The aim of this study was to assess the performance of multivariate statistical technique, principal component analysis (PCA) for investigating the impact of exposure to ambient air pollution on asthma in Moroccan infants under one year old. The histogram of the eigenvalues shows that the first plane, made up of the axes PC1 and PC2, represents 81.87% of the total inertia. It turns out to be sufficient to reflect the bulk of this inertia, which means that the first two axes are sufficient to represent the information as a whole. The results of this study show that sulphur dioxide and nitrogen dioxide were positively correlated with asthma and they are also closely related and move in the same direction. Principal component analysis results confirm effects of environmental air pollution on paediatric asthma in Morocco.

**Keyword:**
- PCA
- air pollution
- Paediatric asthma

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1. INTRODUCTION

Clean air is vital to our health and well-being. Economic activities such as transport, industry and agriculture produce pollutants for the environment and health. This polluted air we breathe affects our respiratory system and causes illnesses like asthma [1-3]. According to the WHO, air pollution is the 5th health risk factor after malnutrition, dietary risks, high blood pressure and smoking. It causes the premature death of seven million people worldwide each year. It is easy to understand that our lungs find it difficult to breathe polluted air, charged with all these oxides of sulphur and nitrogen, and especially these dangerous fine particles which, because of their microscopic size of the order of a micron, will lodge at the bottom of our pulmonary alveoli to commit their irreversible damage [4-5].

Asthma in infants is clinically defined as any episode of breathing discomfort accompanied by wheezing that has occurred at least three times since birth [6]. An asthma attack in infants can be manifested by:

❖ A dry cough, rapid, wheezing, and the nostrils have rapid beating;
❖ Difficulty breathing while inhaling, the spaces between his ribs and above his collarbones are widening, and his chest is distended even when he exhales;
❖ Baby is very pale, his lips like his fingers can turn blue;
❖ Baby eats and drinks with difficulty because he is tired.

If you experience one or more of these symptoms, you should immediately consult the emergency services. Until today, we do not yet know the direct causes but on the other hand we know the factors favouring infant asthma, among these factors is air pollution [7-8].

Among the air pollutants that may have adverse effects on the respiratory system include sulphur dioxide, nitrogen dioxide and particulate matter [9].

Sulphur dioxide is produced from the combustion of fossil fuels (fuel oil, coal, lignite, diesel, etc.). Some industrial processes also emit sulphur oxides (production of sulfuric acid, production of pulp, petroleum refining, etc.). They can also be emitted by nature (volcanoes). This pollutant is also a precursor of secondary particles by combining, under certain conditions, with NOx [10-11].

Nitrogen oxides (NOx) are groups of nitrogen monoxide (NO) and nitrogen dioxide (NO2). They are emitted during combustion (heating, electricity production, thermal engines of vehicles, etc.). Nitrogen chemistry (manufacture of ammonium nitrate, etc.) or the use of nitrated products in industrial processes (glassware, etc.) are also emitters. Finally, the use of nitrogenous fertilizers leads to releases of NOx. Human-made emissions can become very predominant locally. Indeed, once nitrogen monoxide is released into the air, it transforms into nitrogen dioxide. In addition, under certain weather and sun conditions, nitrogen oxides are also a precursor of other pollutants [12-13].

The particulate matter mainly come from all incomplete combustions linked to industrial or domestic activities, as well as to transport [14-16]. They are also emitted by agriculture (spreading, tillage, etc.). They can also be of natural origin (soil erosion, pollen, biomass fires, etc.).

The purpose of this work is to study the impact of ambient air pollution on asthma in Moroccan infants under 1 year old using principal component analysis.
2. **DATA AND METHODS**

2.1. **Study area:**
Morocco is a country located in the far west of North Africa with its capital in Rabat and its largest city, Casablanca, which is the economic capital, and among the most important cities: Sale, Fez, Marrakech, Agadir and Mohammedia (Figure 1).

![Geographical study area](image)

**Figure 1.** Geographical study area.

Morocco overlooks the Mediterranean Sea to the north and the Atlantic Ocean to the west, centred by the Strait of Gibraltar; It is bordered by Algeria to the east and to the south by Mauritania. Geographically, it is particularly characterized by mountainous or desert areas and is one of the only countries to have shores on the Mediterranean Sea on one side and the Atlantic Ocean on the other. Morocco's climate varies according to regions, it is Mediterranean in the north, oceanic in the west, desert in the south. The coastal areas they enjoy a mild climate. This geographical location of Morocco gives it the importance of being a strategic gateway and bridge between Europe and Africa.

