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# Seasonal variations in daily mortality associated with exposure to particulates, in Campo Grande, Brazil

# Variaciones estacionales de la mortalidad diaria asociada a la exposición a partículas, en Campo Grande, Brasil

# Variações sazonais na mortalidade diária associada à exposição a partículas, em Campo Grande, Brasil

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## ABSTRACT

***Objcetive:*** *to investigate short-term effects of air pollution, climate variability on respiratory morbidity and mortality from 2005 to 2020.* ***Method:*** *the study was carried out in the city of Campo Grande, Mato Grosso do Sul, Brazil. Daily counts of hospital admissions from 2005 to 2020 were analyzed in relation to daily variations in atmospheric pollutants ($NO_2$, $O_3$) from the Aurea satellite column, OMI sensor. Poisson regression in generalized additive models was used for analysis. The models were adjusted for the effects of temporal trend, seasonality, meteorological factors and autocorrelation.* ***Results:*** *there was, in the period, an increasing trend in mortality rates and hospital admissions, with an increase in the proportion of deaths from respiratory diseases in relation to other causes.* ***Conclusion:*** *respiratory diseases are worrying causes of hospitalization and death in the population. The results found are consistent with studies that point to an association between short-term*

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*variations in air pollutants and the increase in morbidity and mortality in large urban centers.*
***Descriptors:*** *Respiratory Diseases; Hospitalization; Air Pollutants.*

***RESUMEN***
***Objetivo:*** *investigar los efectos a corto plazo de la contaminación del aire, la variabilidad climática en la morbilidad y mortalidad respiratoria de 2005 a 2020.* ***Método:*** *el estudio se llevó a cabo en la ciudad de Campo Grande, Mato Grosso do Sul, Brasil. Se analizaron los conteos diarios de ingresos hospitalarios de 2005 a 2020 en relación con las variaciones diarias de contaminantes atmosféricos ($NO_2$, $O_3$) de la columna del satélite Aurea, sensor OMI. Para el análisis se utilizó la regresión de Poisson en modelos aditivos generalizados. Los modelos fueron ajustados por los efectos de tendencia temporal, estacionalidad, factores meteorológicos y autocorrelación.* ***Resultados:*** *hubo, en el período, una tendencia creciente en las tasas de mortalidad e ingresos hospitalarios, con aumento en la proporción de muertes por enfermedades respiratorias en relación a otras causas.* ***Conclusión:*** *las enfermedades respiratorias son causas preocupantes de hospitalización y muerte en la población. Las acciones de prevención y atención de estas causas, así como la profundización de la investigación etiológica, deben ser priorizadas en el actual contexto epidemiológico de salud en Brasil. Los resultados encontrados son consistentes con estudios que apuntan a una asociación entre las variaciones a corto plazo de los contaminantes atmosféricos y el aumento de la morbilidad y mortalidad en los grandes centros urbanos.*
***Descriptores:*** *Enfermedades Respiratorias; Hospitalización; Contaminantes Atmosféricos.*

**RESUMO**
**Objetivo:** investigar os efeitos a curto prazo da poluição do ar, variabilidade climática na morbimortalidade respiratória entre os anos de 2005 a 2020. **Método:** o estudo foi realizado na cidade de Campo Grande, Mato Grosso do Sul, Brasil. As contagens diárias de internações hospitalares entre os anos de 2005 a 2020 foram analisadas em relação às variações diárias de poluentes atmosféricos ($NO_2$, $O_3$) da coluna satélite Aurea, sensor OMI. A regressão de Poisson em modelos aditivos generalizados foi utilizada para análise. Os modelos foram ajustados pelos efeitos de tendência temporal, sazonalidade, fatores meteorológicos e autocorrelação. **Resultados**: houve, no período, tendência crescente nas taxas de mortalidade e internações hospitalares, com aumento da proporção de óbitos por doenças respiratórias em relação a outras causas. **Conclusão**: as doenças respiratórias são causas preocupantes de hospitalização e morte na população. Ações de prevenção e atenção a essas causas, bem como a investigação etiológica , devem ser priorizadas no atual contexto epidemiológico da saúde no Brasil. Os resultados encontrados são consistentes com estudos que apontam para uma associação entre as variações de curto prazo dos poluentes atmosféricos e o aumento da morbimortalidade nos grandes centros urbanos.
**Descritores**: Doenças Respiratórias; Hospitalização; Poluentes Atmosféricos.

