Mutagenicity in *Tradescantia pallida* as an Indicator of the Effect of Air Pollution and Human Health

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Abstract: The present study aims to relate the micronucleus frequency in *Tradescantia pallida* to environmental factors and cardiorespiratory diseases to infer the effect of air pollution. The number of hospitalizations, diseases cases, frequency of micronuclei in plants, environmental variables, altitude, and vehicle traffic in cities of Mato Grosso do Sul were evaluated due to the high flow that surrounds agribusiness. The frequency of micronuclei decreased with the increase in relative humidity, while the altitude did not influence the mutagenicity or genotoxicity of the evaluated plants. The municipalities with micronucleus frequencies above 200 had the highest number of vehicle and cardiorespiratory diseases. Biomonitoring data obtained in cities throughout the year indicate that the number of cardiorespiratory diseases was probably due to vehicular pollution, which is evidenced by the increased frequency of micronuclei in *T. pallida.*

Keywords: cardiorespiratory disease; frequency of micronuclei; hospitalizations; genotoxicity; mutagenicity; TRAD–MCN

1. Introduction

Air pollution is a global concern that affects the health of humans, animals, and the environment. Several reports from the International Cancer Research Agency [1] demonstrate an association between environmental pollutants and deteriorating human health. These effects related to mortality, cardiovascular and respiratory disease morbidity,
decreased lung function, and an increased number of respiratory diseases [2–6]. Frequent and prolonged exposure is the leading cause of health problems related to air pollution [7,8].

The coverage area of the present study has agribusiness as its main economy and is located on the main access roads for agricultural outlets. Agribusiness accounts for 30% of the Gross Domestic Product (GDP) of Mato Grosso do Sul (MS), being the fifth largest grain producer, the fourth in corn production, and the third in cattle slaughter in the country [9]. Air pollution is highly correlated to agricultural and livestock systems. According to [10], along the food supply chain, agricultural production, processing, and distribution generate air pollutants, mainly greenhouse gases (GHG), Ammonia (NH₃), and particulate matter (PM).

Polluted air contains lung irritants such as ozone and nitrogen oxides that can induce genetic effects [11,12], chronic inflammatory disorders, and changes in the immune system [13]. Pope [14] reported globally relevant data on monitoring the exposure to fine particles found in polluted air. Considering the influence of factors such as diet, tobacco exposure, and lifestyle on the etiology of cardiopulmonary diseases, they showed that every 10 pg/m³ increase in the concentration of fine particles of fuel burn pollution increased by 4%, 6%, and 8% the risk of death from all causes, cardiopulmonary death, and lung cancer, respectively [14]. The Department of Informatics of the Unified Health System—Datasus [15] shows the most vulnerable groups are children, the elderly, and patients with multiple clinical comorbidities.

In addition to the direct harmful effects of air pollution on human health, it causes and intensifies certain phenomena, such as the destruction of the ozone layer, the greenhouse effect, acid rain, thermal inversion, smog, and global warming [16]. These phenomena are directly and indirectly related to climate change and lead to environmental devastation and health problems that are widespread across the world [17]. On the other hand, the growing pressure from policies and management strategies in industrial areas aimed at reducing the levels of pollution has increased the need to improve the methods of air-quality monitoring in urban environments [5,6,18–20]. These strategies seek to answer the wellbeing and health of the population—the third of the Sustainable Development Goals according to the 2030 Agenda for Sustainable Development—to “improve the quality of life of the population”.

*Tradescantia pallida* (Rose) DR Hunt is known to be a plant used for biomonitoring pollution through the Trad–MCN bioassay that quantifies the frequency of micronuclei [21]. It is considered an important tool by many researchers because of its wide distribution, low maintenance cost, and ease of propagation and cultivation [21–25]. Due to the simplicity of the method and the high sensitivity of the plant to genotoxic agents [26–29], this species was adopted for the present study.

