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AIR TOXIC LEVELS DURING THE 2014 FIFA WORLD CUP MATCHES IN SAO PAULO - BRAZIL

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Introduction

FIFA World Cup is one of the most important mass sport events in the planet. In Brazil, a country identified with this sport, the 2014 World Cup encouraged the mobility of Brazilian and foreign travellers to the host cities. The city of São Paulo built one of the biggest stadiums for the competition, in the Itaquera neighbourhood (Itaquera Stadium), which hosted the opening match and several other ones for about one month, from June 12 to July 13, 2014. São Paulo has the country's main international airport and received a great number of Brazilian and foreign passengers coming to São Paulo or on their way to other host cities. Therefore, the circulation in the city increased.

The municipality developed actions to improve urban mobility and public transportation, in order to ensure easy access to matches, such as several restrictions to vehicle circulation in the urban area; school ´s vacations started on June 10, instead of the 30th of June as usually, and lasted until July 14 in order to decrease traffic; daily restrictions to the two last number of license plates was extended to full day instead of only from 7 to 10 a.m. and 5 to 8 p.m. as usual; a special public transportation scheme that included subway, train and buses to reach the soccer stadium; increased safety actions by police were established; some roads on the way of the Itaquera stadium were blocked at 10 a.m. for private cars, giving priority to buses; there was a communication campaign to ask population to give priority to public transportation; the interval between trains and subway trains were diminished; banks were open only from 8.30 a.m. to 12.30; public servants were allowed to go home at noon; many streets were closed in the way to squares where public TV transmission of games were to happen; many bars stayed open for people to watch the games and the nearby streets were closed from 9 a.m. to 8 p.m. However, all those measures were not enough to prevent huge traffic jams in the city, one or two hours before the matches on weekdays. On June 17, 2014, one hour before and during the match against the México team the city registered 302 kilometres of traffic jam, one hour before the game. Usually, the average for this time of the day is 25 to 50 kilometres of slow traffic1.

This situation was considered a good opportunity to study its influence on air quality and on the health of the local population. This air toxic level assessment project was part of a larger study that tried to analyse the influence of the 2014 FIFA World Cup on the air levels and possible health impacts2.

Polycyclic aromatic hydrocarbons (PAHs) are highly toxic pollutants, some are carcinogenic, and they can cause cellular oxidative stress associated with asthma3; they are intimately associated to combustion and mainly to small fraction particulate matter, and vehicles are the most important source of emission to air in the metropolitan region and in special in the city of Sao Paulo. A big portion of PAH is in the solid phase and is part of the particulate matter serving as a proxy for air toxics, including dioxins and furans (PCDD/Fs).

Materials and methods

Air samples were collected by non-automatic mechanical samplers (PS1 PUF samplers from Andersen Instruments, USA) 24 hours long, using quartz filter followed by polyurethane foam plug. The analysis of the 16 priority HPAs was made by GC/MS technique according to the method US EPA TO13A4, considering solid and gaseous phases as one sample. The samplers were installed and operated in two strategic places to measure repercussions of people and vehicles transit especially during matches in São Paulo, one in downtown, namely the gardens of the School of Public Health (FSP) and the other one near the Itaquera soccer stadium. Gathering of data took place during and after the World Cup, in June, July and August of 2014 to characterize the normal condition of the city and compare it with the period of the event. Usually in the period from May to September (autumn and winter time in the Southern Hemisphere), meteorology present worst pollutant dispersion conditions in the area because of lower wind speed, frequent temperature inversions at low altitudes and and low precipitation rates.

Results and discussion

The results of PAHs during the World Cup and after the World Cup of 2014 in Sao Paulo showed the presence of almost all of the 16 priority PAHs. The total of the 16 PAHs concentrations (gaseous +

particle) varied from 10.86 ng m-3 to 69.36 ng m-3 with average 31.58 ng m-3, during the World Cup period, and from 16.70 ng m-3 to 71.89 ng m-3, and average of 42,19 ng m-3 in the period after the World Cup in Itaquera neighbourhood. Phenanthrene showed highest concentrations.

A comparison of the average total PAH levels in the atmosphere (gaseous + particle) reported in this study and those reported in São Paulo – downtown in 20065 and in 20146 is provided in Figure 1. Interestingly, the average concentration of benzo[a]pyrene in Itaquera neighbourhood after the World Cup (3.88 ng m-3) is bigger than that reported in São Paulo – downtown and was above the annual limit of 1 ng m-3, established by European Legislation (EUD 2004).

