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Statistics Applied to Air Quality on the PaquetáIsland and Governador Island in Rio de Janeiro - Brazil

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ABSTRACT: Over the years, the atmospheric pollution has become more and more a severe problem for the public health. With the increase of traffic flow and industrial activities, for example, the concentration of air pollution increased significantly.For comparison purpose of how much these factors have an influence into the fall of air quality, we analyze the pollutants that are presents in the atmosphere of two regions with different behaviors. The Paquetá Island that does not have a huge traffic flow, neither industrial activities, and the Governador Island, that has traffic and an intensive industrial activity.The air quality analysis involves aspects related to location, rates of pollutants emitted, and outside factors, such as: temperature, wind speed and pressure. The resolution n° 3 of 28/06/1990 by CONAMA, dictates primary and secondary patterns referent to the concentrations of specific chemical compounds, taking into consideration the effects that they may cause for human health.After analyze the data, we compare them with the air quality pattern and highlight the importance of controlling the pollutants emission due to the impact that a particular amount may cause on human health. Finally, we conclude that, even though Paquetá Island does not have activities that cause the emission of harmful pollutants, the same one presented specific compounds in quantities above the primary patterns, like ozone. In this way, we can realize that there is interference of atmospheric pollution from others regions over the atmospheric air in Paquetá Island.

Keywords: Air quality; pollution; Paquetá Island; Governador Island.

I. INTRODUCTION

Climate changes have increasing variables over the years. From the eighteenth century, human activities, fossil fuel began to be used on a large scale, and presents today a description of one of the main fops for a series of consequences currently experienced, the results of an uncontrolled process: The greenhouse effect [1]. Considered to be main factors in temperature rise and disease promotion, pollutants and heavy metals absorb radiation and trap heat in the Earth's low atmosphere, promoting threats to human well-being and health [2]. The pollutants concentration in the air can cause serious health damage. According to analyzes and epidemiological studies, the chances of cardiovascular, respiratory and cancer diseases have factors related to exposure and inhalation of contaminated air [3].

According to the WHO (World Health Organization), about 7 million people die each year due to diseases associated with air pollution [4]. This is mainly due to the increasing urbanization that the cities suffered from the twentieth century. The first reported cases of death due to excessive exposure to pollutants were:

• 1930: Meuse Valley, Belgium — the absence of winds resulted in the non-dispersion of pollutants. Since this was a region with a high concentration of industries, the concentration of pollutants in the atmosphere facilitated the development of respiratory diseases of local population and caused a significant increase in the number of deaths [5].

• 1952: London — The most critical of pollution incidents ever known occurred in the course of five days in the winter of that year, when a thermal inversion, together with a calm and intense mist, made difficult to dissolve the pollutants, which were caused mainly by home heaters and industries, which used coal as fuel. As a consequence of high levels of concentrations of particulate matter and sulfur dioxide in the atmosphere there occurred 4,000 deaths. Similar events registered in the British capital in 1957 and 1962, resulted in 800 and 700 fatalities, respectively.

After these episodes, the intense exposure to the high pollution rates raised a great concern in relation to reduction of the population health.Thus, the first federal regulation granting subsidies for research on air pollution, training, and technical assistance emerged in the USA in 1955.Legislation has been developed and

modified several times over the last few years to adapt to new researches. Brazil began its interest in environmental policies only after the Stockholm Conference in 1972. After this episode, the Special Secretariat for the Environment (SEMA, in Portuguese) has been created [6].
Nevertheless, the mark for the standardization of air quality standards for some pollutants was with Ordinance MINTER 0231, dated 4/27/1976.

By definition, the Environment Ministry (MMA) establishes the air quality as being:
"Interaction product of a complex set of factors such as emissions magnitude, topography and meteorological conditions of region, favorable or not to pollutants dispersion"(MMA).

This being so, for each region, there are different factors that justify air quality.

This study aims to analyze the air quality in Ilha de Paquetá and Ilha do Governador, located in the State of Rio de Janeiro, by means of real statistical methods based on data collected by INEA.

Air quality

Two air quality standards in relation to pollutant control were established by means of a CONAMA resolution:
Primary standards: pollutants concentrations that, out of date, could affect the population health.Secondary standards: pollutants concentrations below which the minimum adverse effect on the population's well-being is expected, as well as the minimum damage to fauna, flora, materials and the environment in general [7].

