BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LIX (LXIII), Fasc. 6, 2013
Secția
CONSTRUCȚII. ARHITECTURĂ

EIGHT YEAR PERIOD ANALYSIS FOR OUTDOOR POLLUTANT CONCENTRATION LEVELS IN BUCHAREST

BY

VALENTIN M. RADU, VLAD IORDACHE[*] and TIBERIU CATALINA

Technical University of Civil Engineering Bucharest
Faculty of Building Services

Received: November 11, 2013
Accepted for publication: December 19, 2013

Abstract. This paper summarizes some of the result of an eight yearlong continuous measurements and study of atmospheric pollutants and meteorological data for Bucharest, with focus on ozone concentration. Higher ozone levels were recorded outside the city and lower towards the city center. Weekday – weekend studies were conducted, to find concentration variations differences along a week, with no major differences. Meteorological data were recorded in order to study the association of pollutants with meteorological parameters, mainly temperature. Temperature correlation analysis was conducted to understand the variation of ozone concentration along with temperature variation. Ozone concentrations recorded outside Bucharest indicate a decrease tendency for the last four years, with no exposure limit exceeding.

Key words: ozone concentration; temperature correlation; Bucharest pollution; monitoring network.

1. Introduction

Bucharest city, capital of Romania, is affected by its air pollution with consequences that may lead to serious problems for the inhabitants and the

[*] Corresponding author: viordach@yahoo.com

environment (Mulholland *et al*., 1998; Grundström *et al*., 2011). Some air quality studies have been performed recently (S.C. FITPOL S.R.L., The Romanian Auto Registry, Onimus *et al*., 1995) but given the great variation of pollutions sources in the city, a large scale, long-term study was needed to emphasize the present pollutant levels of this metropolis. Ozone (O_3) pollutant species was chosen for this study due to its high toxicity (Ardelean & Iordache, 2007). It is estimated that ozone related deaths in Netherlands were 990, 1,140 and 1,400, during June…August 2000, 2002, 2003 (Munn *et al*., 2000).

Pollution is a key aspect for the European Union, with great efforts towards reduction, with the help of the new air quality directive (Directive 2008/50/EC), which merged all the existing legislation except for the fourth "daughter directive".

The Air Quality Framework Directive (European Union (EU), 1996) is responsible for the assessment and management of air quality for the member states and Romania aligned its air quality regulation to the European Union with law no. *104*/2011, in an effort to meet the EU air quality standards.

Ozone pollution is a complex process, varying in time and space, with a variety of factors influencing O_3 concentration variation like: season, meteorological parameters (wind speed and direction, temperature, relative humidity (Walter & Henry, 1976), solar radiation). Other factors influencing ozone variation are urban and industrial activity, the complex geometry of the city, but also pollutant transportation from the nearby.

One of the largest air quality and meteorological monitoring network was used for this study, with seven pollutants and meteorological data targeted (nitrogen oxides, sulfur dioxide, ozone, carbon monoxide, cadmium, particulate matter), being monitored for over eight years (2004…2011). The Bucharest monitoring network is comprised of eight fixed ground stations for air quality monitoring, placed in the urban area, as well as in the city limits with live and simultaneously data acquisition.

The present paper focuses on ambient ozone air pollution in urban and suburban areas of Bucharest city using data resulted after an eight yearlong continuous measurements and study of atmospheric pollutants and meteorological data.

2. Method

2.1. Studied City

Bucharests the capital of Romania and it was chosen for this study for its complexity and high number of residents, with over 1.6 million residents (INSSE, 2012). It is located in the Southeast part of the country (44°25′57″N

26°06′14″E) and has a transitional climate with both continental and subtropical influences (Köppen climate classification *Cfa/Dfa/Cfb/Dfb*).

2.2. Sampling Locations

The Bucharest air quality monitoring network is comprised of a total of eight pollution monitoring stations, being part of the larger Romanian Network for Air Quality Monitoring (RNMCA) launched in 2004. The monitoring network operates under the supervision of the Romanian Ministry of the Environment and the National Agency for Environmental Protection (ANMP). The recorded pollutant concentration includes: nitrogen oxides, sulfur dioxide, ozone, carbon monoxide, cadmium and particulate matter.

