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Weather and Air Quality Factors Contribution to the Hospital Admissions of Patients with Respiratory Diseases: Case Study of Faial Island (Azores)

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Abstract

It is frequently accepted that weather and air quality factors contribute to the development and exacerbation of respiratory diseases. This work within the scope of earlier studies, is assumed in the insular context of the Azores. The base information (epidemiological, meteorological, air quality) used in this work corresponds to daily data from 2008 to 2019 and provided by the Statistics Service of the Hospital da Horta, Meteorological Observatory Príncipe Alberto de Monaco, and Air Quality Monitoring Network of the Autonomous Region of the Azores. The practical study's conclusions show an interesting relationship between hospitalization patterns and seasonality of some specific meteorological or weather factors as temperature, dew point or wind. Also, the air quality (suspended particles, SO_2, NO_2, and O_3) may contribute to a greater number of individuals with pathologies in study.

Keywords: Asthma; Pneumonia; Rhinitis; Hospital; Weather; Air quality; Azores

Introduction

It is frequently accepted that weather and air quality factors contribute to the development and exacerbation of respiratory diseases. There are some developed studies based on laboratory experiments, but the most are based on the determination of statistical relationships between hospital admissions (emergency visits and admissions).

On the other h, especially in the case of asthma [1], most of the studies carried out are based mainly on temperature and relative air humidity (meteorology) and on suspended particulate matter (air quality). Also, in the case of asthma and, according to the incidence and prevalence typical patterns of this pathology [2], the studies are always related to certain age groups (children and adults) and sometimes gender (female and male).

Considering this work within the scope of these studies, it is assumed in the insular context of the Azores. As a scientific justification, it is intended to know the impact of atmospheric factors (weather and air quality) on admissions to hospital emergency services and hospitalizations. As an unprecedented work in this field for the Azores, this study aims to (1) review the effect of atmospheric variables on admissions to emergency rooms and hospital admissions, (2) identify gaps in knowledge and (3) highlight future priorities for research, (3) contribute to raising awareness among the population to reduce exposure to potential exacerbating factors for respiratory diseases, (4) improve management of admissions to emergency rooms and hospital admissions, and (5) contribute for a design of a possible environmental alert system for respiratory diseases.

Finally, the consequences for the Azores region resulting from global climate change [3] are already visible from the change in the background concentration of CO_2 to extreme events such as the increase in drought periods, the number of days with heavy precipitation or the increase in annual number of tropical nights are another motivation. The intensification of the North Atlantic Subtropical Anticyclone in the Azores region (~1.2hPa) and, especially in the north of the archipelago (~1.6hPa), corresponds to a reconfiguration of synoptic scale systems that is consistent with the most significant aspects arising from the current climate change. The decrease in wind speed in this region of the Atlantic, as well as the increase in surface solar radiation resulting from the expansion of the subtropical anticyclone to more northern latitudes, pushing the Jet Stream northward and consequently the Polar Front, could be a clear sign of large-scale change in the cloud pattern in this region, which is also consistent with the decrease in precipitation projected towards the end of the century. The impacts on human health will be significant depending on our knowledge and preparedness to face them [4].

Data and Results

Study area

The Azores are in the subtropical region of the North Atlantic and therefore heavily influenced by the North Atlantic Subtropical Anticyclone, also known as the Azores High. As it is a quasi-stationary high-pressure system, its position, intensity, development, and orientation determine the nature and characteristics of the air masses that reach the region, as well as the frequency and paths of waves and lows of the Polar Front of the North Atlantic which is, also, an important modeling system of weather in the Azores. Thus, according to the NCEP/NCAR Reanalysis for 1961-1990, the maximum value of the mean atmospheric pressure occurs in July, as the Azores High, centered in the vicinity of the archipelago, is more intense at this time of year; on the other hand, as the Azores High is less intense and lows are more frequent and deeper in early spring, the minimum value of mean atmospheric pressure at the surface occurs in March. Another aspect that characterizes the weather in the Azores is the proximity of the Gulf Stream, which consists of a sea current of warm water that makes the climate mild in these latitudes. In fact, the sea surface temperature is very important for the Azores Climate which, according to the Köppen-Geiger Climate Classification, is considered predominantly humid temperate, without a dry season, with precipitation in all months of the year and with a temperate summer.

