EFFECT OF METEOROLOGICAL PARAMETERS ON ATMOSPHERIC POLLUTION AND POSSIBLE CORRELATION WITH CLIMATE CHANGE

E. Zacharis, I. Sempos

[1]School of Sciences and Technology, Hellenic Open University, 26335 Patra

[2]School of Chemical Engineering, National Technical University of Athens, 15780, Zografou email: std135180@ac.eap.gr, isebos@mail.ntua.gr

ABSTRACT

This paper presents the characteristics, sources and effects of atmospheric pollutants CO, NO, SO_2, NO_2, O_3 and PM_{10} and describes the properties of the meteorological parameters of wind, temperature, sunshine and rainfall. The effects of temperature inversions, instability and extreme weather phenomena on pollutant concentrations are also investigated. Furthermore, this work analyzes the causes and effects of climate change and how it affects atmospheric pollution. The correlations of the air pollutants with the meteorological factors in the Attica Basin are calculated and analyzed using the Pearson correlation coefficient and the linear regression. Some of the most important results are the negative correlations between CO, NO, SO_2 and NO_2 with the wind velocity and the positive correlations of O_3 with sunshine and temperature.

KEYWORDS

Atmospheric pollution; meteorological factors; climate change; linear correlation coefficient

1. INTRODUCTION

Human factor with the exploitation of natural resources, combustion, transport and all kinds of activities, has a catalytic effect on the increase of air pollution, especially in urban environments, and the acceleration of climate change [1].

In the area of the Attica Basin which is our study area, high concentrations of PM_{10}, NO_2, O_3, CO, NO, and SO_2 are recorded. The reasons are mainly found in poor urban planning, means of transport, hydrocarbon combustions, geomorphology, prevalence of anticyclonic flows, the effect of winds, the cross-border transport of particles from North Africa as well as the horizontal or vertical transport of O_3.

The results of our research highlight the correlations between air pollutants and the meteorological parameters of wind, temperature, sunshine and rainfall. It also analyzes how phenomena such as stationary anticyclones, temperature inversions and the combination of weather conditions associated with atmospheric instability affect entrapment, dispersion, distribution and transport of pollutants in the troposphere. We further examine the combination of meteorological factors, primary pollution and photochemical reactions in the development of severe pollution phenomena such as smog in winter and photochemical smog in summer at the Attica basin.

2. METHODOLOGY - DATA SOURCES

For the correlations in the area of the Attica Basin, concentrations of atmospheric pollutants were obtained from the Hellenic Ministry of Environment and Energy , while meteorological parameter values from the National Observatory of Athens and the Hellenic National Meteorological Service. The average daily values of pollutants were calculated in excel and matched with the average values of meteorological factors. Pearson coefficient of linear correlation was used to find the degree of negative or positive correlation between pollutants and meteorological factors. Simple linear regression was also used to find the model with which they were linearly connected to each other. In some stations we examined the existence of non-linear regressions as well as the correlation between pollutants. We calculated annual, seasonal and monthly Pearson values in an attempt to detect improved correlations as well as whether pollutant fluctuations are influenced by extreme weather events associated with climate change, such as successive periods of prolonged heat and dust.

3. RESULTS

From the correlation and regression analysis for 2018, results were found at the following study stations:

3.1 Athenas Station

Negative correlations were found between CO and wind speed with a stronger Pearson coefficient -0,568 for winter months, as shown in Table 1. Smaller concentrations and better diffusion of pollutant occur with the synoptic, higher velocity north winds while most maximum concentrations and accumulation of pollutants occur with the lower velocity winds of the southern sector (Figure 1).

Strong positive annual correlations were found between O_3 , sunshine duration and temperature (0.63 / 0.83). Strong positive correlations with wind speed where found in winter, when low speeds prevailed at night due to a combination of stationary anticyclones and temperature inversions of radiation [2]. Higher wind speeds and rise of O_3 concentrations occurred when the inversion was dissolved the following morning with the effect of solar irradiance. The extended duration of sunshine and high temperature values increase the concentrations of O_3 because the photochemical reactions of its production are accelerated especially in summer where there is the maximum of solar irradiance.

For SO_2 the negative correlations that occurred in relation to the wind speed at all intervals are moderate to good. Strong positive correlations were found between the pollutants SO_2 and NO, especially in winter.

