Atmósfera 29(3), 197-207 (2016)
doi: 10.20937/ATM.2016.29.03.02

Isoprene, benzene and toluene levels at the major landmarks of Rio de Janeiro during the 2014 FIFA World Cup

ELAINE CESAR SOUZA, RAFAEL LOPES OLIVEIRA and GRACIELA ARBILLA
Instituto de Química, Universidade Federal do Rio de Janeiro, Av. Athos da Silveira Ramos, 149, Rio de Janeiro - RJ, 21941-909, Brasil
Corresponding author: Graciela Arbilla; email: graciela@iq.ufrj.br

Received: December 15, 2015; accepted: May 31, 2016

RESUMEN

Se recolectaron muestras de aire en los días anteriores al Campeonato Mundial de Futbol FIFA 2014 y durante la celebración de éste, en los principales puntos turísticos de Río de Janeiro, Brasil. Las muestras fueron recolectadas y analizadas siguiendo el método TO-15 de la US-EPA. El isopreno fue seleccionado como indicador de las emisiones biogénicas, y el benceno y el tolueno como indicadores de las emisiones vehiculares primarias. Se encontraron concentraciones de isopreno, benceno y tolueno en los intervalos 0.39 a 2.32 μg m^{-3}, 2.27 a 10.16 μg m^{-3}, y 5.21 a 21.83 μg m^{-3}, respectivamente. También se calcularon las reactividades cinéticas y mecánicas de estos compuestos para estimar su contribución a la formación de oxidantes atmosféricos. Las concentraciones de benceno y tolueno muestran que las emisiones urbanas impactan de manera considerable las áreas verdes de la ciudad. Los niveles de isopreno son similares a los encontrados previamente en otras regiones con vegetación.

ABSTRACT

Air samples were collected in the days before and during the 2014 FIFA World Cup at the major landmarks of Rio de Janeiro, Brazil. Samples were collected and analysed following Method TO-15 (US-EPA). Isoprene was selected as a marker of biogenic emissions, and benzene and toluene were selected as markers of anthropogenic emissions, primarily vehicular emissions. The isoprene, benzene, and toluene concentrations ranged from 0.39 to 2.32 μg m^{-3}, 2.27 to 10.16 μg m^{-3}, and 5.21 to 21.83 μg m^{-3}, respectively. The kinetic and mechanistic reactivities of these compounds were also calculated to estimate the actual contribution of these compounds to atmospheric oxidant formation. The benzene and toluene concentrations indicated that greener areas of the city are strongly affected by urban emissions. Levels of isoprene were similar to those previously determined in other areas with vegetation.

Keywords: Isoprene, benzene, toluene, 2014 FIFA World Cup, air quality.

1. Introduction

Aromatic compounds are mainly emitted by anthropogenic sources. In urban areas they are mainly due to vehicular emissions. As well as other volatile organic compounds, they play a central role in tropospheric chemistry and photochemical air pollution (Atkinson, 2000). Their negative impact on environmental and public health are also of general concern (Liu *et al*., 2009). Biogenic volatile organic compounds are also emitted by vegetation. Diverse factors influence the emission of biogenic compounds such as light and temperature and their atmospheric concentrations depend on emission factors, meteorology, deposition rates and transport (Kesselmeier and Staudt, 1999).

Rio de Janeiro is the second largest city in Brazil and is home to 6 320 446 inhabitants (IBGE, 2015). It is one of the most visited cities in the Southern

