Chapter

Analysis of Temporal Lag in the Impact of Air Quality on the Health of Children, in Barreiro

João Garcia, Rita Cerdeira and Luís Coelho

Abstract

The aim of this work was to study the impact of temporal lag between the exposition to air pollutants and the children admitted to the emergency room of Hospital Nª Srª Rosário pediatric service, in Barreiro, Portugal, with symptoms of respiratory problems. The two variables were recorded by the medical staff and by an air quality monitoring station, in the same periods. From the results, a moderate correlation between different symptoms of respiratory diseases (sdr, cough, and asthma) and pollutants was found, reaching maximum values after temporal lags of 2 to 6 days. The strongest correlation for lag 0 (consequences on the same day) rises for the symptomatology of asthma, reaching the highest values for COmax (ρ = 0.26) and COpeak (ρ = 0.25). Also, an important correlation was found for NO_x, NO_x med and peak NO_x (ρ = 0, 21). The correlation with PM_{10} shows an unrepresentative value (ρ = 0.09), being negative for O_3max (ρ = −0.23) and O_3peak (ρ = − 0.22), as well as for SO_2med (ρ = −0.12). Considering temporal lags of 1 to 8 and 15 days, overall, the maximum correlations between symptoms and NO, NO_2, NO_x, CO, and PM_{10} occur after temporal lags of 2 to 6 days, being constant or negative to SO_2 and O_3.

Keywords: air quality, children's health, correlation, temporal lag, respiratory distress

1. Introduction

There are several air pollutants that can have a significant impact on human health [1, 2], including particulate matter (PM) which can be inhaled into the lungs and cause respiratory and cardiovascular problems, as well as increase the risk of lung cancer [3–5]. Nitrogen oxides (NO_x) can irritate the lungs and aggravate asthma and other respiratory problems. It can also contribute to the formation of ground-level ozone, which can cause respiratory and cardiovascular problems [6]. Sulfur dioxide (SO_2) can irritate the respiratory system and aggravate asthma and other respiratory problems [7]. Carbon monoxide (CO) can be deadly in high concentrations, but even at low concentrations, it can cause headaches, dizziness, and nausea. Also, Ozone (O_3) can cause respiratory and cardiovascular problems, especially in people with preexisting conditions such as asthma [8, 9]. These health effects of these pollutants can vary depending on factors such as the concentration and duration of exposure, age, and preexisting health conditions [10]. It is known that children, the elderly, and the people with chronically ill, particularly respiratory patients, constitute populations that are very sensitive to atmospheric pollution and are therefore usually chosen as a sample for studies in this area [11, 12]. It is known that children, a sensitive population, are more vulnerable to the effects of atmospheric pollution than adults, for several reasons, from the time they spend outdoors to the anatomy and physiology of the respiratory system, which is still under development. In addition, children have higher ventilation rates

	Unit	Variable description
Date		Observation date
Total	#	Total number of children observed
0–2	#	Number of children observed between 0 and 2 years old
3–5	#	Number of children observed between 3 and 5 years old
6–10	#	Number of children observed between 6 and 10 years old
11–15	#	Number of children observed between 11 and 15 years old
Cough	#	Number of children observed with cough symptoms
sdr	#	Number of children observed with of respiratory distress syndrome symptoms
Asthma	#	Number of children observed with asthma symptoms
Intern	#	Number of children admitted to hospital after observation
F	#	Number of female children observed
M	#	Number of male children observed
VEL (IM)	(km/h)	Average daily wind speed
DIREC		Prevailing daily wind direction
TEMP	(°C)	Average daily temperature
$TEMP_{MAX}$	(°C)	Maximum daily temperature
$TEMP_{MIN}$	(°C)	Minimum daily temperature
HUM	(%)	Humidity at 9 am
HUM_{max}	(%)	Humidity at 6 am
Rad	(watt/m^2)	Total daily radiation
$SO_{2\ med}$	(μg/m^3)	Average daily value of the average of all stations
$NO_{\ med}$	(μg/m^3)	Average daily value of the average of all stations
$NO_{2\ med}$	(μg/m^3)	Average daily value of the average of all stations
$NO_{x\ med}$	(μg/m^3)	Average daily value of the average of all stations
$PM_{10\ med}$	(ug/m^3)	Average daily value of the average of all stations
CO $(_{max})_{med}$	(μg/m^3)	Maximum daily value of eight-hour average by eight-hour averages.
O_3 $(_{max})_{med}$	(μg/m^3)	Maximum daily value of the eight-hour average
CO $(_{peak})_{med}$	(μg/m^3)	Maximum daily value, without considering eight-hour averages
O_3 $(_{peak})_{med}$	(μg/m^3)	Maximum daily value, without considering eight-hour averages
NO_x $(_{peak})_{med}$	(μg/m^3)	Maximum daily value

Table 1.
General description of the variables under study.

than adults and the short stature of children further increases their exposure to traffic emissions. All such factors contribute to the triggering of episodes of respiratory distress more frequently, even in the present of lesser pollutant concentrations [13].

The objective of this work was to study the relation between the number of children admitted to the emergency room (ER) of the pediatric service of Hospital Nª Srª do Rosário in Barreiro, with symptoms of respiratory problems, and the levels of atmospheric pollution, recorded by the air quality monitoring network, in the city of Barreiro.

2. Materials and methods

A team of pediatricians of Hospital Nossa Sra. do Rosário, in Barreiro, recorded daily, over a period of 20 months, the number and type of symptoms of children under the age of 15 years who were admitted to the hospital's pediatric emergency service. The children observed who had respiratory complaints of noninfectious etiology were classified according to their age, gender, area of residence, and type of symptom. As for symptoms, only three types of symptoms were considered: cough; respiratory distress (SDR), and asthma. Initially, the data collection by physicians was carried out with a frequency of two or three times a week. In a later phase of the project, collection became daily. As mentioned earlier, the tanking of symptoms by the medical team considered three groups only: cough, asthma, and breathing difficulty, although several international studies rank symptoms according to the List of International Statistical Classification of Diseases (ICD-11) [14], limiting the subjectivity inherent to the classification in these groups. In this case, a decision was made to simplify the classification due to the lack of a supporting computer system.

In parallel and during the same period, the values of pollutant concentrations from the Barreiro air quality network were used. The values of carbon monoxide (CO), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), particles (PM_{10}), and ozone (O_3) were considered, as well as the meteorological variables of temperature and relative humidity. Meteorological variables, namely temperature, relative humidity, wind speed and direction, were provided by the Portuguese Institute of the Sea and the Atmosphere and/or by the CPPE of Barreiro. Thus, and during this period, the following data were recorded regarding the variables described in **Table 1**, for all observation stations.

A summary of the descriptive statistics on the study variables is shown in **Table 2**.

3. Results and discussion

To analyze and process the data, the statistical treatment programs R, SPSS, and Excel were used. The data analysis shows that during the period studied, 1101 children were assisted at the HNSR emergency service, with a daily average of 2.78 children, ranging from 0 to 12 children per day. One of the main challenges in understanding the effect on health of each of the pollutants and meteorological variables is related to the interdependence between these variables. Therefore, in a preliminary phase of this study, and in an attempt to understand the main relation between the most relevant variables, graphs representing two variables were generated, which allow verifying the joint evolution of these very variables.

FS	No. obs.	Ave.	Stand. devi.	Min. value	Max. value	Int.	Var. coef.	Median
Total	399	2.78	2.05	0	12	12	0.73	2
0–2	280	1.85	1.29	1	9	8	0.70	1
3–5	184	1.45	0.68	1	5	4	0.47	1
6–10	152	1.39	0.73	1	4	3	0.52	1
11–15	89	1.27	0.73	1	5	4	0.58	1
Cough	197	1.64	0.95	1	5	4	0.58	1
sdr	245	1.75	1.14	1	9	8	0.65	1
Asthma	197	1.63	0.91	1	5	4	0.56	1
Intern	38	1.11	0.31	1	2	1	0.28	1
F	247	1.71	0.99	1	6	5	0.58	1
M	301	2.14	1.34	0	9	9	0.63	2
VEL (IM)	730	4.87	6.58	0	40.5	40.5	1.35	3.1
DIREC	717	4.81	2.74	1	8	7	0.57	6
TEMP	721	17.72	4.48	7.7	31.0	23.3	0.25	17.4
$TEMP_{MAX}$	721	22.15	5.78	9.1	40.0	30.9	0.26	21.6
$TEMP_{MIN}$	721	14.16	4.06	0.0	26.0	26.0	0.29	14.1
HUM	723	71.93	18.26	6.8	99.1	92.3	0.25	68.0
HUM_{max}	711	84.71	12.58	39.3	99.1	59.8	0.15	87.6
Rad	153	5092.2	1778.02	697.0	7098.0	6401.0	0.35	5802.0
$SO_{2\ med}$	641	12.61	12.26	1.0	88.6	87.6	0.97	8.4
NO_{med}	641	13.98	15.39	1.1	136.1	135.1	1.10	9.1
$NO_{2\ med}$	641	29.98	11.94	5.8	72.5	66.7	0.40	28.5
$NO_{x\ med}$	641	48.94	27.92	9.1	188.9	179.8	0.57	42.8
$PM_{10\ med}$	617	38.04	21.88	3.5	152.5	148.9	0.58	31.7
$CO\ (_{max})_{med}$	641	491.52	367.15	167.6	2684.1	2516.5	0.75	362.8
$O_3\ (_{max})_{med}$	641	68.73	25.63	4.2	169.7	165.5	0.37	68.3
$CO\ (_{peak})_{ad}$	641	668.09	505.69	195.0	3740.5	3545.5	0.76	503.5
$O_3\ (_{peak})_{med}$	641	81.79	29.88	6.7	241.3	234.7	0.37	79.0
$NO_x\ (_{peak})_{med}$	641	88.78	54.91	9.0	452.8	443.8	0.62	79.4

Table 2.
Descriptive statistics of the variables collected.