Several regions in the state of Mato Grosso do Sul, Brazil, have already been biomonitored regarding air quality [21–25]. However, these results have not been correlated with the cardiorespiratory diseases observed in the population. Mato Grosso do Sul comprises three health macroregions: Campo Grande, Dourados, and Três Lagoas. The macroregion of Dourados includes 33 cities, grouped into four microregions: Dourados, Naviraí, Nova Andradina, and Ponta Porã; the microregion of Dourados is composed of three assistance modules: Dourados, Rio Brilhante, and Fátima do Sul, in which the present study was conducted [30]. The aim of this study is to relate the micronucleus frequency in *Tradescantia pallida* to environmental factors and cardiorespiratory diseases to infer the effect of air pollution.

2. Materials and Methods

2.1. Data Collection

The collection of plant samples and observed data were carried out in May, July, September, and November 2014 in the cities of Laguna Caarapó, Rio Brilhante, Itaporã, Douradina, Dourados, Deodápolis, Fatima do Sul, Vicentina, Gloria de Dourados, Caarapó, and Jateí.
We have established two standardized sampling points: point one consisted of an area with the highest vehicle traffic and a shopping center, and point two was located in residential areas with the lowest vehicle traffic.

A hypsometric map was generated using the digital elevation model data provided by the TOPODATA project of the National Institute for Space Research (INPE) and the data were processed in the Geographic Information System software provided by Quantum GIS, version 2.6. Altitude ranges were calibrated at intervals of 50 m from the base elevation.

2.2. TRAD–MCN Assay Procedures

The TRAD–MCN mutagenic test was performed based on the protocol developed by Costa [31], young shoots of ornamental plants of *Tradescantia pallida* (Rose) DR Hunt var. *purpurea* were collected and fixed in Carnoy’s solution (1 acetic acid: 3 ethyl alcohol). After 24 h, the inflorescences were placed in 70% alcohol. In the laboratory of Applied Botany of the Faculty of Biological and Environmental Sciences (FCBA) of the Federal University of Grande Dourados (UFGD), six slides were prepared using the anthers of the inflorescences magnification and stained with acetic carmine. The number of micronuclei in 300 tetrads per slide was quantified using an optical microscope (Nikon YS2) at 400X the results were expressed as percentages (micronucleus frequency). Four collections were carried out with six samples in each city, that is, 24 samples per city.

2.3. Analyses of Charts

The analysis was retrospective, involving all hospitalizations in the University Hospital (HU) in the year 2014. This work was approved by the Committee of Ethics in Research and Extension of the University Hospital of Grande Dourados-HUGD/EBERH.

Data were obtained from medical records accessed in the University Hospital database, where all the information on hospitalizations in the Unified Health System (SUS) [15,32], through Hospitalization Authorizations (AIH) was available. These authorizations contained information such as sex, age, diagnosis, duration of hospitalization, hospital identification, and unity of the Federation, all computerized and available for public use. Men and women of all ages with a hospitalization period greater than 24 h were included. The information collected was kept in total secrecy.

Initially the sampling covered 15,687 hospitalized patients at University Hospital. Only patients who lived in the respective cities were included in the research. For that, a detailed search was carried out by the Postal Address Code (zip code) presented at the time of hospitalization on the website of the Brazilian Institute of Geography and Statistics (IBGE).

After exclusion, the sampling universe of the cities studied was 10,488 inpatients. Next, a new was search held in the Management System of procedures, Medicines and OPM of the SUS (SIGTAP) based on the pathologies listed in the ICD 10 platform, namely: pneumonia, influenza/flu, chronic airway diseases, heart failure, acute myocardial infarction, arrhythmias, general diseases of the respiratory tract, pulmonary embolism, mycosis caused by dust, acute coronary syndrome, chronic heart disease, pulmonary heart disease, and arterial insufficiency. It is important to note that smokers and cancer patients were excluded.

2.4. Assessment of Vehicular Flow and Environmental Conditions

After studying the area, two points were recognized in each city, where the plants were already established. Collection points were marked with the Garminetrex LEGEND HCx GPS. Vehicular traffic was assessed in each city by counting the number of vehicles per hour circulating at the collection point at three different times of the day: from 8:00 to 9:00 a.m., from 11:00 to 11:59 a.m. and from 5:00 to 6:00 p.m. Subsequently, the average vehicular flow obtained in each city was calculated and compared with data provided by IBGE/DENATRAN (National Traffic Department) [32].

