

**URBAN AIR POLLUTION AND RESPIRATORY EMERGENCY VISITS AT PEDIATRIC UNIT, REGGIO EMILIA, ITALY**

Emanuela Bedeschi, Cinzia Campari, Silvia Candela,<sup>1</sup> Nicola Caranci, Gabriella Frasca,<sup>2</sup> Giorgia Collini,<sup>1</sup> Claudia Galassi,<sup>2</sup> Maria Angela Vigotti<sup>3</sup>

**ABSTRACT**

*Short-term effects of air pollution on daily mortality and hospital admissions for respiratory causes are well documented. Few studies however explore the association between exposure to air pollution and daily emergency room visits for respiratory disorders, particularly in Italy and particularly among children as a susceptible population. A time series analysis was conducted to explore the short term association between air pollutants ( $PM_{10}$ , TSP,  $NO_2$ ,  $SO_2$ , CO,  $O_3$ ) and Pediatric Emergency Room Visits (ER) in a small city of Northern Italy (Reggio-Emilia) during the period 03/01/2001 - 03/31/2002. 1051 ER visits were included in the study. Data were analyzed using Generalized Additive Models (GAM), adjusting for various confounding variables, including temperature, humidity and pollens (Graminaceae). The analyses were also stratified according to the nationality of children (Italians and Foreigners). In single pollutants models, the strongest associations were observed at lag 3 for a  $10 \mu g/m^3$  increase of TSP (2.7% increase in ER, 95%CI 0.7;4.6) and  $PM_{10}$  (3.0% increase, 95%CI 0.4;5.7), and at lag 4 for a  $10 \mu g/m^3$  increase of  $NO_2$  (11.0% increase in ER, 95%CI 3.6;18.8). At lag 3, the percentage increase in ER visits is similar for the two groups of children (Italians and Foreigners) for TSP and  $PM_{10}$ . The results of the study support the findings that air pollution is a relevant determinant of deterioration of respiratory health among children.*

---

<sup>1</sup> ASL di Reggio Emilia, Italy.

<sup>2</sup> Regional Agency for Health, Bologna, Italy.

<sup>3</sup> Universita di Pisa, Pisa, Italy.

## INTRODUCTION

A large body of epidemiological research has focused on urban air pollution exposure and its consequences on respiratory health. Most of these studies were conducted measuring the admissions to hospital and mortality for respiratory diseases as main health effects (Atkinson et al., 2001; Atkinson, 2004; Brunekreef and Holgate, 2002; Samet et al., 2000). There are also several studies on emergency room (ER) visits all over the world, but mainly focused on asthmatic children (Norris et al., 1999; Thompson et al., 2001; Tolbert et al., 2000; von Klot et al., 2002). Fewer studies have analysed less severe end points such as ER visits focusing on respiratory symptoms and disorders in the general population and among young children (Atkinson et al., 1999; Delfino et al., 1997; Fusco et al., 2001). Recurrences of respiratory symptoms are certainly more frequent events than admissions to hospital. They enhance the demand for medical attention and, therefore, their increase can be considered as an indicator of deteriorating life quality.

Reggio Emilia is a city of northern Italy with almost 150 000 inhabitants, with only one hospital with a Pediatric Unit where all Emergency Room Visits (ER) are fully registered. Moreover, an air pollution monitoring station network has been in operation since 1989. During the winter of 2001-2002, the alarm threshold for air pollution episodes was often exceeded. Reggio Emilia offers high levels of welfare benefits and presents one of the lowest unemployment rates in Italy; therefore the immigration rate is quite high. Children of foreign parents, either born in town or immigrated very early, are exposed to the same air pollution as the Italian nationals. It is reasonable to expect similar effects on respiratory health, independent of parents' nationality, although socio-economic differences could play a role. The aim of this study was to evaluate the short-term effects of urban air pollution levels on ER visits due to respiratory symptoms among children in the city of Reggio Emilia (Northern Italy), and to investigate possible differences by nationality.

## METHODS

### Health Data

The number of ER visits for all causes among Reggio Emilia inhabitants under 15 years of age is about 13 000 per year.

At the registration desk of the Emergency Department children requiring an urgent visit are usually sent to the Pediatric Unit where, on a paper registry, information concerning the diagnosis, the applied therapy, any additional examination by a specialist or hospital admission are recorded, as well as children's personal data. Further demographic information was obtained using the Registry Office. A medical doctor (EB) collected and coded ER data from the Pediatric Unit registry concerning all the children under 15 years, residing in the Municipality of Reggio Emilia, for whom a diagnosis of respiratory disease was made.