Lighter PAHs, namely Naphthalene (Nap), Acenaphthylene (Acy), Acenaphthene (Acp), Fluorene (Flu) and Anthracene (Ant), that are characteristic in diesel engine exhausts7 (diesel fuel is mainly used in heavy-duty diesel engines - truck and bus), were in higher concentrations during the World Cup in Itaquera neighborhood. On the other hand, PAHs with higher molecular weight, as Chrysene (Chry), Benzo[b]fluoranthene (BbF), Benzo[k]fluoranthene (BkF), Benzo[a]pyrene (BaP), Indeno[1,2,3-c,d]pyrene (IcdP) and Benzo[g,h,i]perylene (BghiP), characteristic in gasolina engine exhausts8 (light-duty passenger vehicle) were the main source of PAHs in the period after the 2014 World Cup. This observation confirms the results of diagnostic sources obtained through rates. The rates of indeno [1,2,3-cd] pyrene/(indeno [1,2,3-cd] pyrene + benzo[ghi]perylene) was 36 and BaP/(BaP + chrysene) was 0.5 suggest the predominance of emissions diesel vehicles9, 10, 11 during the World Cup in the Itaquera neighbourhood. The rates BaP/(BaP+chrysene) equal 0.73, after World Cup, suggests the predominance of emissions from gasoline-powered vehicles11

A comparison of concentrations calculated in equivalent toxicity relative to BaP, with the factors of toxic equivalence (TEF) proposed by Nisbet and LaGoy (1992)12 and US EPA (1993)13, reported in this study and those reported in São Paulo – downtown5, 6 is provided in Figure 2. The results showed the total concentrations in equivalent toxicity relative to BaP from 4.9 ngTEQ m-3, 1.06 ngTEQ m-3, 0.87 ngTEQ m-3 and 4.55 ngTEQ m-3, in the period of Downtown-20065, Downtown - 20146, World Cup and after World Cup, respectively. After World Cup, BaP contributed with 85% for the carcinogenic activity of the place. Phenanthrene, in spite of being more abundant, contributed approximately with 1% for the total toxicity.

In Figure 3 the results of during and after the World Cup are compared, in equivalent toxicity, for the sum of 7 carcinogenic PAHs - BaA, Chry, BbF, BkF, BaP, DahA, IcdP – by using the same Equivalent Toxicity Factors mentioned. It can be observed that carcinogenic levels in the Itaquera sampling point, during the World Cup period were lower than in downtown areas of Nagasaki, Athens, Bangkok and Rome. However, when traffic conditions returned to usual (after World Cup), carcinogenic levels in Itaquera were slightly lower than the Sao Paulo urban levels in 20065 in spite of many improvements in vehicles emissions after 2007 like the use better quality diesel oil (10 ppm sulphur content diesel available since 2013), implementation of new technologies in diesel heavy engines, dissemination of exclusive bus lanes, intensive use (51%) of flex-fuel vehicles (gasoline and ethanol in any proportion) among others. Compared to the PAH concentrations of selected the foreign cities mentioned, PAH concentrations during the 2014 FIFA World Cup period in Itaquera were significantly lower, and also when compared to levels in the period post 2014 World Cup.

Time series analysis showed concentrations of PM10 and NO2 higher in 2014 World Cup period compared to other periods of the same year and in comparison with the same period of the year 2013; respiratory mortality showed a decrease during 2014 World Cup period in comparison with previous periods of the same year2. On the contrary, cardiovascular disease showed a significant increase in death risk in days when matches were in São Paulo, with lag 0 and 1 day2.

In conclusion, PAH concentrations during the World Cup near the Itaquera Stadium were lower than after the World Cup. Among the possible causes are private car restrictions and the many other measures taken by the municipality during the World Cup period. Besides, the metropolitan train and subway lines serve the Itaquera Stadium area and there was a massive and successful campaign for people going to the stadium to use public transportation. Finally, the study has demonstrated that interventions on the dynamics of mobility in the city might bring positive results to air quality and to health in short and long term, as carcinogenic pollutants effects on health are not immediate.

