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Original article

Assessing the genotoxicity of traffic-related air pollutants by means of plant biomonitoring in cities of a Brazilian metropolitan area crossed by a major highway

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ABSTRACT

The aim of the present study was to evaluate the air quality in residential areas near highways with heavy vehicular traffic in five Brazilian cities by measuring markers of vehicular pollution and to assess the genotoxic effects of these pollutants by pollen abortion assay.

Porto Alegre, Novo Hamburg, Canoas, Sapucaia do Sul and Itapuã were the cities chosen for this study. The biomonitoring assay performed was pollen abortion in *Bauhinia variegata*. Concentrations of atmospheric NO_2 and $PM_{2.5}$ were determined by passive monitoring and active monitoring, respectively.

Results were associated with the city location in relation to the regional major highway. Levels of $PM_{2.5}$ and NO_2 as well as pollen rate were high in Porto Alegre Novo Hamburgo and Canoas compared with Sapucaia do Sul and Itapuã ($P < 0.001$). A strong positive correlation was found between NO_2 and $PM_{2.5}$ ($\rho = 0.73$; $P = 0.013$) and pollen abortion and $PM_{2.5}$ ($\rho = 0.90$; $P = 0.02$).

The cities crossed by the major highway had elevated levels of traffic-related air pollutants and increased genotoxic damages. Air pollution is a common problem in the cities in the metropolitan area of Porto Alegre (MAPA) as they are located near busy highways and is not limited to the main city center. Thus, pollen abortion assay is an effective tool for air pollution monitoring in multiple cities.

1. Introduction

Air pollution is characterized by a mixture of pollutants such as particulate matter (PM), ozone (O_3), nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO), volatile organics, polycyclic aromatic hydrocarbons (PAHs) and metals at disproportionate concentrations in air (Akimoto, 2003). In addition, air pollution is exacerbated near heavy traffic routes. Those who live in residential areas near highways are more exposed to high levels of pollutants (Lawson et al., 2011) and more susceptible to genotoxic damage (de Rainho et al., 2013). The genotoxicity of air pollution in urban areas is frequently assessed by means of plants as bioindicators because of their high sensibility to chemical mutagens as well as their ability to accumulate toxic substances (Greguskova and Mičieta, 2013). Examples of these bioassays are the *Tradescantia pallida* micronucleus (Alves et al., 2014; Santos et al., 2015) and pollen abortion assay (Misik et al., 2007).

The effects of genotoxic compounds on plants can be used for the qualitative and quantitative evaluation of environmental contamination and to delimit risks to biological systems exposed to pollutants. The pollen abortion assay with wild plants is a reliable method for biomonitoring polluted environments since the target cells can accumulate harmful substances and express lethal mutations that affect the development of pollen (Misik et al., 2006). The formation of the aborted grain is the result of genotoxic processes that affect the maturity and fertility of the grain. For this reason, the above-mentioned assay has been employed as a bioindicator of genotoxic effects of several stressors such as radioactivity (Mičieta and Murin, 2007), common cytostatic drugs (Mišík et al., 2015), heavy metals (Calzoni et al., 2007) and atmospheric contaminants (Carneiro et al., 2011).

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Because several air pollutants are known to cause damage to genetic material, the pollen abortion assay is a reliable method for evaluation of air pollution-induced genotoxicity in urban areas. Applications of this test include evaluation of genotoxicity of complex mixtures near an industrial area (Solenska et al., 2006), estimation of the area of influence of pollution emissions produced in a traffic corridor (Carneiro et al., 2011) and assessment of the genotoxic effects of air pollution in an urban-rural gradient (Fleck et al., 2014). However, the use of pollen abortiveness to assess genotoxic damages of vehicular emissions in several cities is not described in the literature.

Therefore, the aim of the present study was to evaluate the air quality in residential areas near intense vehicular traffic highways in five cities of a metropolitan area by means of markers of vehicular pollution ($PM_{2.5}$ and NO_2) as well as to assess the genotoxic effects of these pollutants by using the pollen abortion assay in *B. variegata*.

2. Materials and methods

2.1. Study area characterization

The Metropolitan Area of Porto Alegre (MAPA) is located in southern Brazil. There are 4,258,926 inhabitants in this area. Source: Instituto Brasileiro de Geografia e Estatística. The climate is humid subtropical with heavy and regular precipitation throughout the year. In this study, monitoring points were selected in five cities of MAPA (Fig. 1). All points are located in residential areas equidistant (300 m) from a major highway or road.

Porto Alegre (29°59′39.31″S 51°10′23.05″W) is the capital of the state of Rio Grande do Sul. This city is the daily destination of a great number of workers and students from other cities. Most of the traffic between Porto Alegre and the surrounding cities is concentrated in a highway called BR-116. Information regarding the monitoring area in Porto Alegre is shown in Supplementary Fig. 1.