The island of Faial is located at the western end of the Central Group of the Azores archipelago, separated from the island of Pico by a narrow channel of 8.3km (or 4.5 nautical miles) wide, known as the Faial channel. The island has the approximate shape of an irregular pentagon, 21km long in the east-west direction and a maximum width of 14km, which corresponds to an area of 172.43km^2. The resident population is 14,356 inhabitants (2021), most of whom live in Horta city, the only municipality on the island. The climate is temperate oceanic, with average annual air temperatures that fluctuate on average between 13°C in winter and 22°C in summer, with frequent windstorms and an average relative humidity above 79%.

Data

The base information (epidemiological, meteorological, air quality) used in this work corresponds to daily data from 2008 to 2019.

Data on the number of hospitalized individuals (hospitalized including those who visited the Emergency Department) with a diagnosis of a respiratory disease (asthma, pneumonia, and rhinitis). The data analyzed in this study were provided by the Statistics Service of the Hospital da Horta (Faial).

The meteorological data were collected at automated weather station the Meteorological Observatory Príncipe Alberto de Monaco (Faial), belonging to the surface meteorological network of the Instituto Português do Mar e da Atmosfera (https://www.ipma.pt).

The air quality data were collected at the Espalhafatos station (Faial) belonging to the Air Quality Monitoring Network of the Autonomous Region of the Azores (http://qualidadedoar.azores.gov.pt/DadosValidados.aspx).

Results

On a weekly scale, the number of hospitalizations of cases with Asthma shows a seasonal pattern like the daily temperature range (Tmax-Tmin), with maximums in winter, when the daily temperature range is lower, and minimums in summer, when the temperature range is larger (Figure 1). This result can be complemented with the daily minimum temperature, with maximums in winter, when minimum temperatures are lower, and minimums in summer, when minimum temperatures are higher. These results suggest that the influx of individuals with asthma to the emergency room may be related to days with low temperatures and reduced thermal amplitudes, which implies a duration or exposure to relatively colder conditions for longer than normal (Figure 2). On the other hand, the results of the average daily wind speed show an opposite evolution to the number of asthma cases, with the lowest values in the summer months, suggesting that there may be some relationship with suspended particles (dust, pollen, aerosols, etc.) raised locally by the wind and more frequent in the winter, spring, and autumn months, thus favoring the aggravation of this pathology (Figure 3).

The number of weekly hospitalizations of Pneumonia cases shows a seasonal pattern with a maximum at the end of winter, where the dew point has lower values, with a minimum in autumn, just after the dew point maximums. These results suggest that low dew point conditions (low specific humidity) may favor the influx of pneumonia cases. On the other hand, higher dew point conditions may not favor or even counteract the affluence of these patients (Figure 4).

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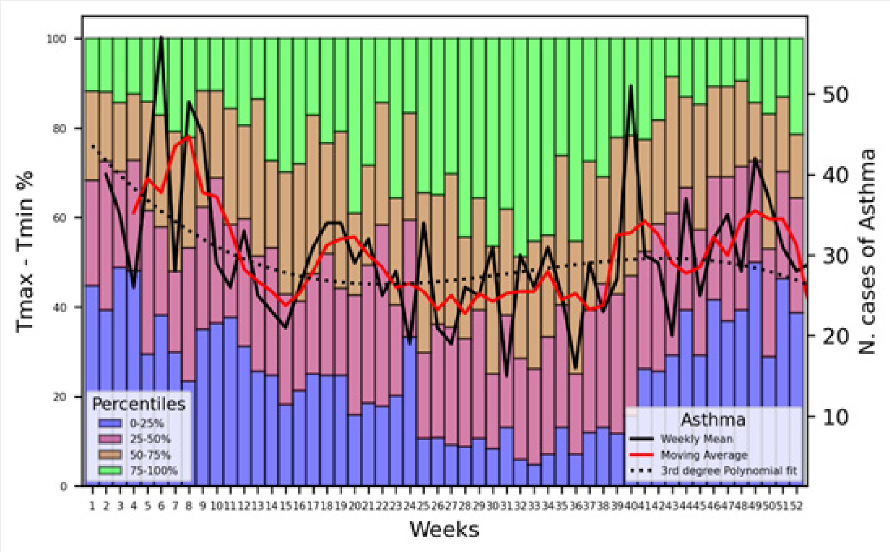

Figure 1: Weekly mean of hospitalizations of cases with Asthma and daily thermal amplitude percentile ranges per week (Faial, 2009-2019).