In this way, **Figure 1** represents the average daily temperature evolution as a function of daily solar radiation. One can see that globally there is an increase of temperature with the increase of radiation. A Pearson correlation with the value ρ = 0.46 (95% CI: 0.33 to 0.58) is observed for these two variables.

Figure 2 represents the evolution of the daily maximum temperature as a function of daily solar radiation. One can see that globally there is an increase of the maximum temperature with the increase of radiation. A Pearson correlation is observed for these two variables with the value ρ = 0.55 (CI at 95%: 0.42 to 0.64).

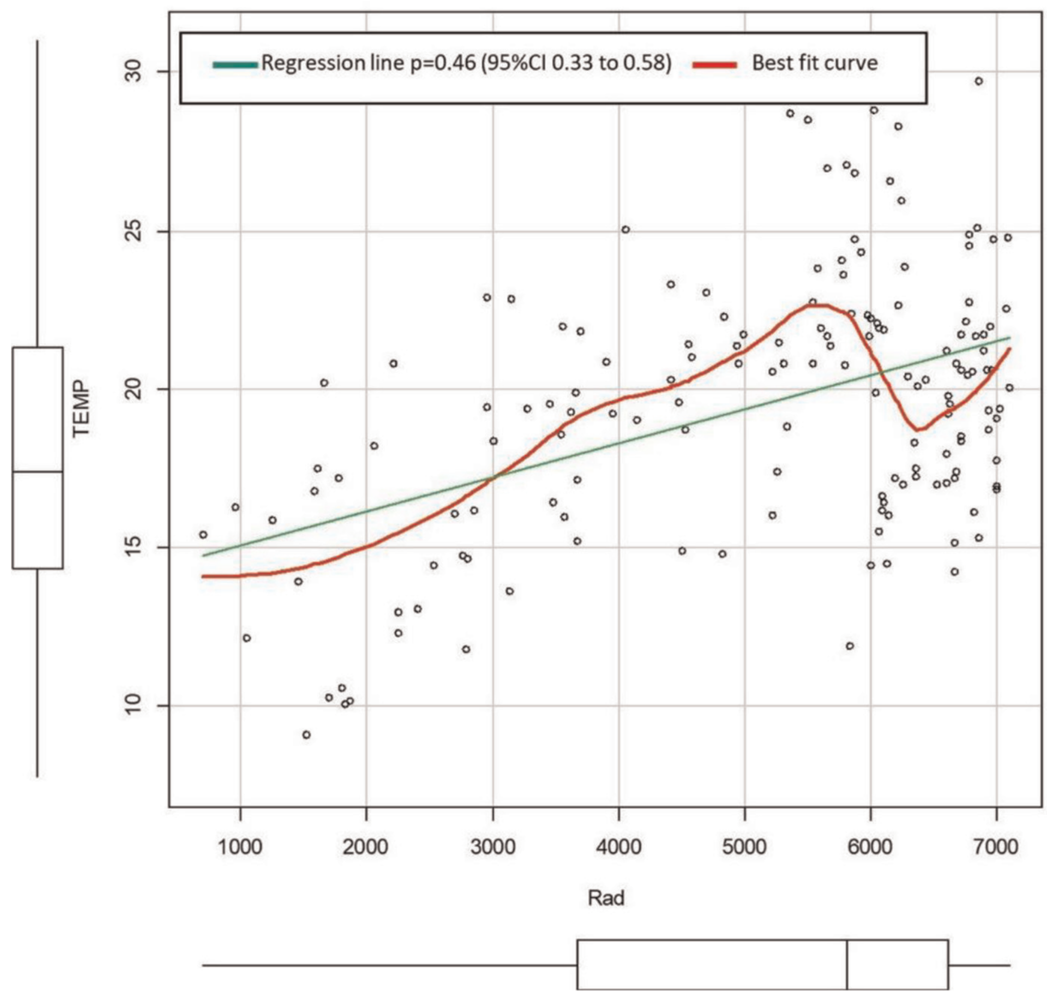


Figure 1.
Average temperature vs. radiation.

Figure 3 plots the evolution of the average daily value of PM_{10} concentration (average of all seasons) as a function of average daily temperature. One can see that, globally, there is an increase in the concentration of particles with the increase in temperature. However, looking at the evolution of the curve that best fits, one observes that for temperatures below 13°C there is a slight increase in particle concentration. This can be explained by the conditions of atmospheric stability that hinder the dispersion of particles. There is a Pearson correlation for these two variables with the value $\rho = 0.22$ (95% CI: 0.15 to 0.30), even though the values of average, maximum, and minimum daily temperatures show correlations above $\rho = 0.9$ between them. The other graphs with these temperatures show similar evolutions, as displayed in **Figure 4**, which presents the evolution of the average particle concentration with the daily maximum temperature. In this case, a Pearson correlation with the value $\rho = 0.30$ (95%CI 0.23 to 0.37) is seen for these two variables.

The detailed analysis of all data shows that the QA station that has the highest correlation between the average daily temperature and the PM_{10} concentration values (daily averages) is the QA station of Lavradio, so only the graph corresponding to this station is displayed (**Figure 5**).

For this specific station, the Pearson correlation coefficient between these variables has the value $\rho = 0.44$ (95% CI: 0.36 to 0.52).

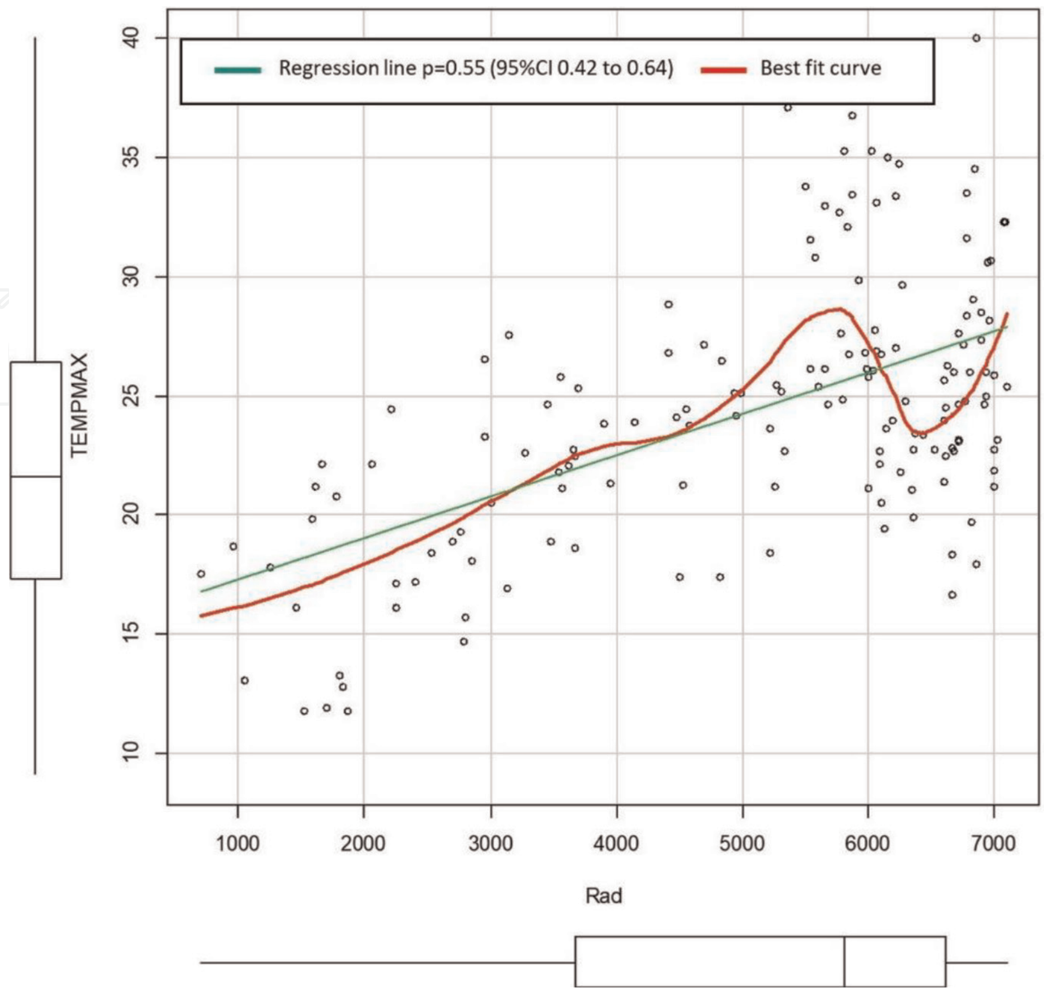


Figure 2.
Maximum temperature vs. radiation.