Acknowledgements
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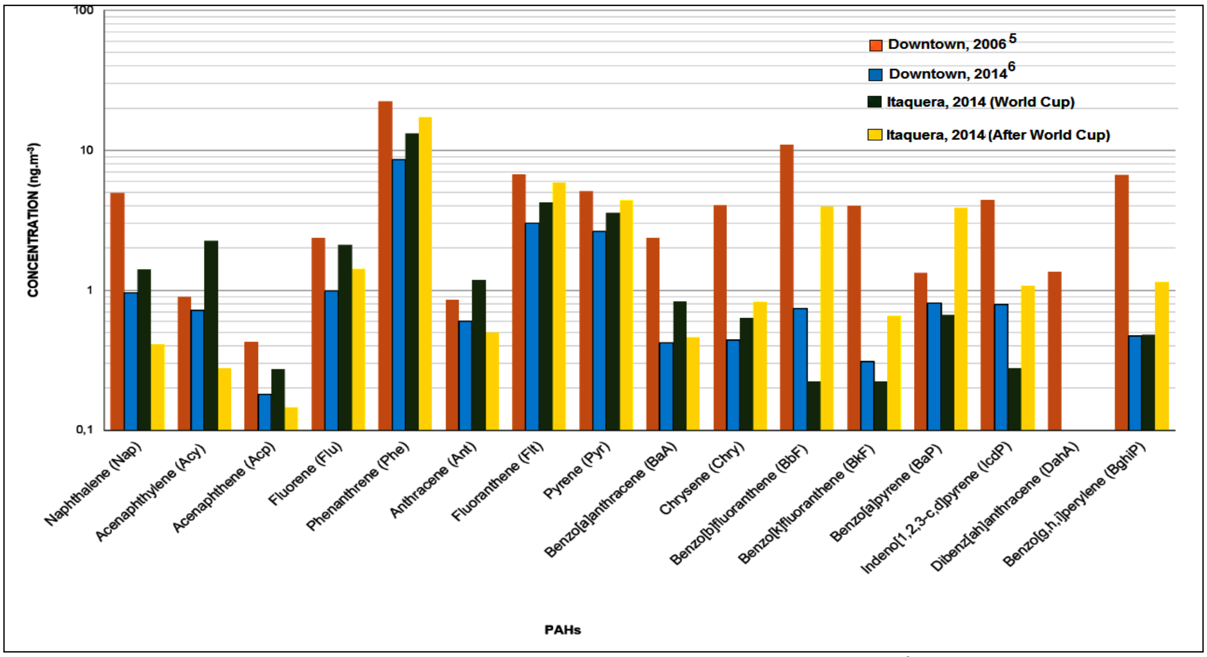

Figure 1. Average total atmospheric (gaseous + particle) PAH concentrations ($ng.m^{-3}$) reported in this study and those reported in São Paulo – downtown in 2006[5] and in 2014[6].