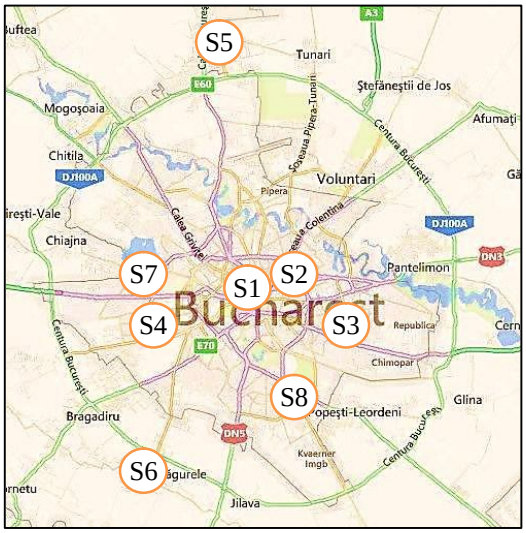


Fig 1 – Bucharest air quality monitoring network stations locations.

Table 1
Real Time Monitoring Station

Station	Location	Station type	Location details
S1	CerculMilitar	Traffic	downtown
S2	MihaiBravu	Traffic	downtown
S3	Titan	Industrial	outskirts
S4	DrumulTaberei	Industrial	outskirts
S5	Baloteşti	Peripheral	outside; 9.63 km North from the city ring road
S6	Măgurele	Peripheral	outside; right after the city ring road
S7	Lacul Morii	Peripheral	outskirts
S8	Berceni	Industrial	outskirts

The monitoring stations location is shown in Fig. 1, with stations located within the urban and suburban areas of Bucharest. Each one records the atmospheric pollutants concentrations along with seven meteorological parameters: wind direction, wind speed, relative humidity, temperature, solar radiation and atmospheric pressure.

2.3. Instrumentations and Measurement Protocol

Each measuring station is houses gas analysers, gas tanks for calibration and computer based data storage and sampling control.All the equipment is installed inside a trailer or fixed container that can be deployed on site (Fig. 2).

Fig 2 – Monitoring station S2.

The O_3 concentration measurement and logging is based on the principle of absorption of light law which passes the probe through a constant length chamber with a beam of UV monochromatic radiation applied. The measurements are precise within the usual measuring range of 0…100 ppb thanks to a small span drift of less than 1% and a zero drift of less than 1 ppb for a 7 day period.

Meteorological data was recorded using sensors mounted 2 m above the roof of each monitoring station. The analysers are calibrated once a day to insure minimum errors, using calibrators and zero air generators. The measured data is stored locally at the measurement stations and sent also to a remote server located at the Bucharest Agency for Environment Protection (ARPMB). A GSM modem is used to send the data to the main server, once per hour.

Also, a technique is used to validate the data for inconsistencies, technique implemented at the main server and at the local station.

3. Results and Discussion

3.1. Annual Variation

Eight hour moving average ground level ozone concentrations, measured from January 2004 to January 2012, is presented in Fig. 3. Analysing the data, we can see a steady downward trend in ozone concentration throughout the 8 year observation, with no 8 hour exposure limit exceeding in the last four years.

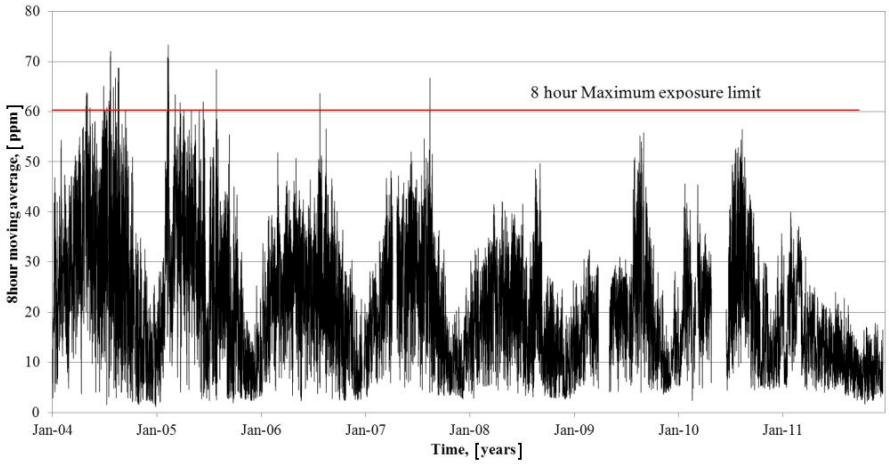


Fig. 3 – Annual O_3 concentration variation for station S5.

The data also shows that the peak ozone concentration can be found in summer and winter, with high peaks in summer and low peaks in winter.

3.2. Monthly Variation

One month ozone concentration variation during January & July 2006 is shown in Fig. 4. The O_3 concentration variation shows a drop in concentration for the winter time and different levels for stations located downtown (S1), at the city limits (S2) and outside the city limits (S8), with ozone concentration rising toward city limits and beyond.

