Original Research

Air Pollution in Bejaia City (Algeria): Measurements and Forecasts

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Abstract

Out study was designed to investigate the levels of air pollutants in the environment of Bejaia (Algeria) and the effects of meteorological factors.

The present investigation includes measurements of carbon monoxide, nitrogen monoxide and sulphur dioxide during the period of March 2005 to December 2006. The measurements were realized near six polluting areas: a heavy traffic area, a public discharge and 4 factories (wood, tar, cork, ceramic). We measured simultaneously the emissions of the three pollutants at chimney exits and at different distances from the sources. The regression between concentration and distance is an exponential decrease.

The amount of pollution in the chimney and in the immediate environment sometimes exceeds the thresholds dictated by regulations.

Meteorological effects are also studied. Pollutant levels have an inverse relationship to wind speed. Also, the relationship of humidity with SO_2 and NO indicate the ability of the acid gases to form sulphuric acid and nitric acid in the atmosphere of Bejaia. The increase in ambient temperature causes a decrease of CO level and an increase of NO and SO_2 levels. The diurnal and seasonal variations of air pollution showed that measured concentrations are strongly correlated with industrial activity and heavy traffic in the centre of Bejaia city.

Applying the Box-Jenking method to the measured pollutant concentrations during 2006, we established a forecasting model for the following year.

Keywords: air pollution, industrial emissions, automobile exhausts, meteorological factors, forecasting model, Bejaia, Algeria

Introduction

Industrial and automobile air pollutants are primarily responsible for pollution that affects public health and, secondly, for the degradation of monuments, the environment and the greenhouse phenomenon. Long-term forecasting for and control of air pollution is needed in order to prevent the situation from becoming worse in the long run. Such forecasting is especially important for children, asthmatics and the elderly [1]. Today many hundreds of air pollutants are identified but only the impacts of a small number have been studied. Each pollutant has effects targeted at health and the environment, acute effects in the short run like asphyxia with CO and chronic effects in the long run. Several studies carried out have shown a great correlation between the strong levels of air pollution and the mortality rate by respiratory and cardiovascular problems. The last years there have shown an increase in public

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Table 1. Air pollutant emissions (10^3 ton) in Algeria during 1995, and national limits.

	SO_2	PM	NO_x	NMVOC	CO
Automobile	4.16	8.71	123.63	249.6	996.6
Industry	44.85	1128.7	53.68	14.06	48.02
Waste combustion	0.21	3.32	1.22	8.95	17.44
Total	49.22	1,140.03	179.53	272.61	1,062.32
Emission limit (mg/m³)	300	50	300	150	150

and government concern about air quality in urban cities. Automobile traffic is one of the most important sources of this pollution [2]. In urban areas, automobile exhaust emissions are more important in road junctions, traffic jams and narrow streets [3]. So we chose a road junction for our measurements that include industrial and traffic pollutants.

Bejaia is a coastal town in the centre of Algeria with an area of about 10 km² and has a population of 200,000 growing at a rate of 2.1%. In a precedent study, we showed the influence of fuel (gasoline or diesel) used and the age of vehicle [4].

The nature of the pollutants emitted by a source depends on the reactions implemented and the environmental conditions (temperature, relative humidity, etc.). As chemical reactions depend on the ambient environment, it would be interesting to see the variations of the concentrations of the pollutants according to meteorological factors. Several studies about dependence of air pollutant levels on meteorological variables have been made in Italy [5], Turkey [6], India [7] and Egypt [8].

Materials and Methods

We used 3 pollution sensors: HS 134 for the carbon monoxide CO, MX21 for nitrogen monoxide NO and sulfur dioxide SO_2; and 3 sensors for meteorological factors: temperature (LM 335Z), wind speed (propeller + dynamo), and relative humidity (H100131). The suitable signal conditioners as well as the digital display on an LCD screen were controlled by a microcontroller 16F877. We chose 4 factories, a public discharge with daily incineration of domestic and industrial waste (an average of 0.5 kg/citizen/day) and the biggest crossroad (Daouadji) with high traffic and pedestrian densities. We measured the pollutant concentrations near the sources and at different distances away from them in order to know the distribution pattern useful to the dispersion model. Table 1 shows the total emissions and the standard industrial emissions in Algeria.