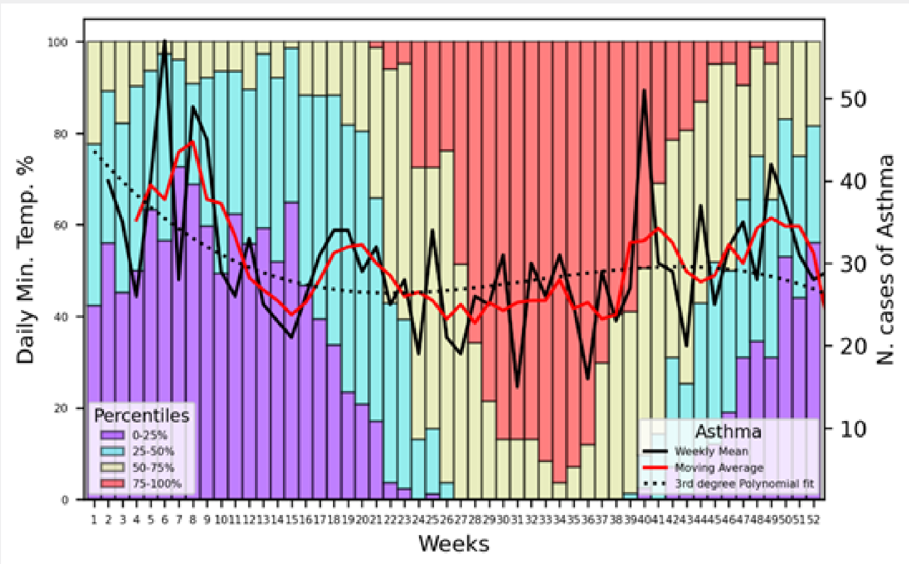

Figure 2: Weekly mean of hospitalizations of cases with Asthma and daily minimum temperature percentile ranges per week (Faial, 2009-2019).

Regarding the number of weekly cases of rhinitis, the results do not show a clear seasonal pattern. However, it is possible to identify a major maximum in late winter and a minor maximum in late spring, followed by a major minimum in autumn. On the other hand, the evolution of minimum temperatures suggests that the disappearance of the first quartile, where minimum temperatures are below 13.1, coincides with the decrease in cases, and that the reappearance of this quartile in October also coincides with the increase in the number of cases. These results partly suggest that the colder days may promote the aggravation of this pathology, but the reason for the occurrence of the two maximums, or the relative minimum verified in March, remains to be explained (Figure 5).

Carrying out an exploratory analysis of the data on a monthly basis and for each variable, complementary conclusions are obtained about its behavior.

Considering the total number of respiratory diseases, the monthly number of hospitalizations (RDH) generally varies between 30 and 70, although it can reach higher (~130) and

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lower (~15) values. It is not easy to identify seasonality in the series, but the months of December to May have median values greater than 45, with the month of February having the highest average (>57), although the median is lower than 45. The lowest median values occur in the month of September (Figure 6a); about hospitalization for asthma (ASTHMA), the monthly values generally vary between 5 and 18 hospitalizations. In this case, the series presents a certain seasonality, with the highest values (average and median) in the months from November to February, (10-15). The lowest values occur in the months of June and July (Figure 6b); Regarding hospitalization for pneumonia (PNEUMONIA), the values generally vary between 5 and 25 hospitalizations, with a clearer seasonal behavior, with the months of January to May showing the highest median (average) values in the range 10-20 (Figure 6c); regarding hospitalization for rhinitis (RHINITIS), hospitalizations generally range from 1 to 12, with no clear seasonal pattern, but the months of May to July have the highest medians (means) (about 5) (Figure 6d).

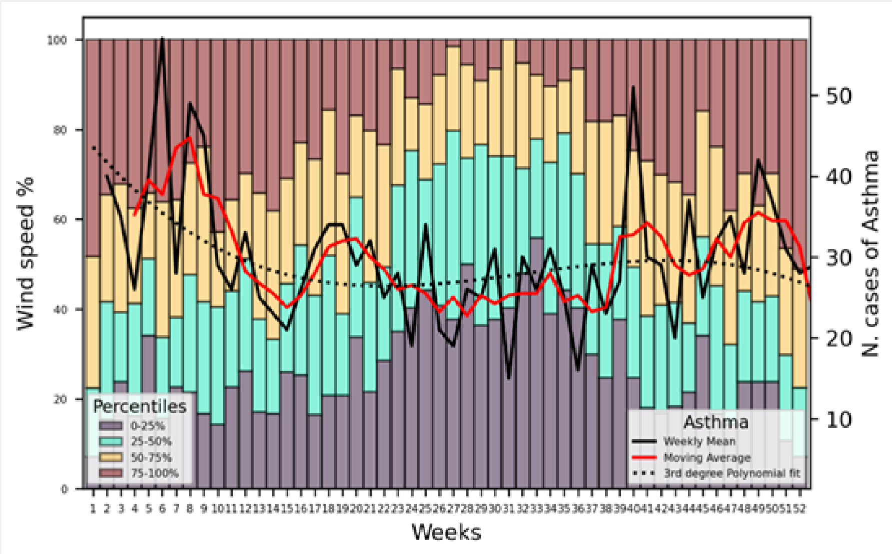

Figure 3: Weekly mean of hospitalizations of cases with Asthma and daily wind speed percentile ranges per week (Faial, 2009-2019).

