American International Journal of Biology
June 2016, Vol. 4, No. 1, pp. 1-19
ISSN: 2334-2323 (Print), 2334-2331 (Online)

Published by American Research Institute for Policy Development
DOI: 10.15640/aijb.v4n1a1
URL: https://doi.org/10.15640/aijb.v4n1a1

Association between Air Pollution and Hospital Admission from Respiratory Disease: Construction of Basics Parameters to Assess the Impact of National Policy Environmental Health Surveillance Related to Air Quality in Brazil

Marcio Sacramento de Oliveira[1], Maria de Fátima Ebole de Santana[2], Inês Echenique Mattos[3] & Antônio Ponce de Leon[4]

Abstract

This ecological time series study aimed to evaluate the effects of air pollution on hospital admission from respiratory diseases, considering differential susceptibility according to age, of the Volta Redonda citizens, Brazil, from January 2002 to December 2006. This period was chosen to define basics parameters to assess the impact of national policy Environmental Health Surveillance related to Air Quality. This epidemiological design using daily data on hospital admission for respiratory diseases for the total population, the elderly, and children. Daily levels of PM_{10}, SO_2 and O_3, minimum temperature and relative humidity were also analyzed. Generalized Additive Models was fitted to Poisson regression analysis. The results showed the increase in risk of hospital admission from PM_{10} was 2.67% (95% CI: 0.40 – 5.00%) in the total population, 4.15% (95% CI: 0.17 – 8.29%) in elderly and 5.22% (95% CI: 0.14 – 10.56%) in children. For exposure to SO_2, only the total population showed increased risk 6.59% (95% CI: 0.76 - 12.71%). The risk wasn´t significant for O_3.

These results reinforce the need for additional studies, focusing on effect modification of air pollution on human health, considering not only the stratification by age but also others susceptibility factors.

Keywords: Air Pollution; Respiratory Diseases; Disease Susceptibility; Hospital Admissions

[1] [1]Marcio Sacramento de Oliveira, EPSJV, Fiocruz, Brazil. EPSJV, Fiocruz, Av. Brasil 4365, Rio de Janeiro,RJ 21045-900, Brazil.
[2] Maria de Fátima Ebole de Santana,EPSJV, Fiocruz, Brazil. EPSJV, Fiocruz, Av. Brasil 4365, Rio de Janeiro,RJ 21045-900, Brazil.
[3] Inês Echenique Mattos, ENSP, Fiocruz, Brazil. ENSP, Fiocruz, Av. Brasil 4365, Rio de Janeiro,RJ 21045-900, Brazil.
[4] Antônio Ponce de Leon,IMS, UERJ, Brazil. IMS, UERJ,R. São Francisco Xavier 524, Rio de Janeiro, RJ 20550-013, Brazil.

1. Introduction

Epidemiological studies provide evidence of the association between different health outcomes and increased daily air pollution levels, especially in more susceptible population groups like children, elderly, pregnant, and individuals with cardio respiratory diseases (Kim *et al.* 2015; Oliveira *et al*., 2011; Moraes *et al*., 2010 and Seo *et al*., 2007).

The surveillance actions taken by Brazil for protecting the health of populations from monitoring data of air pollutants and health indicators began in 2001 with the Environmental Health Surveillance related to Air Quality (VIGIAR). In 2002 we selected five pilot cities (Araucaria / PR; Camaçari / BA, Greater São Paulo / SP, Vitória / ES and Volta Redonda / RJ) for the structure and operation of this surveillance. The results of this pilot study supported the Instruction Regulating VIGIAR in 2005.

Oliveira *et al* (2011) published the first results of the assessment of the effects of air pollution on the health of the in Volta Redonda citizens. The authors observed in women 65 years or older, the increase in risk of respiratory deaths due to a 10 $\mu g/m$ increase in PM_{10} on the first, third, and fourth days was 10.04% (95% CI: 0.90-20.02), 10.57% (95% CI: 1.95-19.92%), and 9.27% (95% CI: 0.66-18.61%), respectively. For men 65 years or older, with a nine-day lag after exposure to PM_{10}, one can expect an increase in risk of deaths of 10.80% (95% CI: 2.18-20.15%).