## *INTRODUCTION*

*In the city of Campo Grande, state of Mato Grosso do Sul (MS), Brazil, studies have shown that the levels of pollution are harmful to the health of the population. Emphasis on the associations between levels of air* *pollutants and deaths, hospitalizations for respiratory diseases and deaths. In Brazil, as in many other countries, there are air quality standards, which in turn establish tolerance limits, to ensure that the population has quality of life. As a response to pollution-related problems, the Ministry of Health (MS), through the General Coordination of Surveillance in Environmental Health, structured, as of 2001, the Surveillance Program in Environmental Health Related to Air Quality (Vigiar).*

*Pollutants are represented by Total Suspended Particles (PTS), Inhalable Particles ($PM_{10}$), Sulfur Dioxide ($SO_2$), Nitrogen Dioxide ($NO_2$), Ozone ($O_3$) and Carbon Dioxide ($CO_2$) and the climatic variables: temperature of air (TA), relative humidity (RH) and precipitation (Prec). This study addresses a current issue that affects a significant part of the population, with the assumption that everyone in society has the responsibility to contribute to the process of change towards a new pattern of behavior towards natural resources, which are essential elements of nature for the survival of the human being. The topic under study is relevant to today's society, as this approach allows for a deep reflection on the effects of pollutants on people's health, promoting changes in behavior and maturing on the topic within society in general.*

*Thus, this study goal to investigate the relationship between pollutants and hospitalizations for respiratory diseases and deaths through statistical analysis, as well as the identification of the most relevant variables in the time series.*

## METHODS

*The modeling strategy was based on a central model with all known information (trend, seasonality, weekdays, holidays, and weather conditions), to explain the number of deaths, hospitalizations for respiratory diseases, concentration of pollutants and climatic variables.*

*The choice of variables and covariates to compose the model was based on tests and diagnoses at each stage of the modeling process. The diagnoses were based on the analysis of the performance indices: (RBE, RMSE, MAPE and $R^2$)[1].*

*Exploratory data analysis was based on the decomposition of time series and autocorrelation graphs. The outcome variable was the number of cases of death and the independent* *variables were hospital admissions for respiratory diseases, monthly mean Prec,relative humidity (RH), hot spots and monthly Tmin and Tmax and concentration of $O_3$ and $NO_2$. After exploratory analysis, cut-off points for mean temperature were evaluated by generalized additive models[2].*

*The daily number of medical visits represents a counting process and the generalized additive model (GAM), with Poisson distribution, was the statistical tool used in the study to estimate the shape of the curve of the relationship between health outcome and air pollution[3-5].*

*Be $\{Y_t\}$ , t = 1,..., N, a time series of count of non-negative integers. The conditional density function of $\{Y_t\}$ given passed information ($F_{t-1}$), denoted by $\{Y_t \mid F_{t-1}\}$, has Poisson distribution, with mean $\mu_t$, if it meets:*

$$f(y_t;\mu_t/F_{t-1}) = \frac{e^{\mu_t}\mu^{y_t}}{y_t^!} \quad t=1, 2, \ldots, N \quad (1)$$

*Where $y_t$ represents hospitalization/ emergency care at moment (day) t.*

*Be $X = (X_1, X_2, \ldots, X_p)$ a vector of p explanatory covariates. The curve that describes the relationship between $y_t$ and the covariates X is obtained by the logarithmic transformation of $\mu_t$ given by equation (2).*

$$log(\mu_t) = \alpha + \sum_{j=1}^{q} \beta_j X_j + \sum_{j=q+1}^{p} f(X_j) \quad (2)$$

*Being q <= p (2) where a is the model intercept; $b_{\downarrow j}$ (j=1,...,q) represent the linear regression coefficients associated with the concentration of $NO_2$ and $O_3$ and with indicative covariates for the days of the week, holidays; and $f(X_j)$ are smoothing spline functions for confusion variables (temperature and humidity) and temporal trend variables (number of elapsed days). The spline function allows the control of the nonlinear dependence between the covariates and outcome variable.*

*The relative risk (RR) is a measure of occurrence between the probability of an epidemiologic event occurring given the exposure to certain level of the exposure factor in relation to those affected by the same event and not exposed to the factor. In this study, RR refers to the increased risk of acute respiratory events occurring given the exposure of concentration levels of NO2 and O3.*

*For the GAM with usual Poisson distribution, RR is expressed by equation (3).*

$$RR(x = k) = e^{k\beta i}\ with\ i = 1, 2, \ldots, p \quad (3)$$

*Being k the concentration variation of NO2 and O3, here considered by the difference between the third and first quartiles, and b^ the coefficient estimated by GAM.*