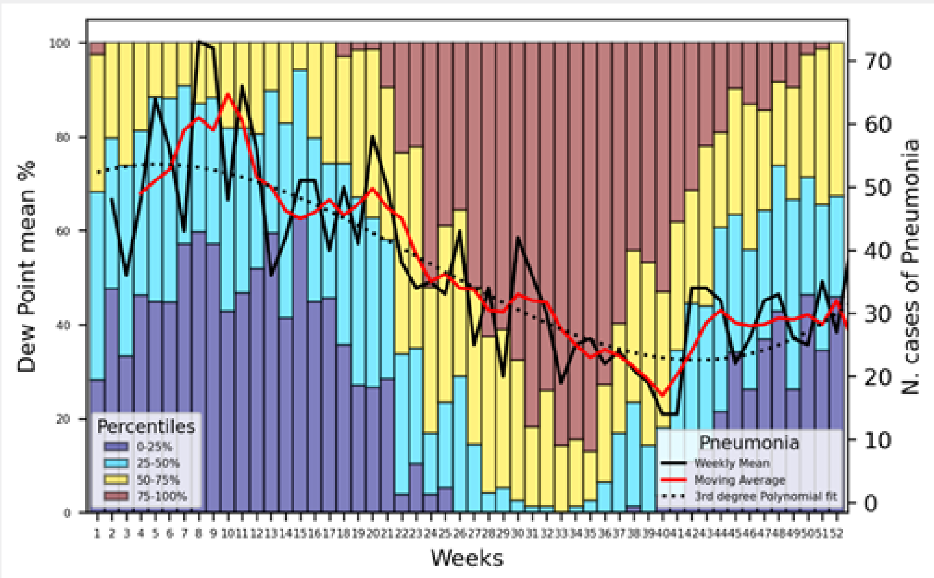

Figure 4: Weekly mean of hospitalizations of cases with Pneumonia and daily dew point mean percentile ranges per week (Faial, 2009-2019).

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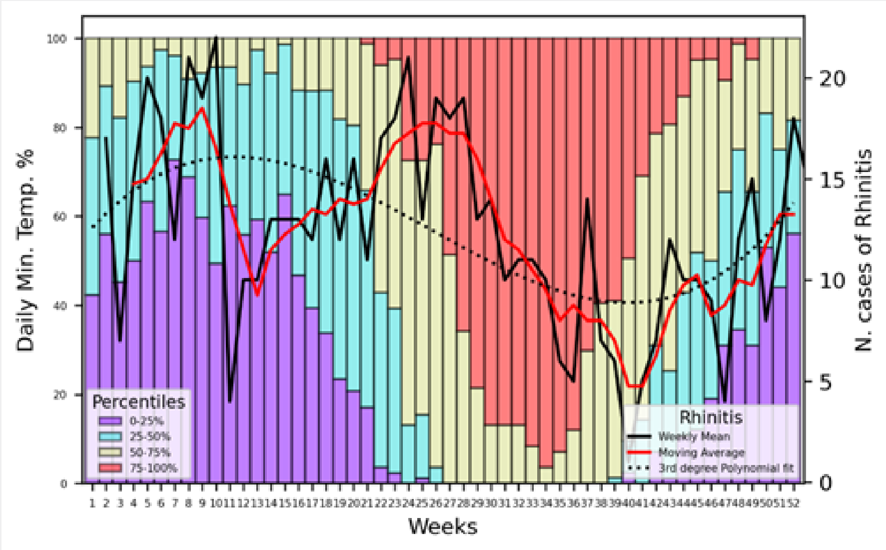

Figure 5: Weekly mean of hospitalizations of cases with Rhinitis and daily minimum temperature percentile ranges per week (Faial, 2009-2019).

