Pollutant and noise impact on child morbidity

C. Linares[1], J. Díaz[2], R. García-Herrera[2], A. Tobías[3] & A. Otero[1]
[1]*Departamento de Medicina Preventi, Facultad de Medicina, Universidad Autónoma de Madrid*
[2]*Departamento de Física del Aire, Facultad de Ciencias Físicas, Universidad Complutense de Madrid*
[3]*Departamento de Estadística, Universidad Carlos III de Madrid*

Abstract

The aim of this paper is to analyse the effects of the urban air pollutants and noise levels on daily emergency hospital admissions of children less than ten years of age in Madrid. Poisson Regression Models were used to quantify the associations. Meteorological variables, influenza epidemics, pollen concentrations and trends and periodicities were used as controlling variables. The main results obtained were the detected relationship ($p<0.05$) between emergency hospital admissions due to organic causes and noise levels and PM10. Significant statistical associations were detected also for pollen concentrations, for cold temperature and for the difference in pressure. The results obtained suggest that particularly PM10 and noise levels are risk factors for the daily emergency hospital for organic causes.
Keywords: air pollution, children's health, emergency hospital admissions, noise levels, time series analysis.

1 Introduction

A growing body of evidence has demonstrated that children's susceptibility to environmental hazards is remarkably different to adults [1]. Children are more vulnerable than adults to environment factors because children are growing and their rapidly developing organ systems are particularly vulnerable, moreover children have a longer life expectancy than adults, giving long latency agents time to work alone or in combination [2]. Between the burdens of environmental risks that children are exposed to, outdoor air pollution is responsible about 6.4%

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of deaths from all causes among children aged 0-4 years in the European region [3]. After extended epidemiological studies on outdoor air pollution as a risk factor for morbidity and mortality on general and older population [4], latest studies [5] indicate that the consequences of air pollution are not spread equally among the population, particularly over children's health. Children may have greater exposure than adults to airborne pollutants, this fact is mostly the consequence of their higher exposure level due to their small size and weight. Children breathe more rapidly and inhale more air per breath compared to adults and they spend more time outdoors being physically active, moreover their breathing zone is lower than adults so they are more exposed to vehicle exhausts and heavier pollutants that concentrate at lower levels in the air [6]. Their immune systems and developing lungs are still immature, so irritation or inflammation caused by air pollution is more likely to obstruct their narrower airways [7].

On the other hand, little attention has been paid to the role of environmental noise as risk factor in urban environments. Noise levels can also be considered an environmental pollutant and in the last decade an increasing number of studies are focusing on the role of environmental noise on health [8, 9], between them, there are really few studies analyzing the impact of noise on children. Children may be more annoyed or otherwise adversely affected by noise than adults, in part because they have less well-developed coping responses and are often less able to control their environments. Noise can adversely affect children, the most well-know and most serious consequences of noise are hearing damage and tinnitus, but noise also provoke stress response in children that includes increased heart rate and increased hormone response. Noise can disrupt sleep and thus hinder needed restoration of the body and brain and high noise levels can negative affect children's learning and language development, can disturb children's motivation and concentration and can result in reduced memory and in reduced ability to carry out more or less complex task [10]. One of the main problems when trying to evaluate the role of environmental noise on health is the scarcity of proper measurements of noise levels adequately representing the real exposure to noise [11]. This has lead to a lack of studies including environmental noise levels as input for the behaviour of health variables. Previous studies [12] do not control the synergic effect which can be originated by air pollutants of chemical origin, thus leading to uncertainties when assessing the noise attributable effects [13].

Nowadays, very few studies have considered the effect of noise and air pollutants together over children morbidity to point out a statistically association between them, after controlling for other potential explanatory variables also related with emergency hospital admissions. In this paper, a time series approach is performed to analyse the effects of the principal urban pollutants (PM_{10}, O_3, SO_2, NO_2, NO_x) and noise levels over daily emergency hospital admissions of children less than ten years of age in Madrid (Spain) for organic causes since 1995 to 2000. Another variables as pollen concentration, meteorological variables and flu epidemics have been into consideration as control variables.

2 Methodology

As dependent variable, the series of daily emergency hospital admissions for children younger than ten years old has been computed during the period of January 1, 1995 to December 31, 2000 (2,192 days). This data serie, was supplied by the "Gregorio Marañon" Hospital of Madrid. Causes of admission were defined according to the *International Classification of Diseases, 9th Revision* [14], were grouped as total organic disease causes (ICD-9: 1-799). On the other side, independent variables analyzed were: Air pollutants (PM_{10}, O_3, SO_2, NO_2, NO_x) and daily noise levels. As covariables were analysed meteorological variables and daily levels of pollen (*Poaceae sp.*).