The study period was from 03/01/2001 to 03/31/2002. Children with more than 5 ER visits due to influenza or influenza syndrome were not enrolled.

The respiratory disorders were analyzed as a whole and included the following diagnoses: "asthma or asthma like disorders" (if a diagnosis of asthma or bronchiolitis or of dyspnea/shortness of breath was recorded by the physician) and "other respiratory disorders" (upper and lower respiratory illness, including sinusitis, bronchitis and pneumonia).

"Non Italian children," i.e. children with a non Italian father, were identified either if the child was born outside of Italy or on the basis of father's surname, and hereafter we will refer to them as "Foreign children."

### Air pollution and weather variables

Since 1989, Reggio Emilia Department of the Regional Environmental Protection Agency (ARPA) routinely monitors levels of air pollutants through a network of 6 monitoring stations located in different sites of the town. Allergenic pollens are also monitored through the network.

Pollutants analysed in this study were: NO<sub>2</sub>, SO<sub>2</sub>, CO, TSP, PM<sub>10</sub>, O<sub>3</sub> and allergenic pollens. Weather variables (temperature, humidity, precipitation) were obtained from the Regional Meteorological Service (SIM).

### Statistical methods

Data were analyzed using Generalized Additive Models (GAM) that take into account the effect of seasonal trend using semi-parametric smoothing function: penalized regression spline, with approximately 5 degrees of freedom (df), obtained specifying a smoothing parameter (sp). The choice of the number of df was made on the basis of minimisation of the AIC criterion and of observation of residual autocorrelation using ACF and PACF. Since GAM estimates using the *gam* function in the S-Plus statistical package may provide biased estimates (Dominici et al., 2002), the analyses were carried out with R software. The daily number of ER visits was considered distributed like a Poisson variable. The confounding factors included in the model were: weekday, dummy for festivity day, humidity, precipitation and temperature (current and delayed temperature, referred to the previous 3 days (Biggeri et al., 2001)), dummy for flu-epidemic (from the National Sentinel Surveillance System: FLU-ISS data base) and pollen concentrations (*Graminaceae*). The models were implemented including single pollutant a time, given the collinearity between the pollutants (Table 1). Associations have been studied for different time lags (from the same day up to 5 days before). Results are presented as the percentage variation of the Relative Risk of having ER visits computed as usual as the:  $RR=100*(\text{exponential}(\beta I) - 1)$  where  $\beta$  is the coefficient obtained for that pollutant and I is a specific increment of pollutant level. We have used  $I=10 \mu\text{g}/\text{m}^3$  for all pollutants except CO ( $I=1 \text{ mg}/\text{m}^3$ ) in order to make results comparable with most of the recent analyses.

Table 1: Matrix of linear correlation coefficients between air pollutants and weather variables; Reggio Emilia, Italy, January 2001-March 2002

	PM <sub>10</sub>	TSP	SO <sub>2</sub>	NO <sub>2</sub>	CO	O <sub>3</sub>	Temp	Hum
PM <sub>10</sub>	1							
TSP	0.89	1						
SO <sub>2</sub>	0.57	0.57	1					
NO <sub>2</sub>	0.57	0.58	0.56	1				
CO	0.61	0.61	0.71	0.77	1			
O <sub>3</sub>	-0.52	-0.52	-0.55	-0.50	-0.63	1		
Temp	-0.51	-0.49	-0.59	-0.63	-0.70	0.83	1	
Hum	0.38	0.41	0.22	0.33	0.37	-0.67	-0.50	1

### RESULTS

Data on 1 051 ER visits were included in the study. 854 children (497 males, 357 females) were involved: 715 children visited once and only 13 visited 4 times during the study period. 210 children were Foreign (24.6%) and accounted for 271 (25.8%) visits. The median age was 2 years in both groups. ER visits were higher for males (611=58.1%) especially among Foreign children (176=64.9%). 254 asthma-related visits were included in the group (24%) and those included in the group of other respiratory disorders were 797 (76%). Only 26 ER visits (2.5%) were followed by a hospital admission; 17 of these admissions were among children included in the "Asthma group." ER visits for asthmatic disorders were much more frequent among Italians (207 = 26.5%) than among the Foreigners (47= 17.3%). ER characteristics such as the hour (of the day), the weekday, the month, as well as the mean number of ER visits per subject did not differ between the two groups of Italians and Foreigners. Most of ER visits were during the week-end and in the winter period (December to March). The rate of ER visits (number of ER visits per 1 000 inhabitants), stratified by nationality, was 43.2% among Italian children and 144.8% among Foreigners.