2.2. **Air pollution data:**
Data on air quality were collected from monitoring sites integrated into the cities of Morocco air quality monitoring network, governed by the National Meteorological Directorate. Monitoring sites measure sulfur dioxide (SO2), nitrogen dioxide (NO2) and particulate matter less than 10 Micrometer in diameter (PM10).
The surveillance sites considered in this study were 4 prefectures of the city of Casablanca; Ain Sebaâ- Hay Mohammadi (Casa- Ain Sebaâ), El Fida-Derb Soltane (Casa-Fida), Moulay Rachid-Sidi Othmane (Casa-MyRachid) and Anfa (Casa-Anfa), and 5 other Moroccan cities; Mohammedia, Agadir, Marrakech, Sale and Fez. Data on air pollution were collected during 2011 and these results are given in Table 1.
2.3. Hospitalization data:

In this investigation, we used the ninth revision of the International Classification of Diseases (ICD-9) code to notify hospitalizations for pediatric asthma (ICD-9: 493). The hospitalization data were collected from the Department of Epidemiology and Disease Control. Study subjects only included children under 1 year of age admitted to hospitals with asthma during the study period. These results are presented in Table 2.

### Table 2. Hospitalization data.

<table>
<thead>
<tr>
<th>Moroccan cities</th>
<th>Population</th>
<th>Pediatric asthma incidence&lt;sup&gt;+&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>&lt; 1 year</td>
</tr>
<tr>
<td>Casa- Ain Sebaà</td>
<td>437701</td>
<td>6566</td>
</tr>
<tr>
<td>Casa-Fida</td>
<td>350095</td>
<td>5251</td>
</tr>
<tr>
<td>Casa-MyRachid</td>
<td>445106</td>
<td>6677</td>
</tr>
<tr>
<td>Casa-Anfa</td>
<td>515515</td>
<td>7733</td>
</tr>
<tr>
<td>Mohammedia</td>
<td>356000</td>
<td>5880</td>
</tr>
<tr>
<td>Agadir</td>
<td>577000</td>
<td>9812</td>
</tr>
<tr>
<td>Marrakech</td>
<td>1208000</td>
<td>20272</td>
</tr>
<tr>
<td>Sale</td>
<td>959000</td>
<td>16010</td>
</tr>
<tr>
<td>Fez</td>
<td>1093000</td>
<td>18252</td>
</tr>
</tbody>
</table>

<sup>+</sup> number of cases per 100000 infants under one year old.
2.4. Statistical analysis:
In this study, principal component analysis was used as a static method to study the effect of air pollution on pediatric asthma in Morocco. The statistical analysis was performed employing NEMRODW® software [17]. It provided several information: i) the eigenvalues of the correlation matrix, ii) the loadings of the rotated principal components, iii) the histogram of eigenvalues, iv) the correlation circle on PC1 and PC2 and v) the projection of the contribution of individuals on PC1 and PC2.

3. RESULTS AND ANALYSIS

Principal component analysis (PCA) is a multivariate analysis method allowing the simultaneous study of a large number of variables whose total information cannot be visualized because of a space with more than three dimensions [18]. This method would make it possible to specify the relationships between the variables and the phenomena at the origin of these relationships. The objective is to have information concentrated on a minimum of axis. This method is widely used to interpret Environmental Health data.

The statistical analysis of environmental health data was carried out on a data matrix made up of five variables and nine Moroccan cities, i.e. 5 variables and 9 individuals. The correlation matrix gives a first idea of the existing associations between the different variables such as asthma, SO2, NO2, PM10 and Population density (PD). These parameters are relatively well positive correlated with each other, except asthma-PM10, asthma-PD and PM10-NO2 which are negatively correlated (Table 3).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Asthma</th>
<th>SO2</th>
<th>NO2</th>
<th>PM10</th>
<th>PD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SO2</td>
<td>0.1443</td>
<td>1.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NO2</td>
<td>0.5188</td>
<td>0.6988</td>
<td>1.0000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM10</td>
<td>-0.4672</td>
<td>0.3675</td>
<td>-0.1098</td>
<td>1.0000</td>
<td></td>
</tr>
<tr>
<td>PD</td>
<td>-0.2449</td>
<td>0.7173</td>
<td>0.4028</td>
<td>0.2913</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

The eigenvalues of the correlation matrix are used to measure the percentage of the variance explained by each factorial. The histogram of the eigenvalues shows that the first plane (Figure 2), made up of the axes PC1 and PC2, represents 81.87% of the total inertia (Table 4). It turns out to be sufficient to reflect the bulk of this inertia. Because if we observe the distribution of eigenvalues, we see that the main setback occurs just after the first two values, which means that the first two axes are sufficient to represent the information as a whole.