Figure 6 shows the evolution of the maximum ozone concentration (average of stations) as a function of average daily temperature. It appears that there is a direct relation between the concentration of ozone in the air and the average daily temperature, with a visible increase in concentration values with increasing temperature. This relation is indicated by the value of Pearson's correlation coefficient with the value ρ = 0.53 (95% CI: 0.47 to 0.58). This relation is even stronger for the QA station at the Hospital, where the correlation between ozone concentration and mean temperature has a Pearson correlation coefficient of ρ = 0.57 (95% CI: 0.52 to 0,63) as can be seen in **Figure 7**.

Figure 8 shows the values of the Pearson correlations (ρ) between the different variables collected at the hospital regarding the medical component. The analysis of **Figure 8** highlights important correlations between some variables analyzed. It appears that, for example, in the case of asthma, the correlation values increase with the increasing age of age groups. The correlation starts with a value of ρ = 0.13 for the 0–2 years age group, rising to ρ = 0.26 (3–5 years) and continuing to rise to ρ = 0.39 (6–10 years) reaching ρ = 0.47 (11–15 years), thus trending toward an increase in asthma symptoms, in visits to the hospital emergency room, with the increasing age of children.

Also noteworthy is the strong correlation between sdr symptoms and children aged 0 to 2 years (ρ = 0.72) and between cough symptoms and children aged 0 to 2 years (ρ = 0.47). There is also a strong correlation between hospital admission and children aged 6 to 10 years, indicating that older children only resort to the hospital emergency

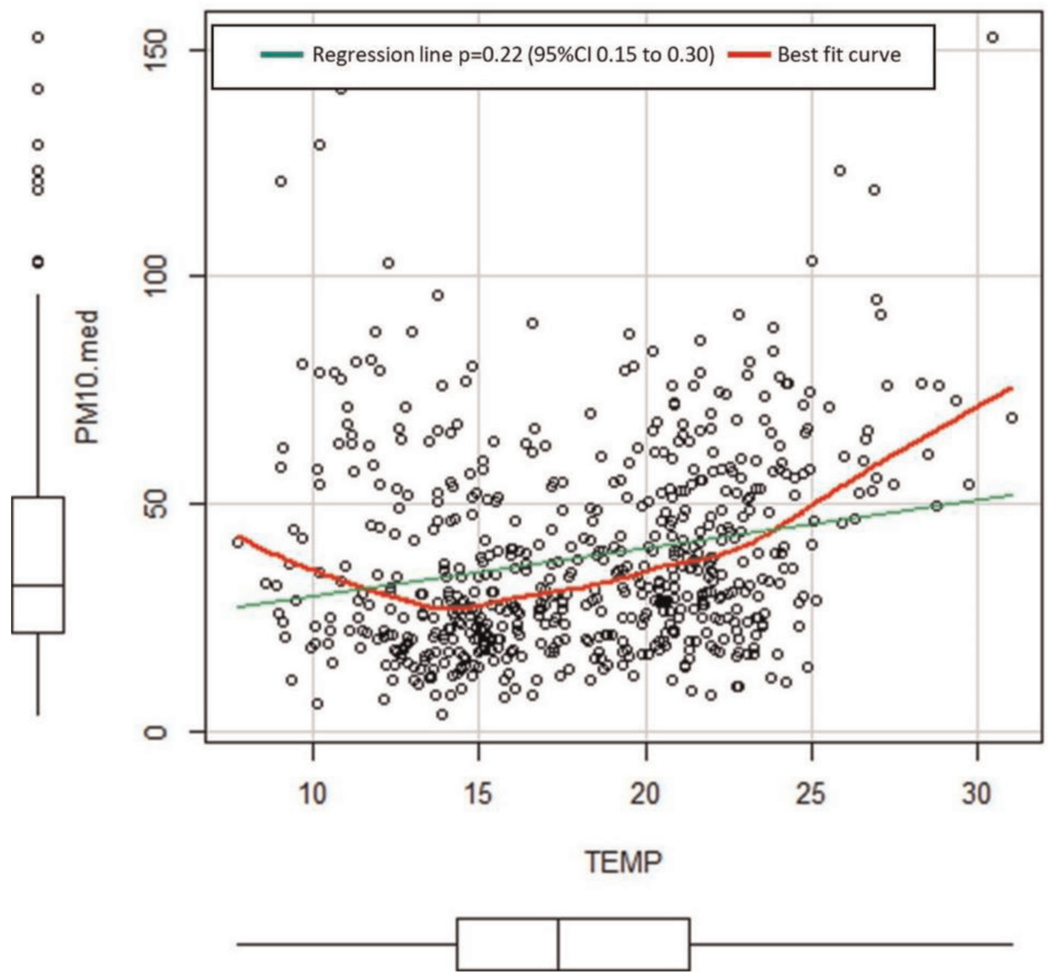


Figure 3.
Average concentration of particles vs. average temperature.

service in situations where seriousness justifies hospital admission, while younger children resort to the hospital emergency for all types of cases, including those that do not require hospital admission.

Figure 9 shows the values of the Pearson correlations (ρ) between the different variables related to the concentration of pollutants considering the mean values of all stations (global). Analyzing the values for Pearson's correlation coefficient (ρ), one can see that there are strong correlations between the average and peak values, for the same pollutant. The Pearson correlation coefficient values $\rho = 0.91$ (CO), $\rho = 0.95$ (O_3), and $\rho = 0.85$ (NO_x) (mean and peak) which expresses that, in fact, the values are very interdependent. This analysis allows concluding that the results obtained are not very different, using mean values of pollutant concentrations or peak values.

Carrying out a global assessment of the relation between pollutants, one can see that, in general, there are correlations between different pollutants, highlighting some important correlation values. For example, between the CO and NO_x families (NO, NO_2 and NO_x), the values of $\rho = 0.82$ (CO_{max} with NO_{med}), $\rho = 0.80$ (CO_{max} with $NO_{x\ med}$), $\rho = 0.84$ stand out (CO_{peak} with NO_{med}), and $\rho = 0.77$ (CO_{peak} with $NO_{x\ peak}$), indicating a strong relation between CO concentrations and NO_x families in an urban environment.

As for SO_2, it does not show strong correlations with any other pollutant, except for the value of the correlation coefficient of $\rho = 0.42$ between SO_2 and $O_{3\ peak}$ concentrations and $\rho = 0.36$ between SO_2 and $O_{3\ max}$ concentrations.

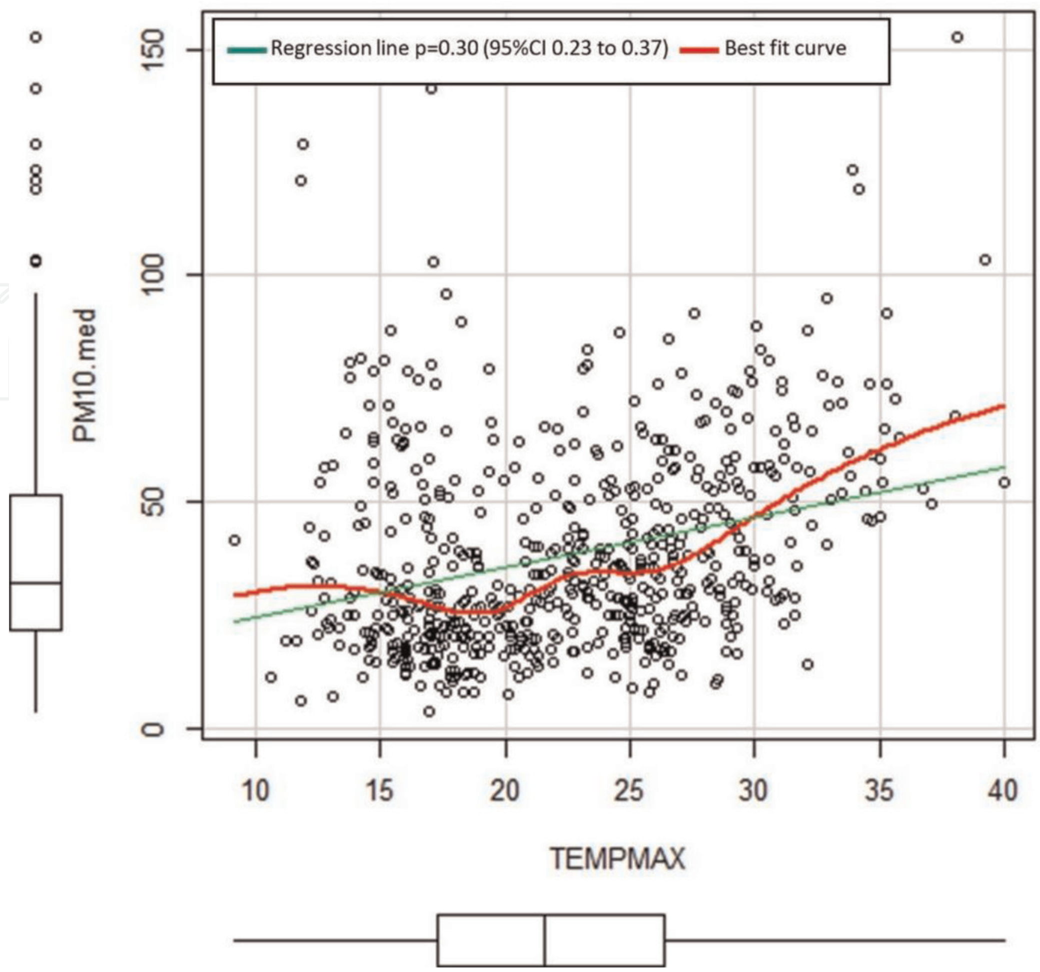


Figure 4.
Average concentration of particles vs. maximum temperature.