As shown in Table 2, daily values of airborne fine particulate were quite high during the study period: daily mean of PM<sub>10</sub> concentration was  $51.2 \mu\text{g}/\text{m}^3$  (air quality standard:  $40 \mu\text{g}/\text{m}^3$  annual mean EC, 1999).

A significant association was found between ER visits for all respiratory disorders and particulate matter daily levels on previous days, either measured as TSP or as PM<sub>10</sub>, i.e. particulate with a dynamic diameter below 10 microns.

Table 2. Statistics for air pollutants, meteorological variables and ER in Reggio Emilia, Italy, January 2001-March 2002 (daily values).

Pollutants	unit	Mean	s.d.	min.	median	max.
PM <sub>10</sub>	$\mu\text{g}/\text{m}^3$	51.2	30.6	5	44.7	196.8
TSP	$\mu\text{g}/\text{m}^3$	60.4	34.3	3.7	52.4	272.9
SO <sub>2</sub>	$\mu\text{g}/\text{m}^3$	9.3	2.3	4.6	8.9	20.9
NO <sub>2</sub>	$\mu\text{g}/\text{m}^3$	49	13.8	21.6	47.5	107.5
CO	$\text{mg}/\text{m}^3$	1.4	0.7	0.4	1.1	4.6
O <sub>3</sub>	$\mu\text{g}/\text{m}^3$	68.6	46.7	4.5	66.2	200.5
Summer-O <sub>3</sub>	$\mu\text{g}/\text{m}^3$	107.5	32.2	30.9	105.4	200.5
<b>Weather variables</b>						
Temperature	$^{\circ}\text{C}$	12.8	8.2	-3.8	13.0	27
Relative Humidity	.	77.5	10.8	45.7	79.4	97.5
Precipitations	mm	1.5	4.3	0.0	0.1	37.8
<b>Respiratory ER visits</b>						
All	count	2.7	2.5	0	2	17
Italians	count	2.0	2.0	0	2	12
Foreigner	count	0.7	1.0	0	0	5

For a rise of  $10 \mu\text{g}/\text{m}^3$  in the daily level of TSP on the 3<sup>rd</sup> previous day (lag 3), the percentage variation in the risk for an ER visit for any respiratory disorder was 2.7% (95%CI 0.7;4.6) among all children residing in Reggio Emilia; among the group of Italian children it was 2.5% (95%CI 0.4;4.7) and among the Foreign children it was 3.7% (95%CI 0.2;7.3) always at lag 3, but in this group the most significant increase was 5% (95%CI 1.1;9.1) at lag 1. Figure 1 reports the results for the entire range of examined lags.

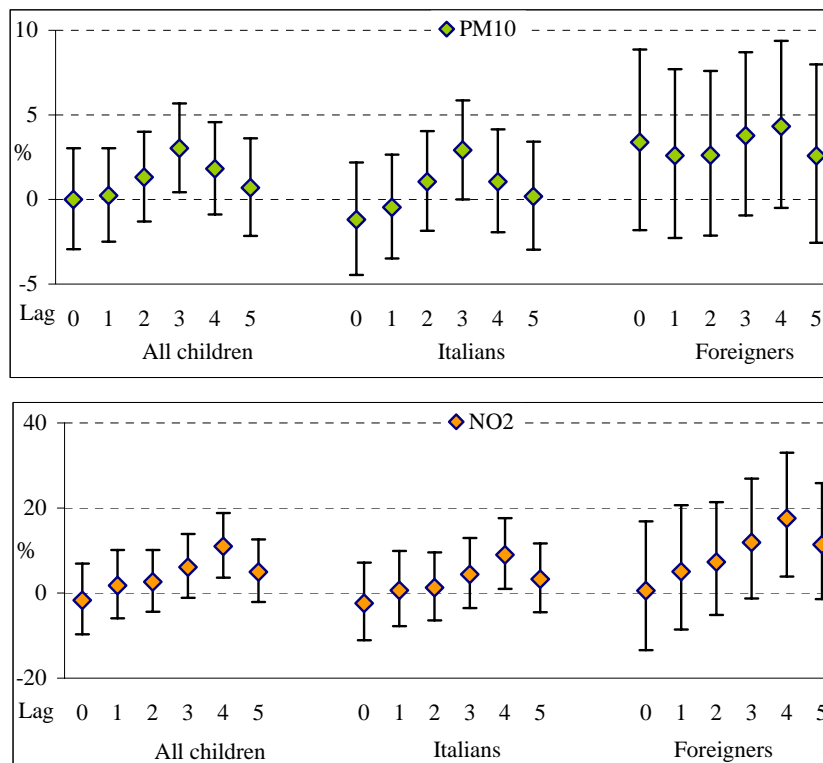


Figure 1: Single pollutant model results for all respiratory disorders. Associations are expressed as a percentage change (95% Confidence Interval) in the number of ER for an increase of  $10 \mu\text{g}/\text{m}^3$  in each pollutant (PM<sub>10</sub>, TSP and NO<sub>2</sub>), at different lags (0-5), and separately for Italians and Foreign children. Reggio Emilia.