In this context, the study aimed to evaluate the effects of air pollution on the health of the resident population, especially at a fraction likely, the elderly and children, in Volta Redonda, mid-sized city located in the state of Rio de Janeiro.

A city with a high degree of industrialization, including a steel producing plant in central region and intense vehicular flow. The evaluation produced basic parameters to estimate the impact of 10 years of regulation of VIGIAR in Brazil.

2. Materials and Methods

This was an ecological time series study conducted in the Volta Redonda city, Rio de Janeiro State, Brazil, from January 1, 2002, to December 31, 2006.

2.1. Study area

Volta Redonda is a mid-sized city located at 22º31'23" latitude South and 44º06'15" longitude west. The municipality's total area is 182.8 km^2, of which 54 km^2 comprise the city limits of the municipal seat. Accompanying the Paraíba do Sul River, which cuts through the city of Volta Redonda from Southwest to East, the urban area is located along the banks of the river on a plain surrounded by hills whose altitude varies from 350 meters above sea level along the river to 707 meters at the northeastern tip. The city has a mesothermal climate and high relative humidity (77%), even in the cooler months, when it varies from 71% to 72%. The adjusted mean temperature is 21°C, with a mean annual low of 16.5°C and means annual high of 27.8°C. Mean annual precipitation is 1,377.9 mm, and January and February are the months with the heaviest rainfall.

Considered the economic hub of the Sul Fluminense mesoregion, the economy of Volta Redonda, although still anchored in industry, is quite diversified, focused to a major extent on services and commerce. The municipality is home to the large steel mill Companhia Siderúrgica Nacional (CSN) and other smaller industries, the Votoran and Tupi cement factories, the White Martins Oxygen and Nitrogen

Plant, the flat steel products company Indústria Nacional de Aços Laminados (INAL), the tin mill Companhia Estanifera Brasileira (CESBRA), and S/A Tubonal (steel pipes).

2.2. Health Outcomes and Data Source

The time series of total hospital admissions was analyzed by the respiratory system diseases (ICD-10, J00-J99), and stratified in children under 5 years and elderly aged 65 or more. Data on hospital admissions to public hospitals and hospitals of the Unified Health System (SUS) were obtained from the SIH-SUS information available at the DATASUS website. These databases contain information of all hospital admissions according to the SUS recorded in Hospital Admissions Authorizations (AIH), which contains the following information that was used: municipality of residence, age, date of admission and principal diagnosis.

2.3. Environmental outcomes and Data Source

The Rio de Janeiro State Environment Institute (INEA) provided daily records of mean concentrations of particulate matter with aerodynamic size up to $10\mu m$ (PM_{10}), sulfur dioxide (SO_2), ozone (O_3), low temperature, and mean relative humidity (RH), from the three automatic stations of air quality monitoring located in the city, in these neighborhoods Belmonte Garden (west of the city), Vila Santa Cecilia (north) and Retiro (central zone).

The daily averages for the environmental variables from these stations were calculated after imputing missing data using the modified Expectation Maximization (EM) algorithm, applied under the assumptions of multivariate normal distribution.

In addition to the dependence structures between variables, this method also considerate the time-dependent structures of each variable. The temporal component of the contribution of each univariate series was estimated *ad hoc* way, which is, it took additional models to estimate μ_t. In this imputation, method was implemented to non-parametric cubic *spline* as estimation option level time series (Junger*et al*., 2015).

2.4. Statistical Analysis

Initially, were determined the descriptive statistical measurements (average, standard deviation, minimum and maximum values) for the variables total deaths from diseases of the cardiovascular system and for the elderly, and for PM_{10}, SO_2, O_3, low temperature, and RH. The *Pearson* correlation coefficient was calculated between atmospheric pollutants, the number of hospital admissions and mortality and between climate variables in order to determine whether these data were linearly associated with the significance level of arbitrated α = 20%.

In the time series analysis, the daily counts of total deaths and deaths in the elderly were considered dependent variables (Y_t) and the mean daily concentrations of PM_{10}, SO_2, and O_3, one-by-one, were the independent variables (X_t).The following control variables were also considered: days of the week, time, national and local holidays, and mean daily low temperature (ºC) and RH (%).