Table 1. Correlations of CO with statistical significance at Athena station in 2018

	Wind speed	Tempera ture	Rainfall
Annual Pearson	-0,38	-0,35	-
Winter Pearson	-0,568	-0,142	-
Summer Pearson	-	0,205	-

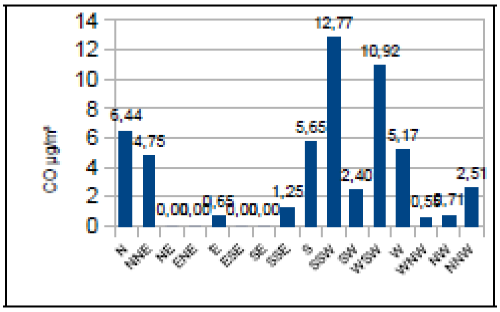

Figure 1. Bar chart of average monthly CO concentrations per wind direction at Athena station, January-February-March 2018

3.2 Nea Smyrni Station

Invasions of hot air masses with dust from the Sahara desert play a major role in increasing PM_{10} concentrations, especially in spring and summer months [3]. Positive correlations of PM_{10} with temperature were found only in the individual periods of March and July, as shown in Table 2, when there were several hot air dust invasions.

For CO, strong negative correlations were found with wind speed mainly in summer with a Pearson coefficient r = -0.584 in accordance with Athenas station.

Table 2. Correlations of PM_{10} with statistical significance at N. Smyrni station in 2018

	Wind speed	Temperatur e	Rainfall
Annual Pearson	-0,255	-	-
Winter Pearson	-	0,339	-
Summer Pearson	-0,182	-	-
Pearson March	-	0,437	-
Pearson July	-	0,631	0,183

3.3 Agia Paraskevi Station

Particularly strong correlations were found between O_3 and temperature and sunshine as shown in Table 3. The extreme period of instability in June-July with heavy rains for several days, dense clouds and strong winds, led to a decrease in sunlight and a slowdown in photochemical reactions helping to reduce O_3 and other pollutants such as NO. Most of the instability phenomena took place at the northern stations of the Attica basin where the strongest negative correlations between rainfall and pollutants such as O_3 (-0,560 for June, -0,771 for July) were found for the first time in this research, confirming its role in reducing air pollution.

Table 3. Correlations of O_3, with statistical significance at Agia Paraskevi station in 2018

	Wind speed	Temperature / sunshine	Rainfall	Stability / instability
Annual Pearson	0,347	0,751 / 0,900	-0,176	
Winter Pearson	0,443	-	-	
Summer Pearson	0,282	0,449	-0,657	Strong instability
Pearson June	0,225	0,604	-0,560	Strong instability
Pearson July	-	0,589	-0,771	Strong instability

3.4 Peristeri Station

When the individual analysis intervals decrease, the correlations of PM_{10} with temperature are strengthened in accordance with the results of Nea Smyrni station. In July, strong positive correlations with both wind speed and temperature were found. The positive correlation between temperature and increase in PM_{10} concentrations is mainly due to the transport of hot air masses with Saharian dust .

From the linear regression analysis of O_3 with temperature, a model was found which explains the correlation between O_3 and temperature with a satisfactory determination coefficient, $R^2 = 0.516$ and linear regression $y = 3.09 x + 3.2$ as shown in figure 2, which can be used to draw future statistical conclusions for O_3 concentrations from known temperature values. Strong annual correlation of O_3 with temperature, sunshine and wind speed in winter months for the same reasons explained at Athenas station. Negative correlations between O_3 and NO_2 were found due to the sequential and conflicting photochemical reactions.