*Data were supplied as mean and standard deviation (SD) and outcome as counts. We used a significance level of 5%. The process of modeling and statistical analysis were made on the R platform*[6]*.*

*The effect of climatic variables on the number of reported cases was evaluated using generalized linear models*[7] *with a logarithmic link function for Poisson and negative binomial distribution.*

*The response variable of a Poisson regression*[7,8] *must follow a Poisson distribution where the mean of the response variable must equal the variance. However, when working with experimental data this is not always the case, and overdispersion (variance greater than the mean) or underdispersion (variance less than the mean) may occur. Even so, it is still possible to apply the Poisson regression model by performing transformations*[8]*.*

*Statistical analysis consisted of calculating measures of position and dispersion of variables (monthly and annually), drawing up line graphs, filtering moving averages, principal component analysis (PCA), cluster analysis and Pearson's correlation coefficient.*

*PCA is a multivariate data reduction technique in which the main objective is the construction of a linear combination of the original variables, generating new orthogonal components that represent and capture the variability of the original set of variables*[9]*, thus seeking a natural relationship, with analysis of independence or dependence, between the variables.*

*Data were collected from hospital admissions for respiratory diseases, provided by the Information Technology Department of the Unified Health System (DATASUS), for the period 2005 to 2020. All admissions for respiratory diseases were selected (ICD-9a revision: 620- 519; ICD-10th revision: J00 to J99). All data are from Campo Grande, MS, and are public domain data. Furthermore, ethical aspects in research with human beings were respected.*

*The performance and accuracy of the tested models were assessed based on various statistical indices. The statistical indicators used in this study can be regrouped into two groups:* ***i)*** *dispersion indicators (error indicators) and **ii**) general performance indicators. Mean Bias Error (MBE), Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) are noted in the dispersion indices and while Coefficient of Determination ($R^2$) are regrouped in the performance indicators[4]. The equations (Eq. 4 to 6) for statistical indicators are listed below:*

$$MBE = \frac{1}{n}\sum_{i=1}^{n}\left(P_i - O_i\right)$$

*(4)*

$$RMSE = \sqrt{\sum_{i=1}^{n}\frac{\left(P_i - O_i\right)^2}{n}}$$

*(5)*

$$MAPE = \sum_{i=1}^{n}\frac{|P_i - Oi|}{P_i}\cdot\frac{100}{n}$$

*(6)*

*Where, Pi is the predicted value, Oi is the observed value, n is the number of observation.*

***RESULTS AND DISCUSSION***

*The air temperature range recorded during the study period was 18°C for Tmin and 30°C for Tmax. The wind speed varied from calm (< 0,1 m/s) to 7,6 m/s, with an average value of 1,9 m/s. The predominant wind directions consist of: SE (58%); NW (31%) and N (11%), in the SE-NW orientation of the Campo Grande region. The RH ranged from 48% to 73%, with an average value of 65%. Variances in variances were within satisfactory limits for the entire statistical setup, as was the standard deviation value. This indicates that all variables behaved according to normal (Gaussian) distributions (Table 1).*

***Table 1 - Descriptive statistics of the variables studied in the year 2005 to 2020.***

| *variables* | *N* | *Mean* | *StDev* | *CV* | *Minimum* | *Q1* | *Median* | *Q3* | *Maximum* | *Skewness* | *Kurtosis* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Death*** | 156 | 870,8 | 116,4 | 13,37 | 655 | 780,3 | 863,5 | 977,5 | 1072 | -0,03 | -0,24 |
| ***DAR*** | 156 | 5501 | 760 | 13,81 | 4342 | 4696 | 5592 | 6222 | 6488 | -0,41 | -1,25 |
| ***$O_3$*** | 156 | 700,8 | 19,79 | 2,82 | 675,33 | 683,2 | 697 | 719,2 | 732,5 | 0,31 | -1,34 |
| ***$NO_2E+15$*** | 156 | 2,972 | 0,316 | 10,62 | 2,647 | 2,686 | 2,863 | 3,203 | 3,513 | 0,71 | -0,83 |
| ***Fire*** | 156 | 8968 | 9956 | 111 | 2415 | 2867 | 3862 | 12121 | 31219 | 1,7 | 1,71 |
| ***Prec*** | 156 | 108,6 | 57,4 | 52,86 | 32,4 | 50,7 | 98,5 | 169,7 | 190,3 | 0,11 | -1,6 |
| ***RH*** | 156 | 65,34 | 8,8 | 13,47 | 48,42 | 59,44 | 67,13 | 72,74 | 76,11 | -0,93 | -0,05 |
| ***Tmax*** | 156 | 30,11 | 1,822 | 6,05 | 26,46 | 28,33 | 30,95 | 31,37 | 31,66 | -1,25 | -0,04 |
| ***Tmin*** | 156 | 18,85 | 2,264 | 12,01 | 15,5 | 16,32 | 20 | 20,76 | 21,37 | -0,52 | -1,62 |