Regarding PM_{10}, the following important correlations are observed, ρ = 0.36 (PM_{10} with $NO_{x\ med}$), ρ = 0.47 (PM_{10} with $NO_{2\ med}$), ρ = 0.46 (PM_{10} with $NO_{x\ med}$), ρ =0.39 (PM_{10} with CO_{max}), ρ = 0.38 (PM_{10} with CO_{peak}), and ρ = 0.41 (PM_{10} with $NO_{x\ peak}$), indicating a relation between PM_{10} concentrations and CO concentrations and families of NO_x. As for the correlations with ozone, the values of ρ = 0.28 (PM_{10} with $O_{3\ peak}$) and ρ = 0.18 (PM_{10} with $O_{3\ max}$) suggest a lower correlation between these pollutants. Also, with regard to SO_2, the value of ρ = 0.29 (PM_{10} with $SO_{2\ med}$) indicates a lower correlation between PM_{10} concentrations and SO_2 concentrations.

One can thus see that PM_{10} concentrations are correlated with all pollutants, with the highest correlation for NO_2 and the lowest correlation for O_3. It should also be noted that ozone has negative correlations with NO_{med} (−0.58) and $NO_{x\ med}$ (−0.46), which can be explained by the fact that NO_x are precursors of Ozone, causing the formation of each molecule of O_3 to lead to a consequent decrease in NO_x.

Figure 10 shows the values of the Pearson correlations (ρ) between all variables analyzed in this study (medical and pollutant variables). Being an extensive figure, the strong correlations between the average concentration values for the different pollutants and the concentration values of said pollutants for the different air quality stations stand out.

Figure 11 shows the Pearson correlation values (ρ) between the medical variables studied and the mean concentrations of pollutants measured at the stations. This figure is important because it allows analyzing the possible relation between the concentrations of pollutants and the symptoms studied. Analyzing the figure one can

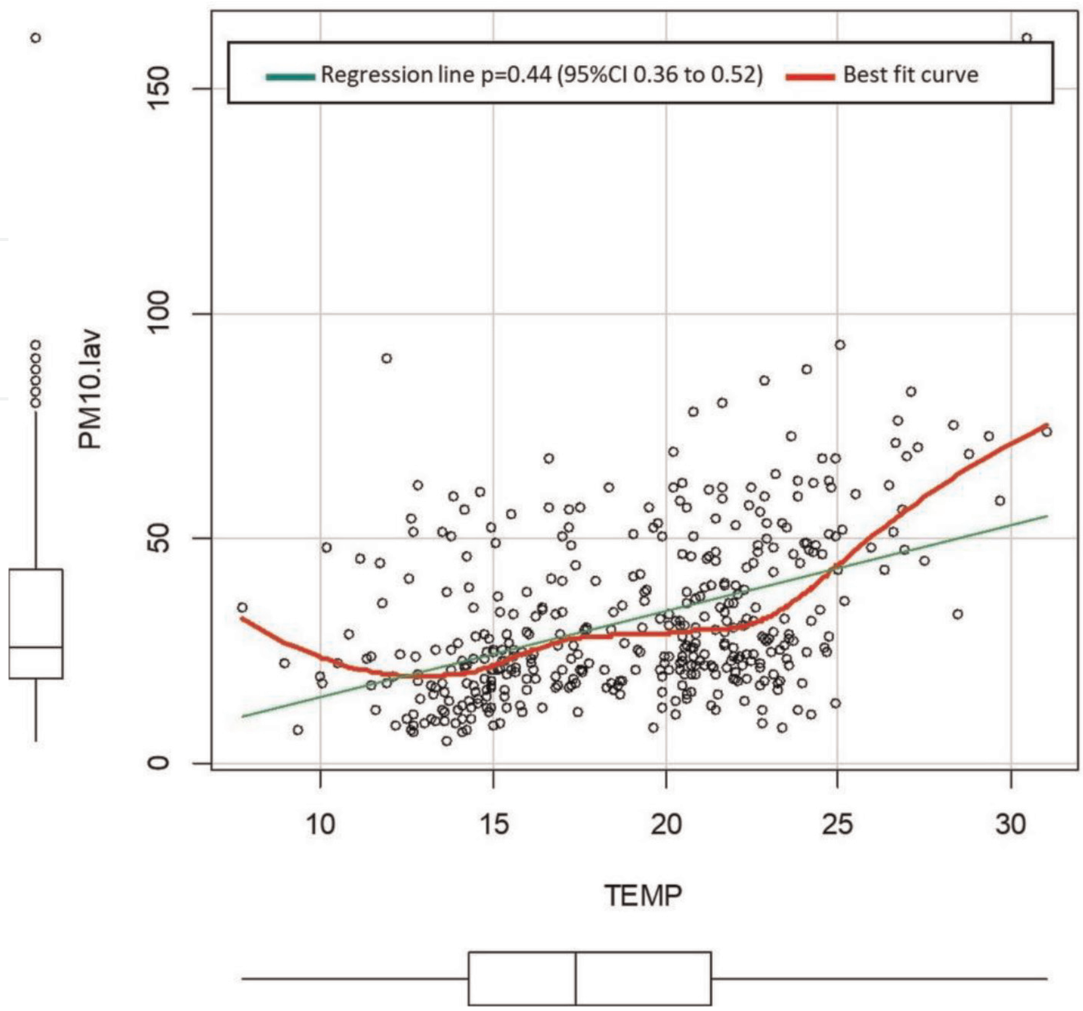


Figure 5.
Particle concentration (Lavradio station) vs. temperature.

see, globally, that the more important values of correlation between the pollutants and the symptoms are obtained for the symptomatology of asthma, with the highest values for the correlation coefficient with CO_{max} ρ = 0.26 and CO_{peak} ρ = 0.25. There is also an important correlation between asthma and NO_x, ρ = 0.21 (with $NO_{x\ med}$), ρ = 0.21 (with $NO_{x\ med}$) ρ = 0.21 (with $NO_{x\ peak}$). The correlation with PM_{10}, however, has an unrepresentative value of ρ = 0.09.

Negative correlation values are also seen between asthma symptoms and O_3 ρ = −0.23 (asthma and $O_{3\ max}$) and ρ = −0.22 (asthma and $O_{3\ peak}$), as well as a negative correlation between asthma and $SO_{2\ med}$ (ρ = −,12).

Figure 12 shows the values of the Pearson correlations (ρ) between all variables referring to the atmospheric concentrations of the pollutants studied. An analysis of this figure reveals, as expected, the existence of important correlations between the average values of the concentrations of the different pollutants and the values of the concentrations of these same pollutants, in the different air quality stations.

With the aim of studying the evolution of the number of children observed in hospital with the symptomatology of asthma, sdr, or cough, it was analyzed the number of days elapsed, considering temporal lags of 0, 1, 2, 3, 4, 5, 6, 7, and 15 days between the values of PM_{10} concentrations and the aforementioned medical variables.

Table 3 and **Figure 13** show the evolution of the Pearson correlation coefficient (ρ) between the asthma variables and the average concentrations of pollutants (O_3, SO_2,

