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Short Communication

Air Pollution and Mortality from Cardiovascular Disease in a Population Living Near by a Steel Producing Plant in Brazil

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

[1]*Escola Politécnica de Saúde Joaquim Venâncio, Fundação Oswaldo Cruz Foundation, Brazil*

[2]*European Network for Smoking and Tobacco Prevention, Fundação Oswaldo Cruz Foundation, Brazil*

[3]*Instituto de Medicina Social, Brazil*

***Corresponding author**

Marcio Sacramento de Oliveira, EPSJV, Fiocruz, Av. Brasil 4365, Rio de Janeiro, RJ 21045-900, Brazil, Tel: 55-21-3865-9777; Email: marciosacramento@fiocruz.br

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Abstract

This study aimed to evaluate the effects of air pollution on deaths from cardiovascular diseases of the Volta Redonda citizens, Brazil, from January 2002 to December 2006. This period was chosen to assess the impact of a national policy Environmental Health Surveillance related to Air Quality. The epidemiological study design was an ecological time series frame work using daily counts of deaths for cardiovascular diseases for the total population and the elderly. Daily levels of PM_{10}, SO_2 and O_3, minimum temperature and relative humidity were regarded in the analysis. Generalized Additive Models under the Poisson assumption was the model framework. The results showed an increase risk of death for an increase of 10μg/m^3 of PM_{10} at lag 2 of 3.67% (95%CI: 0.20 – 7.26%) in the total population and 5.23% (95%CI: 0.85 – 9.81%) for the elderly, respectively. As for exposures to $SO_2$and O_3, the risk was not significant for the total population or for the elderly.

ABBREVIATIONS

AIC: Akaike Information Criterion; CONAMA: Environment National Council; EM: Expectation Maximization; GAM: Generalized Additive Models; ICD: International Classification of Diseases; INEA: Rio de Janeiro State Environment Institute; PM_{10}: Particulate Matter with aerodynamic size up to 10μm; PRONAR: National Program of Quality Air Control; VIGIAR: Environmental Health Surveillance related to Air Quality; SO_2: Sulfur Dioxide; O_3: Ozone; RH: Relative Humidity; RR: Relative Risks.

INTRODUCTION

The technological progress in the modern world has produced an increase in the amount and variety of air pollutants, acting as a risk factor to health. Epidemiological studies have provided strong evidence of the association between different health outcomes and daily levels of air pollution, especially in more susceptible population groups like children, elderly, pregnant, gender and individuals with cardio respiratory diseases. The health outcomes ranging from mortality, especially in children and elderly, through illness for specific causes, especially episodes of respiratory diseases in children, cardiovascular disease, decreased lung function, to congenital malformations or low birth weight [1-5].

Oliveira et al., observed, in Brazil, that in women 65 years or older, the increase in risk of respiratory deaths due to a 10μg/m^3 increase in PM_{10} on the first, third, and fourth days were 10.04% (95% CI: 0.90 - 20.02%; p-value = 0.03), 10.57% (95% CI: 1.95 - 19.92%; p-value = 0.01), and 9.27% (95% CI: 0.66 - 18.61%; p-value = 0.03), 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%; p-value = 0.01).

In South Korea, the effects of PM_{10} on cardiovascular mortality were the highest on extremely hot days (> 99th percentile) in men; the combined analysis showed that a 10μg/m^3 increment in PM_{10} corresponded to a 2.51% (95% CI: −1.27 - 6.44) increase in cardiovascular mortality[1].

The Air Pollution Control Program for vehicles in 1986 and the National Program of Quality Air Control (PRONAR) in 1989 were the first test actions in Brazil at the environmental management of air quality for health protection and welfare of population.

In Health Public area, surveillance actions taken by the Brazilian government to protect the health of populations involved surveying and gathering of available data on air pollutants and health indicators in the country. This effort began in 2001 with the Environmental Health Surveillance related to Air Quality (VIGIAR). In 2002 five pilot urban areas were selected (Araucaria / Paraná State; Camaçari / Bahia State, Greater São Paulo / São Paulo State, Vitória / Espírito Santo State, and Volta Redonda / Rio de Janeiro State) so as to establish the structure and operation of the surveillance net work. The results of this pilot study supported the Instruction Regulating VIGIAR in 2005, and in 2006 were established key indicator of the expositions used in the health surveillance of populations exposed to air pollution: admission rates and ambulatory care for respiratory diseases in children under five years, hospital admissions rate and mortality from cardiovascular disease in the elderly.