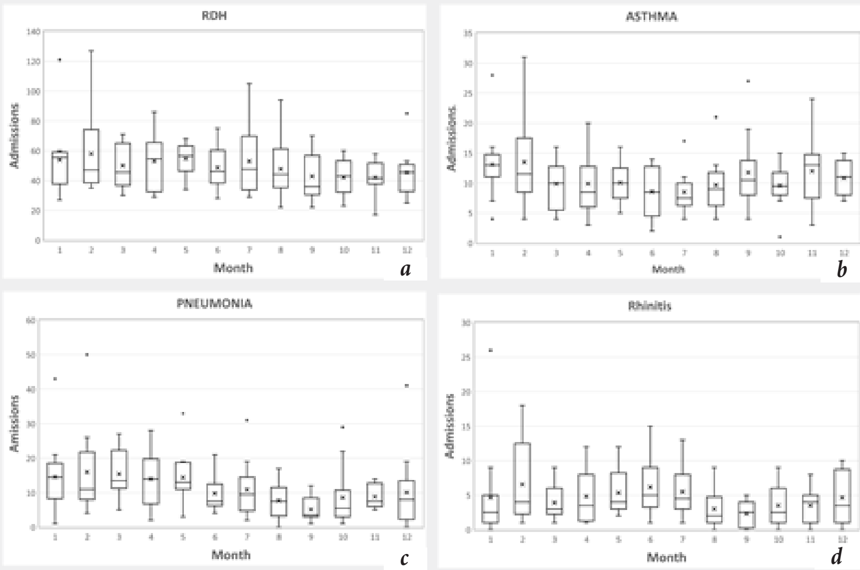

Figure 6: Monthly box and whisker plots for Respiratory Diseases Hospitalizations (RDH) during 2008-2019 in Faial Island for all cases (a), asthma (b), pneumonia, (c) and rhinitis (d).

Figure 7 concerns the meteorological variables. Regarding the daily minimum temperature, it presents distributions with greater dispersion in the winter months (DJF) and outliers for the lowest temperatures (Figure 7a); as for the maximum daily temperature , it presents distributions with less dispersion in relation to the minimum temperature, but with a greater number of outliers , both high and low (Figure 7b); the daily thermal amplitude presents very similar distributions throughout the year, with a maximum in the summer months (JJA) and a minimum in the winter months (DJF). However, the months of December and January show a greater number of outliers for the largest amplitudes (Figure 7c); the dew point temperature shows a similar seasonal pattern for the maximum and minimum temperatures, but the dispersion of the monthly distributions is smaller in the summer months (Figure 7d); the relative humidity generally shows values around 80%, with the highest values in the months of December and

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January and from May to August (Figure 7e); as for the monthly rainfall totals, the series presents very asymmetrical monthly distributions with many outliers . However, the months of July and August show less dispersion in their respective distributions (Figure 7f).

