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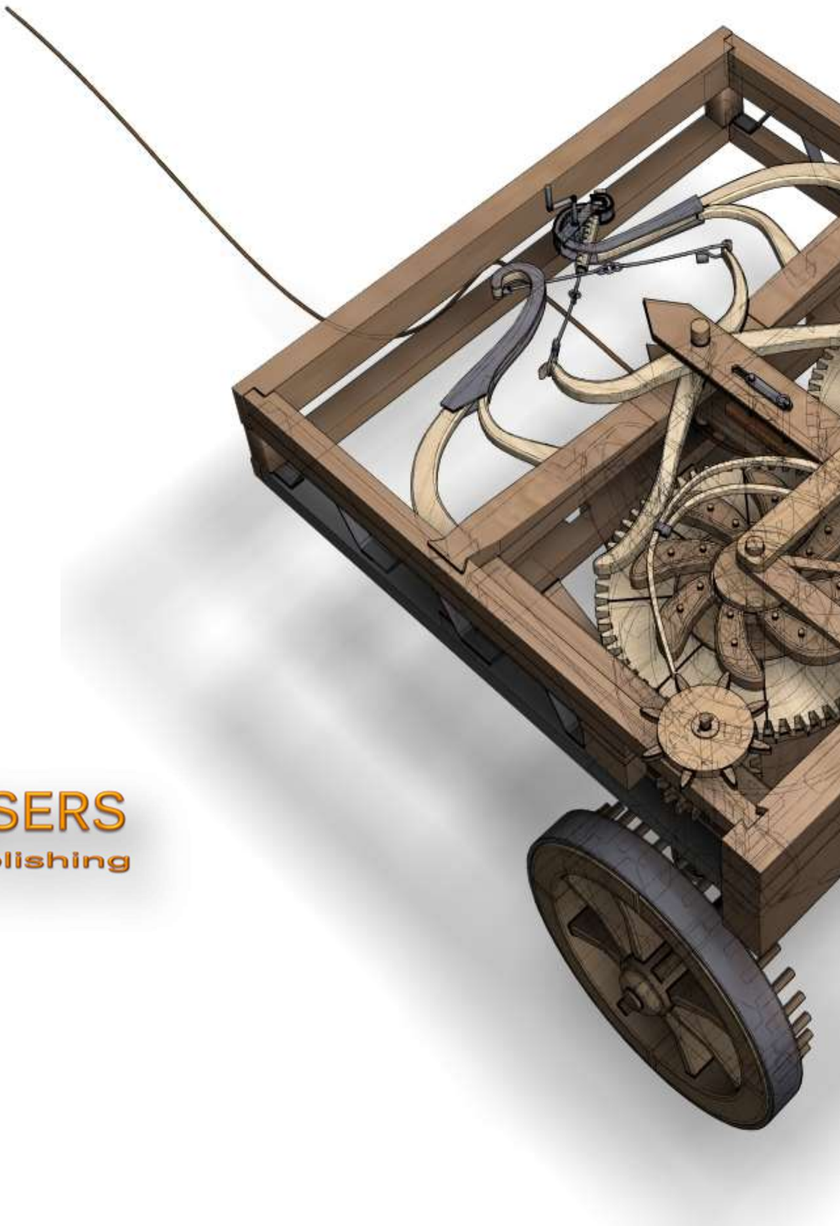

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Productivity Loss Due to Deaths Caused by Cardiovascular Diseases Associated with Exposure to Air Pollutants in Sorocaba, Brazil in the Years of 2015 to 2017

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Abstract

Air pollution from air pollutants has associations with causes of hospitalization. Objective is to evidence the association between exposure to pollutants 0_3, PM_{10} and NO_2, on hospital deaths in the public network. The loss of productive potential of this population was analyzed with "Anos Potencias de Vida Perdidos (APVP)". Methodology used ecological study of the time series, where the dependent variable considered was the number of hospital admissions that died: cardiovascular diseases (41 to 64 years old). The statistical approach used the Poisson Regression model with lags from 0 to 7 days. The financial costs and increases in the number of hospitalizations resulting from increases in the concentration of 10 µg in air were estimated. Coefficients were converted into relative risk of hospitalization adopting alpha = 5%. The result was 232 occurrences, not all exclusive and related to pollution. The value obtained was R$626 thousand and a cost of use of R$319 thousand reais. The APVP, was 2547 years with an associated cost of around R$56 million. Attributing loss of life associated with pollutants in the air, due to an increase of 10 µg in the air, we could avoid 20 deaths and the cost of around 3 million reais.