In this context, this study aimed to evaluate the effects of air pollution on the mortality from cardiovascular disease of the resident population, especially the elderly, in Volta Redonda, a mid-size city located in the state of Rio de Janeiro. This valuation will produce indicators to estimate the impact of 10 years of regulation of VIGIAR in Brazil.

MATERIALS AND METHODS

This research was based on an ecological time series study conducted in the city of Volta Redonda, Brazil, from January 1, 2002, to December 31, 2006.Volta Redonda is a highly industrialized city where the main sources of air pollution are a steel producing plant located at the town central region and an intense vehicular traffic flow.

Registers of deaths from diseases of the cardiovascular system (ICD-10, I00-I99) were obtained from the Mortality Information Data System, Brazilian Ministry of Health, and later compiled in daily counts. Daily records of mean concentrations of particulate matter with aerodynamic size up to 10μm (PM_{10}), sulfur dioxide (SO_2), ozone (O_3), minimum temperature, and mean relative humidity (RH) were provided by the Rio de Janeiro State Environment Institute (INEA) from the three automatic stations of air quality monitoring, located in the city. 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 [6].

Statistical summaries for the two study outcome variables, i.e. total deaths from diseases of the cardiovascular system and those restricted to the elderly (defined as individuals 65 years or older), as well as for PM_{10}, SO_2, O_3, minimum temperature, and RH were calculated. In the time series analysis, daily counts of total deaths orelderly deaths were considered dependent variables (Y_t) and the average daily concentrations of PM_{10}, SO_2, and O_3, regarded in separate models, were the exposure variables (X_{1t}) on day t; X_{it} are the predictor variables, including time, and S_i are the smoothing functions, according to the equation:

$$\ell n(E(Y_t)) = \ell X_{1t} + \sum_{i=2}^{p} S_i(X_{it})$$

The following control variables were also considered: day of the week, chronological time (index from 1 to N, the last day of the analysis), national and local holidays, and mean daily minimum temperature (ºC) and RH (%).

Generalized additive models (GAM) [7] under the Poisson assumption and non-parametric functions of the cubic smoothing spline type were applied to estimate the association between the dependent variable and some control variables, such as time and meteorological variables.

After adjusting the dependent variable for the control factors, the exposure variables were included, one at a time, into the models. Since the effects of air pollution on health outcomes may show a delay in individual exposure to pollutants [8], the exposure variables were regarded with a delay (lag) of 1to 5days as well as on the same day.

The final model goodness of fit was estimated by examining residuals properties and the AIC (Akaike information criterion) [9]. The percentage of relative risks (%RR) for death that were calculated correspond to a 10μg/m^3increase in the concentration of air pollutants and a 5% level of significance. This is derived from RR using the following formula: %RR = ($e^{10\beta}$- 1)*100.

RESULTS AND DISCUSSION

During the study period 8,540 deaths of residents in the Volta Redonda city were registered, of which 2,566 (30.05%) were due to diseases of the cardiovascular system. Among these deaths, 1,592 (62.04%) were in elderly (Table 1). The environmental data summaries are displayed in Table (2)

Considering all ages, the number of deaths from diseases of the cardiovascular system showed a significant positive association with PM_{10}, i.e. an increase of 3.67% (95% CI: 0.20 to 7.26%; p = 0.04) in the risk of death for the lag 2 (Figure 1, Table 3).As for the elderly, there was an increased risk of 5.23% (95% CI: 0.85 - 9.81%; p = 0.02) for the lag 2 (Figure 2,Table 3). No association was observed between cardiovascular deaths risk, considering all ages or only the elderly, and exposure to daily levels of SO_2 and O_3 (Table 3).

Time series analysis is a study framework widely employed to evaluate the association between air pollution and human health. One of its great advantages is that factors such as socioeconomic status, occupation or smoking are unable to confuse the relationship between air pollution and health, as these factors do not show big short time fluctuations [10].

The use of MAG is justified since it allows adjusting for confounders (trend, seasonality, mid-term cycles, temperature, humidity, holidays and day of week), which could interfere with the data analysis, more effectively. We used Poisson regression due to the low average of the daily number of deaths from diseases of the cardiovascular system.