In relation to the dependent variable and some control variables, such as meteorological variables, which are not necessarily linear, Generalized Additive Models (GAM) (Hastie *et al*., 1990) using Poisson regression with non-parametric functions of the *cubic smoothing spline* type were applied to estimate the association between daily deaths from diseases of the respiratory system and daily levels of these meteorological indicators.

It is noteworthy that a straightened is a function of x and y with the same domain of x, defined for every point x_0 or, sometimes, just for x_i sample. For each value x_i flatter associates a value f (x_i) who's estimated $\hat{f}(x_i)$ can be obtained. The values of this function must by definition be "softer" than the y-values, i.e., should have less variability than the values of y (Conceição *et al*., 2001).The smoothing procedure was used for the weather and meteorological variable, to adjust the trend and basic seasonal standards and more outstanding long term.

After adjusting the dependent variable for the control factors, the independent variables were inserted one-by-one into the models. Since the biological manifestations of the effects of air pollution on health outcomes apparently display a lag type behavior in individual exposure to pollutants(Braga *et al*., 2001), the dependent variables were inserted with a lag time of zero to 10 days, considering the day after exposure, in order for a more precise definition of the model to be used.

The final model's goodness of fit was estimated by residuals analysis outcomes and the Akaike information criterion (AIC)(Akaike, 1973). The relative risks (RR) for deaths corresponded to a $10\mu g/m^3$ increase in the concentration of air pollutants and 5% level of significance. Data were analyzed for statistical platform R with ARES and mtsdi statistical library.

3. Results

During the study, 75% of the daily average concentrations of emissions of PM_{10}, SO_2 and O_3 measured remained respectively beneath $35.95\mu g/m^3$, $11.47\mu g/m^3$ and $75.72\mu g/m^3$; the highest average concentration for each pollutant was $122.70\mu g/m^3$ $56.50\mu g/m^3$ and $171.70\mu g/m^3$ (Table 1).

The PM_{10} averaged 30.56 ± 12.16µg/m^3, under Brazilian primary standards of annual emission of 50µg/m^3 established by Environment National Council (CONAMA), through Res. No. 003/1990. The PM_{10} and SO_2 showed no violation of the daily emission standards (mean 24 hours) established respectively in 150µg/m^3 and 100µg/m^3. The O_3 provides three standard violations (161.30, 162.10 and 171.70µg/m^3), the value set by CONAMA for higher hourly average is 160µg/m^3.

As for health data, 73,536 admissions were recorded, and 7976 (10.85%) for diseases of the respiratory system, of which 2251 (28.22%) were elderly and in 1414 (17.73%) of children under five years of age.Table 2 shows the annual distribution of hospitalizations for the period. The daily average of admissions for respiratory diseases in the resident population was 4.29±2.48, ranging between zero and 15.Among the elderly and children the average was respectively 1.23 ±1.20 and 0.77 ±1.00, with a daily variation in the zero to eight hospitalizations among the elderly and zero to six of the children (Table 3).

Table 1: Descriptive analysis of daily measurements of PM_{10}, SO_2, O_3 and meteorological factors in Volta Redonda, Rio de Janeiro, Brazil, from 2002 to 2006.

Variables	Descriptors								
	N	***Missing***	**Days**	**Average**	**SD**	**Min**	**Max**	**P25**	**P50**	**P75**
PM_{10} ($\mu g/m^3$)	1807	19	1826	30.56	12.16	7.58	122.70	22.56	27.77	35.95
SO_2 ($\mu g/m^3$)	1794	32	1826	9.04	5.11	0.00	56.50	5.50	7.95	11.47
O_3 ($\mu g/m^3$)	1790	36	1826	59.16	25.45	6.55	171.70	40.69	57.42	75.72
RH (%)	1763	63	1826	81.05	8.76	51.04	99.60	74.40	82.20	88.90
TemperatureMinimum (ºC)	1790	36	1826	18.39	3.26	7.37	25.45	16.20	18.87	21.03

Abbreviations: SD – standard deviation, Min – Minimum, Max – Maximum

Table 2: Total number of hospitalizations and respiratory diseases (ICD10: J00-99), by year, Volta Redonda citizens, Rio de Janeiro, from 2002 to 2006.