The same increase in daily levels of PM<sub>10</sub> at lag 3 was associated with an increase of 3.0% (95%CI 0.4;5.7) in the risk of ER visits for any respiratory disorder considering all children, and with a rise of 2.9% (95%CI 0.0;5.9) for the Italian children. No statistically significant results were seen among Foreign children (see Figure 1), although the higher values were observed at lag 4 (RR% 4.3, 95%CL: -0.5;9.4).

Finally, the rise of 10 µg/m<sup>3</sup> in the NO<sub>2</sub> levels was found to be correlated with an increase in the risk of ER visits for all groups and always at the same time lag (lag 4): among Italians the percentage increase was 9% (95%CI 1.0;17.6), among the Foreigners it was 17.6% (95%CI 3.9;33.0), while overall the percentage increase was 11.0% (95%CI 3.6;18.8). In Figure 1 the lower graph clearly shows the time trend of the increase of the risk of ER visits associated with NO<sub>2</sub> levels on the previous days, for each group of children.

No significant associations were found with daily levels of O<sub>3</sub>, SO<sub>2</sub> or CO.

## DISCUSSION

The study shows significant associations between urban air pollutants and Pediatric ER visits due to respiratory disorders. These associations are independent of the effect of temperature, humidity and pollen trend (Galan et al., 2003). The main pollutants involved are those linked to road traffic such as particulate matter (PM<sub>10</sub> or TSP) and NO<sub>2</sub>, as already suggested (Ciccone et al., 1998), and their effects are quite time delayed. The delayed time (3 or 4 days) may suggest that their main effect is to start a process of deterioration of respiratory health in children and that as a consequence after a few days they require urgent medical attention.

Another possible explanation of the delayed time is that parents bring children to the Emergency Units after having first consulted their own family practitioner, and if symptoms still persist and the family practitioner could not easily be reached (in the evening or at night, during the week-end).

The more frequent use of the Pediatric Emergency Unit observed for Foreigners compared to Italians, as well as the significant association found for TSP at a shorter lag (lag 1) among the Foreigners, could reflect a more inappropriate use of the Emergency Unit by the Foreigners, meaning that they first go to the emergency room rather than going to the family practitioner. However, this group is supposed to be characterized by a lower socio-economic status; for that reason an effect of air pollution as a modifier among children belonging to the lower socio-economic classes cannot be excluded. This could partially explain the slightly larger percentage increases among Foreigners' children. This matter certainly requires further investigation.

The observed effects of TSP, PM<sub>10</sub> or NO<sub>2</sub> exposure are quite similar for each of the two nationality groups of children although results for the Foreigners exhibit larger confidence limits (for PM<sub>10</sub> not significant), most likely as a consequence of the smaller size of the group. These results support the hypothesis that children experience similar effects in term of respiratory symptoms caused by the exposure in the town of residence, independently from parents' nationality.

Reggio Emilia, in Italy, is considered a town with a high level of welfare, good public health services, including a well functioning, easily accessible hospital. However, Reggio Emilia's weather is quite ugly, with long humid winters, frequent fog and hot humid summers. These climate conditions should likely enhance the noxious effects of air pollution, mainly due to urban traffic.

Although the short-term effect of air pollution on daily mortality and hospital admissions for respiratory causes are well known, few studies have explored the association between exposure to air pollution and emergency room visits, particularly in Italy and particularly among children as a susceptible population (Atkinson et al., 1999; Ribeiro, 1989; Ribeiro and Cardoso, 2003; Orazzo et al., 2001). Our study supports the finding that air pollution is a relevant determinant of deterioration of respiratory health among children.