Analysing the monthly statistics in Figs. 6 and 7 we would expect to find a variation in ozone concentration between weekdays and weekends because of differences in traffic density. Two periods were selected for the statistics, January 2006 and June 2006 to capture the differences in ozone formation and destruction for the two seasons. One would have expected to have different O_3 concentration for weekends compared to weekdays, but this is

not the case, as the differences are insignificant. For example, location 1 has almost the same average ozone concentration of 3 ppb both for weekend and weekday; location 2 has an average ozone concentration of 20.5 ppb, with a slight increase of only 0.4 ppb. There are no major differences in concentration over a week as we would have expected. The highest difference for weekdays and weekends was recorded at station S4 for June 2006 (3 ppb), with 23.3 ppb in weekday and 26.3 ppb in weekend.

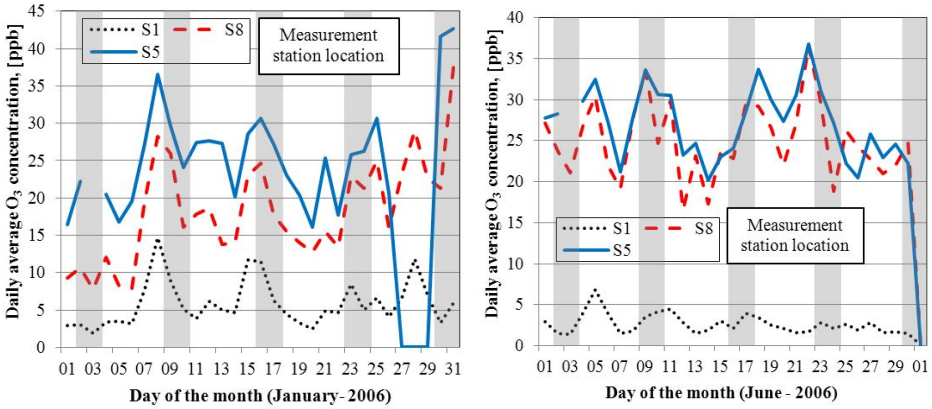


Fig 4 – Monthly average ozone concentration (January & June 2006).

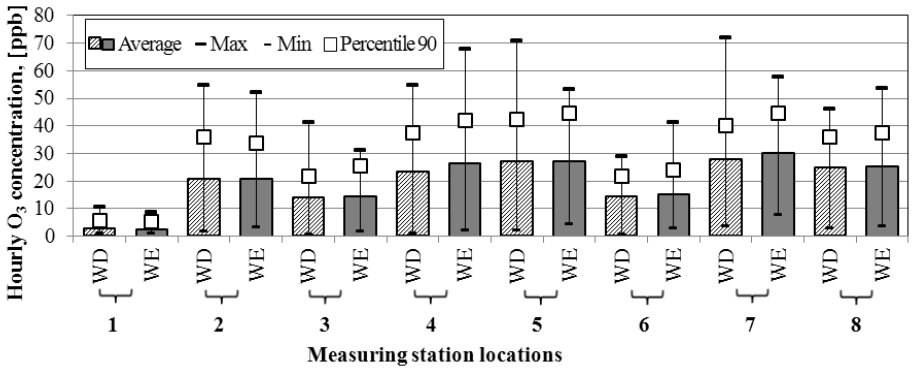


Fig. 5 – Daily average ozone concentration statistics (June 2006).

The same applies for the winter time, having no real differences in O_3 concentration for weekends and weekdays. Slightly higher ozone levels for weekends in winter and summer time may be linked to different meteorological conditions although we would have expected to observe an emphasize of this phenomenon in the summer time, as ozone forms in the presence of sun and VOC.

Differences in ozone concentration was observed in other studies, Kathmandu valley in Nepal recording higher ozone concentration in weekends, with 19% differences over weekdays (Deepak *et al*., 2006).