We have measured the emissions just at the exit of the chimney for the 4 industrial sources and near the discharge. CO represents the maximum concentration for the discharge, the wood unit, automobile traffic and tar unit. The cork unit emits NO quasi exclusively while for ceramics the distribution is balanced. The emitted concentrations largely exceed the Algerian standard limits given in Table 1.

Results and Discussion

Chimney Height Effect

We measured concentration C_0 of CO just at the source (0 m) and at a distance of 5 m from source C_5. The results for the five sources, represented in Fig. 1, show that the higher the chimney is, the dispersion of the pollutants is more important. When the chimney is high, the plume sinks down to the ground only after a long distance and after the wind has ensured a better dispersion of the plume. The decrease follows an exponential shape. The correlation coefficient between C_5/C_0 and exp (-h) is 0.792.

Pollutant Dispersion

We measured the CO concentrations while moving away from the source for the discharge and the wood work until the limit sensitivity of the sensor. We also measured NO at the cork work. The decreases are in the form exp (-D), where D is the distance between the sensor and the source. The correlation coefficients obtained are: 0.7266 for CO in Boulimat, 0.5716 for CO in Transbois and 0.8867 for NO in the cork work. Thus the model of dispersion of the pollutants is rather close to the exponential model.

Effects of Meteorological Factors

We have studied the effects of three meteorological factors (temperature, relative humidity and wind speed) on the pollutant dispersion. These three parameters are the most studied in the literature [7, 8]. With the realized mini weather station equipped with sensors and a microcontroller, we recorded the evolution of the three meteorological variables and the concentrations of 3 pollutants (CO, NO, SO_2).

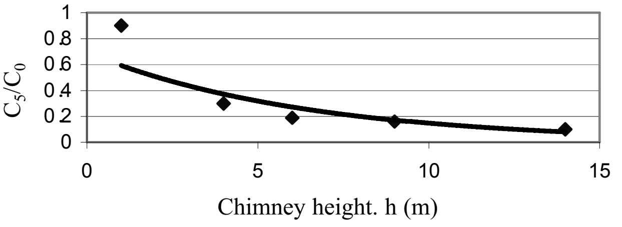

Fig. 1. Relative CO concentration C_5/C_0 versus chimney height of the source.

A correlation regression analysis was performed. With the increase in temperature, the NO and SO_2 levels increase slightly while that of CO decreases. Fig. 2 shows the correlations between CO, NO, SO_2 and the ambient temperature with respective coefficients of -0.361, 0.191 and 0.207. The weak increase in NO can be explained by the secondary formation of aerosols. With the temperature increase, CO goes up more easily and its concentration on the ground decreases.

For relative humidity, measurements gave a significant positive correlation (R = 0.392) with CO, less significant with SO_2 (R = 0.166) and negative (R= -0.364) with NO. With strong moisture, the increase in CO and SO_2 concentrations could come from precipitation of air mass coming from other pollution. When the relative humidity increases, NO reacts with the steam (H_2O + NO gives NO_2 + OH), then NO concentration decreases.

For wind speed, the measured levels for the three pollutants are inversely proportional to wind speed. The negative correlation is even more significant when measurements are taken upstream of the source.

Diurnal and Seasonal Variations

Variations in pollution levels over a 24-h period at Bejaia city show significant increases and decreases of pollutant levels, which primarily reflects the interplay between anthropogenic activity and daily climatic variations. With regard to climatic changes during the year, Fig. 3 separates average daily pollution levels for CO, NO and SO_2 for each month.

The major source for CO, NO and SO_2 is fossil fuel burning (combustion in motor vehicles). Because of the low traffic in the night, the pollutant concentrations are minimal. High levels of CO are strongly correlated with heavy traffic congestion (peak hours). We find three picks each day at 8.00 h, 13.00 h and 17.00 h. NO concentration presents two peaks at 8.00 h and 18.00 h, while SO_2 presents only one at 13.00 h.

CO is maximal in summer in spite of higher temperatures because of the heavy traffic during the tourism season in Bejaia city. On the other hand, NO is maximal in autumn and winter because of low humidity and ozone.