Upshots	Year					Total
	2002	2003	2004	2005	2006	
Total admissions for all causes	14751	14330	15314	14237	14904	**73536**
Total admissions for respiratory diseases	1670	1516	1638	1537	1615	**7976**
	1660	1506	1652	1441	1572	**7831**
Hospitalizations for respiratory diseases in the elderly	462	415	487	423	464	**2251**
Hospitalizations for respiratory diseases in children	314	280	284	237	299	**1414**

Table 3: Descriptive analysis of daily counts of hospital admissions by respiratory system diseases (ICD10: J00-99) in Volta Redonda, Rio de Janeiro, Brazil, from 2002 to 2006.

Upshots	Descriptors							
	N	%	Days	NA[1]	Average	SD[2]	Min	Max
Total admissions for respiratory diseases	7831	100	1826	0	4.29	2.48	0	15
Hospitalizations for respiratory diseases in the elderly	2251	28.22	1826	0	1.23	1.20	0	8
Hospitalizations for respiratory diseases in children	1414	17.73	1826	0	0.77	1.00	0	6

Abbreviations: SD – standard deviation, NA – missing, Min – Minimum, Max – Maximum

In the analysis of the number of total admissions for respiratory system diseases, was possible to find a significant association to an increase of 10 $\mu g/m^3$ in the levels of PM_{10} and SO_2. The increased risk of hospitalization after two days of exposure to PM_{10} was 2.67% (95% CI: 0.40 to 5.00%, p-value = 0.02) and, respectively, 5.89% (95% CI: 0.11 to 12.00%; p value = 0.04) and 6.59% (95% CI: 0.76 - 12.71%; p = 0.03) for the current day and two days after exposure to SO_2 (Figures 1 and 2). The lack of association for exposure to O_3 was observed.

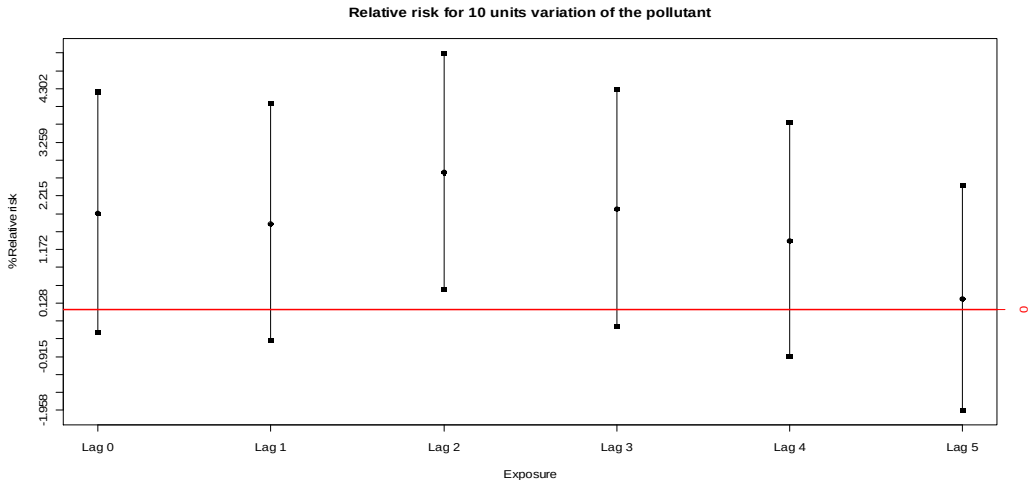

Figure 1: Percentage of relative risk to the total of hospitalizations for respiratory diseases, related to an increase of 10 $\mu g/m^3$ in the levels of Particulate Matter (PM_{10}), in Volta Redonda, Rio de Janeiro, Brazil, from 2002 to 2006.