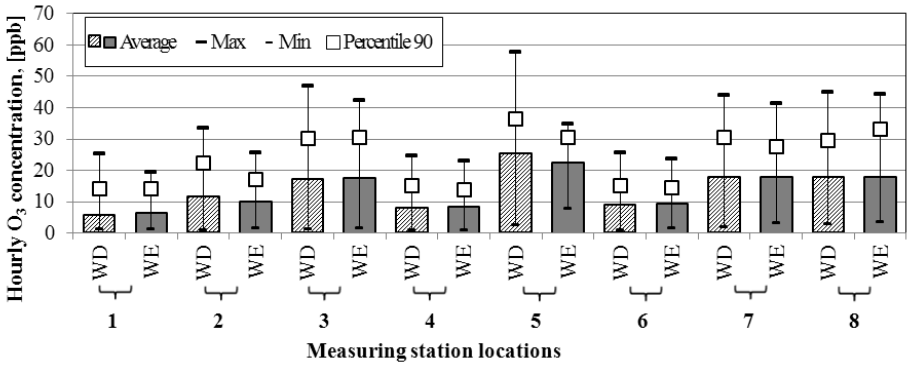
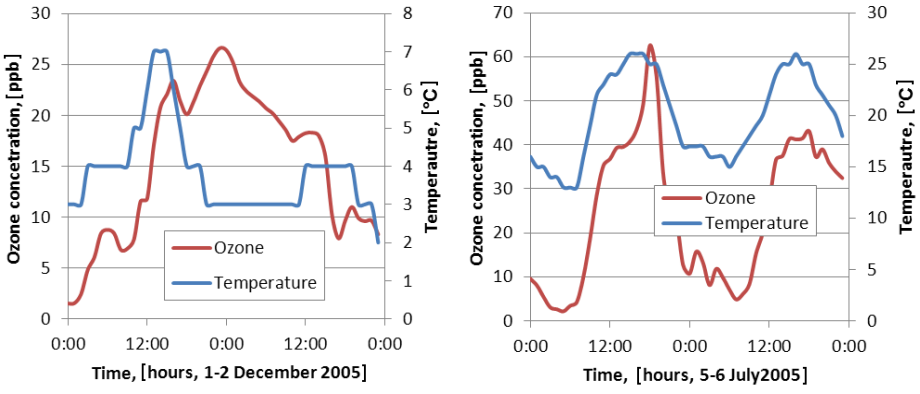


Fig. 6 – Daily average ozone concentration statistics (January 2006).

3.3. Association of Ozone with Meteorological Parameters

Ozone formation is influenced by season, with more ozone formation in spring and summer than in winter. Thus, ozone formation is associated with the intensity of solar radiation, temperature, relative air humidity, the absolute concentration of NO_x and VOC_s, and the ratio of NO_x and VOC_s (Nevers, 2000).



a *b*

Fig. 7 – Ozone *vs.* temperature variation: *a* – winter time; *b* – summer time.

Fig. 7 shows the ozone concentration and temperature variation, both for the summer and the winter time. A strong correlation can be seen in the summer time, with temperature and ozone concentration simultaneous peaks. There is a correlation in the winter time, but not as clear as for the summer time.

4. Conclusions

Pollution is a key aspect for all major cities, including Bucharest, efforts being made to reduce air pollution and its effects. A large monitoring network was used to study the ozone concentration variation in Bucharest, both for the winter and summer time. Bucharest tends to have higher ozone concentration in the summer time, but no real differences when analysing weekends and weekdays. The conclusion regarding weekend – weekday differences are in opposite to those of other experimental studies (Deepak *et al.*, 2006).

There is also a correlation with meteorological parameters, as O_3 concentration tends to increase or decrease along with air temperature. A strong correlation can be found in the summer time, but the in winter times other factors are affecting ozone formation and further studies have to be made.

Ozone concentrations recorded outside Bucharest indicate a decrease tendency for the last four years, with no exposure limit exceeding.

Acknowledgements. The study was performed during the PN II RU TE 2011 3 209 projects up ported by Romanian Research Council (CNCSIS) and the financing organism UEFISCSU. Wethank Romanian Environment Agency for the data base with the pollutants concentrations and meteorological parameters for Bucharest.

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ANALIZA PE O PERIOADĂ DE OPT ANI A NIVELULUI CONCENTRAȚIILOR POLUANȚILOR ATMOSFERICI DIN BUCUREȘTI

(Rezumat)

Se rezumă rezultatele unei campanii de măsurări continue şi studiu a poluanților atmosferici şi a datelor meteo pentru Bucureşti pe o perioada de opt ani, cu accent pe variația concentrației de ozon. Niveluri ridicate de ozon au fost înregistrate în afara oraşului cu tendința de scădere spre centrul oraşului. Studii comparative între zillele de weekend şi celelalte zile ale săptămănii au fost efectuate, pentru a găsi variații diferite ale concentrațiilor de ozon de-a lungul unei săptămâni, fără însă a se evidenția diferențe majore.Au fost înregistrate date meteo, în scopul studierii corelațiilor dintre poluanți şi parametrii meteo, în special cu temperatura aerului exterior. Analiza corelației cu temperatura a fost efectuată pentru a înțelege mecanismul variației concentrației de ozon în funcție de variația temperaturii. Concentrațiile de ozon înregistrate înafara Bucureştiului indică o tendință de scădere în ultimii patru ani, fără a se depăşi limitele de expunere.