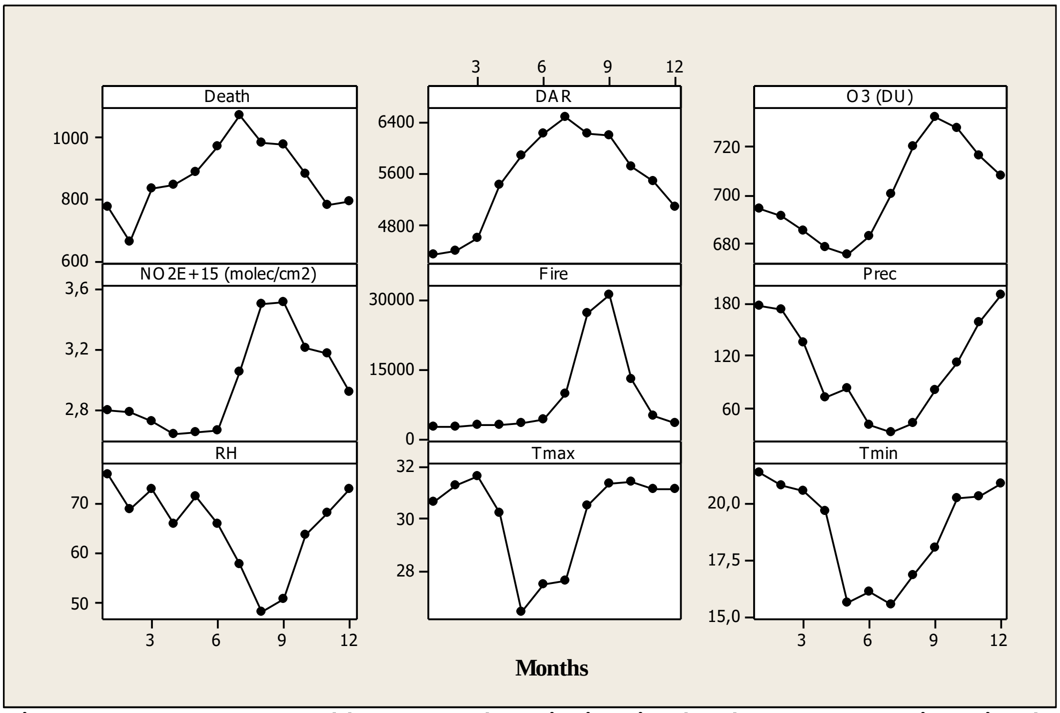



***Figure 1 - Average monthly seasonal variation in deaths, concentrations in the column of $NO_2$, $O_3$ from the Aurea satellite, OMI sensor, hospital admissions for respiratory diseases, precipitation (mm), relative humidity (%), maximum and minimum temperature (°C), in Campo Grande, Mato Grosso do Sul, Brazil, from 2005 to 2020.***

*It was found that the months with the highest percentage of hospitalizations are the months of July, August and September with 29%, and finally the months of January, February and March with a inferior value of 19.2% (Figure 1).*

*It is important to mention that biomass burning influences the variation of $NO_2$ and $O_3$ columns in the atmosphere of Campo Grande The practice of biomass burning is related to the meteorological conditions observed in Campo Grande during the winter and spring seasons.*

*The mothly changes in the $O_3$ column showed the following pattern, averaging over the period 700 DU with a range of 733 DU (maximum/September) to 675 DU (minimum/May). This variability was similar throughout the year.*

*The results obtained indicate two well-defined periods: rainy season (October to April) and dry season (May to September). It should be emphasized that the $O_3$ column over the years showed a decreasing trend with a rate of 0.47% per year.*

*The monthly changes in $NO_2$ showed the following pattern, with a mean over the period of 2.97E+15 molec/cm$^2$ and a variation of 3.51E+15 molec/cm$^2$ (maximum/September) to*

*2.65E+15 molec/cm$^2$ (minimum/May). This trend was also similar throughout the year. It should be emphasized that $NO_2$ over the years also showed a decreasing trend with a rate of 0.002% per year.*