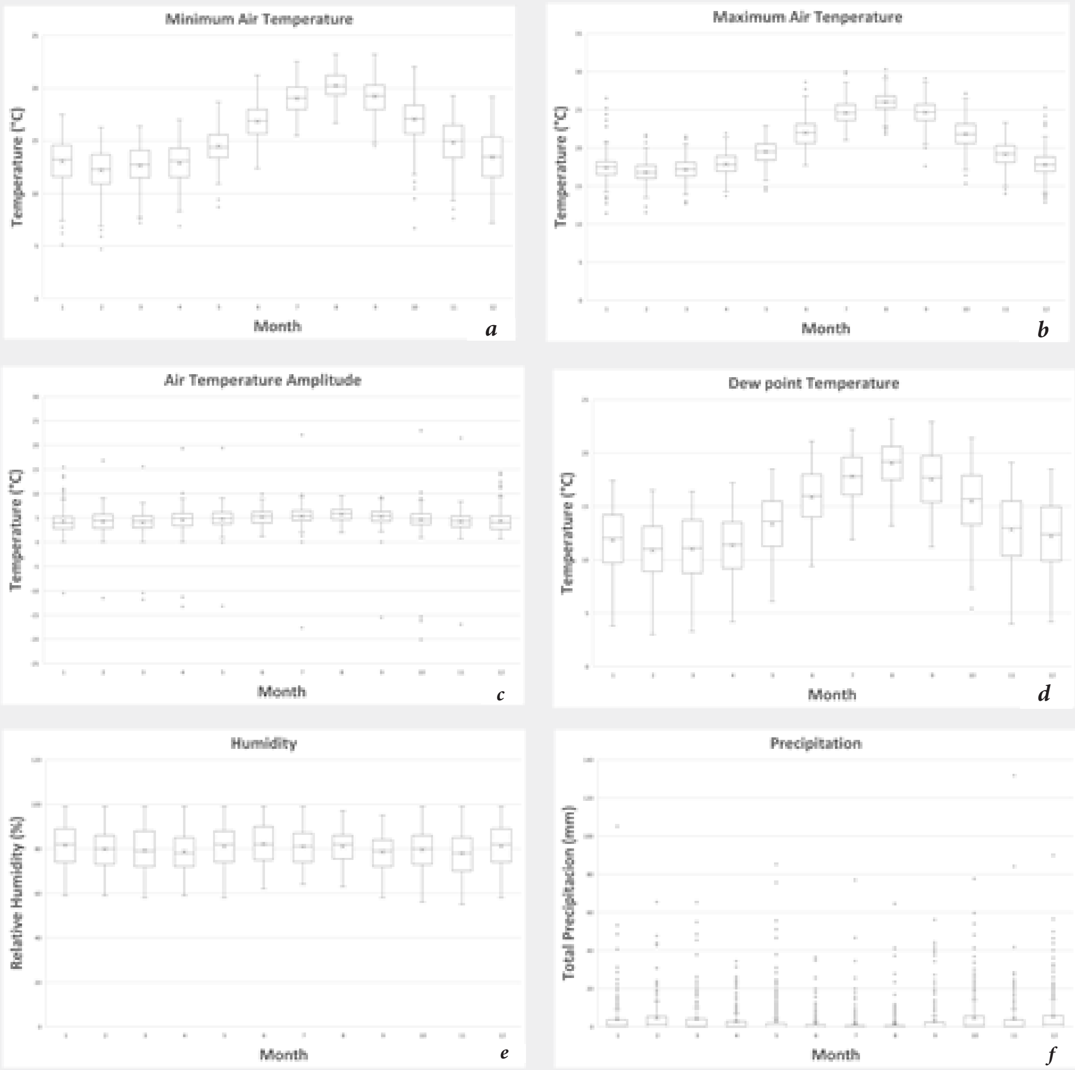

Figure 7: Monthly box and whisker plots for daily climatic data during 2008-2019 in Horta weather station for minimum temperature (a), maximum temperature (b), daily thermal amplitude (c) dew point (d), relative humidity (e), and total precipitation (f).

Regarding the air quality results [5], we can say that the average daily values of nitrogen dioxide (NO_2) concentration show relatively similar monthly distributions throughout the year, without a clear seasonal pattern. Daily values are generally lower than 5μg/m^3, but higher than background values for marine regions (~0.08μg/m^3), thus suggesting the presence of nearby emitting sources (Figure 8a); in relation to the average daily values of sulfur dioxide (SO_2), the monthly distributions obtained do not show a clear seasonality, but clearly superior to the typical background levels of the marine boundary layer (~0.14μg/m^3), therefore suggesting the presence from relatively close sources of pollution (Figure 8b); As for the average daily values of surface ozone concentration (O_3), the monthly distributions show a clear seasonal pattern, typical of the subtropical regions of the North Atlantic, that is, with a maximum in spring and a minimum in summer, but with values slightly above the tropospheric background levels expected for this region (~80μg/m^3), suggesting the influence of large-scale transport of polluted air masses, generally from the American continent (Figure 8c); the average daily concentrations of suspended particles

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with diameters less than 10µm (PM10) show a slight seasonal behavior, with maximums in spring and minimums in summer . The spring maximums may be related to Saharan dust transport events, which may justify the outliers verified especially in March (Figure 8d).