The air pollutants variables have been computed as daily average values and have been provided by the City Council. Daily mean concentrations of nitrogen oxides (NO_x), sulphur dioxides (SO_2), particles with a median aerodynamic diameter of < 10 µm (PM_{10}) and ozone (O_3) were considered, as furnished by Madrid's Municipal Automatic Air Pollution Monitoring Grid.

Acoustic pollution variables were provided by a real-time acoustic pollution network. Diurnal equivalent Level (Leqd) (including the 08-22h period), Night equivalent Level (Leqn) (including the 22-08h period) have been considered. Total daily values for the 24h period (Leqt), have also been considered. Data were provided by the Madrid City Council Noise Pollution Measurement Network.

Meteorological variables included in the models (maximum daily temperature, minimum daily temperature, median daily temperature, pressure and relative humidity at 7 a.m.) were provided by the Spanish National Institute of Meteorology, from the Madrid-Retiro observatory of reference, because of its convenient location in the vicinity of the "Gregorio Marañon" Hospital.

A new variable called "difference in pressure" (dP) was created and included in the models. It was defined as: $dP = P_t - P_{t-1}$, where P_t represents the pressure on the day in question and P_{t-1}, the pressure on the preceding day, so this new variable represents the following:

if $dP<0$ $P_t<P_{t-1}$ means cyclonic trend

if $dP>0$ $P_t>P_{t-1}$ means anticyclonic trend

Pollen data were drawn from the Madrid Regional Health Authority Palinology Network. Information was collected on the daily average levels of *Poaceae* pollen, which is one having highest allergenic potential in Madrid [15].

In previous papers [16], a V-relationship between temperature and emergency in-patients was established, with a minimum daily emergency admissions or comfort value of temperature. Maximum temperature has been used because the maximum daily temperature shows a significant relationship with child mortality, which is not the case for the minimum daily temperature [17] . In the case of ozone, a similar behavior pattern was observed [16]. These previous results have been found in morbidity for general population.

With regard to SO_2, analysis of scatter-plots obtained in previous papers [18], recommended the use of a log transformation for it before entering the models.

The rest of the variables have been used without any previous transformation due to their linear behavior [17]. Fast Fourier Transform method [19] was used to identify trends and periodicities through spectral density function analysis. This led to the introduction of dummy variables to control periodicities, as annual; biannual and three-month seasonalities and also trends. Additionally, influenza epidemics were described through, covariables computed as 1 if it was an epidemic day and as 0 otherwise. To control weekly variation dummy variables for weekdays were introduced in the models.

To eliminate analogous periodicities and autocorrelations a pre-whitening procedure [20] was performed. The cross-correlation function (CCF) between the residuals of the pre-whitened series was computed.

Poisson Regression Models were used in order to describe the association between daily emergency admission and the independent variables, through a step-by-step procedure. In the first step, the individual effect of all the environmental variables was assessed, taking into account the control covariables. Since the environmental variables exhibit a significant degree of colineality, a model describing their joint effect was obtained. Goodness-of-fit was evaluated through simple (ACF) and partial autocorrelation functions (PACF) of the residuals, using as well the Akaike´s information criteria [21]. The environmental variables influence on daily emergency hospital admissions was assessed through the attributable risk (AR), assuming that the whole population was exposed to its effects. In this way, attributable risk can be easily computed as follows: AR = (RR-1)/RR [22], where RR is the relative risk obtained by Poisson models. The analysis was carried out using S-Plus 2000 statistics pack.

3 Results

The descriptive statistics for emergency hospital admissions in children under ten years old and for meteorological and pollutants variables for the study period are shown in Table 1. It should be noted that organic causes show significant decreasing trend. Respect air pollutants, they showed annual seasonality and seven days periodicity and only pollen and noise levels show an increasing trend.

Scatter-plot diagrams of the different independent variables and hospital emergency admissions for organic causes, showed a linear relationship without threshold for PM_{10}, NO_x, NO_2 and a logarithmic relationship for SO_2 (as previously commented). Ozone (O_3) troposphere levels fit a quadratic curve when related to hospital emergency admissions; minimum admissions occurred when ozone was at a concentration of 50 µg/m^3, that value served as the basis for defining high and low ozone and it corresponds with 95 percentile of the daily mean concentrations values of ozone in the studied period:

$$O_3h = O_3 - 50\ \mu g/m^3, \text{ if } (O_3) > 50\ \mu g/m^3$$
$$O_3l = 50\ \mu g/m^3 - O_3, \text{ if } (O_3) < 50\ \mu g/m^3$$

For noise levels and pollen concentrations and organic causes a threshold is observed in both. These thresholds are 65 dB (A) for Leqd (Figure 1) and about 300 grains/m^3 for pollen concentrations.

Table 1: Statistics for emergency hospital admissions in children under ten years old and environmental variables in Madrid (1995-2002).