Keywords: environmental management; sustainability engineering; environmental practices; air pollution.

JEL Classification: Q56; Q53; Q01.

Introduction

Air pollution is a problem that affects millions, especially in large urban centers when considering the possible adverse effects of pollution on health. Studies have evaluated the adverse effects of air pollutants on the health of the population, showing that levels of air pollution increase the rates of morbidity and mortality, cardiovascular and respiratory diseases, among others (Machin *et al.* 2019; Nascimento *et al.* 2004). Other studies have shown that air pollution levels, generally represented by concentrations of pollutants Particulate Material (PM_{10} and/or $PM_{2.5}$), Nitrogen Dioxide (NO_2), Sulfur Dioxide (SO_2), Ozone (O_3), are associated with the short-term increase in visits resulting from respiratory problems (Furie and Balbus 2012; Guo *et al.* 2009). Another aspect is the epidemiological studies that have found an association between exposure to air pollutants and adverse health effects, such as the increase in the number of hospital admissions, increased mortality and reduced life expectancy (Halonen *et al.* 2009; Oudin *et al.* 2009; Samoli *et al.* 2008; Santos *et al.* 2008). This study was organized based on data collected from the Public Health System (DATASUS) and the Environmental Company of São Paulo (CETESB) in order to identify the association between exposure to pollutants PM_{10}, O_3 and NO_2 and hospitalizations with subsequent death from cardiovascular diseases. To demonstrate the impact caused by this exposure to pollution for individuals and society, was calculated the APVP value (potential years of life lost), in order to contribute to the construction of public policies, as well as stricter legislation. This theme is justified in the absence of research in this area in medium-sized cities in Brazil.

1. Methodology

Sorocaba is a Brazilian municipality, located in the state of São Paulo. It has an area of 450.38 km². Metropolitan Region of Sorocaba comprises 26 municipalities with approximately 2.06 million inhabitants, being the fourth largest in the state, after the Metropolitan Region of São Paulo, the Metropolitan Region of Campinas and the Metropolitan Region of Vale do Paraíba and North Coast (https://www.ibge.gov.br/government).

According to estimates (https://www.ibge.gov.br/government), the population is 671,186 million inhabitants, with 1304.18 inhabitants/km2. It has an HDI (Human Development Index) of 0.798 and has 17 private hospitals and 11 hospitals that serve the Unified Health System (SUS), which provide around 1400 inpatient beds (https://www.ibge.gov.br/government). The levels of pollution present in Sorocaba originate mainly from emissions from industries, in addition to the large vehicle fleet that exceeds 430 thousand vehicles (https://www.ibge.gov.br/government). It borders Tatuí, Itu, Itapetininga and Osasco, at coordinates 23.45º South and 47.48º West.

Studies carried out by Paiva (2004) confirmed the association between hospitalizations, exposure to carbon monoxide concentration and respiratory diseases. Thus, an ecological time series study methodology was applied to identify areas and population groups more vulnerable to this environmental pollution type (Amancio and Nascimento 2014; Mantovani 2016; Leite *et al.* 2011; Gavinier and Nascimento 2014).

The methodology allowed to quantify in monetary values, a value that could be directed to public policies to reduce health problems related to air pollution. To express the APVP we observe the expression:

The expression 1.1 that provides the APVP is the following:

$$APVP = \Sigma(70 - i - 0{,}5)^* d_i \qquad 1.1$$

Where i is the death age and d_i is the death number.

As the biological manifestations of pollution effects in the individual may or may not occur on the same day, or on subsequent days, the lag structure model of up to seven days after exposure was adopted, to facilitate statistical calculations (Tadano, Ugaya and Franco 2009).

From database DATASUS we used data referring to the municipality of residence, birth, sex, total value, date of admission, date of departure, main diagnosis, age, days of stay and death were used. And from database CETESB we used data referring to levels of environmental pollutants, particulate matter (PM_{10}), in their daily averages, as well as estimated average temperature.

Hospitalization data with diagnosis according to ICD 10 I-00 to I-99 were obtained from DATASUS. Data from 01/01/2015 to 12/31/2017 were filtered from the daily number of admissions with the diagnoses ICD 10 I-20 to I-25, I-50 and I-64 and the daily concentrations of pollutants atmospheric and meteorological variables. Daily means were calculated for each pollutant in the study PM_{10}, O_3 and NO_2 measured in μg/m^3. The concentrations of pollutants PM_{10}, O_3 and NO_2 in addition to air humidity and temperature were considered as independent variables, as these can directly or indirectly interfere with the diseases under study.