The air quality map was based on the frequency of micronuclei. Spatial features of each municipality with the spatial variation of the attribute under analysis were displayed.
The darker tonality indicated a greater impairment of air quality through a choropleth map, while the lighter color was associated with lower values of impairment. The amplitude of classes (AC) that compose the map was made based on the difference between the highest and lowest value of the micronucleus frequency, being the reference value of 18.19.

During the experimental period weather information obtained in the different seasons of the year was recorded: temperature (°C), relative humidity (RH), and rainfall obtained from the meteorological stations of each locale.

2.5. Statistical Analysis

The experimental design used for the statistical analysis was completely randomized using a factorial scheme with 11 cities, 5 times, and with 6 replicates. After verification of the assumptions of the normality and homogeneity of variances, the data were evaluated using an F-test at 5% probability level. Where a significant difference was found, the means were compared using the Scott–Knott test ($p \leq 0.05$). Cluster analysis, based on Euclidean distance, was performed using the statistical program R version 2.15.2 [33].

Pearson’s correlation analysis was performed for the following environmental variables (mean ambient temperature, relative air humidity, and average rainfall), altitude, frequency of micronuclei, total population, total hospitalizations, registered diseases, and vehicular flow. The significance of the correlation analysis was assessed with a coefficient using a $t$-test at 5% probability level.

The Pollution Indicators Tetrad consists of a four-axis graphical interface where each axis represents an analyzed index; its interpretation is given by checking the position of each end of the polygon formed on the axis in question; the closer to the outer edge, the more representative is the indicator at the studied point. Four pollution indicators (population estimate, cardiorespiratory diseases, micronucleus frequency, and vehicle flow) were used. The indicators were standardized to the same scale (NI), from the sum of the RTM (Ratio to Maximum-value), according to the equation:

$$RTM_{yi} = \frac{V_{yi}}{V_{my}}$$

where: $V_{yi}$ is the value of the evaluated parameter (population estimate, cardiorespiratory diseases, micronucleus frequency, and vehicle flow) at station $i$; $V_{my}$ is the maximum average value of the parameter among all sampling stations; NI is the new index calculated for each component of the analysis (population estimate, cardiorespiratory diseases, micronucleus frequency, and vehicle flow), which at the reference station is equal to 1 for each variable; $RTM_{i}$ corresponds to the $RTM$ of the station under analysis; $RTM_0$ is the corresponding $RTM$ of the reference station.

3. Results

Population data were estimated according to the Brazilian Institute of Geography and Statistics (IBGE), and the total hospitalization according to the Management System procedures, Medicines (SIGTAP) table. The level of pollution was obtained using the micronucleus frequencies observed in each city (Table 1). The city of Dourados had the highest population estimate, the highest record of cardiorespiratory diseases, and the highest frequency of micronuclei, but it was the second largest city in vehicular flow.

It is important to understand the relative importance of the adopted variables in this study for each city in the microregion of Dourados (Figure 1). We found four distinct patterns: (1) high representation of cardiorespiratory diseases and population estimate (Dourados); (2) high representation of population estimates (Laguna Caarapã and Itaporã); (3) high representation of the frequency of micronuclei (Itaporã, Douradina, Fatima do Sul, Deodápolis, Glória de Dourados, and Vicentina); and (4) high representation of ve-
The city of Dourados showed high representation of cardiorespiratory diseases and population estimate, explained by its population that is about seven times larger than the second largest city sampled (Rio Brilhante). In the cities Deodápolis, Glória de Dourados and Vicentina, and Rio Brilhante there was a high representation of the frequency of micronuclei and vehicular flow, explaining that the cumulative pollution recorded in the micronuclei may be related to the high flow of the highway used directly and indirectly for the flow of agricultural production.

Table 1. Estimated population, cardiorespiratory diseases, average micronucleus frequency, and average number of vehicles circulating during the seasons observed in 11 cities in the microregion of Dourados in the year 2014.