	Max	Min	Mean	S.D.	Trend	Periodicity
Organic	21	0	7.0	3.0	Yes ↓	Annual, 3 months, 3-4 days
Tmax (ºC)	39.5	1.1	20.0	8.2	Non	Annual, 5 days
Tmin (ºC)	25.4	-3.4	10.4	6.2	Non	Annual, 3 days
Hr (%)	100	31	73.7	14.8	Non	2-3 days
P (mb)	956.9	916.5	940.4	6.2	Non	7-15 days
PM_{10} ($\mu g/m^3$)	109	6	33.4	13.7	Yes ↑	Annual, 7, 4-5, 3 days
SO_2 ($\mu g/m^3$)	113	5	22.0	14.0	Non	Annual, 7, 4-5, 3 days
O_3 ($\mu g/m^3$)	76	2	28.2	15.2	Non	Annual, 7,4-5, 3 days
NO_2 ($\mu g/m^3$)	144	23	64.8	17.1	Non	Annual, 7, 4-5, 3 days
NO_x ($\mu g/m^3$)	617	35	150.1	77.6	Non	Annual, 7 , 4-5, 3 days
Pol(grain/m^3)	552	0	13.5	39.4	Yes ↑	Annual, 6 & 3 months, 3 days
Leqd (dBA)	73.7	56.2	68.4	1.7	Yes ↑	Annual, 7, 2-3 days
Leqn (dBA)	71.8	55.9	63.4	1.4	Yes ↑	Annual, 7, 2-3 days
Leqt (dBA)	71.3	57.2	66.4	1.4	Yes ↑	Annual, 7 , 2-3 days

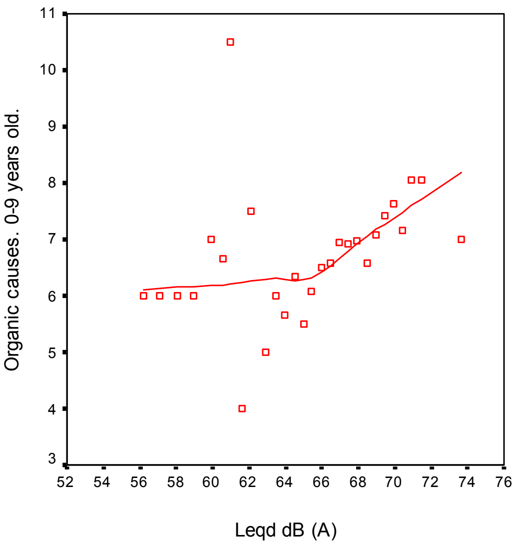

Figure 1: Scatter-plot diagram of Leqd (diurnal equivalent level of noise) and emergency hospital admissions for organic causes in the group of 0 to 9 years old.

Respect temperature, a V-shaped distribution was observed with a minimum daily emergency admissions or confort value of 33º, indicating the existence of admissions peaks related to low and high temperatures. To control the temperature effect, two additional variables were used, defined as:

$$Tcold = 33\ ºC – Tmax, \text{ if } Tmax < 33\ ºC$$
$$Thot = Tmax – 33\ ºC, \text{ if } Tmax > 33\ ºC$$

Table 2 shows the cross-correlation function outputs between environmental variables and emergency hospital admissions for organic causes, after the prewhitening process. Figure 2 shows the CCF for Leqt versus organic causes. Table 3 shows the results for the Autoregressive Poisson Regression Models that describe the association between daily emergency admissions by organic causes, in which can be observed that Leqt and PM_{10} are the variables with main attributable risk. Temperature showed statistically significant associations with emergency hospital admissions only when Tcold was considered, no effect was found due to Thot. The effect of cold was in long-term effect.

Table 2: Lags with significant pre-whitened CCF values between organic causes emergency hospital admissions and environmental factors.

Variables	Organic Causes
Tmax	10 (negative coefficient)
PM_{10}	0
NO_x	Without relation
Leqt	3
Pollen	4

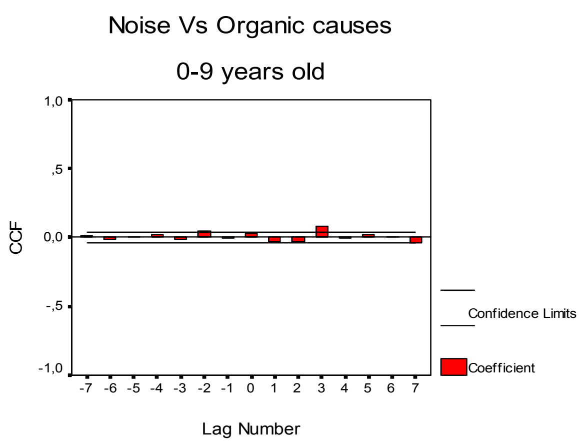

Figure 2: Cross correlation function between Leqt versus emergency hospital admissions for organic causes in the group of 0 to 9 years old.