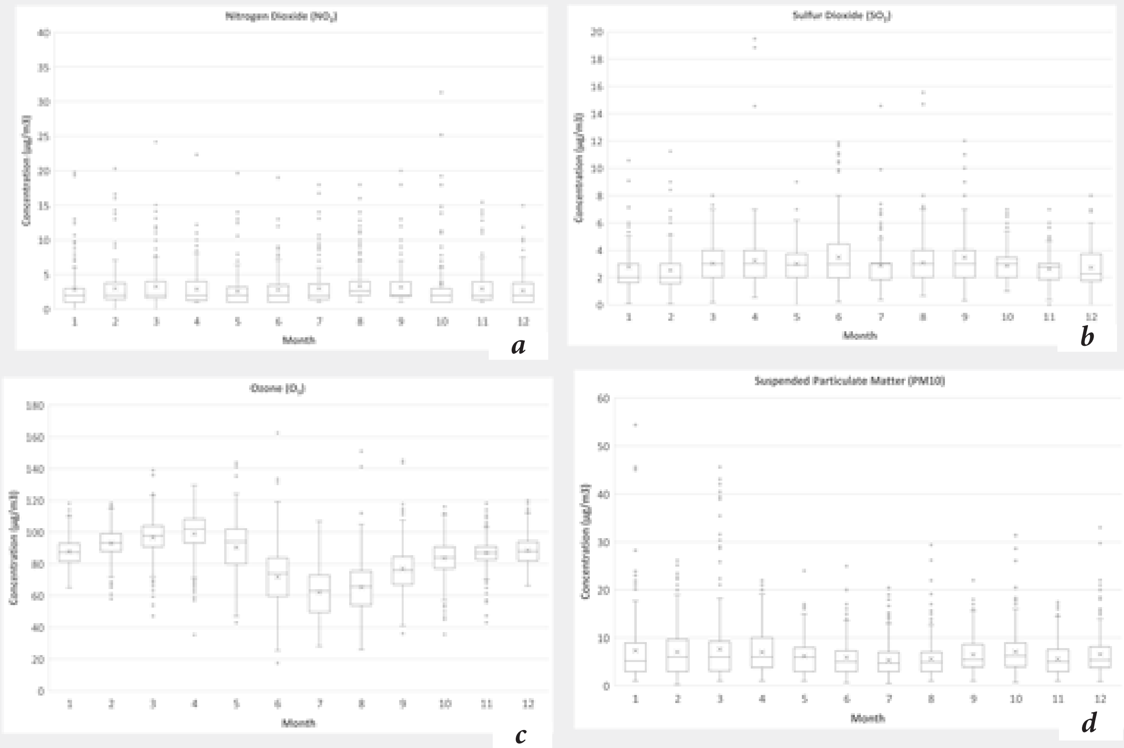

Figure 7: Monthly box and whisker plots for daily climatic data during 2008-2019 in Horta weather station for minimum temperature (a), maximum temperature (b), daily thermal amplitude (c) dew point (d), relative humidity (e), and total precipitation (f).

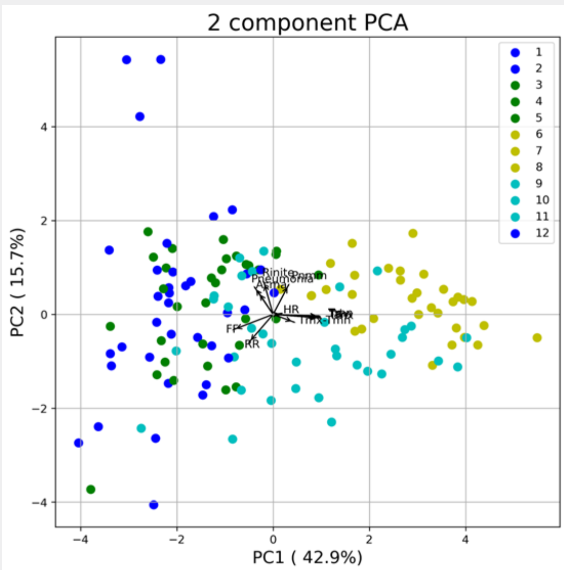

Figure 9: First two principal component analysis (PCA) for monthly cases of Asthma, Rhinitis and Pneumonia, as well as for monthly means sea level pressure (Pnmm), maximum (Tmx), minimum (Tmn) and mean (Tam) daily temperatures, thermal amplitude (Tmx-Tmn), dew point (DP), relative humidity (HR) and wind speed (FF) means and daily rainfall (RR). Colored dots correspond to the twelve months (jan=1, feb= 2,…, dec=12).

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Figure 9 shows a principal component analysis (PCA) using the monthly totals of diagnosed Asthma, Pneumonia and Rhinitis cases, together with the monthly averages of mean (Tam), maximum (Tmx), minimum (Tmn) daily temperatures (Tam), daily temperature range (Tmx-Tmn), dew point (TD), relative humidity (HR) and wind speed (FF), mean sea level pressure (Pnmm) as well as monthly rainfall totals (RR).

The first component explains about 43% of the variance and that the summer and autumn months (6 to 11) are distributed on the positive side of PC1 (Principal Component 1), where the vectors of temperatures, relative humidity and pressure are projected. atmospheric. On the negative side, the winter and spring months (1 to 5 and 12) and the vectors of precipitation and wind, as well as the pathologies Asthma, Rhinitis and Pneumonia, are distributed. However, the pathologies vectors are almost perpendicular to the wind and precipitation vectors, suggesting that they are two sets of variables that are little dependent on each other. However, the daily thermal amplitude (Tmx-Tmn) presents a small component in the opposite direction to asthma and pneumonia, revealing a certain dependence in the opposite direction or negative correlation. These results indicate that these cases have a certain tendency to occur in the winter and spring months, but with small daily temperature amplitudes and relatively low temperatures and humidity.