<table>
<thead>
<tr>
<th>Cities</th>
<th>Estimated Population</th>
<th>Cardiorespiratory Diseases</th>
<th>Frequency of Micronuclei</th>
<th>Vehicular Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caarapó</td>
<td>25.767</td>
<td>403</td>
<td>213.2</td>
<td>561.87</td>
</tr>
<tr>
<td>Deodápolis</td>
<td>12.139</td>
<td>169</td>
<td>253.3</td>
<td>219.33</td>
</tr>
<tr>
<td>Douradina</td>
<td>5.364</td>
<td>157</td>
<td>112.6</td>
<td>40.33</td>
</tr>
<tr>
<td>Dourados</td>
<td>196.035</td>
<td>8.230</td>
<td>448.0</td>
<td>559.16</td>
</tr>
<tr>
<td>Fátima do Sul</td>
<td>19.065</td>
<td>287</td>
<td>340.3</td>
<td>274.49</td>
</tr>
<tr>
<td>Glória de Dourados</td>
<td>9.927</td>
<td>201</td>
<td>258.1</td>
<td>356</td>
</tr>
<tr>
<td>Itaporã</td>
<td>20.865</td>
<td>294</td>
<td>162.1</td>
<td>110.83</td>
</tr>
<tr>
<td>Jatei</td>
<td>4.011</td>
<td>102</td>
<td>11.3</td>
<td>52.66</td>
</tr>
<tr>
<td>Laguna Caarapã</td>
<td>6.491</td>
<td>143</td>
<td>23.4</td>
<td>40.25</td>
</tr>
<tr>
<td>Rio Brilhante</td>
<td>30.663</td>
<td>180</td>
<td>274.49</td>
<td>674</td>
</tr>
<tr>
<td>Vicentina</td>
<td>5.901</td>
<td>86</td>
<td>251.2</td>
<td>251</td>
</tr>
</tbody>
</table>

Figure 1. Analysis of the Tetrad of Pollution Indicators used for the eleven cities in the microregion of Dourados.
The patterns presented above can be corroborated by the analysis of the correlation between the presented indicators and other environmental variables (Table 2). A high positive correlation was observed between frequency of micronuclei and vehicular flow; a lower significance between the number of the diseases and the estimated total population, followed by the frequency of micronuclei and the estimated total population. Temperature and average rainfall were negatively correlated with total registered diseases.

Table 2. Pearson correlation analysis between the variables: total registered diseases (PR); estimated total population (PT); frequency of micronuclei (MCN); vehicular flow (VF); altitude (ALT); temperature (T °C); relative humidity (RH%); and rainfall (PP mm).

<table>
<thead>
<tr>
<th></th>
<th>PT</th>
<th>MCN</th>
<th>VF</th>
<th>ALT</th>
<th>T (°C)</th>
<th>RH (%)</th>
<th>PP (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PR</td>
<td>0.71 *</td>
<td>0.15</td>
<td>0.13</td>
<td>−0.13</td>
<td>−0.63 *</td>
<td>−0.11</td>
<td>−0.61 *</td>
</tr>
<tr>
<td>PT</td>
<td>0.64 *</td>
<td>0.51</td>
<td>0.15</td>
<td>0.074</td>
<td>−0.20</td>
<td>−0.12</td>
<td>−0.12</td>
</tr>
<tr>
<td>MCN</td>
<td>0.77 **</td>
<td>0.27</td>
<td>0.49</td>
<td>−0.11</td>
<td>0.49</td>
<td>−0.11</td>
<td>0.49</td>
</tr>
<tr>
<td>VF</td>
<td>−0.33</td>
<td>0.31</td>
<td>−0.27</td>
<td>0.31</td>
<td>0.27</td>
<td>0.32</td>
<td>0.32</td>
</tr>
<tr>
<td>ALT</td>
<td>0.016</td>
<td>0.47</td>
<td>0.052</td>
<td>0.052</td>
<td>0.052</td>
<td>0.052</td>
<td>0.052</td>
</tr>
</tbody>
</table>

* significant at 5% level (p ≤ 0.05) and ** 1% (p ≤ 0.01) of probability.