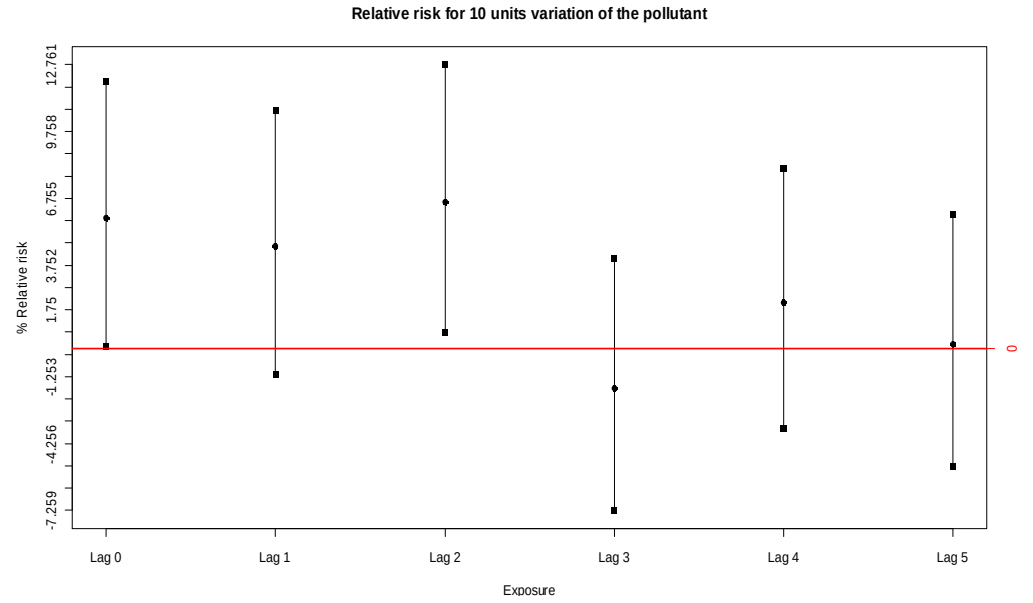

Figure 2: Percentage relative risk to total hospital admissions for respiratory diseases, related to an increase of 10$\mu g/m^3$ in the levels of sulfur dioxide (SO_2), in Volta Redonda, Rio de Janeiro, Brazil, from 2002 to 2006.

When we performed the analysis of the number of hospitalizations in the elderly aged 65 or more, an increase in the risk of hospitalization for 04.15% is observed (95% CI: 0.17 to 8.29%, p-value = 12.04) with respect to the risk percentage for all age groups, after two days of exposure to PM_{10} (Figure 3). The magnitude of the effect on risk was also observed in the analysis of the number of hospitalizations in children under five years, an increase of 5.22% (95% CI: 0.14 to 10.56%; p-value = 0.04) after two days of exposure to PM_{10} (Figure 4).

When analyzing exposure to daily levels of SO_2 and O_3 there was no association between sets of admissions by respiratory diseases that occurs in the elderly and children and their pollutants.