Table 3: Statistically significant variables in Poisson Regression Models.

Factor (Lag)	RR (95% CI)	AR(%)
PM_{10} (0)^{I}	1.02 (1.01 1.03)	2.1
Tcold (10)^{II}	1.00 (1.00 1.01)	0.5
Leqt (3)^{III}	1.02 (1.01 1.04)	2.4
Pollen (4)^{IV}	1.01 (1.00 1.01)	0.9
dP (2)^{V}	1.01 (1.00 1.01)	0.5

^{I}RR for an increase of 10 $\mu g/m^3$ in the PM_{10} concentration.
^{II}RR for each degree of Tmax (maximum temperature is less than 33ºC).
^{III}RR for an increase of 1 dB(A) in Leqt.
^{IV}RR for an increase of 10 grain/m^3 in the Pollen concentration.
^{v}RR for a decrease of 1mb in dP.

4 Discussion and conclusions

The relationship detected through the scatter plot diagrams between the air pollutants and children emergency hospital admissions is similar to that obtained in others studies that analyze the effects of the air pollutants in general population [18], and similar to that detected over children mortality [17]. About the pattern detected for ozone concentrations and maximum temperature, indicating the existence of admissions peaks related to low and high ozone concentrations and the existence of two branches of temperature called Thot and Tcold, are comparable to the values detected in morbidity for general population in Madrid [16] but not reported until now in children morbidity. Moreover concerning to the relation found in the scatter plot with noise levels and children hospital admissions that establish a strong increase about a level of 65 dB (A), two previous papers centred in Madrid City, establish this identical level for morbidity in general population too [13, 23]. The relation found for pollen levels it also has been detected previously in Madrid over daily number of asthma emergency room admissions and high levels of *Poaceae* pollen that suggests their implication in the epidemic distribution of asthma, during the period coinciding with their abrupt release into the environment [24].

The results of cross-correlation functions (CCFs) found that daily Tmax is the best indicator for thermal impact [17]. Cold temperature give rises to bronchoconstriction, which can enhance previously existing pulmonary diseases, leading to casualties in the short-medium term.

The association found between air pollutants and emergency hospital admissions in this group of age for PM_{10} levels in the short-term are also coherent with the results obtained by others authors [25], which reported the short-term effect (0 and 3 days lag) of this pollutant and its relationship with circulatory and respiratory diseases.

About noise levels, a relationship between Leqt and organic causes was established at short-term (lag 3). The results obtained suggest that the associations indicating the short-term effects of exposure to high noise levels are non spurious and point out that the current levels of environmental noise have a considerable epidemiological impact on children emergency hospital admissions [8, 9]. The association at lag 3 for *Poaceae* pollen concentrations has been reported also, as previously commented in asthma hospital emergencies in the metropolitan area of Madrid [23]. This is line with the biological mechanisms of allergens, since the clinical consequences of a given pollen load increased as the pollination season progressed.

About difference of pressure that appears as statistically significative in the models, its behaviour is similar in another previous study about general population and mortality in Madrid [26]. This pattern means that an anticyclonic trend is associated with an increasing of children emergency hospital admissions due to organic causes.

For last, the results obtained for the Autoregressive Poisson Regression Models that describe the association between children daily emergency admissions and the environmental variables are according to the associations obtained in the CCFs. The relative risk and the attributable risk are similar to those reported for other studies in children [27, 28].

The results obtained suggest that the urban air pollution, particularly PM_{10} and noise levels, are risk factors for the daily emergency hospital admissions of children less than ten years of age in Madrid for organic causes. Hence, the importance of this study does not lay simply in the establishment of a relationship between air pollution and hospital admissions. Rather, it lies in the quantification of this relationship; by establishing models capable of diagnosing and forecasting for hospital management purposes. On the other hand, it is well-known that traffic is the major source of air pollutants and noise levels in urban areas, but despite the important contribution of traffic sources to reduced urban air quality, relatively few studies have evaluated the specific effects of traffic-related air pollution over children health. Moreover, respect noise levels; Madrid is a city with an unacceptable high background noise level. In this sense, a reduction of the noise levels could be accompanied by a possible decrease in the number of children emergency admissions in Madrid due to organic causes. So it must be emphasized that traffic appears to be one of the main environmental risk factors for children health in Madrid.

…..Although these environmental risks are not the leading cause of death or morbidity in children in the developed world, it seems interesting to know how affect children's health, because there is increasingly strong evidence that air pollution and high noise levels are associated with nontrivial increases in the risk of death and chronic diseases in children, moreover, what is important to realize is that this is an modifiable risk.

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