The interaction between the analyzed cities and micronucleus frequency was determined using ANOVA (F = 3.1834; p ≤ 0.01) at different times of the year (Table 3). In general, seasonal patterns were observed: in the month of May, the micronuclei frequency values were low for all cities and did not show any significant difference; in July, the cities of Dourados and Fátima do Sul showed significantly higher values; in September, the cities of Dourados, Rio Brilhante, Fátima do Sul, Glória de Dourados, and Caarapó had significantly higher values; in November, only Dourados had significantly higher values.

Table 3. Micronuclei Frequency (MCN) observed in Tradescantia pallida cells in eleven cities of the Grande Dourados Microregion in four collection periods.

<table>
<thead>
<tr>
<th>Cities</th>
<th>May</th>
<th>July</th>
<th>September</th>
<th>November</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dourados</td>
<td>3.66 ± 1.88</td>
<td>10.00 ± 0.00</td>
<td>18.33 ± 5.03</td>
<td>40.00 ± 1.8</td>
</tr>
<tr>
<td>Rio Brilhante</td>
<td>3.00 ± 1.00</td>
<td>7.16 ± 0.83</td>
<td>15.33 ± 0.33</td>
<td>17.33 ± 0.33</td>
</tr>
<tr>
<td>Laguna Caarapã</td>
<td>3.33 ± 0.03</td>
<td>4.66 ± 0.05</td>
<td>4.66 ± 1.23</td>
<td>-</td>
</tr>
<tr>
<td>Douradina</td>
<td>2.66 ± 1.05</td>
<td>3.49 ± 2.16</td>
<td>7.16 ± 5.21</td>
<td>-</td>
</tr>
<tr>
<td>Fátima do Sul</td>
<td>2.66 ± 0.99</td>
<td>12.66 ± 3.54</td>
<td>11.66 ± 2.00</td>
<td>20.00 ± 3.0</td>
</tr>
<tr>
<td>Glória de Dourados</td>
<td>1.66 ± 0.83</td>
<td>4.33 ± 3.00</td>
<td>10.16 ± 1.83</td>
<td>15.66 ± 1.0</td>
</tr>
<tr>
<td>Vicentina</td>
<td>4.50 ± 2.5</td>
<td>7.99 ± 0.66</td>
<td>8.33 ± 1.67</td>
<td>10.66 ± 3.66</td>
</tr>
<tr>
<td>Deodápolis</td>
<td>1.99 ± 0.33</td>
<td>7.83 ± 0.83</td>
<td>8.66 ± 2.33</td>
<td>16.31 ± 6.94</td>
</tr>
<tr>
<td>Jateí</td>
<td>3.16 ± 0.83</td>
<td>7.33 ± 0.81</td>
<td>6.33 ± 0.00</td>
<td>8.99 ± 2.0</td>
</tr>
<tr>
<td>Caarapó</td>
<td>2.33 ± 0.71</td>
<td>7.99 ± 0.00</td>
<td>10.16 ± 0.5</td>
<td>22.00 ± 8.8</td>
</tr>
<tr>
<td>Itaporã</td>
<td>2.49 ± 0.64</td>
<td>9.33 ± 0.00</td>
<td>9.33 ± 1.67</td>
<td>-</td>
</tr>
</tbody>
</table>

Means followed by the same lowercase letter in the column do not differ from each other by the Tukey (p ≤ 0.05) probability test. - There was no collection.

A Euclidean distance of 125% was used, and five clusters were generated (Figure 2). Dourados was the only city that did not form a cluster with any other city based on higher micronucleus frequency. Smaller clusters were formed between Laguna Caarapã and Jateí, between Douradina and Itaporã, between Deodápolis, Vicentina, Glória de Dourados, and Caarapó and between Fátima do Sul and Rio Brilhante, with the latter being the closest cluster to Dourados. There was a high similarity in micronucleus frequency between Deodápolis and Vicentina, between Rio Brilhante and Fátima do Sul, and between Laguna Caarapã and Jateí.