For the elderly, physiological changes associated with aging may explain the increased susceptibility to the effects of air pollutants. The pattern of harvesting observed with the increase in deaths, could be associated with a high prevalence of chronic cardiovascular diseases in this age group, as in this case, exposure to air pollutants would be mainly affecting more susceptible

Table 1: Number of deaths and descriptive analysis of the cardiovascular system diseases (ICD-10, I00-I99),Volta Redonda citizens, Rio de Janeiro, Brazil, from 2002 to 2006.

Outcome variables	Nº of deaths						Descriptors						
	2002	2003	2004	2005	2006	Total	%	Day	Missing	Average	SD	Min	Max
cardiovascular deaths	519	571	520	478	478	**2,566**	100	1,826	0	1.40	1.16	0	7
cardiovascular deaths in the elderly	303	357	326	302	304	**1,592**	62.04	1,826	0	0.87	0.93	0	7

Abbreviations: SD- Standard Deviation, Min– Minimum, Max- Maximum

Table 2: 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*	Day	Average						2002-2006					
				2002	2003	2004	2005	2006	2002-2006	SD	Min	Max	P25	P50	P75
PM_{10} (µg/m³)	1,807	19	1,826	33.82	32.73	28.39	27.53	29.83	30.56	12.16	7.58	122.70	22.56	27.77	35.95
SO_2 (µg/m³)	1,794	32	1,826	8.86	6.34	11.25	11.57	7.95	9.04	5.11	0.00	56.50	5.50	7.95	11.47
O_3 (µg/m³)	1,790	36	1,826	67.09	70.83	71.83	28.46	57.16	59.16	25.45	6.55	171.70	40.69	57.42	75.72
UR (%)	1,763	63	1,826	72.79	76.37	77.65	88.35	89.81	81.05	8.76	51.04	99.60	74.40	82.20	88.90
Temperature Minimum (ºC)	1,790	36	1,826	19.72	18.79	17.67	18.07	17.75	18.39	3.26	7.37	25.45	16.20	18.87	21.03

Abbreviations: SD: Standard Deviation; Min: Minimum; Max: Maximum

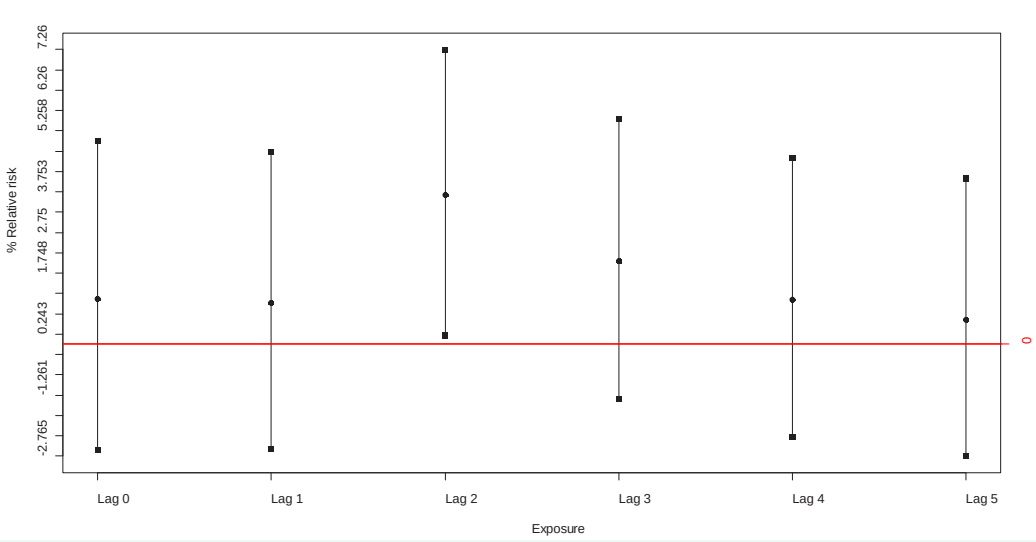

Figure 1 Percentage of relative risk for all deaths from cardiovascular system diseases, for an increase of 10µg/m³ in the levels of particulate matter (PM_{10}), in Volta Redonda city, Rio de Janeiro, Brazil, from 2002 to 2006.

subgroup populations, within days after exposure to increased levels of pollutant.

The results of this study are consistent with some ecological time series studies available in the literature whose used the same methodology [1,11-13]. Atkinson et al., [11] analyzing London data found that for an increase of 10.166 µg/m³ of PM_{10} there was an increase in risk of cardiovascular deaths of 2.2% (95% CI = 0.6 - 3.8%), lagged 1-day. Another study was conducted in Panama City, it was found an increase in cardiovascular mortality of 9.7% (95% CI 5.8–13.6%) for PM_{10} levels ≥ 40 µg/m³[12]. O_3 levels ≥20 µg/m³ were associated with an increase of 1.7% (CI –0.039% to 7.5%) in cardiovascular total mortality after a 2-month lag from the time exposure.