*Based on the Principal Component Analysis (PCA) extraction method with Varimax rotation and Kaiser normalization, and Cluster analysis obtained by the Ward method, nine main factors were obtained that explained 95.8% of the total variance (Table 3) and three homogeneous groups via the clustering technique, factor 1/group 1 (58.1% of explained variance) consisted of the number of hospital admissions, with positive intercorrelations.*

*Factor 2/group 2 (33.8% of the explained variance) groups the parameters $NO_2$, $O_3$ and hotspots that have low values of correlation coefficients (r) with the number of deaths. Factor 3/group 3 (3.8% of explained variance), which are the climatic variables: UR, Prec and Tmax and Tmin. Thus, the CP matrix was also formatted using the Varimax rotation method and the Kaiser type normalization method, which presented three CPs (Table 2).*

*The r coefficients between deaths and air pollutants ranged from (0.216 for $O_3$, 0.395 for $NO_2$ and 0.570 for hot spots) and for the climate variables measured over the years, it ranged from (-0.886 for Prec; -0.696 for RH; -0.518 for Tmax; -0.818 for Tmin). Statistical analysis revealed the existence of a significant positive correlation between deaths and number of hospitalizations with the other correlations ranging from 0.891.*

***Table 2 - Factors extracted by PCA on death data within the studied area, which represented 95.8% of the total explained variance.***

| Variable | Deaths | $NO_2$ | $O_3$ | DAR | Prec | UR | Tmax | Tmin | fire | Eigenvalue | Proportion | Cumulative |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| PC1 | 0,397 | 0,284 | 0,198 | 0,408 | -0,371 | -0,395 | -0,156 | -0,342 | 0,348 | 5,2313 | 0,581 | 0,581 |
| PC2 | 0,144 | -0,422 | -0,48 | 0,122 | -0,247 | 0,178 | -0,508 | -0,335 | -0,306 | 3,0463 | 0,338 | 0,92 |
| PC3 | -0,018 | -0,225 | -0,49 | -0,312 | -0,454 | -0,39 | 0,42 | 0,134 | 0,241 | 0,342 | 0,038 | 0,958 |

***Residual Plots for Death.***

*Table 3 - Results of mortality analysis for diseases of the respiratory system, pollutants, and climate for the period 2005-2020, regression coefficients, error, correlation coefficient 95%, confidence interval.*

| Predictor | Coef | SE Coef | T | P |
|---|---|---|---|---|
| Constant | 1,7445 | 0,3276 | 5,32 | 0 |
| DAR | 0,000734 | 0,000119 | 6,17 | 0 |
| $O_3$ | 7,24E-05 | 0,000469 | 0,15 | 0,878 |
| $NO_2$ | 0,02319 | 0,03225 | 0,72 | 0,473 |
| FIRE | -4,6E-06 | 1,44E-05 | -0,32 | 0,751 |
| Tmin | 0,003228 | 0,003665 | 0,88 | 0,38 |
| Tmax | -0,01195 | 0,004405 | -2,71 | 0,007 |
| UR | -0,00115 | 0,000978 | -1,18 | 0,241 |
| Prec | 0,000029 | 0,000136 | 0,21 | 0,831 |
| S=0.1133562 | R-Sq = 34.4% | R-Sq(adj) = 30.8% | | |
| Analysis of Variances | | | | |
| Source | DF | SS | MS | F |
| Regression | 8 | 0,99485 | 0,12436 | 9,64 |
| Residual Error | 147 | 1,89575 | 0,0129 | |
| Total | 155 | 2,8906 | | |