Table 4. Correlations of O_3 with statistical significance at Peristeri station in 2018,

	Wind speed	Temperat ure / sunshine	Rainf all	NO2
Annual Pearson	0,267	0,726/ 0,948	-	-0,547
Pearson January	0,606	-	-	-0,641
Pearson June	-	0,470	-	-0,442

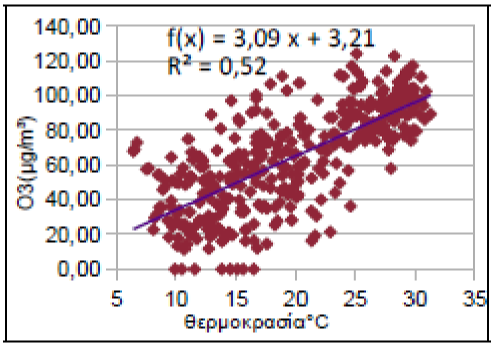

Figure 2. Dispersion O3 - Temperature at Peristeri station for 2018 (Linear regression)

3.5 Maroussi Station

Strong negative correlations were found between NO, NO_2 and wind speed as shown in Table 5. The NO and NO_2 concentrations increase during periods of stationary anticyclonic systems and temperature inversions, both participating in the photochemical production of O_3.

In winter, the combination of meteorological factors such as clear night skies, light winds, high humidity, low temperatures, stationary anticyclones, together with overnight concentration of primary pollutants and temperature inversions due to radiative cooling of surface air, intensified the pollution and created episodes of smog. In summer, stationary anticyclones, high temperatures, low humidity, anticyclonic temperature inversions and sea breezes trapped primary pollutants, PM, RH and NO_2 and together with the increase of photochemical production of O3 ,created episodes of photochemical smog.

Table 5. Correlations NO of Maroussi station in 2018, with statistical significance

	Wind speed	Temperature / sunshine	Rainfall	O3
Annual Pearson	-0,378	-0,371 / -0,682	-	-
Winter Pearson	-0,541	-0,001	-0,210	-0,739
Summer Pearson	-0,444	-	-	-0,608

4. CONCLUSIONS

The correlation analysis at the Attica Basin shows that wind speed has a strong negative correlation with CO, NO, SO_2 and NO_2. Light south winds are present in all episodes of severe pollution while strong north winds disperse pollutants into the Saronic Gulf and clean the atmosphere. Wind also plays an important role in the cross-border transport of pollutants such as the dust invasions from North Africa which increase the levels of PM_{10}, as well as in the horizontal transport of O_3 from the north, which in combination with its photochemical formation, increase its concentrations, mainly at the suburbs of Athens.

Temperature inversions favor the entrapment and increase of pollutants in the lower layers of the troposphere. In winter, when nocturnal temperature inversions due to overnight radiative cooling of surface air coexist with stationary anticyclones and low temperatures, they lead to episodes of severe smog in the city. In summer, when long-lived anticyclonic inversions and inversions caused by sea breezes coexist with stationary anticyclones and high temperatures, they lead to the appearance of photochemical smog. Meteorological conditions that form when there is instability in the atmosphere, such as increased rainfall, extensive cloud cover and strong winds, contribute to the removal of primary and secondary pollutants mainly due to the reduce of solar irradiance and photochemical reactions, making instability very significant to the reduction of pollution. Human factor with its participation in the increase of greenhouse gases and especially CO_2, plays a catalytic role in climate change, with the alteration of the thermal balance in the atmosphere and the acceleration of the greenhouse effect which has an impact on meteorological parameters and primarily on global warming. In recent years in the Attica Basin, as well as throughout the eastern Mediterranean, heat waves, stationary anticyclonic synoptic systems accompanied by light winds, prolonged droughts and transport of hot air masses with dust from North Africa are more and more frequent. These phenomena modify the microclimate of the Attica Basin in a warmer and drier one and also enhance the positive correlations of temperature with the secondary pollutants NO_2 and O_3 by increasing their concentrations. They also enhance the positive correlations of temperature with PM_{10} at short intervals of months when hot dust invasions prevail.

REFERENCES

[1] Lionello, P. & Scarascia, L. (2018). The relation between climate change in the Mediterranean region and global warming. *Regional Environmental Change*, Volume 18, pages 1481–1493.

[2] Kassomenos, P. A. & Paschalidou, A. K. & Lykoudis, S. & Koletsis, I. (2014). Temperature inversion characteristics in relation to synoptic circulation above Athens, Greece. *Environ Monit Assess.* 186(6):3495-3502.

[3] Grigoropoulos, K. N., Nastos, P. T. & Ferentinos, G. (2009). *Spatial distribution of PM1 and PM_{10} during Saharan dust episodes in Athens, Greece.* Department of Geology and Environment, University of Patras, Laboratory of Climatology and Atmospheric Environment, University of Athens.