Hemisphere, and it is known for its natural settings, beaches, music and events. Rio de Janeiro's Maracanã stadium held the finals of the 2014 FIFA World Cup, the 2013 FIFA Confederations Cup and both the opening and closing ceremonies of the XV Pan American Games. The city also hosted the 2011 World Military Games and the World Youth Day in 2013. During the 2014 FIFA World Cup, the city hosted 886 000 tourists (471 000 from other countries and 415 000 from Brazil), who spent approximately nine days in the city. A total of 580 000 spectators attended the seven football matches that were held at Maracanã stadium, and 814 000 people participated in the FIFA Fan Fest in Copacabana (Portal da Copa, 2014). These tourists spent an average of R$639/day each in the city, including expenditures for meals, accommodations, travel and leisure; thus, these visitors as a whole injected more than R$4.7 billion into the economy (Portal da Copa, 2014). Rio de Janeiro will host the 2016 Summer Olympics and the 2016 Summer Paralympic Games, which will be the first time a South American and Portuguese-speaking nation has hosted this event and will be the third time the Olympics have been held in a Southern Hemisphere city (Rio 2016, 2015). These major events have provided a unique opportunity to hasten needed infrastructure investments in the city. During these major events, the eyes of the world will be on Rio de Janeiro and its transportation, security, education and environmental quality, the latter of which is discussed in both Brazil and other countries.

In this work, the concentrations of three selected compounds were determined in the most visited locations within the city during the 2014 FIFA World Cup (June 12, 2014 to July 13, 2014). Isoprene (2-methyl-1,3-butadiene) was selected as a marker of biogenic emissions, and benzene and toluene were selected as markers of anthropogenic emissions, primarily vehicular emissions. To the best of our knowledge, isoprene concentrations have never been reported for the Tijuca Forest and the greener areas of the city of Rio de Janeiro. The kinetic and mechanistic reactivities of these compounds were also calculated to estimate the actual contribution of these compounds to atmospheric oxidant formation.

2. Experimental

2.1 Sampling sites

Air samples were collected in the days before and during the 2014 FIFA World Cup at the major landmarks in Rio de Janeiro. A map of the city with the sampling locations highlighted is presented in Figure 1 and the coordinates of the sampling locations and the sampling dates are listed in Table I. All sampling was performed in duplicate using 1.8 L canisters at a height of approximately 1.5 m, as described below.

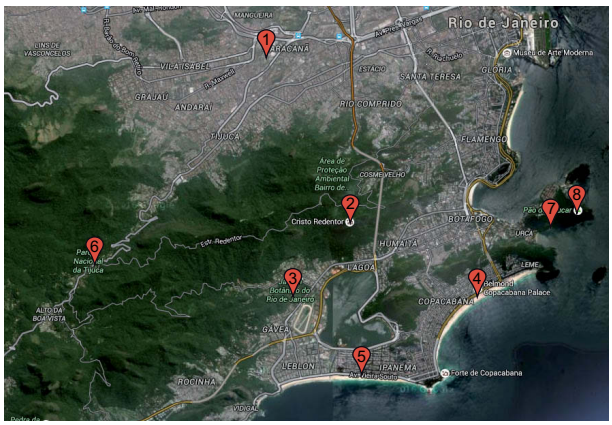

Fig. 1. Map of Rio de Janeiro showing the sampling locations: (1) Maracanã stadium; (2) Corcovado; (3) Botanical Garden; (4) Copacabana; (5) Ipanema; (6) Tijuca forest; (7) Claudio Coutinho trail; (8) Sugarloaf mountain (top). Source: Google Maps.

2.1.1 Copacabana

Copacabana is a neighbourhood located in the south zone of Rio de Janeiro. It is known for its 4.15 km beach located on the Atlantic shore (Rio Guide, 2015). According to the Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics, IBGE), 160 000 people live in Copacabana, and 44 000 or 27.5% of them are 60 years old or over (IBGE, 2015). Hotels, restaurants, bars, nightclubs and residential buildings dot the famous promenade between the ocean and Atlantic Avenue, which is built of black and white Portuguese pavement. Samples were collected in the promenade before the World Cup opening (June 8) and during the event (June 29) in front of the Copacabana Palace Hotel (Post 7), one of the most frequented places in Copacabana. On both days, only one line of Atlantic Avenue was open to traffic. On June 29, many tourists were attending the TV exhibition of the FIFA Fan Fest.

2.1.2 Ipanema

Ipanema is also a neighbourhood located in the south zone of Rio de Janeiro, between Arpoador and