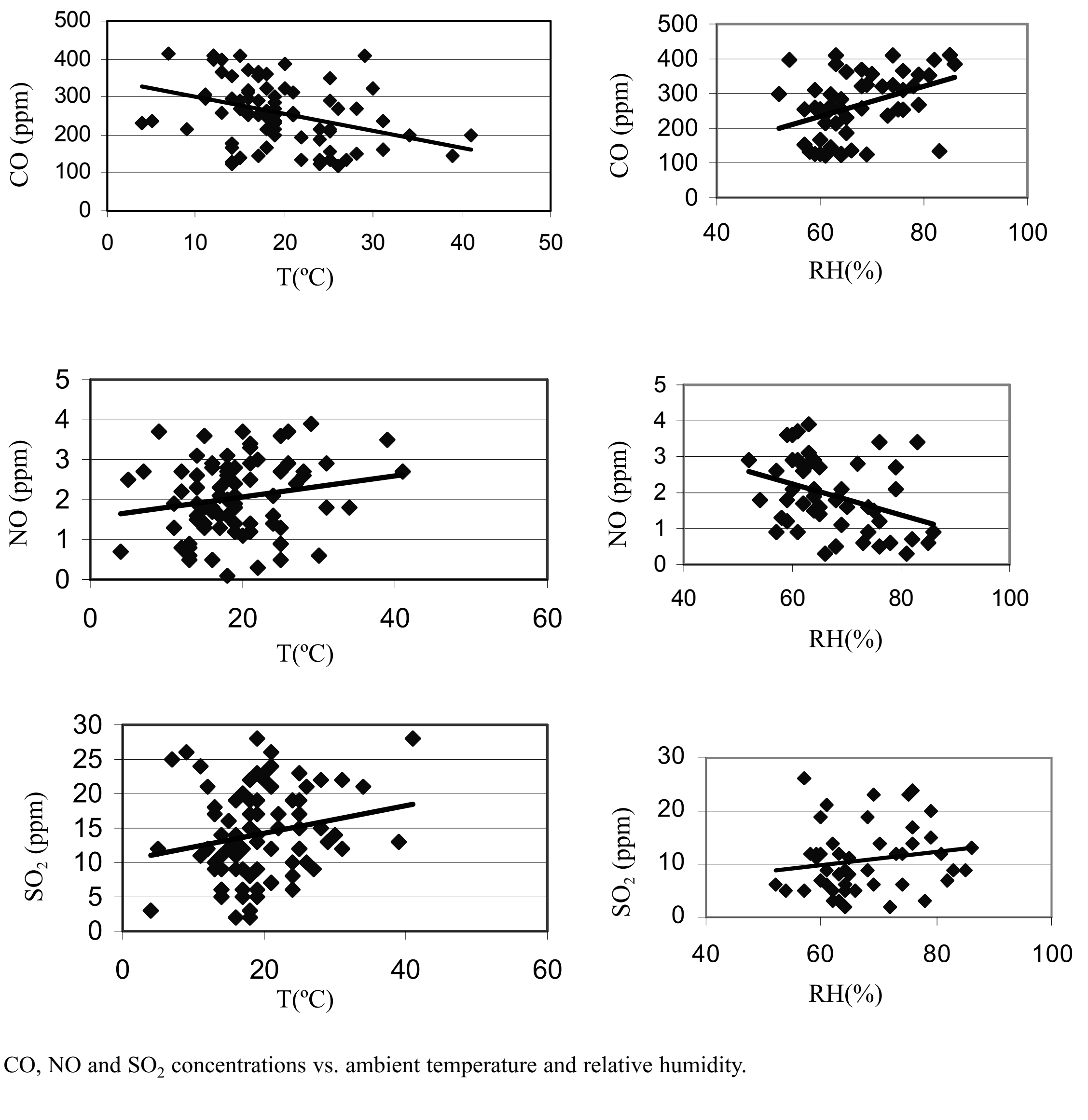

Fig. 2. CO, NO and SO_2 concentrations vs. ambient temperature and relative humidity.

The diurnal pattern of SO_2 is characterized by maximum concentration in the morning because of combinations of anthropogenic emissions, boundary layer process, and chemistry, as well as local surface wind patterns.

These results are in accordance with those found by Moreno [9].

Forecasting Model

With the use of the Box and Jenkins method [10], we established a forecasting model for each pollutant. The model choice is based on auto-correlations and partial auto-correlations of observed data. Model validation is based on the Student test for coefficients and residues non-correlations (correlation coefficients $\rho(\varepsilon_t, \varepsilon_s) = 0$ if $t \neq s$).