Pollutant	Sampling Time	Primary Standard µm³	Secondary Standard µm³
Total Suspended Particulates	24h*	240	150
	Mga**	80	60
Inhalable Particles	24h*	15	150
	Maa***	50	50
Nitrogen Dioxide	1h	320	190
	Maa***	10	100
Sulfur Dioxide	24h*	365	100
	Maa***	80	40

Table 1 - Air quality standard [8].
*It must not be exceeded more than once in the year; **Annual geometric mean; ***Annual arithmetic mean

2.1 Air Quality Index (AQI)

Elaborated in Canada and the USA in the 1980s, this index standardizes all pollutants evaluated on a unique scale in order to simplify the exposure of conclusions of air quality monitoring. By means of the air quality index the effect of a certain pollutant can be compared with that of another because a similar index value means an identical effect. Standards included in the index are: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), inhalable particles (P1), total suspended particulates (PTS), and smoke (Belo Horizonte City Hall).Elaborated in Canada and the USA in the 1980s, this index standardizes all pollutants evaluated on a unique scale in order to simplify the exposure of conclusions of air quality monitoring. By means of the air quality index the effect of a certain pollutant can be compared with that of another because a similar index value means an identical effect. Standards included in the index are: sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO), inhalable particles (P1), total suspended particulates (PTS), and smoke (Belo Horizonte City Hall). Based on the concentrations of pollutants inspected and the concentration ranges stipulated for each pollutant, the AQI is measured for each pollutant at the station, and the air quality will be classified from the highest index, that is, it will be established by the pollutant that presents the worst result. The AQI is a numerical value between 0 and 300. The higher the value it emits, the greater the air pollution, and thus the greater the concern for health.
In Brazil, the air quality standards are established by CONAMA Resolution 03/90, for the following indicators:

- Total Suspended Particles (TSP)
- Inalable Particles (IP)
- Sulfur Dioxide (SO_2)
- Nitrogen Dioxide (NO_2)
- Nitrogen Oxide (NO)
- Carbon monoxide (CO)
- Ozone (O_3)

2.2 Air Pollution.

According to the definition of CONAMA [8], atmospheric pollutant is any form of matter or energy with intensity and in quantity, concentration, time or properties in incompatibility with the established levels and that modifies or can modify the air, making it improper or harmful to health [8].According to the Environment Portal [8], pollutants can be divided into two categories: primary pollutants and secondary pollutants. The primary ones are those emitted directly by pollution sources. However, the secondary ones are identified as those formed in the atmosphere by chemical reaction within the primary pollutants and the natural compounds in the atmosphere.

Pollutants	Emission Sources	Health Effects
Particles in suspension (dust)	Incomplete combustion from industry, combustion engines, fires and miscellaneous dust.	It interferes with the respiratory system and can affect the lungs and the whole organism.
SulfurDioxide(SO_2)	Burning fossil fuels containing sulfur, such as fuel oil, mineral coal and diesel oil.	Irritating effect in respiratory tract, which causes coughing and even breath shortness. Aggravating the symptoms of asthma and chronic bronchitis. It also affects other sensory organs.
Nitrogen Oxides (NO_2 and NO)	Burning of fuels at high temperatures in vehicles, airplanes and incinerators.	They act on the respiratory system, which can cause irritations and, in high concentrations, respiratory problems and pulmonary edema.
CarbonMonoxide(CO)	Incomplete combustion of carbon-containing materials, such as petroleum products and coal.	It causes respiratory distress and suffocation. It is dangerous for those who have heart and lung problems.
Ozone (O_3)	It is not a pollutant emitted directly by the sources but formed in the atmosphere by means of reaction between volatile organic compounds and oxides of nitrogen in the presence of sunlight.	Irritation in the eyes and respiratory tract, aggravating preexisting diseases such as asthma and bronchitis, reducing lung functions.

Table 2: Monitored pollutants, their origins and effects to the health

Source: INEA, 2010 [9]

- Total Suspended Particles (TSP)

Any and all solid or suspended material in the atmosphere which is emitted by polluting sources. For example, dust, powder and soot. These particles are classified according to their size. The thicker ones can be retained in the nose and throat, causing irritation and discomfort, besides making the body more susceptible to diseases like influenza [10].

- Inhalable particles (IP orMP10)

Because they are present in air, soot, smoke, dust, mist and aerosol, the inhalable particles belong to the group of suspended solids or liquids that are in the air and do not exceed the size of 10 microns. They are largely a combustion process and can cause premature deaths and respiratory failure due to deposition of the same in the lung [11].