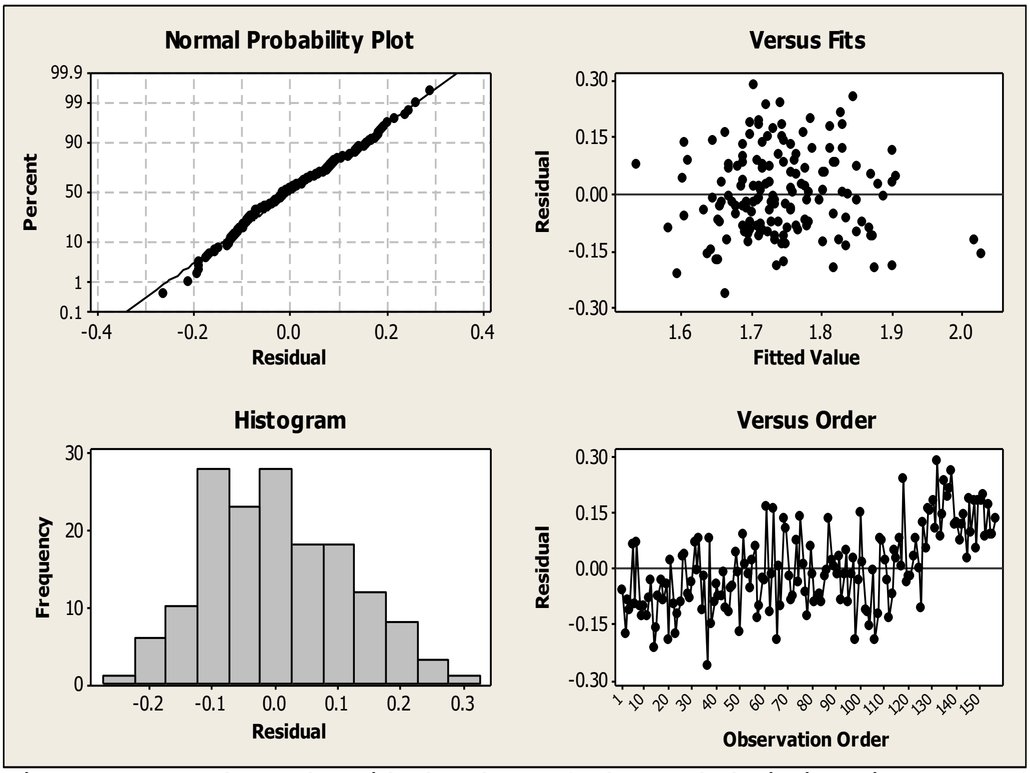


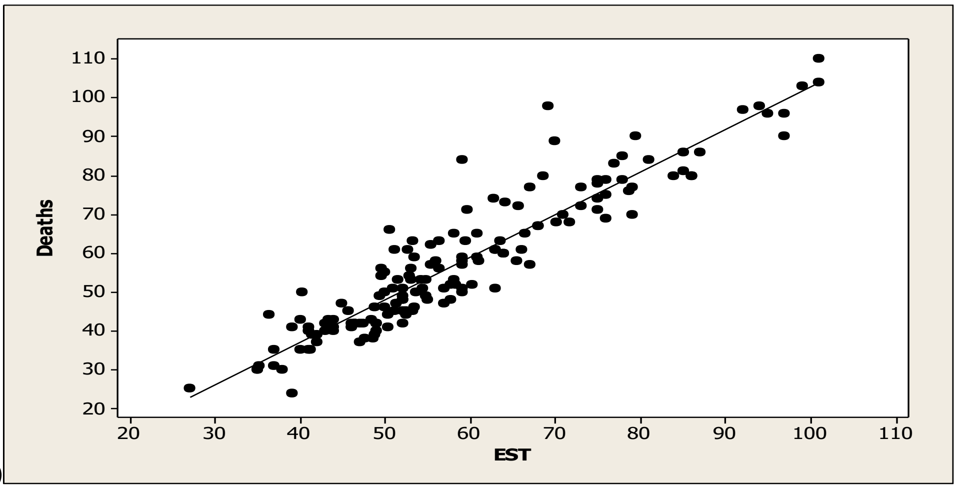

*Figure 2 - Graphs and residual values of observed deviations in terms of adjusted values, the response variable histogram for the death model.*

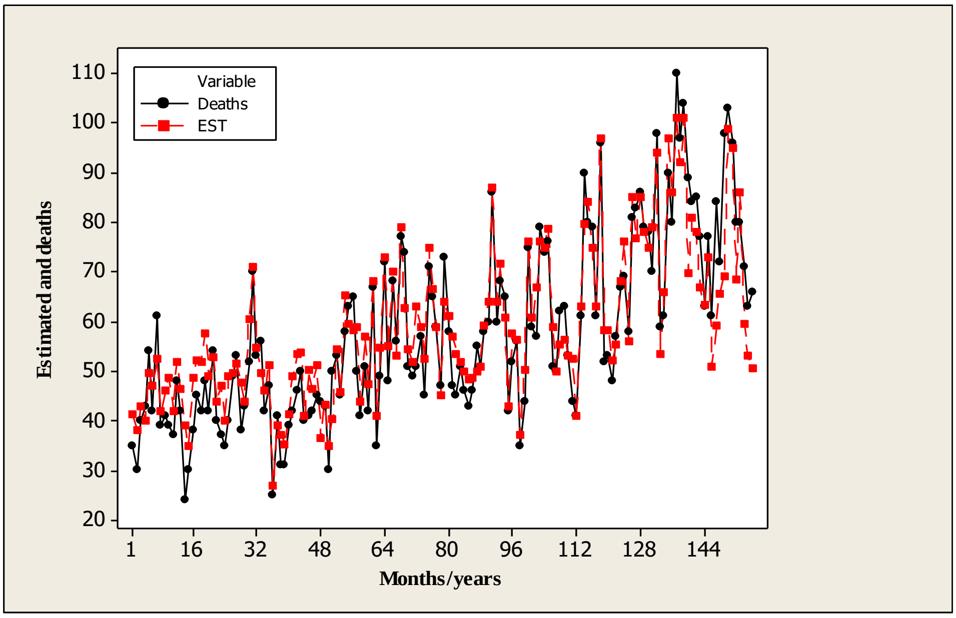
*The analysis of time trends was performed using scatter diagrams that showed the relationship between mortality rates from respiratory diseases, pollutants, climate data and years of study (Figure 2). It was observed that the assumption of a linear evolution over time could be assumed. Therefore, for trend analysis, linear regression models were estimated[10]. Then, the modeling was carried out, considering the mortality rates due to respiratory diseases as dependent variables (Y) respiratory diseases, pollutants, climate data and years of study as independent variables (X).*

