Air Quality Characterization in Ploiesti Urban Area Affected by Industrial and Traffic Pollution

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Abstract

Emissions of air pollutants derive from almost all economic and societal activities. Due to the concentration of crude oil processing activities around Ploiesti city, which is an urban agglomeration of Romania, this area was carefully monitored regarding air pollutants concentrations. The aim of this work was the characterization of air quality in the city of Ploiesti, affected by industrial and traffic pollution, the analysis of nitrogen dioxide (NO₂) and sulfur dioxide (SO₂) concentrations collected from a continuous monitoring system and the identification of some relationships between air pollution and meteorological parameters in the studied area. Descriptive statistics was applied to analyze the time series of air pollutants monitored by an automated monitoring network composed by six stations, in order to establish the relationship between air pollutants and important weather factors. Data were measured in Ploiesti urban area between November 2011 and March 2012. The statistical models indicated that weather variables such as temperature and relative humidity had significant impact on the most air pollutants.

Keywords: *air quality, monitoring, meteorological factors, statistical analysis*

INTRODUCTION

Emissions of air pollutants derive from almost all economic and societal activities. In Europe, emissions levels of many air pollutants have decreased. However, air pollutant concentrations are not only affected by emission sources but also by meteorological variables (Elminir, 2005; Ordonez *et al.*, 2005). Meteorological variables play an important role in the dispersion, transport, photochemical reactions and formation of secondary air pollutants (Habeebullah, 2013). In recent years, many statistical methods have been used to study air pollution in urban areas. The relationship of air pollution with meteorological parameters can be described better using time series analysis, which is a useful tool in providing important information about air pollution (Elminir, 2005). Meteorological factors such as temperature, relative humidity, wind velocity, wind direction, together with rainfall and atmospheric

pressure play an effective role in transformation of air pollutants (Ocak *et al.*, 2008; Nenadović *et al.* 2010; Luvsan *et al.* 2012; Iordache and Dunea, 2011). Many research studies emphasize the role of meteorology in the dispersion, transformation, and removal of air pollutants from atmosphere (e.g. the wind speeds determine the amount of dispersion of pollutants in the atmosphere, the temperature contributes to the transformation of pollutants in the atmosphere (Mavroidis 2012; Whiteman, 2014; Turalioglu *et al.*, 2005).

By using some statistical techniques such as regression analysis is possible to establish how close are the relationships between pollutants concentration and important weather parameters. Multiple linear regression analysis was used to estimate SO₂ and PM concentrations using meteorological parameters (relative humidity, temperature, wind speed, and pressure) and previous day's pollutants concentration in winter

season (Ocak *et al.* 2008; Turalioglu *et al.* 2005). Other studies pointed out that local meteorological parameters such as temperature, solar radiation, wind speed and wind direction affects O_3 and NO_2 concentrations (Chiu *et al.*, 2005; Mavroidis, 2012). Critical meteorological factors affect the daily particulate matter (PM) concentrations during cold months (Whiteman *et al.*, 2014; Dunea *et al.*, 2014). Meteorological influence on air pollutants was studied both based on correlation analysis and other convenient methods (Iordache and Dunea, 2013).

In Romania, the air quality monitoring is performed continuously using the automated stations of the National Network for Air Quality Monitoring (RNMCA) located in various areas of the country. Currently, there are more than 150 automatic monitoring stations with various instrumentation configurations measuring air pollutants of interest in a specific area (Iordache and Dunea, 2011). National Air Quality Monitoring Network (RNMCA) comprises 41 local centers, which collect and transmit raw data from stations to the public panels and forward them, after primary validation for certification, at the National Reference Laboratory (LNR) in Bucharest (RNMCA).

Due to the multitude of crude oil processing activities around Ploiesti city, which is an urban agglomeration of South-Est Romania, this area was carefully monitored regarding air pollutants having in view that it is affected by industrial and traffic pollution.

In this study, two air pollutant concentrations - Nitrogen dioxide (NO_2) and Sulfur dioxide (SO_2) and meteorological parameters measured in the city of Ploiesti during cold months were analyzed statistically using various time series. The relationships between the monitored ambient air quality data and the meteorological factors, such as wind speed, temperature, air pressure, relative humidity, and precipitations were investigated in order to determine potential correlations.

MATERIALS AND METHODS

Air quality is monitored by measuring pollutants in some specific intervals of mediation. Pollutants monitored are described in the Romanian legislation by M.O. 592/2002, which transposes the EU limit values. It aims

to avoid, prevent, and reduce the harmful effects of aerosols' high levels on health and the environment. Ploiesti city was selected for this study because its residential areas are under the emissions' impact of petrochemical industry and heavy traffic. We used the data acquired by six automatic monitoring stations of the National air quality monitoring network, located in Ploiesti, namely PH-1, PH-2, PH-3, PH-4, PH-5, and PH-6. Table 1 presents the characteristics of these stations. Data have been collected from November 2011 until March 2012, at one hour sampling rate and contained meteorological parameters, gaseous pollutants, and particulate matters concentrations. The considered interval for data analysis has included the cold months, when residential heating contributes to the air pollution.