The frequency distribution of the different variables expressed as mean, standard deviation and minimum and maximum values was performed, considering the concentrations of pollutants: PM_{10}, O_3 and NO_2 adjusted for air humidity, temperature and days of the calendar week of the year of study. All analyzes were performed using the Stata 10 statistical program. The significance level adopted was 5%.

For this analysis, the Generalized Linear Poisson Regression Model was used, controlling for seasonality and days of the week. The coefficients provided by the model were transformed into Relative Risk (RR) according to expression 1.2:

$$RR= \exp(\beta) \qquad 1.2$$

where β is the coefficient obtained by Poisson Regression. The confidence interval (IC95%) for the RR was also calculated.

The coefficients provided by the model were also transformed into Relative Risk (RR) when the mean PM_{10} concentrations were increased by 10μg/m^3 according to expression 1.3:

$$RR= \exp(\beta^*\Delta pollutant) \qquad 1.3$$

where Δ pollutant is the pollutant value when increased by 10μg/m3 in its concentration, minus the estimated pollutant valeu on site.

In addition, the effect of the increase in the number of hospital admissions, depending on the increase in PM_{10} levels, was estimated using formula 1.4:

$$AP = (\exp(\beta * \Delta poluente) - 1) * 100 \quad 1.4$$

The proportional attributable ratio (RAP) was calculated according to expression 1.5:

$$RAP = [1 - 1/RR] \quad 1.5$$

Where RR = relative risk with increase, to verify the percentage of hospitalized due to pollutants.

With this value, the population attributable fraction (FAP) that allowed estimating the number of hospitalizations associated with this increase was estimated, according to expression 1.6:

$$FAP = RAP * N \quad 1.6$$

Where N is the number of hospitalizations for cardiovascular disease in the period studied. The cost to the Health System was also estimated, according to the average value of each hospitalization for these selected diseases, which could be avoided by reducing PM_{10} concentrations.

The results do not translate into conclusions about the impacts of pollution, as its effects depend on more factors such as concentration, duration of exposure, climate, nutritional status, predisposition, age. Therefore, it is expected that the negative effects of pollution are widely studied and demonstrated, so that policies can be built to reduce these impacts.

In the Hospital Admission System (SIH/SUS), to obtain the variables, the Health Information (TABNET) was accessed by choosing the option of consolidated data, by place of admission. The costs reported in this study only address hospitalization and do not include rehabilitation costs, days off, lost productivity or socioeconomic impact on the state or family, among others. An average of the values of each income bracket was considered, resulting in R$1700.00 per month. The adopted average on the value of the retirement consists of R$1700.00, being 12 months + 13th, totaling 22 thousand reais, an approximation for the Brazilian context of the calculated values of the APVP. No discounts or inflation adjustment were applied due to the short period of time. The cost was based on values in reais (R$) in 2015. The salary value was arbitrarily chosen, being 2 thousand reais, for both men and women, using the column of the average age of men and women. For the purposes of the calculations, from 41 to 64 years for men and women was considered, without considering that women retire before men.

2. Case Studies and Results

The result for the year 2015-2017 was 232 occurrences (I20-64 with death, over 41 to 64 years), not all exclusive and correlated with pollution, the total cost value, using DATASUS data, was of R$ 626 thousand reais and the cost of use of R$ 319 thousand reais. Thus, using the table on life expectancy in Brazil, to calculate the APVP, the average column was multiplied (not specifying the calculations for men or women), the sum of lost years 2547 years lost, reaching a cost of around R$ 56 millions of reais. Attributing a loss of life correlated to pollutants in the air with a reduction of 5%, we could avoid the cost of around 3 million reais in the year 2015-2017.

In Tables 1 and 2, organized data on diseases, hospitalizations and data filtering from ICD 10 I-20 to I-99 are presented. We observed the sum of hospitalization days for all diseases, and the sum of lost years of individuals who died due to dying before the organized statistical average of the IBGE.

In Table 3, using the generalized linear Poisson Regression model, the relative risk for hospitalizations for ischemic heart disease was calculated for all associated pollutants analyzed, adjusted for temperature and humidity, with a confidence interval of 95%. Deaths were numerical data that followed the Poisson distribution. This model provided a coefficient transformed into relative risk (RR), as the expression RR = exp (coefficient). These RRs were calculated with their respective 95% confidence intervals for hospitalizations that died.