## REFERENCES

- Atkinson, R.W., Anderson, H.R., Strachan, D.P., Bland, J.M., Bremner, S.A., and Ponce de Leon, A. 1999. Short term associations between outdoor air pollution and visits to accident and emergency departments in London for respiratory complaints. *Eur. Respir. J.* 13:257-265.
- Atkinson, R.W., Anderson, H.R., Sunyer, J., Ayres, J., Baccini, M., Vonk, J.M., Boumghar, A., Forastiere, F., Forsberg, B., Touloumi, G., Schwartz, J., and Katsouyanni, K. 2001. Acute effects of particulate air pollution on

- respiratory admissions: results from APHEA 2 project. Air pollution and health: a European approach. *Am. J. Respir. Crit. Care Med.* 164:1860-1866.
- Atkinson, R.W. 2004. APHEA 2 Project. Acute effects of air pollution on admissions: reanalysis of APHEA 2. *Am. J. Respir. Crit. Care Med.* 169:1257-1258.
- Biggeri, A., Bellini, P., and Terracini, B. 2001. Metaanalisi italiana degli studisugli effetti a breve termine dell'inquinamento atmosferico. *Epidemiol. Prev.* 25:1-72.
- Brunekreef, B., and Holgate, S.T. 2002. Air Pollution and health. *Lancet* 1233:42.
- Ciccone, G., Forastiere, F., Agabiti, N., Biggeri, A., Bisanti, L., Chellini, E., Corbo, G., Dell'Orco, V., Dalmasso, P., Volante, T.F., Galassi, C., Piffer, S., Renzoni, E., Rusconi, F., Sestini, P., and Viegi, G. 1998. Road traffic and adverse respiratory effects in children. SIDRIA Collaborative Group. *Occup. Environ. Med.* 55:771-778.
- Delfino, R.J., Murphy-Moulton, A.M., Burnett, R.T., Brook, J.R., and Becklake, M.R. 1997. Effects of air pollution on emergency room visits for respiratory illnesses in Montreal, Quebec. *Am. J. Respir. Crit. Care Med.* 155:568-576.
- Dominici, F., McDermott, A., Zeger, S.L., and Samet, J.M. 2002. On the use of generalized additive models in time-series studies of air pollution and health. *Am. J. Epidemiol.* 156:193-203.
- EC 1999. Council directive 1999/30/EC of April 1999 relating to limit values for sulphur dioxide, nitrogen dioxide and oxide of nitrogen, particulate matter and lead in ambient air. *Official Journal of the European Commission* (26.6.1999). L 163/41-60.
- Fusco, D., Forastiere, F., Michelozzi, P., Spadea, T., Ostro, B., Arca, M., and Perucci, C.A. 2001. Air pollution and hospital admissions for respiratory conditions in Rome, Italy. *Eur. Respir. J.* 17:1143-1150.
- Galan, I., Tobias, A., Banegas, J.R., and Aranguel, E. 2003. Short-term effects of air pollution on daily asthma emergency room admissions. *Eur. Respir. J.* 22:802-808.
- Norris, G., Young Pong, S.N., Koenig, J.Q., Larson, T.V., Sheppard, L., and Stout, J.W. 1999. An association between fine particles and asthma emergency department visits for children in Seattle. *Environ. Health Perspect.* 107:489-493.
- Orazio, F., Rossi, G., Tassinari, D., DallaCasa, C., Dell'Erba, G., and Giardina, A. 2001. Air pollution, aeroallergens and emergency room visits for wheezing in very young children. *Am. J. Resp. Crit. Care Med.* 163, A562, Suppl.
- Ribeiro, S.H. 1989. Air pollution and respiratory diseases in children in Sao Paulo, Brazil. *Soc. Sci. Med.* 29:959-964.
- Ribeiro, S.H., and Cardoso, M.R. 2003. Air pollution and children's health in Sao Paulo (1986-1998). *Soc. Sci. Med.* 57:2013-2022.
- Samet, J.M., Zeger, S.L., Dominici, F., Curriero, F., Coursac, I., Dockery, D.W., Schwartz, J., and Zanobetti, A. 2000. The National Morbidity, Mortality, and Air Pollution Study. Part II: Morbidity and Mortality from Air Pollution in the United States. Research Report 94. Cambridge MA: Health Effects Institute.
- Thompson, A.J., Shields, M.D., and Patterson, C.C. 2001. Acute asthma exacerbations and air pollutants in children living in Belfast, Northern Ireland. *Arch. Environ. Health* 56:234-241.
- Tolbert, P.E., Mulholland, J.A., MacIntosh, D.L., Xu, F., Daniels, D., Devine, O.J., Carlin, B.P., Klein, M., Dorley, J., Butler, A.J., Nordenberg, D.F., Frumkin, H., Ryan, P.B., and White, M.C. 2000. Air quality and pediatric emergency room visits for asthma in Atlanta, Georgia, USA. *Am. J. Epidemiol.* 151:798-810.
- von Klot, S., Wolke, G., Tuch, T., Heinrich, J., Dockery, D.W., Schwartz, J., Kreyling, W.G., Wichmann, H.E., and Peters, A. 2002. Increased asthma medication use in association with ambient fine and ultrafine particles. *Eur. Respir. J.* 20:691-702.