- Sulfur Dioxide (SO_2)

Sulfur Dioxide is a colorless gas resulting from anthropogenic sources and industrial processes, as well as from volcanic gases. The emission of SO_2 can lead to the formation of acid rain and is considered one of the main substances that results from inhalable particles: sulfates. This gas irritates the nose, throat and lungs, causing coughing, shortness of breath, wheezing and phlegm, besides being one of the gases responsible for respiratory and cardiovascular diseases [12].

- Nitrogen Dioxide (NO_2)

One of the responsible for the ozone formation, the nitrogen dioxide is formed by means of the chemical reaction between nitrogen oxide and reactive oxygen. This compound can cause irritation of the nose mucosa and aggressive damage to the lungs in humans [10].

- Nitrogen Oxide (NO)

Nitrogen oxides also belong to the family of air pollutants.Among its emission sources, one can highlight the anthropogenic and natural activities, volcanic activities, lightning, soil microbial activity, ammonia oxidation and photolytic or biological processes in the oceans[13]. In an analysis about health effects, it is extolled eye irritation and increased sensitivity to people with asthma, chronic heart and lung diseases [11,17].

- Carbon monoxide (CO)

According to Peres [14], this compound is a colorless, odorless and tasteless gas.As an example of natural sources, we have volcanic eruptions, spontaneous forest fires and chlorophyll decomposition. For anthropogenic character, we have energy production by hydroelectric plants, among others[15]. In addition, carbon monoxide has a high affinity with blood hemoglobin and can cause serious complications to human health.

- Ozone (O_3)

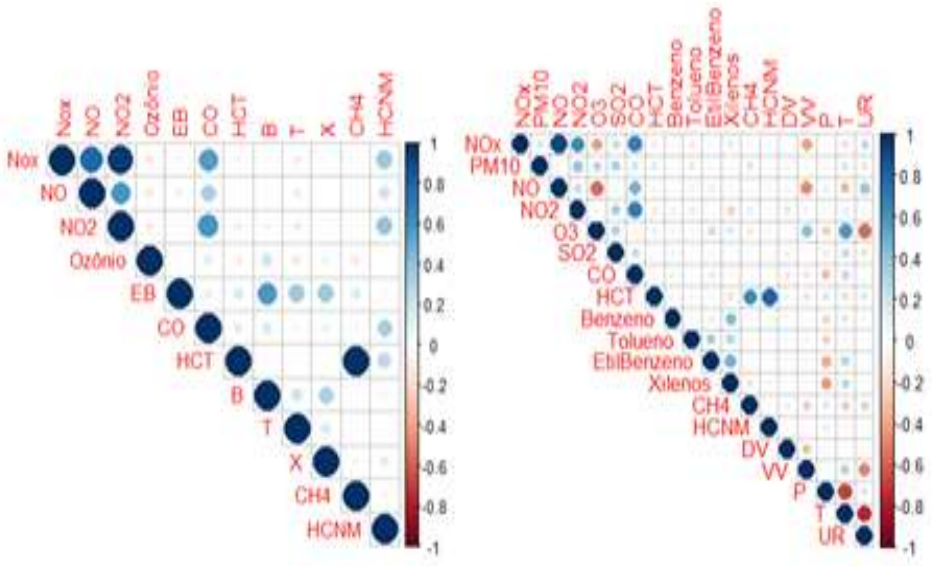
This compound, when present in the higher layers of atmosphere, is charged with protection against ultraviolet rays. However, when formed near the ground, it is a pollutant[10]. The effects of this pollutant are: eye irritation, respiratory difficulties, decreased lung capacity, among others [11,16].