*Figure 3 shows the temporal variation of observed and predicted rates for the number of deaths, with a correlation coefficient ranging from $R^2$ = 30.8%. t tests (based on Student's t distribution) were performed to test the significance of the coefficients in the equations. The results obtained show that the regression coefficients were statistically significant. The t values for both coefficients were less than 0.05 (p value < 0.05). The results of this analysis indicate that the number of deaths is highly affected by hospital admissions, air pollution and weather conditions, with an $R^2$ of 30.8%; MBE=0.19; RMSE=15.35 and MAPE=21.13.*

*The simple multiple linear regression model proved to be quite appropriate, as the analysis of residuals revealed that they had a normal, random distribution, without biases, and without the presence of extreme values in the series. A significant trend was considered to be that whose estimated model obtained p<0.05.*

*a)*






b)

***Figure 3 - a) Observed and estimated values for deaths in the model validation phase. b) Estimated and observed deaths for the years of study from 2005 to 2020.***

*The relative risk and confidence interval of deaths from respiratory diseases, hospital admissions, pollutants ($O_3$, $NO_2$ and fire) and climate variables are: DAR (1.000734; 0.950698-1.050771); $O_3$ (1.00072; 0.950068-1.050076); $NO_2$ (1.023471; 0.972298-1.074645); Fire (1.000005; 0.950005-1.050005); Tmin(1.003235; 0.953073-1.053397); Tmax (1.011971; 0.961373-1.06257); RH (1.001151; 0.951093-1.051208); Prec (1.000029; 0.950028-1.05003), whose calculations showed statistical significance for p<0.005.In this study, two air pollutants ($O_3$ and $NO_2$) were identified as causes of increased mortality rates and hospital admissions in the study area. Each pollutant affects a number of diseases, commonly cardiovascular, respiratory and cerebrovascular diseases. Some of the health effects may be immediate, while others may appear several days after the initial exposure.*

*By monitoring the mortality rates over time, there was a real increase in respiratory diseases in the period from 2005 to 2020, in the city of Campo Grande, MS - Brazil. Thus, there was a significant increase in mortality rates from respiratory diseases of 34% and an increase in hospital admissions of 314% in this period.*

*It evaluated the impact of non-ideal temperature on the respiratory health of elderly people (over 60 years of age) residing in Brazil and may support the implementation of proactive actions in 27 Brazilian cities with critical temperature variations the association* *between average daily temperature and mortality from respiratory diseases, exposure to extreme heat increased the risk of mortality, while exposure to extreme cold increased the risk of mortality. The heterogeneity between cities was explained by the city-specific average temperature and temperature range[11].*

*Nascimento et al[5] investigated the short-term association between air pollution and emergency care for respiratory diseases, in children aged 0 to 6 years, in the Espírito Santo state of Brazil. The points relevant were increase of 10µg/m³ in the concentration levels of air pollutants increased the risk of emergency care for respiratory disease, for $PM_{10}$, the increase was 2.43%, 2.73% and 3.29% in the accumulated of 5, 6 and 7 days, for $SO_2$, the increase was 4.47% on the day of exposure, 5.26% two days later, 6.47%, 8.8%, 8.76% and 7.09% in the accumulated of 2, 3, 4 and 5 days, for the CO. Even within the limits established by the World Health Organization, the pollutants $PM_{10}$, $SO_2$, $NO_2$ and $O_3$ are associated with a higher risk of care for respiratory diseases in children aged 0 to 6 years, and some effects were only identified in the localities disaggregated by region[12].*