Zhang et al., [13] in Chaoyang district of Beijing showed an increase of daily concentration of PM_{10}, and SO_2 by 10µg/m³ will augment the mortality from circulatory system diseases by 0.20% (95% CI: 0.01% - 0.39%) and 0.36% (95%CI: -0.13% - 0.85%), respectively. In this present study, the increase in cardiovascular deaths was of 3.67% for PM_{10}, for the others pollutants did not observe statistical association.

In the results for the elderly there was an increased risk of

Table 3: Percentage of relative risk (%RR) and 95% confidence interval (95%CI) for all deaths and elderly deaths from diseases of the cardiovascular system, for an increase of 10 μg/m³ in the levels of PM_{10}, SO_2 and O_3, in Volta Redonda city, Rio de Janeiro, Brazil, from 2002 to 2006.

Pollutant	Lag	Alldeaths		Elderlydeaths	
		%RR	95%CI	%RR	95%CI
PM_{10}	Currentday	1.12	-2.604 4.991	2.18	-2.516 7.102
	1-daylag	1.01	-2.582 4.735	2.76	-1.774 7.514
	2-daylag	**3.67**	**0.203 7.263**	**5.23**	**0.847 9.811**
	3-daylag	2.04	-1.355 5.552	2.50	-1.772 6.968
	4-daylag	1.10	-2.286 4.606	2.15	-2.124 6.622
	5-daylag	0.61	-2.765 4.094	0.27	-3.973 4.709
SO_2	Currentday	-0.29	-8.055 8.131	-3.78	-13.326 6.813
	1-daylag	-3.75	-11.400 4.567	-4.61	-14.160 5.997
	2-daylag	1.34	-6.609 9.971	2.10	-7.913 13.197
	3-daylag	1.46	-6.533 10.132	0.77	-9.200 11.833
	4-daylag	-2.89	-10.665 5.555	-3.96	-13.586 6.744
	5-daylag	0.54	-7.312 9.069	-1.63	-11.302 9.099
O_3	Currentday	-1.08	-3.265 1.160	-0.96	-3.723 1.876
	1-daylag	0.14	-2.073 2.396	-0.15	-2.936 2.725
	2-daylag	0.62	-1.492 2.781	2.13	-0.558 4.900
	3-daylag	0.50	-1.519 2.566	0.46	-2.084 3.071
	4-daylag	0.60	-1.385 2.620	-0.31	-2.813 2.264
	5-daylag	1.25	-0.715 3.247	0.92	-1.566 3.470

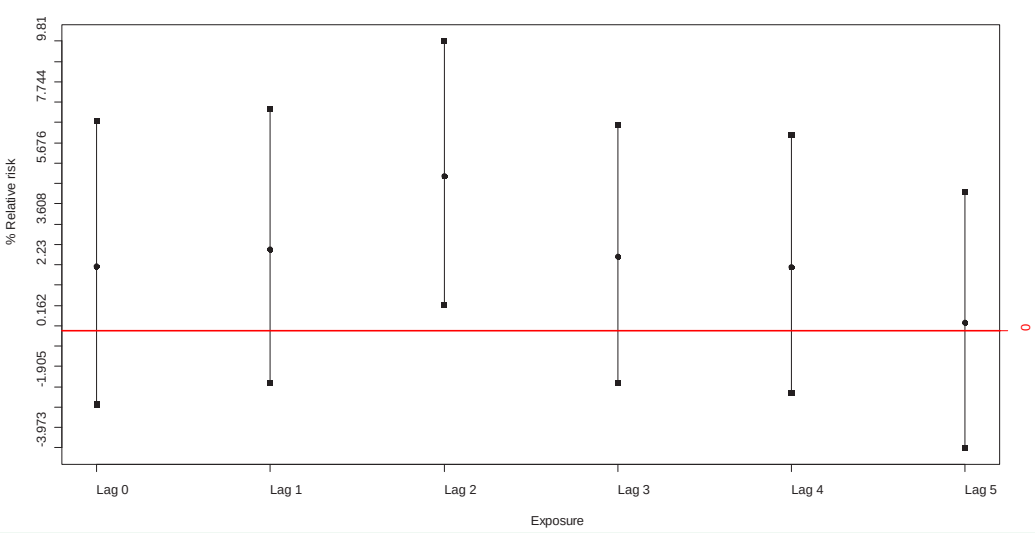

Figure 2 Percentage of relative risk to the elderly deaths from diseases of the cardiovascular system, for an increase of 10μg/m³ in the levels of particulate matter (PM_{10}), in Volta Redonda city, Rio de Janeiro, Brazil, from 2002 to 2006.