For CO, the chosen model SARIMA$(1,0,0)(1,1,0)_{12}$ can be written in the following form:

$$Y_t = 0.601Y_{t-1} + Y_{t-12} - 0.929Y_{t-12} - 0.601Y_{t-13} + + 0.558\, Y_{t-13} + 0.929\, Y_{t-24} - 0.558\, Y_{t-25} + \varepsilon_t$$

...where ε_t is a white noise process.

Fig. 4 represents the measured concentrations during 2006 and the forecasted data in the first months of 2007 with a confidence interval of 90%.

For NO, the chosen model SARIMA$(1,0,1)(1,1,0)_{12}$ can be written in the following form:

$$Y_t = 0.482Y_{t-1} + Y_{t-2} - 0.128Y_{t-2} + 0.128Y_{t-13} + + 0.061Y_{t-13} + 0.128Y_{t-24} - 0.061Y_{t-25} + \varepsilon_t + 0.791\, \varepsilon_{t-1}$$

And for SO_2, the chosen model SARIMA $(1,0,0)(1,1,0)_{12}$ can be written in the following form:

$$Y_t = 0.763Y_{t-1} + Y_{t-12} - 0.817Y_{t-12} - 0.763Y_{t-13} + + 0.623\, Y_{t-13} + 0.817\, Y_{t-24} - 0.623\, Y_{t-25} + \varepsilon_t$$

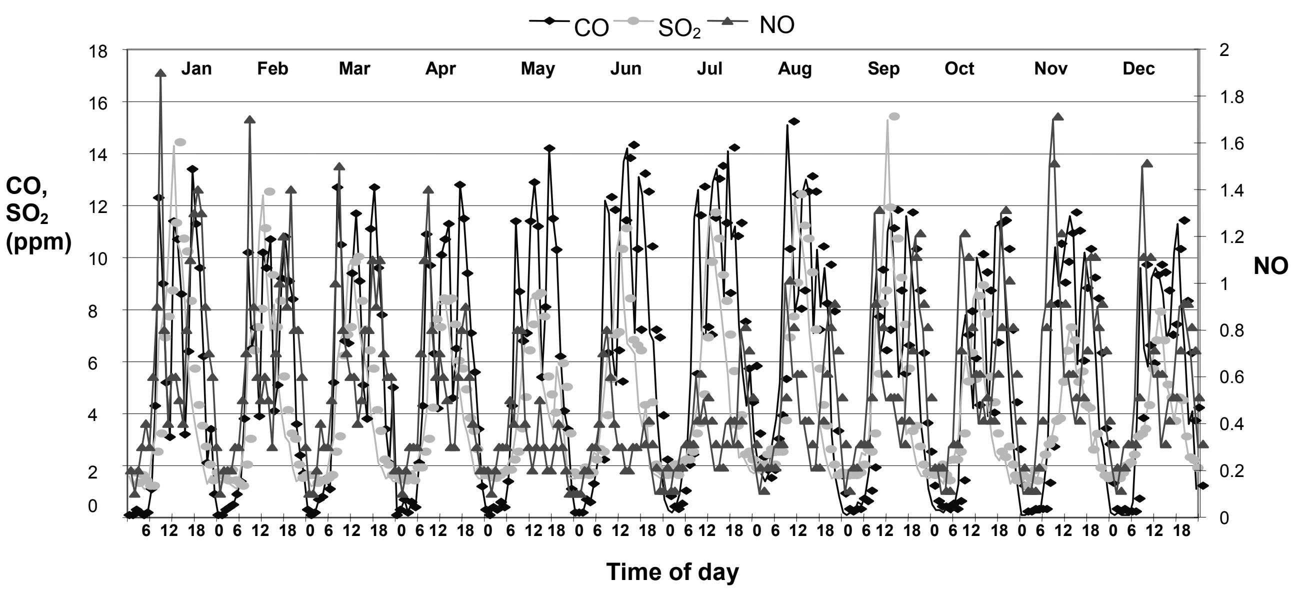

Fig. 3. Daily variations of pollutant concentrations measured in Bejaia city during 2006.