Canoas (29°54′41.80″ S 51°10′15.78″ W), Novo Hamburgo (29°40′54.86″ S 51°08′22.49″ W) and Sapucaia do Sul (29°49′47.13″ S 51°09′27.15″ W) are cities located around BR-116, near to Porto Alegre. Novo Hamburgo (Supplementary Fig. 2) and Canoas (Supplementary Fig. 3) are crossed by this highway, resulting in increased vehicular traffic from other cities. However, Sapucaia do Sul does not receive direct traffic from BR-116, despite being close to this highway (Supplementary Fig. 4).

Itapuã (30°16′43.62″ S 51° 00′ 43.02″ W) is a small district on the border of Lake Guaíba. This point was selected as the control because it is located far from the urban center. Itapuã (Supplementary Fig. 5) does not have any industrial activity or significant vehicular flow. Table 1 presents detailed information about the studied cities and the vehicular fleet.

2.2. Particulate matter 2.5 μm ($PM_{2.5}$) monitoring

$PM_{2.5}$ monitoring was performed in residential areas of the studied cities. The equipment consisted of a real-time aerosol monitor (DustTrak II Modelo 8532, TSI Incorporated, St Paul, MN, USA) equipped with an impactor which allows the input of particles smaller than 2.5 μm in diameter. These particles are carried to an optical chamber with an infrared beam which, by light scattering, provides the measurement of particles in real time. The flow was programmed to 3 L/min. The equipment records the concentration of PM at the minute level.

The period of sampling was 24 h in every city for two weeks in August (winter) and December (summer) in 2012. The monitoring period was chosen to match the NO_2 sampling period and to provide a link between these pollutants and the pollen abortion assay.

2.3. Passive nitrogen dioxide measurement

Passive nitrogen dioxide measurements were made by assessing NO_2 diffusion in 37 mm cellulose filters (Energética, Rio de Janeiro, Brazil). Exposures were conducted simultaneously with $PM_{2.5}$ monitoring.

Filters (n = 6 per city) were impregnated with 2 mL of an absorbent triethanolamine solution and dried in an oven at 37 °C

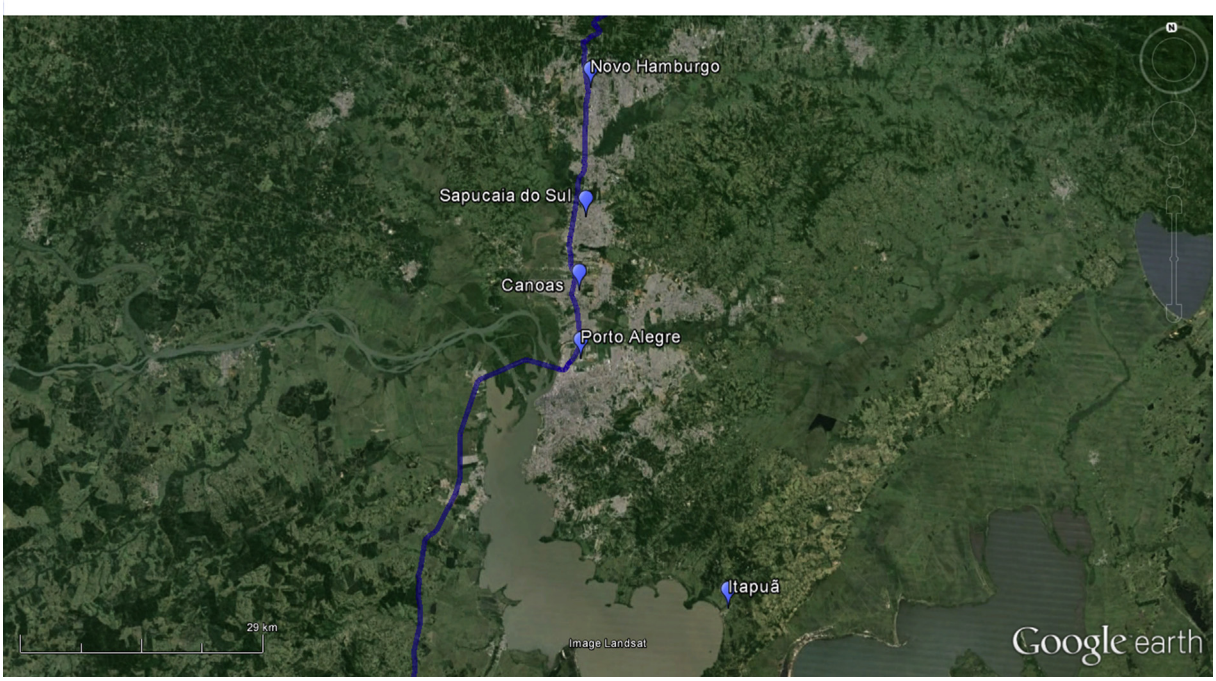

Fig. 1. Location of the studied cities in the Metropolitan Area of Porto Alegre, Brazil.