By presenting a positive association between hospitalizations in the multipollutant model and O_3 (Lag1-4, Lag 6-7), and PM_{10} (Lag1-2 and Lag7), hospitalizations presented a relative risk that indicates that the pollutant was correlated with death. The results are:

- **Lag2 PM_{10}($\mu g/m^3$)**
  - ✓ RR = 1,0072, RAP = 0,0064 (6,4%), FAP = 1,48
  - ✓ Cost = R$ 2.301,44 mil reais or US$ 460,29 dollar (considering the dollar value = R$ 5,00 reais)
- **Lag2 PM_{10}($\mu g/m^3$)** with increase of 10µg
  - ✓ RAP = 0,064, FAP = 14,85

- ✓ Cost = R$ 23.018,33 mil reais or US$ 4.603,67 dollar (considering the dollar value = R$ 5,00 reais)
- **Lag2 O_3 (µg/m^3)**
- ✓ RR = 1,0014, RAP = 0,0028 (2,8%), FAP = 0,649
- ✓ Cost = R$ 1,006,88 mil reais or US$ 201,38 dollar (considering the dollar value = R$ 5,00 reais)
- **Lag2 O_3 (µg/m^3)** with increase of 10µg
- ✓ RAP = 0,028, FAP = 6,496
- ✓ Cost = R$ 10.069,13 mil reais or US$ 2.013,83 dollar (considering the dollar value = R$ 5,00 reais)

Table 1. Disease data (CID 10 I-20 to I-25, I-50 and I-64) of individuals who died*

	Total	Means	Min	Max
Total years	13189	57,09	41	64
Hospitalization days	1933	8,36	1	65

***disease**: I200, I210, I211, I219, I500, I607, I616, I620, I629, I635, I640

Table 2. Data from six disease (CID 10 I-20 to I-25, I-50 and I-64)

	Occurrences	Deaths	Percentage*
Total	232	214	90,6
I200	12	12	5
I210	9	9	3,8
I211	9	9	3,8
I219	14	14	6
I500	71	71	30
I64	99	99	42

* Approximate sum of disease occurrences.
** Table built only with individuals who died

Table3. Coefficients and standard deviations arising from the Poisson Regression for seven-day lags (Lag 0 – Lag 7), in multipollutant model, PM_{10}(µg/m^3), NO_2 (µg/m^3) and O_3 (µg/m^3), about Sorocaba São Paulo from 2015-2017

	PM_{10}(µg/m^3)	NO_2 (µg/m^3)	O_3 (µg/m^3)
Lag 0	-0.0004 (0.0015)	0.0003 (0.0007)	-0.0000 (0.0006)
Lag 1	**0.0032 (0.0015)***	-0.0013 (0.0007)	**0.0014 (0.0006)***
Lag 2	**0.0031 (0.0015)***	-0.0008 (0.0007)	**0.0014 (0.0006)***
Lag 3	0.0004 (0.0015)	-0.0005 (0.0007)	**0.0024 (0.0006)***
Lag 4	0.0027 (0.0015)	-0.0013 (0.0007)	**0.0019 (0.0006)***
Lag 5	**0.0057 (0.0015)***	-0.0012 (0.0007)	0.0001 (0.0006)
Lag 6	**0.0068 (0.0014)***	-0.0010 (0.0007)	0.0009 (0.0006)
Lag 7	**0.0042 (0.0015)***	-0.0002 (0.0007)	0.0009 (0.0006)

*** p-value < 0,05**

Thus, we can see in Table 3, that exposure to the pollutant PM_{10} has significantly positive association values in Lag 1, 2, 5, 6.7 with p-value < 0.05, with the same situation of positive significance in Lag 1, 2, 3, 4 of the O_3 pollutant. Several studies have evaluated the adverse effects of air pollutants on the health of the population, including rates of mortality, hospitalization and emergency care in hospitals, cardiovascular, respiratory and other diseases (Nascimento *et al.* 2004; Guo Y *et al.* 2009; Halonen *et al.* 2009; Oudin *et al.* 2009; Samoli *et al.* 2008). Some studies demonstrate that high levels of air pollution increase morbidity and mortality rates (Santos *et al.* 2008).

In Table 4, we observed a negative association for NO_2, therefore with little relevance to hospitalizations, that is, suggesting a protective effect for the analyzed outcome. Data were not adjusted with CO, as this item is not monitored in the data collection station, which could find associations, as this compound would potentiate the action of fine particulate matter in the number of hospitalizations for cardiovascular diseases.