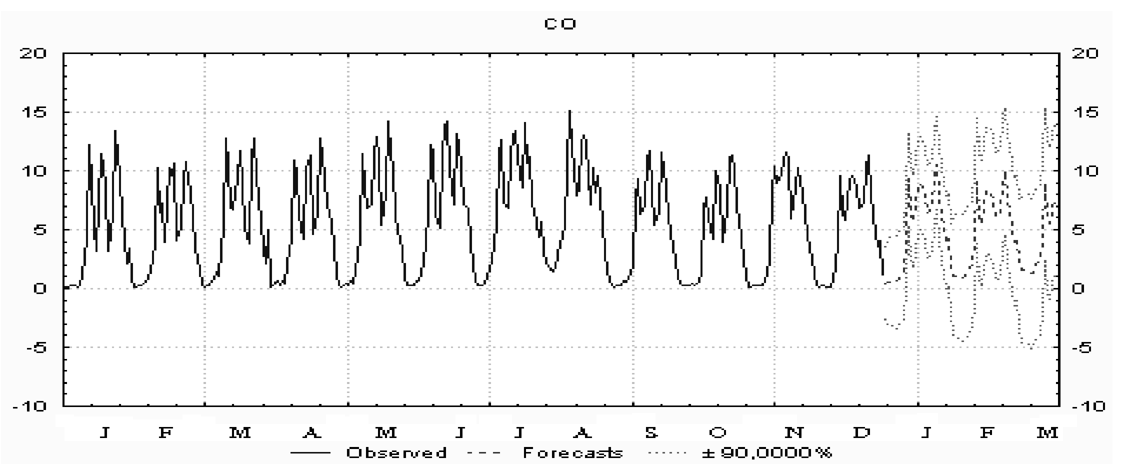

Fig. 4. Observed CO concentration during 2006 and forecasts for 2007.

Differences between measured concentrations and forecasted data in January, February and March 2007 are less than 17% for all three pollutants.

Conclusion

The pollutants emitted by various sources are rather different in kind and in concentration. The height of the chimney influences enormously the dispersion of the pollutants, which follows an exponential decreasing model. Atmospheric concentrations of the three pollutants in Béjaia city have been found to be consistently higher than the permissible limits.

On the basis of the present study, it can be concluded that wind and relative humidity are shown to be the most important meteorological parameters influencing the behaviour of air pollutants. Temperature has a weak association with the concentrations of the pollutants, while the wind and relative humidity influence dispersion and transformation of the pollutants. Diurnal and seasonal variations of air pollution showed that measured concentrations are strongly correlated with industrial activity and heavy traffic in the centre of Bejaia city.

References

1. KOLEHMAINEN M., MARTIKAINEN H. RUSKANEN J. A neural networks and periodic components used in air quality forcasting. Atmosph. Environ. **35**, 815, **2001**.
2. GRAMER L., CHEVREUIL M. Automobile traffic: a source of PCBs to the atmosphere, Chemosphere, **23**, (6), 785, **1991**.
3. JICHA M., KATOLICKY J. Dispersion of pollutants in street canyon under traffic induced flow and turbulence, Jour. for Environ. Monit. and asses., **65**, 343, **2000**.
4. ALKAMA R., AITIDIR F., SLIMANI Z., Estimation and measurement of the automobile pollution: application to Bejaia case. Glob. NEST jour. **8**, (3), 277, **2006**.
5. LATINI G., COCCI GRIFONI R., PASSERINI G. Influence of meteorological parameters on urban and suburban air pollution. Adv. In Air Pollution, **11**, 753, **2002**.
6. CELIK B., KADI I. The relation between meteorological factors and pollutants concentrations in Karabuk city. G.U. Jour. Sci. **20**, (4), 87, **2007**.
7. GUPTA A.K., RASHMI S., GUPTA S.K. Influence of meteorological factors on air pollution concentration for a coastal region in India. Int. Jour. Env. Pol. **21**, (3), 253, **2004**.
8. HAMDI K. Dependence of urban air pollutants on meteorology. Sci. Tot. Environ. **350**, 225, **2005**.
9. MORENO T., QUEROL X., ALASTUEY A., SANTOS S., GIBBONS W. Controlling influences on daily fluctuations of inhalable particles and gas concentrations: local versus regional and exotic atmospheric pollutants at puertollano, Spain. Atmos. Env. **40**, 3207, **2006**.
10. BOX G. E., JENKINS G. M., Time Series Analysis Forecasting and Control, Holden Day, San Fransisco, **1976**.