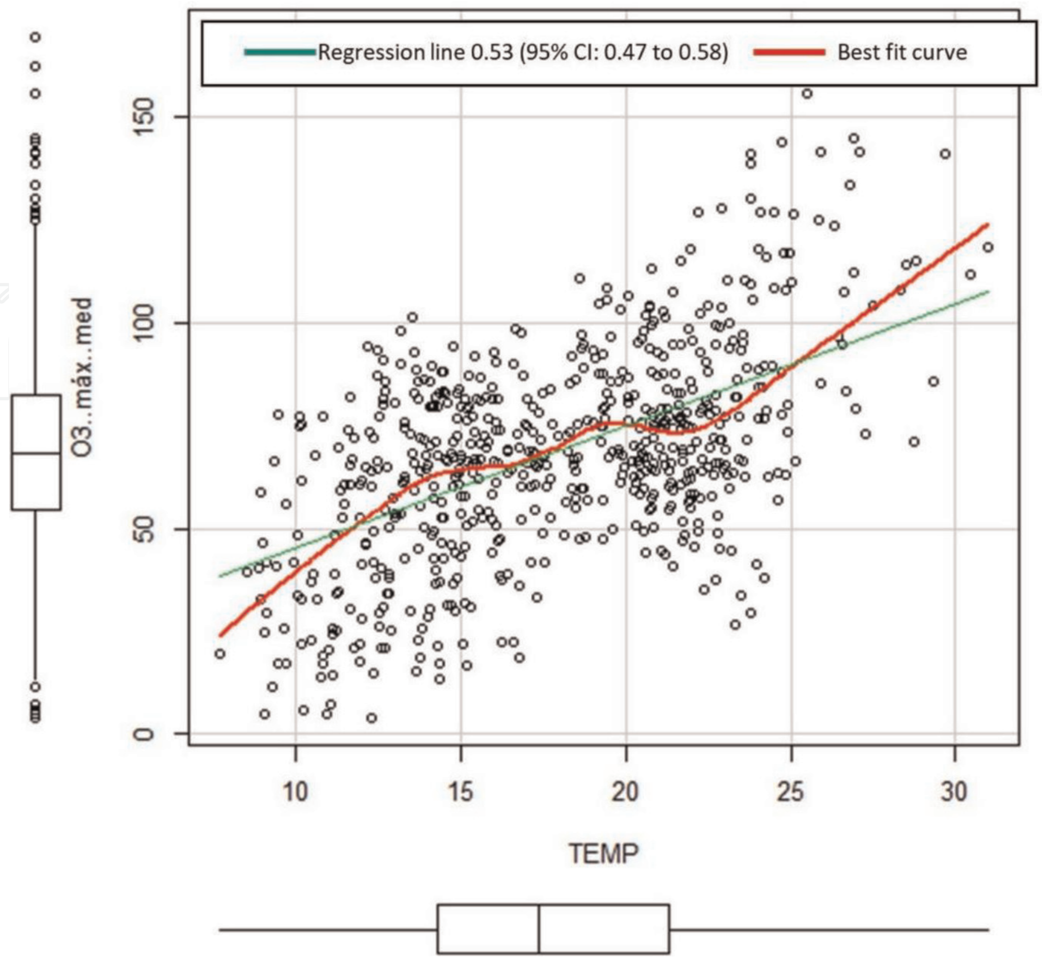


Figure 6.
Maximum ozone concentration (average of stations) vs. average air temperature.

NO, NO_2, NO_x PM_{10}, and CO) for the temporal lags of 0, 1, 2, 3, 4, 5, 6, 7, and 15 days. It appears that, overall, the maximum correlations between asthma symptoms and the concentrations of pollutants NO, NO_2, NO_x, CO, and PM_{10} occur after lags of 2, 3, or 4 days (depending on the symptoms and the pollutant analyzed). The following Pearson's correlation coefficient values are also observed, ρmax = 0.35 (asthma and CO, 2-day lag), ρmax = 0.32 (asthma and NO, 3-day lag), ρmax = 0.33 (asthma and NO_x, lag 3 days), ρmax = 0.22 (asthma and NO_2, lag 2 days), and ρmax = 0.18 (asthma and PM_{10}, lag 4 days). There is, for these pollutants, an increase in Pearson's correlation coefficient values (ρ), over the days until it reaches its maximum after 2, 3, or 4 days. For PM_{10} and NO_2 there is a slight decrease in the correlation coefficient from lag 0 to lag 1, this coefficient increasing again from lag 2 onward.

For SO_2 and O_3 pollutants, it appears that Pearson's correlation coefficient (ρ) remains relatively constant and negative throughout the period analyzed, (ρ approx −0.2; asthma and O_3) and (ρ approx −0,1; asthma and SO_2) for all lags analyzed, suggesting lack of short-term correlations between observations with asthma symptoms and atmospheric concentrations of these two pollutants.

Table 4 and **Figure 14** show the evolution of the Pearson correlation coefficient (ρ) between the variable sdr and the mean concentrations of pollutants (O_3, SO_2, NO, NO_2, NO_x, PM_{10}, and CO) for the temporal lags of 0, 1, 2, 3, 4, 5, 6, 7, and 15 days. One can see that, globally, the maximum correlations between the symptomatology of

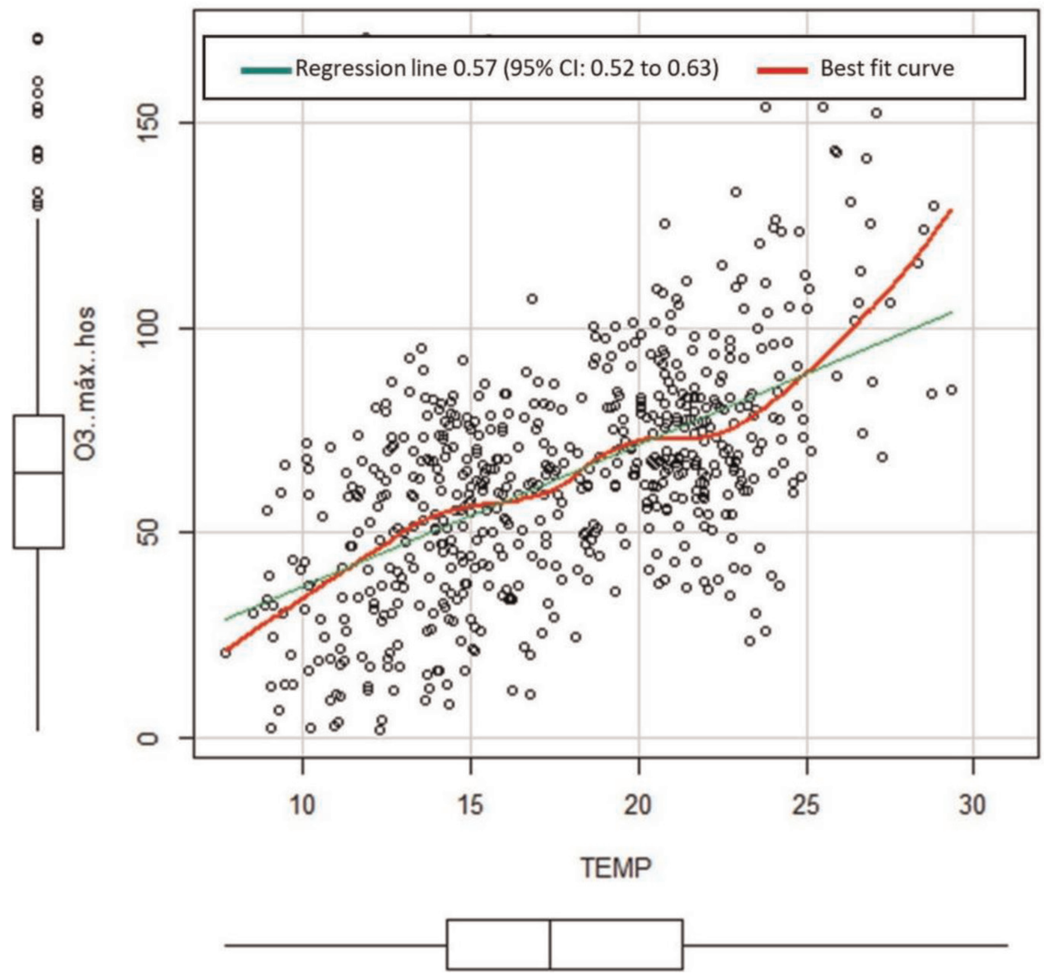


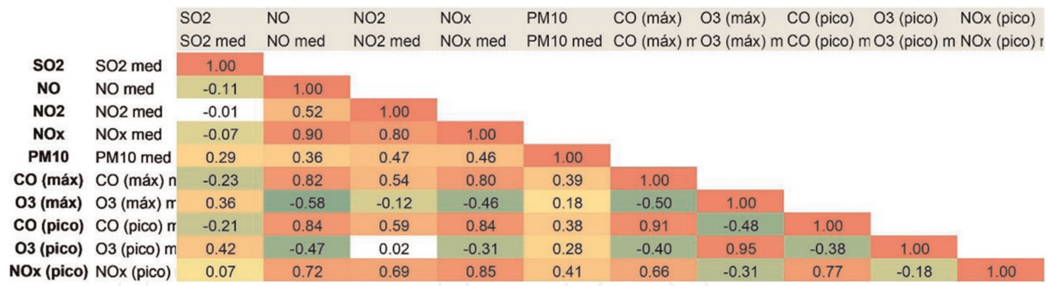
Figure 7.
Maximum ozone concentration (hospital QA station) vs. average air temperature.

		N.C				Doenças				Sexo	
	Total	0-2	3-5	6-10	11-15	tosse	sdr	asma	intern	F	M
Total	1.00										
0-2	0.76	1.00									
3-5	0.35	0.00	1.00								
6-10	0.37	0.14	0.02	1.00							
11-15	0.38	0.24	0.12	-0.22	1.00						
tosse	0.55	0.47	0.26	0.03	0.22	1.00					
sdr	0.72	0.72	0.15	0.27	0.12	0.19	1.00				
asma	0.55	0.13	0.26	0.39	0.47	0.03	0.20	1.00			
intern	0.25	0.25	0.13	0.77	-0.23	-0.17	0.37	0.04	1.00		
F	0.72	0.55	0.31	0.20	0.10	0.50	0.51	0.31	-0.03	1.00	
M	0.81	0.66	0.14	0.28	0.43	0.28	0.65	0.46	0.29	0.25	1.00

Figure 8.
Medical data correlations.

sdr and the concentrations of pollutants NO, NO_2, NO_x, CO, and PM_{10} occur after temporal lags of 4 days. Observing the following Pearson correlation coefficient values, ρmax = 0.20 (sdr and NO_x, 4 day lag), ρmax = 0.17 (sdr and NO_2, 4 day lag), ρmax = 0.15 (sdr and PM_{10}, lag 4 days), ρmax = 0.14 (sdr and CO, lag 4 days), ρmax = 0.13 (sdr and NO, lag 4 days). For these pollutants (NO, NO_2, NO_x, PM_{10}, and CO), there is a decrease in the correlation coefficient from lag 0 to lag 1, and this coefficient increases again from lag 2 and up to lag 4.