Thus, having a result:

- **Lag5 PM_{10}(µg/m^3)**
- ✓ RR = 1,0044, RAP = 0,0088 (8,8%), FAP = 2,041
- ✓ Cost = R$ 3.164,49 mil reais or US$ 632,90 dollar (considering the dollar value = R$ 5,00 reais)
- **Lag5 PM_{10}(µg/m^3)** with increase of **10µg**
- ✓ RAP = 0,088, FAP = 20,42

- ✓ Cost = R$ 31.655,01 mil reais or US$ 6.331,00 dollar (considering the dollar value = R$ 5,00 reais)
- **Lag1 O_3 (µg/m³)**
- ✓ RR = 1,0016, RAP = 0,0032 (3,2%), FAP = 0,742
- ✓ Cost = R$ 1.150,72 mil reais or US$ 230,14 dollar (considering the dollar value = R$ 5,00 reais)
- **Lag1 O_3 (µg/m³)** with increase of **10µg**
- ✓ RAP = 0,032, FAP = 7,424
- ✓ Cost = R$ 11.507,69 mil reais or US$ 2.301,54 dollar (considering the dollar value = R$ 5,00 reais)

Table 4. Coefficients and standard deviations arising from the Poisson Regression for seven-day lags (Lag 0 – Lag 7), in multipollutant model, PM_{10}(µg/m³) and O_3 (µg/m³), about Sorocaba Sao Paulo from 2015-2017

	PM_{10}(µg/m³)	O_3 (µg/m³)
Lag 0	-0.0002 (0.0013)	-0.0001 (0.0006)
Lag 1	0.0014 (0.0012)	**0.0016 (0.0006)***
Lag 2	0.0019 (0.0012)	0.0011 (0.0006)
Lag 3	0.0002 (0.0013)	**0.0024 (0.0006)***
Lag 4	0.0023 (0.0012)	**0.0020 (0.0006)***
Lag 5	**0.0044 (0.0012)***	0.0004 (0.0006)
Lag 6	**0.0058 (0.0012)***	**0.0013 (0.0006)***
Lag 7	**0.0040 (0.0012)***	0.0008 (0.0006)

*** p-value < 0,05**

Thus, we can see in Table 4 that exposure to the pollutant PM_{10} has significantly positive association values in Lag 5, 6, 7 with a p-value < 0.05, with the same situation of positive significance in Lag 1, 3, 4, 6 of the O_3 pollutant. Industrial developments associated with increased consumption of fossil fuels have caused enormous air pollution. For example, in China, the occurrence of air pollution with high concentrations of fine particles ($PM_{2,5}$) (Chen and Li 2017; Yang, Gbaguidi, Yan and Zhang 2017), in recent decades, is affecting people's health. Empirical observations of an association between air pollution and cardiovascular risk have been validated in many epidemiological and observational studies, which have demonstrated adverse effects of various components of air pollution on mortality and morbidity in select cohorts of patients (Folino and Buja 2017).

The data in Table 4 were presented with coefficients and standard deviations derived from the Poisson Regression for the seven-day lags (Lag 0 – Lag 7), in the multipollutant model of PM_{10}(µg/m³) and NO_2 (µg/m³), about Sorocaba-SP from 2015-2017. So as a result we have:

- **Lag1 PM_{10} (µg/m³)**
- ✓ RR = 1,0054, RAP = 0,0108 (10,8%), FAP = 2,5056
- ✓ Cost = R$ 3.883,70 mil reais or US$ 776,74 dollar (considering the dollar value = R$ 5,00 reais)
- **Lag1 PM_{10} (µg/m³)** with increase of **10µg**
- ✓ RAP = 0,108, FAP = 25,068
- ✓ Cost = R$ 38.855,68 mil or US$ 7.771,14 dollar (considering the dollar value = R$ 5,00 reais)

It is verified that the exposure to the PM_{10} pollutant presents significantly positive association values in Lag 1,2,5,6,7, with a p-value < 0.05, but not finding positive significance in the NO_2 pollutant.

The data in Table 4 were presented with the coefficients and standard deviations arising from the Poisson Regression for the seven-day lags (Lag 0 – Lag 7), in the multipollutant model of NO_2 (µg/m³) and O_3 (µg/m³), about Sorocaba-SP from 2015-2017. So as a result we have:

- **Lag1 O_3 (µg/m³)**
- ✓ RR = 1,0014, RAP = 0,0028 (2,8%), FAP = 0,649)
- ✓ Cost = R$ 1.006,88 mil reais or US$ 201,38 dollar (considering the dollar value = R$ 5,00 reais)
- **Lag1 O_3 (µg/m³)** with increase of **10µg**
- ✓ RAP = 0,028, FAP = 6,496
- ✓ Cost de R$ 10.069,13 mil reais or US$2.013,83 dollar (considering the dollar value = R$ 5,00 reais).