*It studied the seasonal variations in daily mortality associated with increases in concentrations of $NO_2$ (nitrogen dioxide) and $O_3$ (ozone) were calculated for Stockholm during the period 2000 to 2016[13]. Excessive risks in daily mortality are presented in models of single pollutants and pollutants into four different seasons. The risks of excess in the single pollutant models associated with an increase in the interquartile range (IQR) for a lag 02 throughout the year were −1.5% (95% CI: −0.5−−2.5) for $NO_2$, and 1.9% (95% CI: 1.0 -2.9) for $O_3$. When divided into different seasons, the excessive risks for $NO_2$ were negative during all seasons. The risks of excess $O_3$ in the single pollutant models were also statistically significantly positive during all seasons.*

*DE SOUZA et al[14] analyzed cithe study, the results obtained showed that temperature is temperature as a risk factor for hospital admissions in 70 cities in MS, responsible for the advance of stantial fraction of admissions, corresponding to 6.62% of morbidity.*

*Air pollution consistently acted as a risk factor for respiratory mortality and hospital admission[15-17]. Two explanations can be offered. The first explanation is related to the fact that $O_3$ is a highly seasonal pollutant, as its* *formation is catalyzed by sunlight, resulting in higher concentrations of $O_3$ in summer compared to winter. The second explanation is related to the high reactivity of $O_3$ leading to the formation of other pollutants such as $NO_2$ and particulate matter. Therefore, $O_3$ must be analyzed as a combined effect of $NO_2$ (known as the Ox effect)[18].*

*In Istanbul-Turkey, hot temperatures were associated with mortality[19], Korea, hot temperatures were associated with an increase in cardiovascular hospitalizations[20]. The elderly are more vulnerable to the health effects associated with air pollution, hot or cold temperatures and other climatic variables[15,21,22], due to the physiological degeneration of the human body with increasing age, aging affects the normal function of the body's organs, lower immunity and antioxidant defense compared to young people, putting them at greater risk[23], in addition to reduced mobility and mental abilities[24].*

*In addition to the association of air pollution and climate exposure with mortality and hospital admission outcomes, individual, socioeconomic and environmental factors play an important role in modifying this association. Effect modifiers identified by other authors would be pre-existing health conditions, age, sex, educational attainment, wealth or income or socioeconomic deprivation and influenza epidemics.*

*Nevertheless, it is worth mentioning that the modification of the effect of gender in the association of air pollution and climate exposure with mortality and hospital admission outcomes is believed to be confounded by age, as in many of the reviewed studies, greater risks were found among the elderly. women (age > 65 years) and elderly men (age > 70 years)[25,26]. This confounding effect could be reduced by evaluating the combined effect of age and gender modification through an interaction term or by stratifying the analysis according to age and gender groups.*

*Educational level was also considered by some of the studies reviewed as an effect modifier, with higher risks detected among individuals with a lower level of education[27]. Despite considering age, gender, education and wealth effect in the association of air pollution and climate with mortality and hospital admissions in Europe, our scope analysis revealed a lack of investigation into the role of other important socio-demographic factors such as ethnicity. Research has* *extensively shown that ethnic minorities live in disadvantaged communities and have lower socioeconomic status as well as poor housing conditions. This results in an increased risk of chronic health problems associated with increased exposure, on the one hand, and less access to quality health care, on the other hand[28].*

*Finally, it is worth noting that most time series or case-crossover studies have adjusted their analysis for the season effect. It is well established that air pollution, temperature and other climatic variables vary with the seasons. Not to mention that the emission, formation and dispersion of air pollutants are affected by seasonal variations in weather, which in turn affect individual exposure levels. Outdoor activities and daily habits (eg, window ventilation in homes) may also vary depending on the season, reflecting changes in the level and duration of individual exposure to air pollution and climate change[29-33].*

## CONCLUSION

*The study clearly points out that air pollution and exposure to the climate lead to several impacts on human health, especially respiratory problems, resulting from the increase in mortality rates and hospital admissions. However, further research is needed, as the modification of sociodemographic effects, such as ethnicity and the interaction between air pollution and climate, is omitted. Understanding this should provide enough evidence for policy makers to plan and act on the goal of reducing the effects of air pollution and climate change on public health. Furthermore, research should focus on projecting future health behavior and mortality patterns in relation to air pollution and climatic variations in order to guide the planning of effective preventive environmental and health measures.*

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