For SO_2 and O_3 pollutants, one can see that Pearson's correlation coefficient (ρ) remains relatively constant and negative throughout the period analyzed, for all lags



		SO2	NO	NO2	NOx	PM10	CO (máx)	O3 (máx)	CO (pico)	O3 (pico)	NOx (pico)
		SO2 med	NO med	NO2 med	NOx med	PM10 med	CO (máx) m	O3 (máx) m	CO (pico) m	O3 (pico) m	NOx (pico) r
SO2	SO2 med	1.00									
NO	NO med	-0.11	1.00								
NO2	NO2 med	-0.01	0.52	1.00							
NOx	NOx med	-0.07	0.90	0.80	1.00						
PM10	PM10 med	0.29	0.36	0.47	0.46	1.00					
CO (máx)	CO (máx) n	-0.23	0.82	0.54	0.80	0.39	1.00				
O3 (máx)	O3 (máx) m	0.36	-0.58	-0.12	-0.46	0.18	-0.50	1.00			
CO (pico)	CO (pico) m	-0.21	0.84	0.59	0.84	0.38	0.91	-0.48	1.00		
O3 (pico)	O3 (pico) m	0.42	-0.47	0.02	-0.31	0.28	-0.40	0.95	-0.38	1.00	
NOx (pico)	NOx (pico)	0.07	0.72	0.69	0.85	0.41	0.66	-0.31	0.77	-0.18	1.00

Figure 9.
Correlations between pollutants.

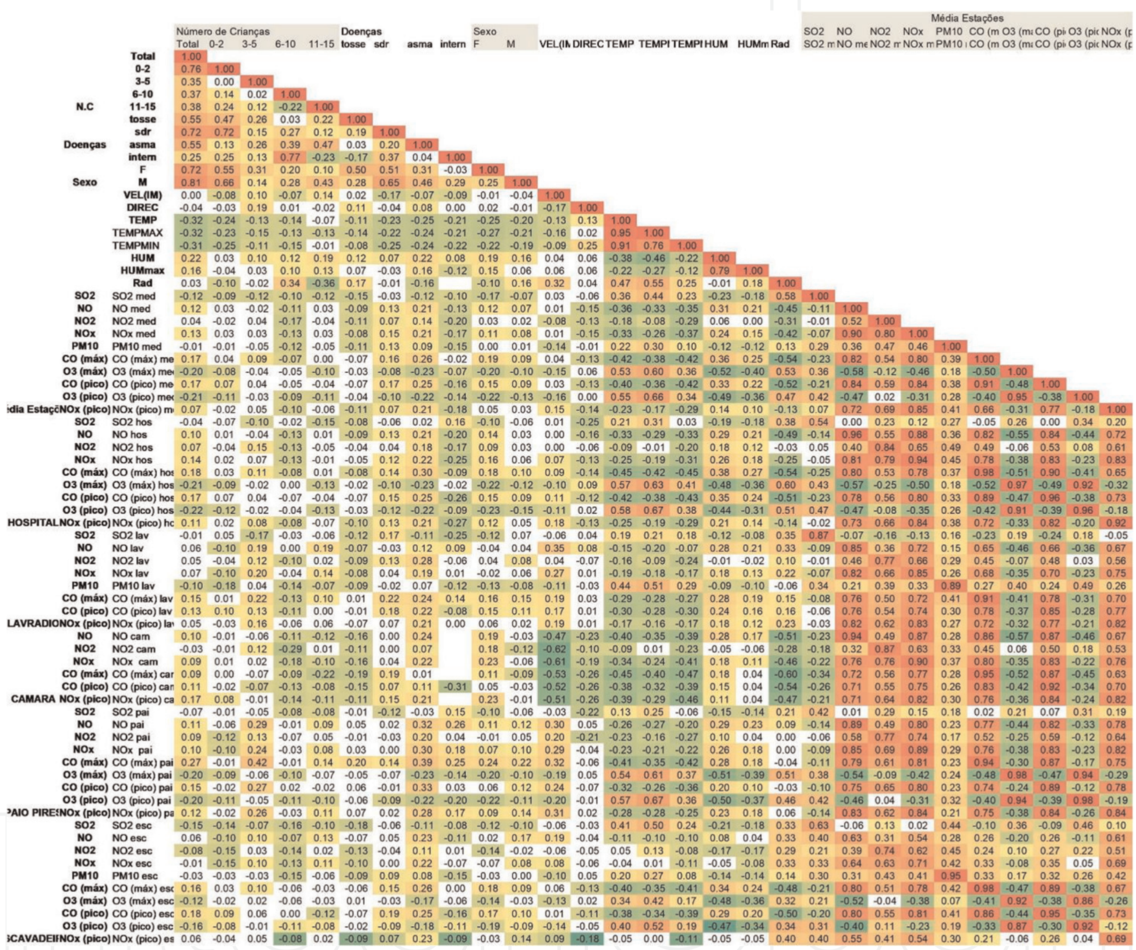


Figure 10.
Correlations between all variables studied.

considered, suggesting the inexistence of short-term correlations between observations with sdr symptoms and atmospheric concentrations of these two pollutants.

Table 5 and **Figure 15** show the evolution of the Pearson correlation coefficient (ρ) between the cough variable and the mean concentrations of pollutants (O_3, SO_2, NO, NO_2, NO_x, PM_{10}, and CO) for the temporal lags of 0, 1, 2, 3, 4, 5, 6, 7, and 15 days.

One can see that, globally, the maximum correlations between the symptoms of cough and the concentrations of pollutants NO, NO_2, NO_x, CO, and PM_{10} occur after temporal lags of 6 days, except for SO_2, which has the maximum correlation with a temporal lag of 5 days, albeit with a maximum correlation value of $\rho max = 0.07$ (cough and SO_2, lag 5 days), which is not significant. In addition, the following Pearson correlation coefficient values stand out, $\rho max = 0.20$ (cough and PM_{10}, 6-day

	lag 0	lag 1	lag 2	lag 3	lag 4	lag 5	lag 6	lag 7	lag 15
O_3	−0.23	−0.19	−0.26	−0.26	−0.26	−0.27	−0.26	−0.25	−0.06
SO_2	−0.12	−0.09	−0.10	−0.08	−0.09	−0.05	−0.08	−0.14	−0.06
NO	0.21	0.23	0.30	0.32	0.26	0.25	0.31	0.20	−0.02
NO_2	0.14	0.09	0.22	0.21	0.22	0.18	0.15	0.12	0.01
NO_x	0.21	0.20	0.30	0.33	0.28	0.25	0.30	0.21	0.00
PM_{10}	0.09	0.00	0.06	0.12	0.18	0.11	0.09	0.06	−0.07
CO	0.26	0.28	0.35	0.33	0.27	0.34	0.29	0.26	0.12

Table 3.
Pearson's correlation coefficient (ρ) between the variable mean concentrations of pollutants (O_3, SO_2, NO, NO_2, NO_x, PM_{10}, and CO) and asthma for time lags of 0, 1, 2, 3, 4, 5, 6, 7, and 15 days.

Figure 11.
Correlations of medical data with station averages.

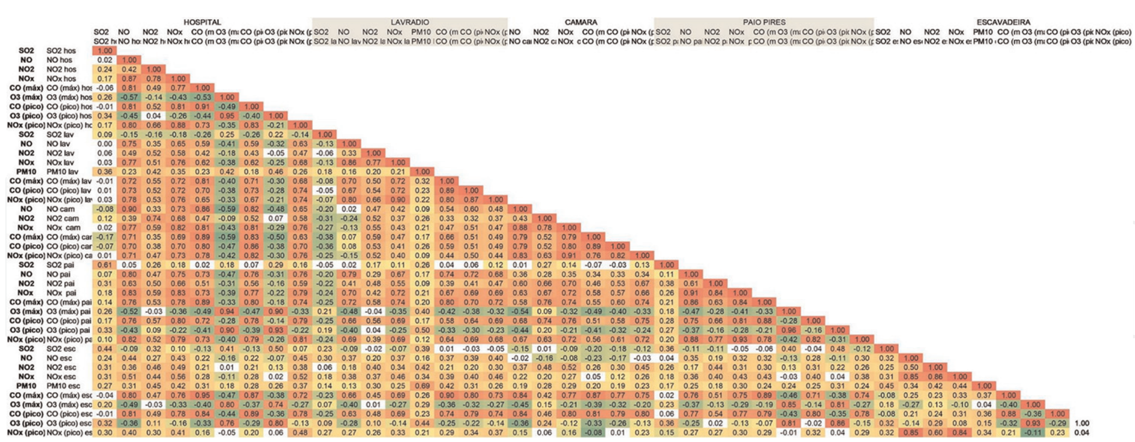


Figure 12.
Correlations between seasons.

lag), ρmax = 0.20 (cough and NO_x, 6-day lag), ρmax = 0, 18 (cough and NO, lag 6 days), ρmax = 0.17 (cough and CO, lag 6 days), and ρmax = 0.09 (cough and NO_2, lag 6 days), representing nonsignificant values.