Figure 10 shows the PCA analysis for the average concentrations of ozone (O_3), nitrogen dioxide (NO_2), sulfur dioxide (SO_2) and particulate matter below 10μm (PM10).

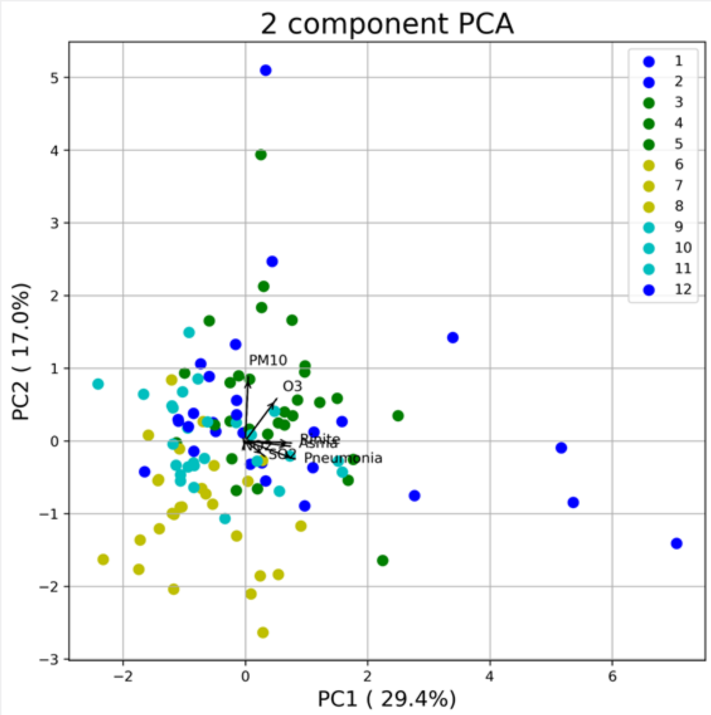

Figure 10: First two principal component analysis (PCA) for monthly cases of Asthma, Rhinitis and Pneumonia, as well as for monthly means of NO2, SO2, O3 and PM10. Colored dots correspond to the twelve months (Jan=1, Feb= 2,…, Dec=12).

These results show that PC1 explains only 29.4%, that is, less than the meteorological variables. On the other hand, the pathologies vectors present a direction closer to the NO_2 and SO_2 vectors, especially in the winter and spring months. These results indicate that the presence of primary pollutants such as NO_2 and SO_2, in the winter and spring months, may contribute to a greater entry into hospital services of individuals with pathologies under study. Interestingly, PM10 are not dependent on these pathologies and their contribution to PC1 is practically nil, being more significant for PC2.

Conclusion

The practical conclusions of this study can be summarized in the following points:

i. In the case of asthma, the influx of individuals to the emergency room may be related to days with low temperatures and reduced thermal amplitudes, which implies a duration or exposure to relatively colder conditions for longer than normal.

ii. There may be some relationship with suspended particles (dust, pollen, aerosols, etc.) raised locally by the wind

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and more frequent in the winter, spring, and autumn months, thus favoring the aggravation of this pathology).

iii. In the case of pneumonia, low dew point conditions (low specific humidity) seem to favor the influx of cases with pneumonia; on the other hand, higher dew point conditions may not favor or even hinder the affluence of these patients.

iv. In the case of rhinitis, if there is no clear seasonal pattern, it is possible to identify a major maximum in late winter and a minor maximum in late spring, followed by a major minimum in autumn; on the other hand, the data suggest that the colder days may promote the worsening of this pathology.

v. Regarding asthma and pneumonia, the results indicate that these cases have a certain tendency to occur in the winter and spring months, but with small daily thermal amplitudes and relatively low temperatures and humidity.

vi. With respect to serious pathologies (asthma, pneumonia, and rhinitis) the results indicate that the presence of primary pollutants such as NO_2 [6] and SO_2 [7] in the winter and spring months, may contribute to a greater number of individuals with pathologies in study; curiously, PM10 are not dependent on these pathologies.

For conclusion we will refer some aspects that we consider relevant for future studies in this area:

a) The clarification of the control mechanism of the interrelationship between environmental and genetic determinants to identify high-risk groups and key modifiable exposures [2], and

Carrying out more controlled experiments at laboratory level [8].

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