In the first step, the statistical indicators of SO_2 and NO_2 time series recorded at 6 monitoring stations from Ploiesti were computed.

Collected data have been analyzed statistically in order to establish the status, variability, and correlation of monitored parameters. SPSS (SPSS Inc., Chicago, IL, 2011) was used to perform statistical analyses of recorded time-series establishing the central tendency, dispersion, and distribution for the two pollutants of concern, namely: sulfur dioxide (SO_2) and nitrogen dioxide (NO_2).

Central tendency described the location of the data distribution including the mean, median, mode, and sum of all the values. Dispersion measured the amount of variation or spread in the data including the standard deviation, variance, range, minimum, and maximum. Distribution was estimated using skewness and kurtosis that describe the distribution's shape and symmetry.

Table 2 presents the number of observations that forms the time series, the number of zero recorded values, and the available data for each variable of air pollutants (sulfur dioxide - SO_2 and nitrogen dioxide - NO_2), and the weather data (air temperature, relative humidity, atmospheric pressure, wind speed and direction, and precipitations).

Secondarily, the study aimed at determining the potential correlations between air pollutants concentrations and weather parameters monitored by the six automated monitoring stations from Ploiesti.

Tab.1. Description of automated stations and weather data monitoring from Ploiesti city considered for analysis

Monitoring Station	PH-1	PH-2	PH-3	PH-4	PH-5	PH-6
Type of station	traffic	urban	suburban	industrial	traffic	urban
Number of air pollutants parameters	12	20	17	19	12	13
Measured meteorological parameters	0	7	7	7	0	7

Tab. 2. Number of observations and available data that forms the analyzed time series

Variable	Sulfur dioxide (µg m-3)	Nitrogen dioxide (µg m-3)	Temperature (°C) 2 m from the ground	Relative Humidity (%)	Pressure	Wind speed	Wind direction	Precipitations
PH-1								
N=0	309	2004	-	-	-	-	-	-
Total N	3299	1644	-	-	-	-	-	-
PH-2								
N=0	1523	2851	369	364	364	2317	364	2787
Total N	2125	797	3279	3284	3284	1331	3284	861
PH-3								
N=0	620	-	609	607	607	2281	607	3208
Total N	3052		3063	3066	3066	1391	3066	464
PH-4								
N=0	399	386	384	382	382	380	382	503
Total N	3249	3262	3264	3266	3266	3268	3266	3624
PH-5								
N=0	411	1982	-	-	-	-	-	-
Total N	3261	1690	-	-	-	-	-	-
PH-6								
N=0	406	486	368	365	365	365	365	431
Total N	3242	3162	3280	3283	3283	3283	3283	3648

Resulted time series were tested for correlations using the Pearson coefficient (r). All recorded time series were preprocessed for each station before performing correlation tests by filtering incoherent values (e.g. zero value for atmospheric pressure) and outliers.

The values recorded for other parameters in the same time with an incoherent value were ignored from analysis to maintain chronological and seasonal pattern of the pollutant and weather time series at each station.

For this reason, the sample interval (N) differs at each station (Tab. 2). The bi-variate correlations have considered SO₂ and NO₂ concentrations

at each station on one side and each weather parameter on the other side i.e. air temperature and wind speed, both being measured at a height of 2 meters above ground, relative humidity, atmospheric pressure, precipitations, and wind direction.

RESULTS AND DISCUSSION

Time series recorded by the stations analyzers were plotted using graphs showing the evolution of pollutants' concentrations. Several differences in the size of collected samples, which were considered in the analysis, have occurred because

of monitoring system failures (sensor or analyzer failure, errors in data transmission).

The descriptive analysis realized for SO_2 showed that the highest average value was recorded at PH4 station ($10.93 \mu\text{g}/\text{m}^3$) and the maximum concentration value was recorded at PH6 station, followed closely by PH4 station. However, the maximum value of concentration did not exceed the limit value ($\text{VL} = 350 \mu\text{g}/\text{m}^3$).

PH4 and PH6 are industrial stations. Regarding the median values, it was observed that for PH4 station, the median is close to the average values recorded, which shows a uniform statistical distribution. For the other stations, collected data showed a median value that is displaced and dispersed from the mean value.

By analyzing the Skewness coefficient, which is a measure of the degree of distribution asymmetry, it was observed a left asymmetric

distribution of SO_2 concentrations measured by the monitoring stations.

Kurtosis coefficient, which is a measure of the spreading values around the central value (median), showed a leptokurtic distribution for all monitoring stations, which means that the SO_2 distributions are more clustered around the mean values, and have a relatively small standard deviation (Fig. 1).

For NO_2 , the analysis of central tendency indicators showed that the highest value of the average was recorded at PH6 station ($30.54 \mu\text{g}/\text{m}^3$), but the concentration limit was not exceeded at this station. Maximum concentration value ($237.06 \mu\text{g}/\text{m}^3$) was recorded at PH1 station, which is a traffic station. It was observed that the limit value of $200 \mu\text{g}/\text{m}^3$ NO_2 has been exceeded. Regarding the median values, they are relatively close to the average values; this means a uniform statistical distribution.