II. METHODOLOGY

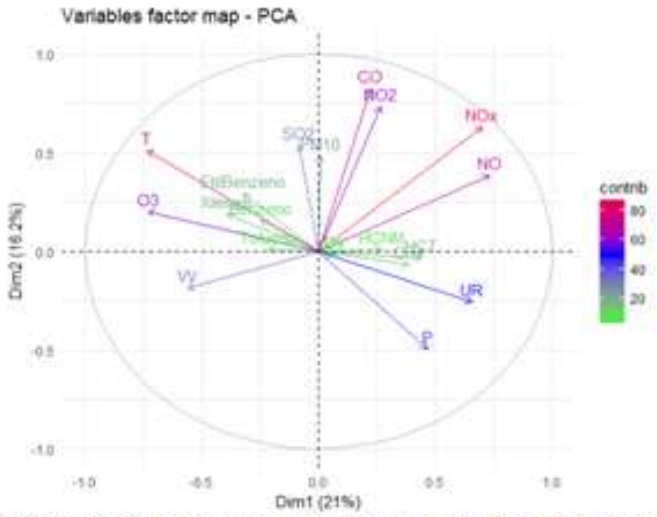
In this study, it was used data of atmospheric pollutant concentrations from the period of 2011 to 2013, collected by air quality monitoring stations and assigned by INEA (State Environmental Institute) [9].These data are obtained by means of the statistical treatment of results regarding the collection and analysis of the air samples in laboratories. During the sampling period of the pollutants concentration, there were problems in monitoring, which made impossible to obtain these data in some periods. The pollutants analyzed were: nitrogen oxides (NOx), ozone (O_3), benzene (C_6H_6), ethyl benzene (C_8H_{10}), toluene (C_6H_5-CH_3), xylene (C_8H_{10}), methane (CH_4), carbon monoxide), sulfur dioxide (SO_2), hydrocarbons (total and non-methane) and inhalable particles (MP10). After data collection, statistical calculations were carried out using R Studio software, in order to correlate the pollutants and their concentrations. For this, the pollutant data listed above, per hour, and the following meteorological conditions were used: wind direction, wind speed, rainfall, pressure, temperature and relative humidity. Also, for comparative purposes, the CONAMA air quality standard was used, in order to verify possible overruns of the standards established by the environmental and health agencies.

III. RESULTS AND DISCUSSION

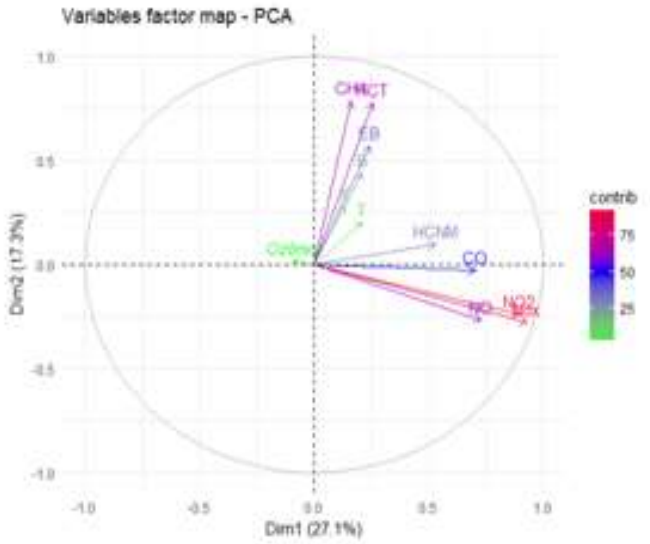
After refining and analyzing the data, it was constructed, by R Studio, the correlation matrices of the two islands. These graphs demonstrate which pollutants and/or weather conditions are related to each other. It is noted that in the Governor's Island matrix, nitrogen monoxide has a great relation with sulfur because they are released during the industrial burning of fossil fuels.
One can also analyze these relationships by means of the dendrograms of each island.



Graph 1: Correlation matrix among the pollutants of Ilha de Paquetá (left) and Ilha do Governador (right).



Graph 3: Dendrogram demonstrating the relationship among the components of Ilha de Paquetá.



Graph 4: Dendrogram demonstrating the relationship among the components of Ilha do Governador.

Considering variations of activities along the days, in the monitoring region, the components that presented the most preponderance were hydrocarbons, nitrous oxides, benzenes and ozone. Much of the emission of these are explained by the presence of anthropogenic activities, in case of Ilha do Governador. The other components did not present significant results.It must be considered that there is the transportation of pollutants by the wind, which may explain the presence of the same in the localities of Ilha de Paquetá.

IV. CONCLUSION

Governador Island has a higher population density when compared to Paquetá Island. Due to several logistic factors of locomotion, way of life and natural and anthropogenic influences, the Paquetá Island also presented pollution and poor air quality.As specified, concentration of several substances in the air may indicate adverse effects on human health. Although Ilha de Paquetá does not enjoy vehicular flow and industries, correlation between factors and substances in the atmosphere shows that, even without vehicular and industrial movement, the presence of pollutants may be present.

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