For O_3, it appears that Pearson's correlation coefficient (ρ) remains relatively constant and negative throughout the period analyzed for all lags considered, indicating the inexistence of short-term correlations between observations with symptoms of cough and atmospheric concentrations of this pollutant.

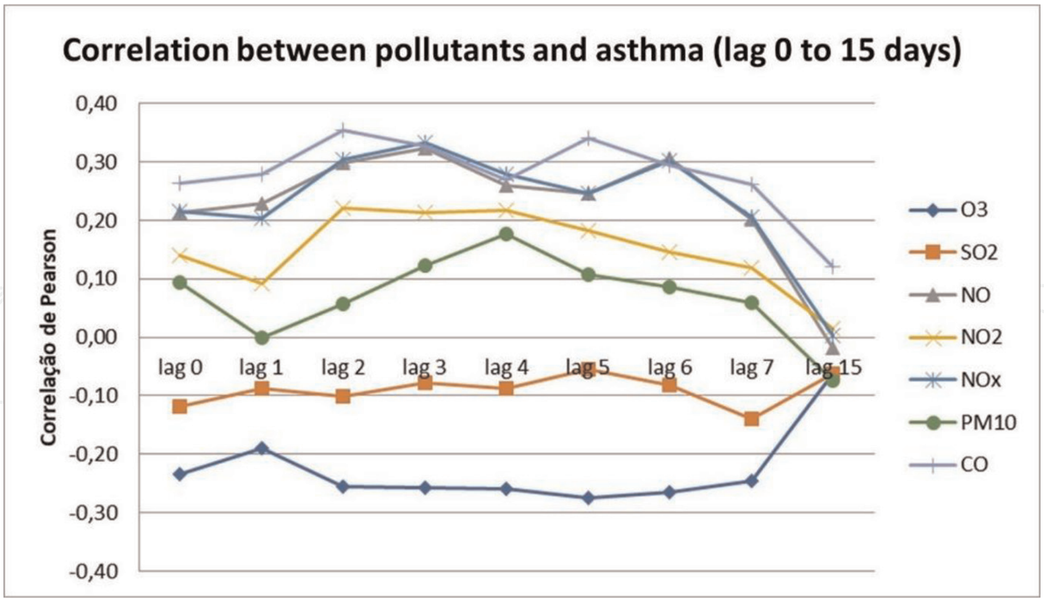


Figure 13.
Evolution of the correlation coefficient between concentrations of air pollutants and asthma symptoms (lag 0 to 15 days).

	lag 0	lag 1	lag 2	lag 3	lag 4	lag 5	lag 6	lag 7	lag 15
O_3	−0.08	−0.11	−0.11	−0.16	−0.15	−0.14	−0.14	−0.13	−0.17
SO_2	−0.03	−0.04	−0.04	−0.11	0.01	−0.05	−0.17	−0.11	−0.09
NO	0.13	0.09	0.11	0.12	0.13	0.07	0.13	0.11	0.12
NO_2	0.07	0.01	0.07	0.12	0.17	0.13	0.14	0.09	−0.02
NO_x	0.15	0.09	0.13	0.16	0.20	0.14	0.19	0.15	0.10
PM_{10}	0.13	0.00	0.07	0.14	0.15	0.12	0.05	0.08	−0.03
CO	0.16	0.08	0.14	0.11	0.14	0.09	0.12	0.10	0.15

Table 4.
Pearson's correlation coefficient (ρ) between the variable mean concentrations of pollutants (O_3, SO_2, NO, NO_2, NO_x, PM_{10}, and CO) and sdr for temporal lags of 0, 1, 2, 3, 4, 5, 6, 7, and 15 days.

4. Conclusions

The results presented in this chapter allow concluding some important aspects for the study and understanding the relation between the concentrations of atmospheric pollutants, meteorological variables, such as air temperature and solar radiation, and medical variables related to the different symptomatologies studied, in admissions of children in the ER, at Hospital do Barreiro (sdr, cough, and asthma). From the development and analysis of the results of this study, the following aspects stand out:

There is an increase of the ambient air temperature with the increase of solar radiation. This fact is visible in the values of Pearson's correlation coefficient ρ = 0.46 (mean daily air temperature with radiation) and ρ = 0.55 (maximum daily air temperature with radiation).

There is an increase in the concentration of PM_{10} with the increase of the ambient air temperature. This is more relevant for temperatures above 25°C - ρ = 0.22 (average

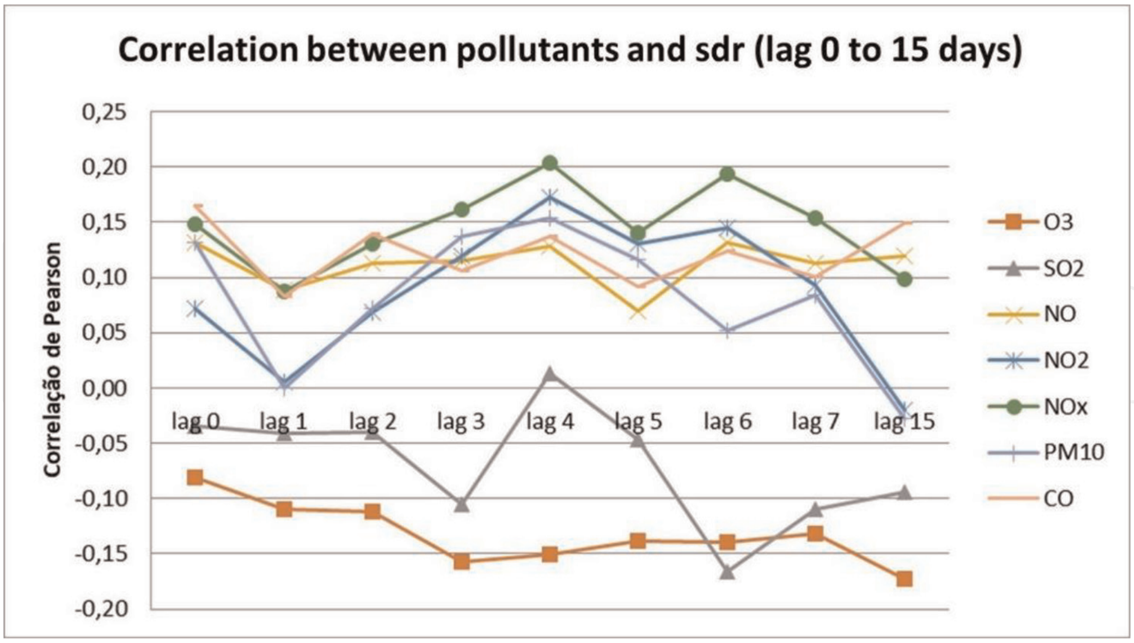


Figure 14.
Evolution of the correlation coefficient between air pollutant concentrations and sdr symptomatology (lag 0 to 15 days).

	lag 0	lag 1	lag 2	lag 3	lag 4	lag 5	lag 6	lag 7	lag 15
O_3	−0.03	−0.09	−0.11	−0.15	−0.16	−0.19	−0.17	−0.12	−0.14
SO_2	−0.15	−0.11	−0.05	−0.02	−0.07	0.07	0.01	−0.02	−0.07
NO	−0.09	−0.02	0.03	0.03	0.06	0.15	0.18	0.06	0.10
NO_2	−0.11	−0.01	0.02	0.02	0.05	0.02	0.09	−0.02	−0.05
NO_x	−0.08	0.01	0.04	0.06	0.10	0.15	0.20	0.08	0.07
PM_{10}	−0.11	−0.07	0.03	−0.03	−0.04	0.11	0.20	0.11	0.02
CO	−0.07	−0.03	−0.03	0.02	0.09	0.12	0.17	0.12	0.07

Table 5.
Pearson's correlation coefficient (ρ) between the variable mean concentrations of pollutants (O_3, SO_2, NO, NO_2, NO_x, PM_{10}, and CO) and cough for temporal lags of 0, 1, 2, 3, 4, 5, 6, 7, and 15 days.

concentration of PM_{10} with average daily air temperature) and ρ = 0.30 (average concentration of PM_{10} with maximum daily air temperature). One can also see that for air temperatures below 13°C there is a slight increase in the concentration of particles, probably due to atmospheric conditions that hinder the dispersion of particles.

There is a strong correlation between the maximum concentration of ozone in the air and the average daily air temperature ρ = 0.53, with an increase in the values of ozone concentration with the increase in average air temperature.

There is a trend toward an increase in asthma symptoms, in visits to the hospital's emergency room, with increasing age of children (ρ = 0.13 0–2 years, ρ = 0.26 3–5 years; ρ = 0.39 6–10 years; ρ = 0.47 11–15 years).