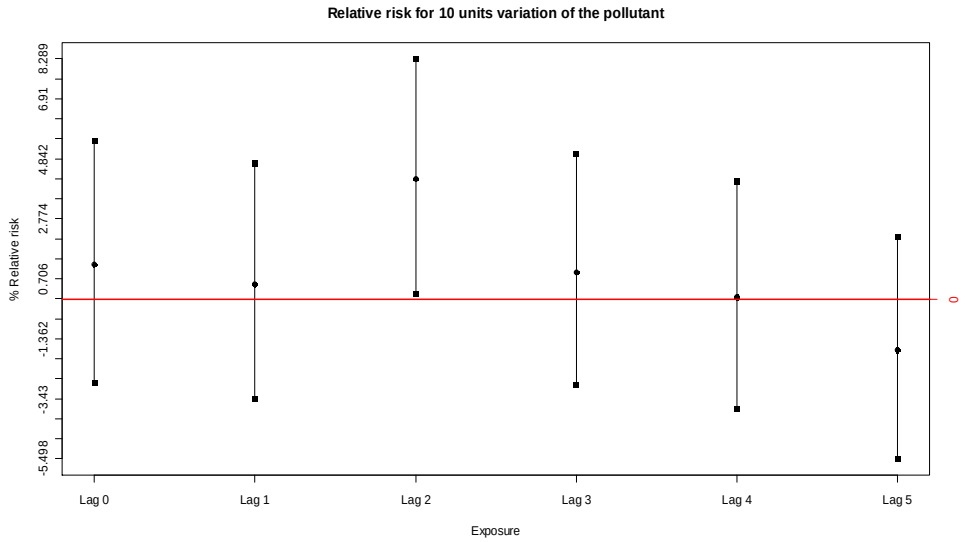

Figure 3: Percentage of related risk to the admissions of the elderly by respiratory system diseases relative to an increase of $10\mu g/m^3$ in the levels of Particulate Matter (PM_{10}), in Volta Redonda, Rio de Janeiro, Brazil, from 2002 to 2006.

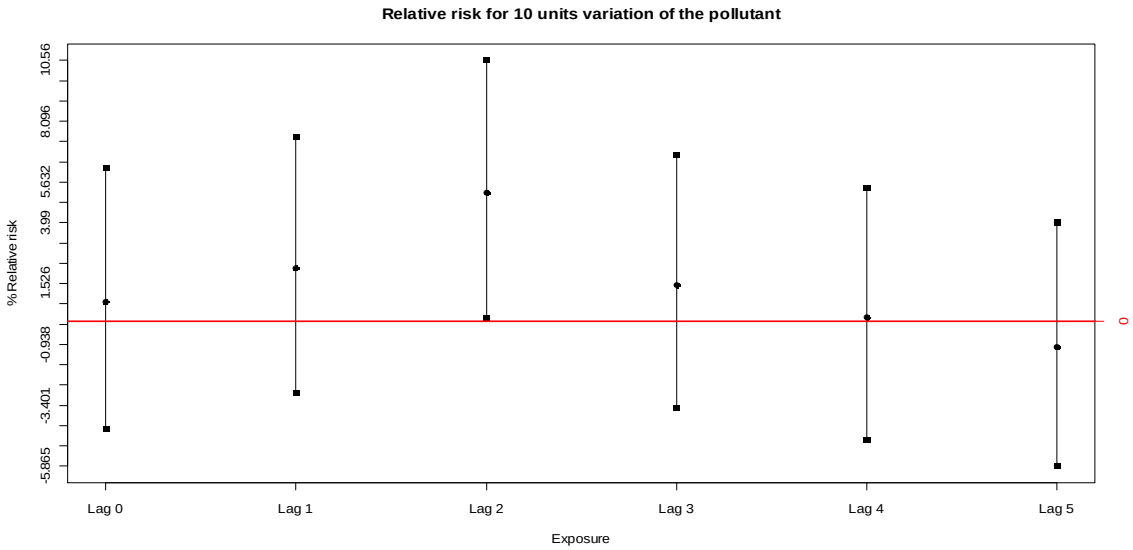

Figure 4: Percentage of the relative risk for admissions of children by respiratory system diseases relative to an increase of $10\mu g/m^3$ in the levels of Particulate Matter (PM_{10}), in Volta Redonda, Rio de Janeiro, Brazil, from 2002 to 2006.

4. Discussion

A study model rather employed in research associations between pollution and human health effects is the analysis of time series. According to Castro *et al.*(2003), one of the great time-series analysis of the advantages is that factors such as socioeconomic status, occupation or smoking are not able to confuse the relationship between air pollution and health effects, as these factors don´t present variations significant daily. On the other hand, the factors that have such variation and also correlated with pollution are potential confounders and should be adjusted in the analysis.

Among some factors who suffered adjustment in this work are the meteorological variables (temperature and humidity) and chronological factors such as day of the week (variable for the calendar effect adjustment), the total number of days spent in the study period (variable for the adjustment long-term seasonality) and holidays.

The use of MAG allowed confounders (trend, seasonality, cycle, temperature, humidity, holidays and calendar effect), which could interfere with the data analysis, to be controlled more effectively. The MAG selection as an analysis tool in this study was madden because this model allows measure up nonparametric functions to variables that exhibit this behavior, minimizing potential errors of effect estimates and their standard errors. We used Poisson regression, for allowing them to be analyzed count data, daily number of deaths from diseases of the respiratory and cardiovascular system.