5.23%, a multi-city study in South Korea showed the effects of PM_{10} on cardiovascular mortality were the highest on extremely hot days (> 99th percentile) for elder lies. The combined analysis showed that a 10μg/m³ increment in PM_{10} corresponded to a 5.53% (95% CI: 0.4 - 10.91) increase in cardiovascular mortality [1].

This study corroborates the results that showed the PM_{10} like the best exposure indicator [14]. As health sector in Brazil does not have legal mechanisms for air pollution control, this contributes for the implementation of health public policies that involve the quantification impact of pollution on people's disease burden.

CONCLUSION

In Volta Redonda city, it has been found the association between daily PM_{10} concentrations to deaths due to this cause, with greater magnitude of effect on the elderly.

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.

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REFERENCES

1. Kim SE, Lim YH, Kim H. Temperature modifies the association between particulate air pollution and mortality: A multi-city study in South Korea. Sci Total Environ. 2015; 15: 524-525: 376-383.
2. Oliveira MS, Leon AP, Mattos IE, Koifman S. Differential susceptibility according to gender in the association between air pollution and mortality from respiratory diseases. Saude Publica. 2011; 27: 1827-1836.
3. Moraes AC, Ignotti E, Netto PA, Jacobson Lda S, Castro H, Hacon Sde S. Wheezing in children and adolescents living next to a petrochemical plant in Rio Grande do Norte, Brazil. J Pediatr. 2010; 86: 337-344.
4. Seo JH, Ha EH, Kim OJ, Kim BM, Park HS, Leem JH, et al. [Environmental health surveillance of low birth weight in Seoul using air monitoring and birth data]. J Prev Med Public Health. 2007; 40: 363-370.
5. Hansen CA, Barnett AG, Jalaludin BB, Morgan GG. Ambient air pollution and birth defects in brisbane, australia. PLoS One. 2009; 4: 5408.
6. Junger WL, Ponce de Leon, A. Imputation of missing data in time series for air pollutants. Atmospheric Environment . 2015; 102: 96-104.
7. Hastie TJ, Tibshirani RJ. Generalized additive models. New York: Chapman and Hall. 1990; 43: 87.
8. Braga AL, Zanobetti A, Schwartz J. The lag structure between particulate air pollution and respiratory and cardiovascular deaths in 10 US cities. J Occup Environ Med. 2001; 43: 927-933.
9. Akaike H, Petrov BN, Csaki F. Information theory as an extension of the maximum likelihood principle. Second International Symposium on Information Theory. Budapest: Akade´miai Kiado´. 1973; 267-281.
10. Castro HA, Gouveia N, Escamilla-Cejudo JA. Questões metodológicas para a investigação dos efeitos da poluição do ar na saúde. Rev Bras Epidemiol. 2003; 6: 135-149.
11. Atkinson RW, Fuller GW, Anderson HR, Harrison RM, Armstrong B. Urban ambient particle metrics and health: a time-series analysis. Epidemiology. 2010; 21: 501-511.
12. Zúñiga J, Tarajia M, Herrera V, Urriola W, Gómez B, Motta J. Assessment of the Possible Association of Air Pollutants PM10, O3, NO_2 With an Increase in Cardiovascular, Respiratory, and Diabetes Mortality in Panama City: A 2003 to 2013 Data Analysis. Medicine (Baltimore). 2016; 95: 2464.
13. Zhang JY, Zhang Z, Meng HY, Zhang GB, Zhao W, Pan XC. Time-series analysis on relationship between air pollution and mortality from circulatory system diseases among registered residents in Chaoyang district of Beijing. Zhonghua Yu Fang Yi Xue Za Zhi. 2012; 46:139-142.
14. Freitas CU, Junger W, Leon AP, Grimaldi R, Silva MAFR, Gouveia N. Poluição do ar em cidades brasileiras: selecionando indicadores de impacto na saúde para fins de vigilância. Epidemiol Serv Saude. 2013; 22: 445-454.

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