and lognormal distribution laws was carried out with the help of the χ^2 Pearson and Kolmogorov-Smirnov criteria at a significance level $\alpha = 0,05$. The results of the calculated statistics for the spring months 2015-2016 are displayed in table 5.

Table 5. Values of statistics of the sample PM_{10}.

Year	Distribution law	Statistical values			
		X-square		Kolmogorov-Smirnov	
		χ^2_{obs}	χ^2_{crit}	λ	λ_0
2016	normal	20,87	14,067	1,035	1,36
	log-normal	9,078	14,067	1,058	1,36
2015	normal	3, 977	14,067	0, 471	1,36
	log-normal	6. 506	14,067	0,850	1,36



(a) (b)

Figure 1. Histogram and the theoretical distribution curve of the maximum daily dust concentration in the spring months of the city of Kabul: (a) 2016, (b) 2015.

According to χ^2 Pearson's criterion, if the observed value of the criterion is less than the critical one, i.e. an inequality $\chi^2_{obs} \le \chi^2_{crit}$ is satisfied, then the hypothesis of the chosen theoretical law agrees with the empirical data. When the Kolmogorov-Smirnov criterion is applied, the theoretical law agrees with the experimental data if the inequality $\lambda \le \lambda_0$ holds. According to table 5, it can be concluded that for both criteria a logarithmic normal law with parameters (5.529, 133.45) can be used to describe the maximum daily dust concentration for the spring months of 2016. For the spring months of 2015, considering that for the normal law the values of the statistics χ^2_{obs} and λ are less than the corresponding statistics of the lognormal law, the empirical data are in better agreement with the normal law with the parameters (161; 36.59). Knowing the distribution law and its parameters, one can identify its density and distribution functions.

4. Conclusion

The conducted studies showed that in order to describe the distribution of the maximum single values of PM_{10} in the spring months in the city of Kabul, a normal law, as in 2015, or a log-normal law, as in 2016, can be used. The concentration of PM_{10} fine dust varies from 61 mg/m³ to 301 mg/m³ in 2015 and from 122 mg/m³ to 877 mg/m³ in 2016.

5. References

[1] Azarov V N, Borovkov D P and Redhwan A M 2014 Application of swirling flows in aspiration systems *International Review of Mechanical Engineering* **8(4)** pp 750-3

[2] Azarov V N, Lukanin D V, Borovkov D P and Redhwan A M 2014 Experimental study of secondary swirling flow influence on flows structure at separation chamber inlet of dust collector with counter swirling flows *International Review of Mechanical Engineering* **8(5)** pp 851-6

[3] Azarov V N, Logachev I N and Logachev K I 2014 Methods of reducing the power requirements of ventilation systems Part 4 The theoretical prerequisites with swirling air flows *Refractories and Industrial Ceramics* **55(4)** pp 365-70

[4] Azarov V N, Menzelitseva N V and Redhwan A M 2016 Main trends of conditions normalizing at cement manufacturing plants *International Review of Mechanical Engineering* **6(6)** pp 145-50

[5] Koshkarev S A and Azarov V N 2015 Evaluation of wet dust separator effectiveness in the dedusting of emissions from expanded clay kiln *Civil Engineering Magazine* **2** pp 18-32
[6] Azarov V N, Evtushenko A I, Batmanov V P, Strelyaeva A B and Lupinogin V V 2016 Aerodynamic characteristics of dust in the emissions into the atmosphere and working zone of construction enterprises *International Review of Mechanical Engineering* **7(5)** pp 132-6
[7] Azarov V N, Koshkarev S A and Azarov D V 2016 The decreasing dust emissions of aspiration schemes applying a fluidized granular particulate material bed separator at the building construction factories *Procedia Engineering* **165** pp 1070-9
[8] Solovyova T V 2017 On the calculation of the coefficients of the integrated distribution function of the maximum concentrations of atmospheric dust pollution. *Problems of industrial and environmental protection: a collection of materials and scientific publications by. engineers-ecologists* ed V N Azarov (Volgograd: VolgGTU) **7** pp 75-77
[9] Azarov V N, Trokhimchuk M V and Sidelnikova O P 2016 Research of dust content in the earthworks working area *Procedia Engineering* (Amsterdam: Elsevier) **150** pp 2008-12
[10] Stefanenko I V, Solovyeva T V, Nasimi M H and Azarov V N 2017 Fine dust concentration PM_{10} in the atmosphere of the city of Kabul, Afghanistan in spring months *Applied Mechanics and Materials: Proc.of 2nd Int. Conf. on Civil, Architectural, Structural and Constructional Engineering* (Busan: Trans Tech Publication) **878** pp 255-8
[11] Stefanenko I V, Solovyeva T V, Nasimi M H and Azarov V N 2018 On the calculation model of fine dispersed dust pollution of Kabul's atmosphere for ventilation design *Applied Mechanics and Materials: Proc. of 3rd Int. Con.on Civil, Architectural, Structural and Constructional Engineering* (Busan: Trans Tech Publication) **875** pp 132-6
[12] Nasimi M H, Solovyova T V and Bataev D K-C 2018 On the distribution laws of PM_{10} in the atmosphere of Kabul city *Engineering Journal of Don* **2**
[13] Nasimi M H and, Solovyova T V 2017 On contamination of air of Kabul city with PM_{10} fine dust *Engineering Journal of Don.* **2**
[14] Azarov V N, Barikaeva N S and Solovyeva T V 2016 Monitoring of fine particulate air pollution as a factor in urban planning decisions *Procedia Engineering* (Amsterdam: Elsevier) **150** pp 2001-7
[15] Azarov V N, Trokhimchuk M V and Trokhimchuk A K 2016 Experimental study of the propagation of dust in the construction areas stockpiles *News Higher Educational. Institution. Geological. Exploration*. **1** pp 55-9
[16] Nikolenko D A and Solovyeva T V 2015 Analysis of experience of monitoring of pollution by a fine dust of the roadside territories in the EU and Russia *Engineering Journal of Don.* **3**.
[17] Azarov V N, Barikaeva N S, Solovyeva T V and Nikolenko D A 2015 On the study of air pollution by finely dispersed dust using random functions *Engineering Journal of Don.* **4**
[18] Kyoyken M P 2013 Source deposits to $PM_{2.5}$ and PM_{10} against the background of the city and the adjacent street *Atmospheric Environment* **7** pp 26-35
[19] Barratt B, Carslaw D, Fuller G, Green D and Tremper A 2012 *Evaluation of the impact of dust suppressant application on ambient PM_{10} concentrations in London Environmental Research Group Report* (London: King's College) November p 56
[20] Azarov V N, Sergina N M and. Stefanenko I V 2018 Air flow straighteners' application to reduce the power consumption of exhaust ventilation schemes. *Applied Mechanics and Materials: Proc. of 3rd Int. Con.* **875** pp 137-40
[21] Koshkarev S A, Azarov V N and. Stefanenko I V 2018 Applying absorption in environmental mechanics' decreasing of aspiration emissions of gas station. *Applied Mechanics and Materials: Proc. of 3rd Int. Con.* **875** pp 145-8
[22] Stefanenko I V, Azarov V N and. Sergina N M 2017 Dust collecting system for the cleaning of atmospheric ventilation emissions *Applied Mechanics and Materials: Proc.of 2nd Int. Conf. on Civil, Architectural, Structural and Constructional Engineering* (Busan: Trans Tech Publication) **878** pp 269-272