In epidemiological studies to assess these effects, the existence of missing data in the environmental series is often a complicating factor and sometimes limiting. Even when data from large quality network monitoring air with appropriate quality control, it isn´t uncommon occur missing data.

The measure of exposure of a population is usually defined as the average concentrations of atmospheric pollutant measurements at various stations on a given day. As suggested Junger *et al*. (2015), even with small amounts of missing data, it´s possible observe bias in the measured association and precision overestimation. In this case, the amount of missing data is too small for statistical compromising efficiency. The authors show that with 5% of missing data for the analysis with complete units, the database produces good estimates, regardless of the mechanism of missing data.

In this case, the amount of missing data is too small for statistical compromising efficiency. Even with this amount of missing data, the authors suggest that the imputation by the average or median should been avoided.

Junger *et al*. (2015) analyzed and suggested the imputation procedures performed in this study because they have good accuracy for missing data patterns with varying lengths gaps in one day or more contiguous days. According to the author, imputation via the EM algorithm for the multivariate normal distribution with no time adjustment presented good estimates in all evaluated data absences settings.

As the concentrations of the pollutants and climate information of the three existing stations in Volta Redonda were strongly correlated, provided the high accuracy of this method. In this application, an important contribution of the temporal component of the adjustment was to increase the accuracy of the estimates. Association measures estimated with the data allocated by the method with temporal contribution showed less dispersion; the percentage of missing data after imputation were between 1.04% (PM_{10}) and 3.45% (RH).

However, noteworthy that it is an ecological study, as an association observed at the aggregate level does not necessarily mean that this association exists at the individual level. The results of this study showed increase in risk de hospital admission from de air pollution, especially in the elderly and children. They are consistent with studies available in the literature. Physiological changes associated with aging explain the increased susceptibility of the elderly to the effects of air pollution, especially particulate matter (PM).

All components of the respiratory system are often affected by aging, including spirometry, oxygen diffusion capacity, lung elasticity, capacity expansion of the chest wall, muscle inspiratory strength, maximal oxygen uptake, and cardiac output maximum (WHO, 2005). In addition, the elderly are more susceptible to respiratory infections, partly because of a decline related to age, the specific immune response, ciliary function and reflex tosse(Martins *et al*., 2002a; Martins *et al*., 2002b and WHO, 2005).

The greater susceptibility of the elderly to particulate matter can also be due to exposure to harmful environmental agents health throughout life and previous respiratory infections, as noted by Meyer *et al.* (1996) in a study of healthy volunteers and non-smokers between 65 and 78 years. The authors observed increase in neutrophils, immunoglobulins (IgG, IgA and IgM) and interleukin-6 (IL-6) in broncho-alveolar lavage fluid, vs. samples of individuals aged 20 to 36 years. It can be assumed, for the age group $\geq$ 65 years, a high prevalence of chronic respiratory diseases. Differences in the magnitude of effect, modulated by age, are also observed in hospitalizations. The association between increased $10\mu g/m^3$ of PM_{10} and increased risk of hospitalization for respiratory diseases was 2.67% for the total population to 4.15% among the elderly. Among children, the risk was even greater, is being estimated at 5.22%.

Macedo *et al*. (2007) also emphasize the importance of social aspects and behavioral factors of the family, as well as the child's previous respiratory disease as risk factors for hospitalization for acute respiratory disease.

The greater susceptibility of children to air pollution is also linked to the fact of their immunological immaturity, reduced airway diameter and their lungs are not fully developed, favoring the development of mild or moderate respiratory symptoms to severe forms with significant respiratory dysfunction; thus, when exposed, they developed a different response from that observed in adults (Schwartz, 1994 and Macedo *et al*., 2007).

The absence of statistically significant association, in the case of hospitalization, maybe related to inconsistencies in the database, linked to problems of information system to which it belongs.