Exposure to the O_3 pollutant presents significantly positive association values in Lag 1,2,3,4 with a p-value < 0.05, but not finding positive significance in the NO_2 pollutant. Epidemiological studies provide evidence of an association between exposure to air pollutants and their negative effects, focusing on the number of hospitalizations and deaths and on the decrease in the individual's life expectancy, for example, with studies carried out in urban areas with a lot of traffic and pollution, where it surrounds 5% of all deaths from respiratory causes each year can be attributed to air pollution (Habermann and Gouveia 2011).

Table 5 allows viewing the percentages of all diseases and their occurrences, illustrating the association found from the calculations presented below, organizing subsidies for future research to specify and design public policies.

Descriptive analysis of the variables with their means, respective standard deviations (SD) and minimum (MIN) and maximum (MAX) values, Sorocaba Sao Paulo, 2015-2017.

Table 5. Descriptive analysis of the variables with their means, respective standard deviations (SD) and minimum (MIN) and maximum (MAX) values, Sorocaba Sao Paulo, 2015-2017

Variables	Obs*	Means	DP	MIN-MAX
NO_2 (µg/m³)	1023	38,4	20,13	5-99
O_3 (µg/m³)	1045	66,38	27,03	10-165
PM_{10} (µg/m³)	1061	25,70	11,51	9-80
Temperatura (ºC)	1095	27,6	4,14	16,5-37,1
Umidade (%)	1095	49,76	15,13	17-96

* Obs: number of days that there was a mediation

Table 5 shows the concentrations for NO_2 (38,4 µg/m³), O_3 (66,38 µg/m³) and PM_{10} (25,7 µg/m³) in the year 2015-2017, also the Variations in Average Relative Humidity (17-96) and Average Temperature (16.5-37.1) in the year should be observed. We observe, as a reference in the year 2015-2017, the use of R$ 1336.00 reais as an average per hospitalization, reaching the total amount higher than 56 million reais in the period. Regarding deaths, individuals who were hospitalized and eventually died, the result was a total of 232 individuals. These associations cannot be fully explained by co-exposure to MP, but it has been suggested that other components in the mixture (such as organic carbon and nitrous acid vapor) may explain part of the observed association.

3. Discussion

Air pollution can be considered the greatest risk to global environmental health, as it is estimated around 5.5 million premature deaths annually due to it. The epidemiological evidence for this association is solid, consisting of a large number of mainly North American and European cohort studies, and negative health effects have been consistently associated with fine particles ($PM_{2.5}$) (Furie and Balbus 2012; Beelen, Raaschou-Nielsen and Stafoggia 2014; Brook and Rajagopalan 2010; Cesaroni *et al.* 2013; EEA Air Quality in Europe Report. EEA Report No 5/2014; Forouzanfar and Lily 2015; NRC. Research Priorities for Airborne Particulate Matter: III. 2001; Raaschou *et al.* 2012; Stockfelt *et al.* 2017; WHO. 2014). More specifically, particulate matter comprises fine particles ($PM_{2.5}$) present in ambient air (Moore, Akinyemijua and Wang 2017). The economic expansion associated with the increased consumption of fossil fuels has caused an increase in air pollution, for example, in China and other places with high concentrations of fine particles ($PM_{2,5}$) (Chen and Li 2017; Yang, Gbaguidi, Yan and Zhang 2017; Azevedo, Sartori and Campos 2017; Bartington *et al.* 2017; Hérick *et al.* 2017; Kelly and Fussell 2017).

In recent decades, empirical observations of an association between air pollution and cardiovascular risk have been validated in many epidemiological and observational studies, which have shown adverse effects of various components of air pollution on mortality and morbidity in select cohorts of patients (Folino and Buja 2017). Studies on air pollution and the effects on the health of the population have shown that pollutants below the levels determined by law pose less health (Gavinier and Nascimento 2014; Dapper, Spohr and Zanini 2016).

Other studies indicate that PM_{10}, O_3 and NO_2 levels were associated with short and long-term exposure to increases in cardiovascular, respiratory and diabetes mortality (Guo *et al.* 2009; Daniels *et al.* 2004). We can mention the relationship of air pollution with respiratory and cardiovascular diseases, verifying the association between particulate matter and hospitalizations for total respiratory diseases (Nardocci *et al.* 2013).