We will pay significant attention to variables with a strong positive or negative contribution to the factorial axis, which will facilitate understanding of the source of variability explained by the axes. The graph resulting from the principal component analysis, highlights groupings, oppositions and directional trends (Figure 3). The first component (PC1) expresses 46.41% of the variance and contrasts sulfur dioxide, nitrogen dioxide and population density. It reflects the air pollution data. The second component (PC2) which accounted for 35.46% of the total variance, was loaded heavily on asthma and PM10. It
defines an axis of hospitalization data. The strong positive correlations between SO$_2$ and NO$_2$ indicate that the characteristics and origins of emission for these elements might be similar.

**Table 4.** The loadings of the first three rotated principal components.

<table>
<thead>
<tr>
<th></th>
<th>PC 1</th>
<th>PC 2</th>
<th>PC 3</th>
<th>PC 4</th>
<th>PC 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asthma</td>
<td>0.148</td>
<td>0.905</td>
<td>-0.288</td>
<td>-0.263</td>
<td>0.079</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>0.961</td>
<td>-0.028</td>
<td>-0.103</td>
<td>-0.066</td>
<td>-0.246</td>
</tr>
<tr>
<td>NO$_2$</td>
<td>0.786</td>
<td>0.518</td>
<td>-0.036</td>
<td>0.322</td>
<td>0.097</td>
</tr>
<tr>
<td>PM10</td>
<td>0.328</td>
<td>-0.759</td>
<td>-0.553</td>
<td>-0.014</td>
<td>0.109</td>
</tr>
<tr>
<td>PD</td>
<td>0.806</td>
<td>-0.329</td>
<td>0.435</td>
<td>-0.181</td>
<td>0.140</td>
</tr>
<tr>
<td>Eigenvalues</td>
<td>2.3206</td>
<td>1.7729</td>
<td>0.5888</td>
<td>0.2102</td>
<td>0.1075</td>
</tr>
<tr>
<td>% VT</td>
<td>46.41</td>
<td>55.46</td>
<td>11.78</td>
<td>04.20</td>
<td>02.15</td>
</tr>
<tr>
<td>% VC</td>
<td>46.41</td>
<td>81.87</td>
<td>93.65</td>
<td>97.85</td>
<td>100.00</td>
</tr>
</tbody>
</table>

**Figure 2.** Histogram of eigenvalues.

**Figure 3.** Correlation circle on PC1 and PC2.
This study shows an increase in admissions of infants under 1 year to the emergency room for asthma on the one hand when the amount of sulfur dioxide and nitrogen dioxide in the air increases, and on the other hand when the population density decreases (Figure 4).

![Figure 4](image.png)

**Figure 4.** Projection of the contribution of individuals on PC1 and PC2.

In contrast, the values of particulate matter less than 10 Micrometer in diameter do not seem to better reflect these effects on the pediatric asthma in the short term, but in the long term and according to numerous studies these particles can cause diseases such as lung cancer and cardiovascular diseases [19-23].

Finally, principal component analysis results confirm effects of environmental air pollution on pediatric asthma in Morocco.

### 4. CONCLUSION

In summary, the principal component analysis results for this work showed that two ambient air pollutants; sulphur dioxide and nitrogen dioxide, were positively associated with admissions of infants under 1 year to the emergency room for asthma. In the short term, the values of particulate matter less than 10 Micrometer in diameter do not seem to better reflect these health effects. But in the long term and according to numerous studies, a strong possibility of establishing links between PM10 and the appearance of diseases (lung cancer, cardiovascular diseases). To our knowledge, this investigation is the first to study the effects of Environmental Air Pollution on pediatric asthma in Morocco.

### ACKNOWLEDGEMENTS

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REFERENCES