When the data on micronucleus frequency obtained in the various cities were arranged using kernel mapping, a difference in the color that marks the intensity of pollution was observed (Figure 3). The difference between the highest and lowest values of micronucleus frequency, obtained based on class interval, identified that the cities with micronuclei
over 200, namely Dourados, Rio Brilhante, and Fátima do Sul, showed an indication of the highest pollution indices and highest numbers of cases of cardiorespiratory diseases (shown in navy blue in the map). At the other extreme, the cities of Laguna Caarapã, Douradina, and Jatei, in light blue, with an interval between 1.87 and 20.06, were the cities with an indication of the lowest pollution indices. The cities of Deodápolis, Glória de Dourados, Vicentina (medium blue), and the cities of Itaporã and Caarapó (royal blue) had intermediate levels of pollution (Figure 3). Therefore, there was high similarity between the clusters obtained in the dendrogram represented in Figure 2 and in the spatial distribution map of pollution intensity based on the class interval represented in Figure 3.

Figure 2. Dendrogram of a cluster analysis of the cities evaluated based on frequency of micronuclei.

Figure 3. Kernel map indicating the spatial distribution of the frequency of micronuclei in the microregion of Dourados based on the range of classes.
4. Discussion

In general, the results showed that the high micronucleus frequencies in *Tradescantia pallida* were mainly related to the high vehicular flow and high population density. However, when *T. pallida* was analyzed temporally, it was found that there was a seasonal pattern, with low frequency of micronucleus in autumn, intermediate frequency in winter and spring, and higher frequency in early summer. A correlation was also observed between seasonal aspects, such as temperature and precipitation, linked to cardiorespiratory diseases. Thus, the seasonal characteristics of the region can interfere with the mutagenic action of air pollutants on the tested plant, in the same way as it can act on the incidence of cardiorespiratory diseases in the population.

The relationship between the high values of vehicular flow and the frequency of the micronucleus in at least 11 cities responds to our hypothesis that the mutagenic alteration may be an indicator of air pollution, mainly fomented by urban traffic and agribusiness. With the exception of Dourados, cities such as Caarapó, Deodápolis, Fátima do Sul, Glória de Dourados, Rio Brilhante, and Vicentina have lower populations. They had higher means of micronucleus frequencies, probably as a result of vehicular traffic, which has lately increased in these localities because they are directly involved in the agricultural sector.

BR 163 is the main highway in the state of Mato Grosso do Sul. It passes through the city of Caarapó and is a quick access road to the states of São Paulo and Paraná. The detour that connects the state of Mato Grosso do Sul to São Paulo passes through Glória de Dourados and Deodápolis, resulting in a higher traffic of vehicles. Crispim [22,23] and Spósito [24,25] conducted studies in cities of Mato Grosso do Sul and observed higher micronucleus frequencies in the cities of Dourados, Rio Brilhante, and Caarapó; in addition, they found that the intensity of vehicular traffic resulted in damages to the genetic material and changes in leaf structure of *T. pallida*.

Vehicular traffic in the city of Dourados is more intense than in the other assessed cities. Dourados is made up of several streets and avenues and has a large fleet of vehicles (a mean of approximately 131,095 vehicles) due to its industrial and agricultural and educational activities, according to Departamento Nacional de Trânsito (National Department of Transit) [32]. Rio Brilhante has approximately 14,812 vehicles [32] and is one of the main agricultural hubs in southern Mato Grosso do Sul. Therefore, micronucleus frequency increases with increasing vehicular traffic because this change is directly linked to excess CO₂, nitrogen oxide, and sulfur released by vehicles.

Another important aspect of the study was the seasonal variation in micronucleus frequency, with a significant increase in the winter (cold) and spring (hot) seasons, with a higher mutagenic potential in the warmer months. Other studies reported higher mutagenicity in colder months in North and South America countries [34,35], Europe [36–39], and New Zealand [40]. In general, plants reflect changes in the environment through cellular, biochemical, and molecular responses [22,41]. Thus, the frequency of micronuclei is not only related to an isolated factor, but other factors that depend on site characteristics may influence air quality. Average rainfall and relative humidity were not directly related to the frequency of the micronucleus and other variables. More evidently, Spósito [24] and Rocha [21] observed that the frequency of micronuclei in *T. pallida* decreased with increasing relative humidity, mentioning that low air humidity can lead to a higher molecular weight of the atmospheric pollutant.