Authorizations for Hospitalization (AIH) can often present problems typing errors and change the ICD, the first related to the high turnover of professionals who launch these data in the system and/or lack of adequate training, the second because of the need increase in financial transfers from the Union to the municipality that provided the service. Moreover, many times hospitalization or may be scheduled dependent upon the availability of beds in the network, leading to a hard error fit in the analysis.

We can conclude that in Volta Redonda city it has been found the association between daily PM_{10} emissions to hospital admission due to this cause, with greater magnitude of effect on the elderly and children. The study helped in the creation of parameters to assess the impact of environmental health policy in the VIGIAR, after 10 years of its regulation in Brazil.

References

Akaike, H. (1973). Information theory as an extension of the maximum likelihood principle. In: Petrov, B. N., Csaki, F., editors. Second International Symposium on Information Theory. Budapest: Akadémiai Kiadó, 267-281.

Braga, A. L.F., Zanobetti, A., & Schwartz, J. (2001). The lag structure between particulate air pollution and respiratory and cardiovascular deaths in 10 US cities. J OccupEnvironMéd, 43(11): 927-933.

Castro, H. A., Gouveia, N., &Escamilla-Cejudo, J. A. (2003). Questões metodológicas para a investigação dos efeitos da poluição do ar na saúde. RevBrasEpidemiol, 6(2), 135-149.

Conceição, G. M. S., Saldiva, P. H. N., &Singer, J. M. (2001). Modelos MLG e MAG para análise da associação entre poluição atmosférica e marcadores de morbi-mortalidade: uma introdução baseada em dados da cidade de São Paulo. Rev. Bras. Epidemiol, 4(3), 206-219.

Hastie, T. J., & Tibshirani, R. J. (1990) Generalized additive models. New York: Chapman and Hall, v. 43.

Junger, W. L., &Ponce de Leon, A. (2015). Imputation of missing data in time series for air pollutants. Atmospheric Environment, v. 102, 96-104.

Kim, S. E., Lim, Y. H.,& Kim, H. (2015). Temperature modifies the association between particulate air pollution and mortality: A multi-city study in South Korea. Science of The Total Environment, v 524–525, 376–383.

Macedo, S. E. C., Menezes, A. M. B., Albernaz, E., Post, P., &Knorst, M. (2007). Fatores de risco para internação por doença respiratória aguda em crianças até um ano de idade. Rev Saúde Pública, 41(3), 351-358.

Martins, L. C., Latorre, M. R., Saldiva, P. H.,&Braga, A. L. F. (2002a). Air pollution and emergency room visits due to chronic lower respiratory diseases in the elderly: an ecological time-series study in Sao Paulo, Brazil. J Occup Environ Med, 44, 622-627.

Martins, L. C., Latorre, M. R., Cardoso, M. R., Gonçalves, F. L., Saldiva, P. H.,& Braga, A. L. (2002b).Air pollution and emergency room visits due to pneumonia and influenza in Sao Paulo, Brazil. Rev Saúde Pública, 36, 88-94.

Meyer, K.C., Ershler, W., Rosenthal, N. S., Lu, X. G., Peterson, K. (1996). Immune dysregulation in the aging human lung. American Journal of Respiratory and Critical Care Medicine, 153, 1072-1079.

Moraes, A. C., Ignotti, E., Netto, P. A., Jacobson, L. S., Castro, H., & Hacon, S. S. (2010). Wheezing in children and adolescents living next to a petrochemical plant in Rio Grande do Norte, Brazil. J Pediatr (Rio J), 86(4),337-344.

Oliveira, M. S., Ponce de Leon, A., Mattos, I. E., &Koifman, S. (2011). Differential susceptibility according to gender in the association between air pollution and mortality from respiratory diseases. Cadernos de Saúde Pública, v. 27, 1627-1836.

Schwartz, J. (1994). Air pollution and daily mortality: a review and meta analysis. Environ Res, 64, 36-52. WHO (2005). *Air Quality Guidelines – Global Update 2005*. Germany, 496.

Seo, J. H., Há, E. H., Kim, O. J., Kim, B. M., Park, H. S., Lêem, J. H., *et. al*. (2007).Environmental health surveillance of low birth weight in Seoul using monitoring and birth data. J Prev Med Public Health, 40(5),363-370.