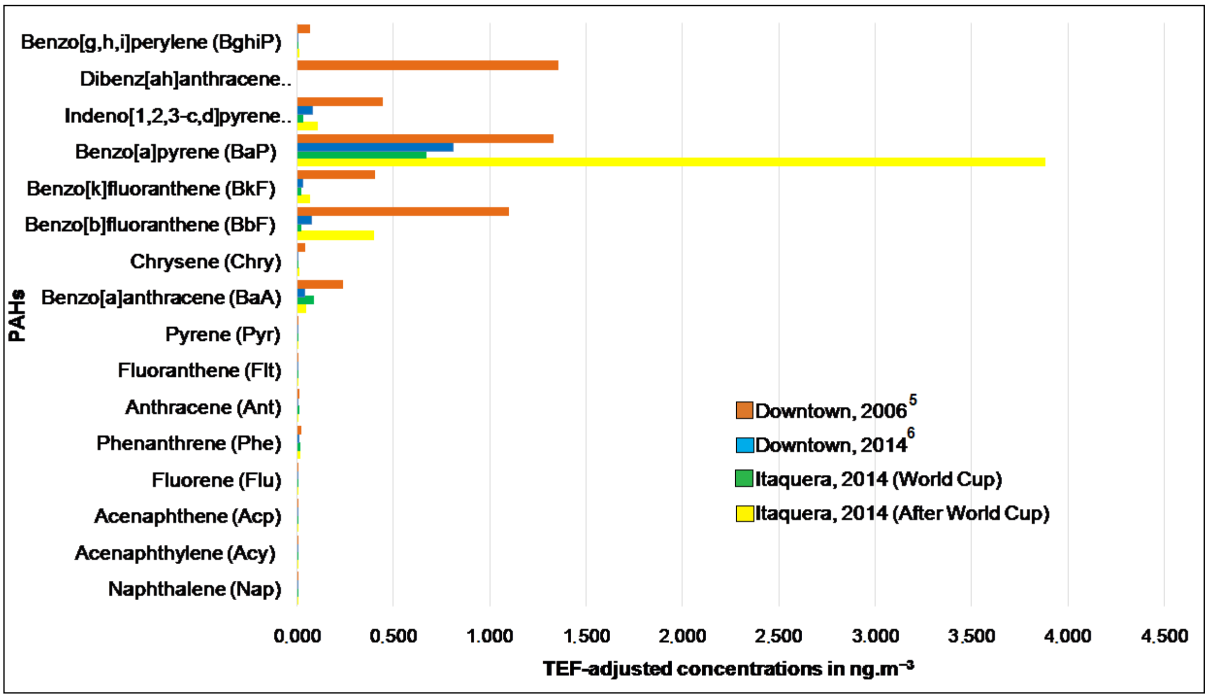

Figure 2. Concentrations calculated in equivalent toxicity relative to BaP, with the factors of toxic equivalence (TEF) proposed by Nisbet and LaGoy (1992)[12] and US EPA (1993)[13], reported in this study and those reported in São Paulo – downtown [5, 6]

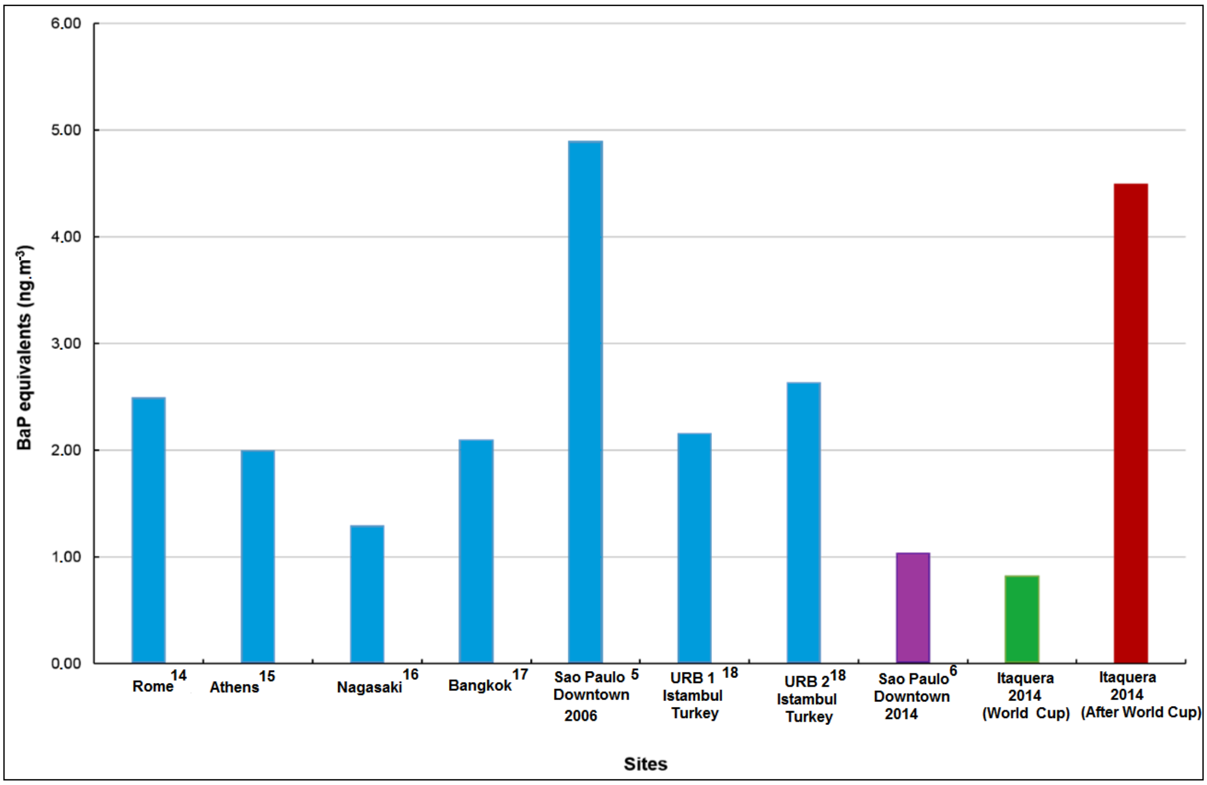

Figure 3. Comparison of concentrations during and after World Cup with those from other studies with the sum of seven selected carcinogenic PAHs, referred to BaP with TEFs of Nisbet and LaGoy (1992)[12] and US EPA[13].