The hypothesis that low temperatures and low average rainfall are related to a higher frequency of micronucleus in cities with a high vehicular flow is well presented by Rocha [21]. Cities presenting low temperature days have a layer of resting cold air covered by another layer of resting warm air, creating a smog that contains higher concentration of air pollutants in urban areas, contributing to the higher frequency in micronuclei observed.

The primary risk factors for hospitalization for respiratory diseases include exposure to environmental pollutants, lack of basic sanitation, and exposure to biological and agrotoxic agents. All these factors affect individuals primarily in the extreme age groups, i.e., children up to 5 years of age and individuals over 60 years of age [42]. Some researchers
have studied the occurrence of cardiorespiratory diseases in populations that live or work in places with heavy traffic, who are at high risk of cancer, cardiovascular, and respiratory diseases [43–46].

The principal diagnoses in the analyzed medical records were pneumonia and influenza, followed by chronic diseases of the lower airways (such as acute exacerbation of chronic obstructive pulmonary disease). According to Pitton and Domingos [47], adverse conditions such as heat waves in the summer and extreme cold in the winter associated with a low humidity affect health and wellbeing in several ways, increasing the cases of pneumonia, influenza, and chronic diseases of the lower airways. Climate changes are becoming more frequent and can damage the health of the population. An important fact is that influenza is part of a list of conditions that are manageable under outpatient care and adequately treated in primary care services, not always requiring secondary or tertiary care.

Hospitalizations for respiratory diseases increased from July onwards, i.e., during the winter. According to Costa and Merchán-Hamann [48], the influenza virus has increased viral activity in the winter. The months of extreme drought increase the risk of respiratory tract irritation and exacerbation of chronic conditions because of the reduced relative air humidity and increased level of air pollutants. Thus, the micronucleus frequency in *T. pallida* can be used to infer risks to human health due to exposure to air pollutants, even at low concentrations.

When the relative humidity in air is high, the presence of fungi in the household environment may also explain the number of hospital admissions recorded in July (during winter) because these microorganisms are important allergens, especially in predisposed individuals, and are particularly important in acute crises of asthma and chronic bronchitis [49]. In the months of February and March, i.e., at the beginning of autumn (when people return from holidays), the contact between children with a weakened immune system and children with microorganisms brought from the various family households is a problem reported by Low [50] and is a persistent cause of new cases of hospitalization.

The analysis of each age group shows that children start school at a mean age of 6 years, when they start having closer and longer contact with microorganisms from fomites and direct and indirect contact with other children. According to Freitas [51] and Gouveia [52], the effects of pollution on children were consistent over the studied period, thus demonstrating that pollutants are associated with hospitalizations for infectious and inflammatory respiratory diseases in children and adolescents [53].

Studies conducted by Gouveia [2] in the cities of São Paulo and Rio de Janeiro, in Brazil, showed that the impact of pollution on the number of hospital admissions appear to affect the elderly more than other people. This is particularly relevant in the city of Rio de Janeiro where the levels of pollution are closer to the range with the potential to cause cardiorespiratory damage. The authors emphasize that although the levels of many pollutants are within acceptable limits, especially in Rio de Janeiro, this fact raises awareness of the need to gain further knowledge on the relations between levels of pollutants and their deleterious effects on human health. The Trad–MCN test, which has a low initial investment cost and is simple to handle, can be used to alert residents of these potential risk areas.

5. Conclusions

The changes in micronuclei frequency infer the genotoxic effect resulting from atmospheric pollutants. The cities with the highest frequency micronuclei in *Tradescantia pallida* had the highest vehicle flow and cardiorespiratory diseases rates. In most cities, there has been a gradual increase in genotoxicity parameters over the seasons, with a significant increase in the winter and spring seasons.

Among the abiotic conditions that showed a tendency to potentiate mutagenic changes in the test plant and increase the risk of cardiorespiratory diseases, low environmental temperature and low precipitation can be highlighted.
The frequency of mutagenic alterations in the micronucleus of *T. pallida* were considered adequate for biomonitoring air pollution and inferring the incidence of cardiorespiratory diseases.

It is expected that these data can contribute to the proposition of public policies with the purpose of mitigating such impacts of pollution by vehicular traffic on the environment and public health.

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