Epidemiological studies show an association between exposure to air pollutants and their negative effects, focusing on the number of hospitalizations, deaths and reduced life expectancy and health of the individual (Nascimento *et al.* 2004; Nascimento *et al.* 2006). Thus, air pollution contributes substantially to the global burden of disease, which has increased over the past 25 years, with the result that the challenges for future reductions in the disease burden attributable to air pollution are substantial (Cepeda *et al.* 2017; Cohen and Brauer 2017). Therefore, public policies, being complex and requiring a multidisciplinary effort, can lead to improved health and reduce air pollution and climate change in the medium and long term (Arbex *et al.* 2012; Arbex *et al.* 2004; Fajersztajn, Veras and Saldiva 2016; Gioda and Aquino Neto 2003).

3.1 Air Pollution

Air pollution consists of the presence of chemical substances in the atmosphere in concentrations high enough to harm organisms and materials (Arbex *et al.* 2012; Miller 2011; Oliveira and Ignotti 2011). Life in the urban environment has worsened health (Fajersztajn, Veras and Saldiva 2016). Since Industrial Revolution accelerated air pollution, due to the large contact area between the surface of the respiratory system and the environment, air pollutants rival tobacco smoke as the main risk factor for these diseases and can be credited to these pollutants, increases in disease symptoms, in the search for assistance in emergency services and in the number of hospitalizations and deaths (Arbex *et al.* 2012).

Brazil, for example, had about 10% of the expenses of the Unified Health System (SUS), from September 2012 to August 2013, with hospital admissions for the treatment of respiratory diseases (Paiva 004). Therefore, the estimated increase in mortality was greater in places with poorer air quality (Furie GL and Balbus J. 2012). As the adverse effects of particles and other environmental pollutants are, therefore, well known (Torricelli *et al.* 2011).

Exposure to pollutants is a risk factor for the aggravation of diseases and chronic diseases, hospital admissions, intrauterine mortality, birth defects (Nascimento *et al.* 2006). Air pollution represents one of the biggest public health problems, as it causes negative health effects. It is estimated that exposure to particulate matter causes 800,000 deaths worldwide, of which 35,000 occur in Latin America (Mascarenhas *et al.* 2008).

3.2 Particulate Matter

Air pollution is one of the most serious environmental health risks in Brazil. It can be formed by suspended particles arising not only anthropogenic but also from natural processes. With the definition of an air considered polluted, classified into primary and secondary, being a mixture of gases and particles (particulate matter - PM) that are emitted into the atmosphere by automotive vehicles, burning of fossil fuels, by industries, burning of biomass and thermoelectric. Thus, public policies against pollution improve the quality of life and reduce the number of deaths, where estimating the value of such benefit is a key input (Furie and Balbus 2012; Arbex *et al.* 2012).

Air pollution consists of a complex mixture of solid and liquid particles suspended in the air (Torricelli *et al.* 2011; Cançado *et al.* 2006). External air pollution is responsible for 1.3 million deaths per year (Furie and Balbus 2012). Hence, governments can use a combination of subsidies, tax rebates and taxes to promote development in alternative renewable energy (Miller 2011).

Thus, PM is a pollutant that varies in shape, surface area, number, size and chemical composition, depending on the emitting source. It is classified according to its suspended particle size: particles up to 30 μm in diameter; particles less than 10 μm in diameter (PM_{10} or inhalable fraction); particles less than 2.5 μm in diameter ($PM_{2.5}$ or fine); and particles smaller than 10 μm in diameter ($PM_{0.1}$ or ultrafine). They can be formed by various chemicals, including an elemental or organic carbon nucleus, organic and inorganic compounds, soluble salts, transition metals and biological material (Arbex *et al.* 2012). Coarse particles (mainly soil material and ash) are hardly transported by the winds and fine particles are transported over long distances (Arbex *et al.* 2004; Cançado *et al.* 2006).

Conclusion

Hospitalization data refer only to those that occurred in the public network, excluding private hospitalizations, health plans or health care providers. Our findings should be used mainly for accounting purposes, as it is not possible to establish a cause-and-effect relationship between exposure to pollutants and hospitalizations.

This study has some limitations. The strength of the winds at the study site was not considered, which could dilute or increase the concentration of pollutants, bringing pollutants from nearby regions. Another possible limitation is that, although hospitalization data were obtained from an official source (DATASUS), they may contain diagnostic errors. In addition, it does not provide information on nutritional status, medical history, living conditions, smoking, among others that may be associated with respiratory diseases.