Fig. 1. Histograms – Distribution of SO_2 concentrations

By analyzing the Skewness coefficient, a left asymmetric distribution of NO_2 concentrations at PH2 and PH5 stations was observed; in the same time, PH1, PH4 and PH6 stations showed normal distributions. Kurtosis coefficient indicated a platykurtic distribution at PH1 station. For the other stations, the distributions were of leptokurtic type, having the values grouped around average (Fig. 2).

The calculation of correlation coefficients allowed a better understanding of the relationship between various air pollutants and meteorological factors.

The most important meteorological factors such as temperature, precipitations, relative humidity, wind speed, atmospheric pressure and wind direction, were taken into account. It is important to

Fig. 2. Histograms – Distribution of NO_2 concentrations

mention that PH1 and PH5 stations did not measure weather parameters being traffic stations.

The correlation between two variables reflects the degree to which the variables are related. Table 3 summarizes the correlation matrix of all bivariate pairs of the parameters measured at a specific station. Many significant bivariate correlations were observed in the total of 42 possible pollutants– meteorological factor pairs.

Consequently, 25 strong correlations ($p < 0.01$) and 5 moderately strong correlations ($p < 0.05$) were identified. The remaining 12 pairs did not show significant correlations.

The most correlated meteorological factors were the relative humidity and wind speed (6 correlations), followed by temperature (5).

Site conditions may have significant influence on air pollutants pattern in correlation with meteorological factors. As it was showed before, the SO_2 concentrations did not correlate with temperature excepting two stations, where it showed a strong positive correlation at PH-6, and PH-2. In the same time, a good correlation between SO_2 concentration and relative humidity was observed at all stations

Tab. 3. Correlations between pollutants concentrations and weather data recorded at the corresponding air quality monitoring stations of Ploiesti

Station		Temperature (°C)	Precipitations	Relative Humidity (%)	Wind speed	Atmospheric Pressure (mbars)	Wind direction
Sulfur dioxide - SO_2							
PH-2	Pearson Correlation	0.369**	0.013	-0.047*	-0.269**	0.140**	0.016
	p	<0.001	0.512	0.016	<0.001	<0.001	0.402
	N	2647	2647	2647	2647	2647	2647
PH-3	Pearson Correlation	0.026	-0.010	-0.043*	0.040*	0.013	0.007
	p	0.148	0.593	0.017	0.026	0.455	0.683
	N	3081	3081	3081	3081	3081	3081
PH-4	Pearson Correlation	0.002	0.036*	-0.150**	0.131**	0.108**	0.023
	p	0.912	0.041	<0.001	<0.001	<0.001	0.180
	N	3286	3262	3286	3286	3286	3286
PH-6	Pearson Correlation	0.208**	-0.056**	-0.187**	0.000	0.003	-0.130**
	p	<0.001	0.001	<0.001	0.982	0.868	<0.001
	N	3291	3291	3291	3291	3291	3291
Nitrogen dioxide - NO_2							
PH-2	Pearson Correlation	-0.176**	0.004	0.350**	-0.280**	0.235**	0.124**
	p	<0.001	0.915	<0.001	<0.001	<0.001	<0.001
	N	824	824	824	824	824	824
PH-4	Pearson Correlation	-0.343**	-0.115**	0.101**	-0.384**	0.124**	0.150**
	p	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
	N	3286	3262	3286	3286	3286	3286
PH-6	Pearson Correlation	-0.080**	-0.065**	-0.040*	-0.323**	-0.019	0.174**
	p	<0.001	<0.001	0.021	<0.001	0.288	<0.001
	N	3291	3291	3291	3291	3291	3291

*. Correlation is significant at the 0.05 level (2-tailed); **. Correlation is significant at the 0.01 level (2-tailed).

Temperature and NO₂ showed strong negative significant correlations ($p < 0.001$) at all monitoring stations, confirming the effect of temperature on NO₂ photochemical transformation in secondary pollutants.

In addition, wind speed and NO₂ concentration showed a significant correlation. Relative humidity showed strong negative correlation with NO₂ at PH6 and positive correlations at the other stations.

CONCLUSIONS

Weather parameters are important factors influencing air pollutants concentrations and evolution trends along with emission sources characteristics, and seasonal fluctuations under anthropic influence (e.g. residential heating during cold months). In the city of Ploiesti, air quality has been improved, but there are certain vulnerable areas under the direct impact of road traffic or industrial areas that need to be supplemented with forecasting tasks in order to improve people protection to air pollution exposure.

The present work has analyzed statistically the relationship between two gaseous air pollutants (NO₂ and SO₂) and meteorological factors monitored during a period of five cold months in the city of Ploiesti. The statistical models proved that weather variables such as temperature and relative humidity had a significant impact on both air pollutants. Pearson correlation analysis indicated that the most correlated meteorological factors are the relative humidity and the temperature, which had statistically significant influence on NO₂ and SO₂ concentrations both at industrial and urban stations.

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