There are important correlations between the values of the concentrations of the different atmospheric pollutants, correlated among themselves, there being a strong

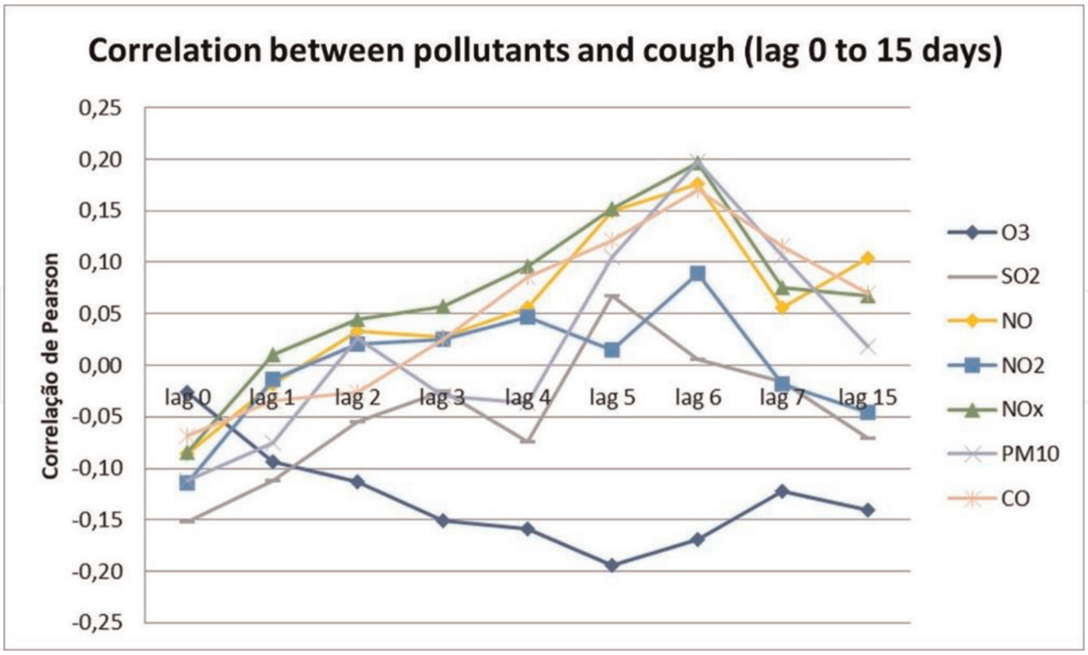


Figure 15.
Evolution of the correlation coefficient between concentrations of air pollutants and cough symptomatology (lag 0 to 15 days).

relation between the concentrations of CO and the NOx families (ρ = 0.82 CO_{max} with NO_{med}, ρ = 0.80 CO_{max} with $NO_{x\ med}$, ρ = 0.84 CO_{peak} with NO_{med}, ρ = 0.77 CO_{peak} with $NO_{x\ peak}$). On the contrary, SO_2 does not show strong correlations with any other pollutant, except for an important correlation value between peak SO_2 and O_3 concentrations (ρ = 0.42) and between SO_2 and $O_{3\ max}$ concentrations (ρ = 0,36). PM_{10} concentrations are correlated with the concentrations of all pollutants, with the highest correlation for NO_2 (ρ = 0.47 PM_{10} with $NO_{2\ med}$) and the lowest correlation for O_3 (ρ = 0.28 PM_{10} with $O_{3\ peak}$; ρ = 0.18 PM_{10} with $O_{3\ max}$).

The strongest correlations between the variables of health symptoms (sdr, cough, and asthma) and the concentrations of air pollutants for situations of lag 0 (consequences on the same day) are observed for the symptoms of asthma, presenting the highest values for the correlation coefficient with CO_{max} (ρ = 0.26 asthma CO_{max}) and with CO_{peak} (ρ = 0.25 asthma CO_{peak}). There is also an important correlation between asthma and NO_x for situations of lag 0, ρ = 0.21 (asthma with $NO_{x\ med}$), ρ = 0.21 (asthma with $NO_{x\ med}$), and ρ = 0.21 (asthma with peak NO_x). The correlation with PM_{10}, on the other hand, has an unrepresentative value ρ = 0.09 (asthma with PM_{10}) for the situation of lag 0 (same day);

For the situation of temporal lag 0 analyzed (consequences on the same day), negative correlation values are observed between asthma symptoms and O_3 $\rho = -0.23$ (asthma and $O_{3\ max}$) and $\rho = -0.22$ (asthma and peak O_3), as well as a negative correlation between asthma and $SO_{2\ med}$ ($\rho = -0.12$);

Staggering the analysis among health symptoms (sdr, cough, and asthma) and the concentrations of air pollutants (O_3, SO_2, NO, NO_2, NO_x, PM_{10}, and CO) considering temporal lags of 1, 2, 3, 4, 5, 6, 7, 8, and 15 days, overall, the maximum correlations between these symptoms and the concentrations of pollutants NO, NO_2, NO_x, CO, and PM_{10} occur after time lags ranging from 2 to 6 days depending on the pollutant and the symptomatology considered;

For SO_2 and O_3 pollutants, analyzing the evolution of the Pearson correlation coefficient (ρ) between these pollutants and the symptoms analyzed, for temporal lags of 1, 2, 3, 4, 5, 6, 7, 8, and 15 days, this correlation coefficient remains relatively constant or negative throughout the period analyzed, indicating lack of short-term correlations between observations with asthma symptoms and concentrations of atmospheric emissions of these two pollutants.

Author details

João Garcia[1,2]*, Rita Cerdeira[3] and Luís Coelho[2,4]

1 Lisbon Superior Institute of Engineering, Lisbon, Portugal

2 CINEA-IPS, Energy and Environment Research Centre, IPS Campus, Setúbal, Portugal

3 Independent Researcher, Setúbal, Portugal

4 Mechanical Engineering Department, Polytechnic Institute of Setúbal, Higher School of Technology, Setúbal, Portugal

*Address all correspondence to: joao.garcia@isel.pt

References

[1] HEI. State of Global Air 2018. Special Report. Boston, MA: Health Effects Institute; 2018

[2] European Environment Agency. Air quality in Europe 2022; Technical Report No 05/2022. 2022. DOI: 10.2800/488115

[3] Vallius M. Characteristics and Sources of Fine Particulate Matter in Urban Air. Kuopio, Finland: National Public Health Institute, Department of Environmental Health; 2005

[4] Garcia J, Cerdeira R, Coelho L, Kumar P, Carvalho MG. Important variables when studying the influence of particulate matter on health. In: Particulate Matter: Sources, Impact and Health Effects. Setubal, Portugal: Nova Publishers; 2017

[5] Wang X-Q, Huang K, Cheng X, Cheng-Yang H, Ding K, Yang X-J, et al. Short-term effect of particulate air pollutant on the risk of tuberculosis outpatient visits: A multicity ecological study in Anhui, China. Atmospheric Environment. 2022;**280**:119129. DOI: 10.1016/j.atmosenv.2022.119129. ISSN 1352-2310

[6] Usmani RSA, Pillai TR, Hashem IAT, et al. Air pollution and cardiorespiratory hospitalization, predictive modeling, and analysis using artificial intelligence techniques. Environmental Science and Pollution Research. 2021;**28**: 56759-56771. DOI: 10.1007/s11356-021-14305-7

[7] Guilbert A, Cox B, Bruffaerts N, et al. Relationships between aeroallergen levels and hospital admissions for asthma in the Brussels-capital region: A daily time series analysis. Environmental Health. 2018;**17**:35. DOI: 10.1186/s12940-018-0378-x

[8] Nel A. Air pollution-related illness: Effects of particles. Science. 2015; **308**(5723):804-806. DOI: 10.1126/science.1108752

[9] European Environment Agency. Air Quality in Europe – 2011 Report. EEA Technical Report. Denmark – Copenhagen; 2011. no. 12/2011

[10] Gasparrini A. Modeling exposure-lag-response associations with distributed lag non-linear models. Statistics in Medicine. 2014;**33**(5): 881-899. DOI: 10.1002/sim.5963. Available from: wileyonlinelibrary.com

[11] Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E. Environmental and health impacts of air pollution: A review. Frontiers in Public Health. 2020;**8**:14. DOI: 10.3389/fpubh.2020.00014

[12] Dhital S, Rupakheti D. Correction to: Bibliometric analysis of global research on air pollution and human health: 1998–2017. Environmental Science and Pollution Research International. 2019 Aug;**26**(24):25386. DOI: 10.1007/s11356-019-05792-w. Erratum for: Environmental Science and Pollution Research International. 2019 May;26 (13):13103-13114. PMID: 31240646

[13] Sicard P, Agathokleous E, De Marco A, et al. Urban population exposure to air pollution in Europe over the last decades. Environmental Sciences Europe. 2021;**33**:28. DOI: 10.1186/s12302-020-00450-2

[14] World Health Organization. ICD-11 Implementation or Transition Guide. Geneva: License: CC BY-NC-SA 3.0 IGO; 2019

Airborne PM Impact on Health, Overview of Variables, and Key Factors to Decision Making in Air Quality

WRITTEN BY

João Nuno Pinto Miranda Garcia , Joana Borrega and Luís M. R. Coelho

Submitted: 10 June 2018 , Reviewed: 21 June 2018 , Published: 05 November 2018

DOI: 10.5772/intechopen.79695

FROM THE EDITED VOLUME

Air Pollution - Monitoring, Quantification and Removal of Gases and Particles

Edited by Jorge Del Real Olvera