It is important to emphasize that the study indicates an association and not causality. The results presented should influence the development of public policies to reduce air pollutants, reducing costs for the SUS and improving the quality of life of the population in general. It is possible to find an association between air pollution and deaths from cardiovascular diseases, where exposure to PM_{10} had statistical significance in some Lag and can be considered a risk factor for the diseases presented. As significance was found in some of the Lag, it is concluded that a decrease in the concentration of particulate matter or pollutants would represent a decrease in hospitalizations and in the cost for the Unified Health System (SUS). We also noted an important role for PM_{10} when associated with the risk of death from cardiovascular disease at the study site.

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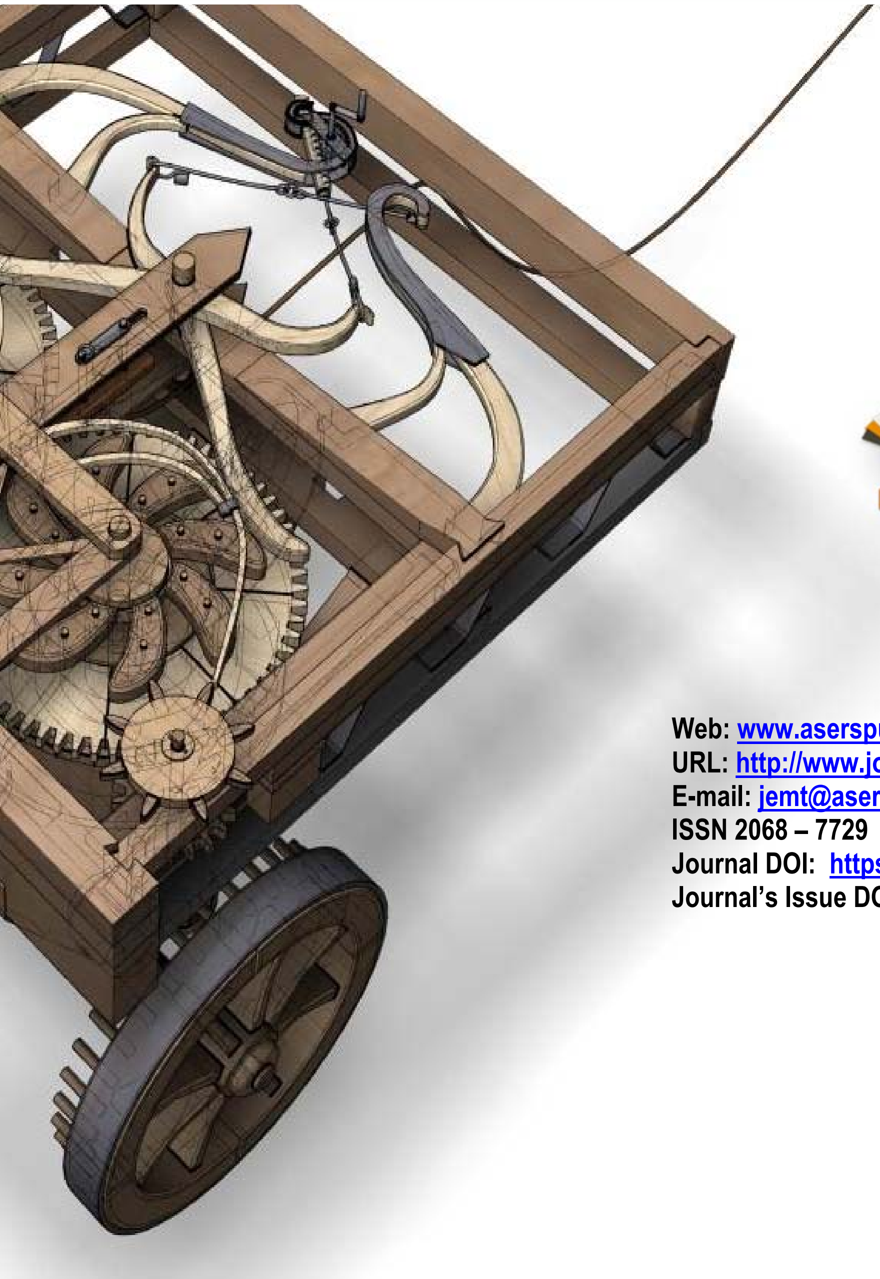

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