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Clean air for a good start: children are the future of the planet

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Abstract: In early childhood, air pollution leads to an increased risk of disease, premature death, and development of disruptions. Fine particulate matter ($PM_{2.5}$) is considered the classical pollutant of major concern. However, in Brazil, fine particulate monitoring is still limited and restricted to a few cities. Particularly, in the city of Rio de Janeiro, only one automatic station obtains $PM_{2.5}$ concentrations and publishes the air quality indexes daily. This study is part of the project "Clean air for a good start" managed by the Horizon Citizen Foundation, with the goal of obtaining evidence to set a plan to reduce children exposition to air pollution. Data is shared on a global web platform. Results showed that $PM_{2.5}$ levels are high when compared with WHO guidelines and coordinated actions would be needed to decrease emissions of primary pollutants and secondary aerosol's precursors.

Keywords: Childhood health; fine particulate matter; low-cost monitoring; cooperative network; air pollution and health.

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Introduction

According to the World Health Organization (WHO, 2018), in 2016 ambient air pollution was responsible for 4.2 million premature deaths. Of these deaths, approximately 300,000 were children under the age of five years. Air pollution has a devastating impact on children's health, mainly in low- and middle-income countries (LMICs). Indoor air pollution, mainly household pollution produced by the incomplete combustion of fuels (solid fuel and kerosene) used for cooking, produced 3.8 million premature deaths (403,000 among children under the age of five). Household pollution also contributes to ambient (outdoor) pollution as a source of fine particulate matter ($PM_{2.5}$).

The Sustainable Development Goals (SDGs, 2022) show that health, education, environmental and poverty alleviation are the pillars of human development in harmony with nature. Children are the future of the planet and the hope of a more equitable, sustainable, and fair world. Children are, also, the most vulnerable to the effects of air pollution. According to the Global Health Observatory (WHO, 2018), the main causes of deaths among children under five years are prematurity (18%) and acute respiratory infection (16%). The global probability of dying by age five per 1000 live births is 38, ranging from 74 in Africa to 4 in Europe. In Brazil, this number is 12-15, a high value in comparison to United States and Canada (5) and western Europe (3) (WHO, 2021a).

There is ample evidence of air pollution's effects on children's health and survival. Although all key air pollutants (particulate matter, ozone, nitrogen oxides, sulfur dioxide and carbon monoxide) affect different aspects of health, $PM_{2.5}$ is of particular relevance. Fine particulate matter can penetrate deep into the lungs and even enter the bloodstream, predominantly resulting in cardiovascular and respiratory impacts, and also affecting other organs. Several studies published in the last decade showed that exposure to particulate matter is associated with low birth weight, stillbirth, infants born small to gestational age and to the risk of preterm birth. Prenatal and postnatal exposure to air pollution, and in particular to $PM_{2.5}$ can affect neurodevelopment, mental and motor development and lead to behavioral disorders, such as attention deficit/hyperactivity disorder and autism spectrum disorders. Lung function and development may also be affected by $PM_{2.5}$, NO_2 and O_3 and especially particulate matter could lead to pneumonia, other respiratory infections and risk of developing asthma (WHO, 2018).

In 2005, the WHO published the Global Air Quality Guidelines (AQGs), with recommendation for maximum concentration of six pollutants, the so called "classical pollutants": particulate matter with diameter equal or smaller than 10 μm (PM_{10}) and 2.5 μm ($PM_{2.5}$), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide (WHO, 2005). As written by Dr. Maria Neira, Director of WHO's Department for Public Health, Environmental and Social Determinants of Health, "Few risks have a greater impact on global health today than air pollution; the evidence signals the need for concerted action to clean up the air we all breath" (WHO, 2014).

In 2015, the World Health Assembly adopted a resolution, endorsed by 194 Member States, addressing the health impact of air and the need to redouble the efforts of Member States and WHO to protect populations from those risks. As a response to this resolution, WHO organized an expert consultation to identify and discuss the latest evidence on health effects and contribute to future update of the AQGs (WHO, 2015). In September 2021, after 15 years, new AQGs were published (WHO, 2021b). The new document stresses the risks associated with particulate matter and reduced the guideline values. For PM_{10} values were reduced from 20 and 50 $\mu g\ m^{-3}$ to 15 and 45 $\mu g\ m^{-3}$, for the annual mean and the 24-hour mean, respectively. For $PM_{2.5}$ maximum values were reduced from 10 and 25 $\mu g\ m^{-3}$ to 5 and 15 $\mu g\ m^{-3}$, for the annual mean and the 24-hour mean, respectively. The new AQGs are a clear response of WHO to the stronger body of evidence showing how air pollution affects different aspects of health, even at low concentrations.

Facing all these facts, the Brazilian National Air Quality Standards (NAQS) published on November 19, 2018 (CONAMA, 2018), after more than six years of discussions, are clearly outdated, especially considering the proposed interim targets. The new Resolution (number 491/2018) follows the 2005 AQGs and has been fully discussed by Siciliano et al. (2019). The first Interim target values (IT-1) were adopted immediately but there is no predetermined data to adopt the following interim targets (IT-2 and IT-3) and the final NAQS. For PM_{10} and $PM_{2.5}$ the IT-1 annual means are 40 and 20 $\mu g\ m^{-3}$, respectively. The IT-1 24-hour means are 120 and 60 $\mu g\ m^{-3}$, PM_{10} and $PM_{2.5}$, respectively. These values are too high in comparison to the 2005 AQGs and even higher considering the 2021 recommendations and require an urgent update to meet the main goal of protecting public health.

The Air Quality Indexes (AQI) are calculated using the main six pollutants ($PM_{2.5}$, PM_{10}, O_3, NO_2, SO_2 and CO). For PM_{10} and $PM_{2.5}$, the top limit for the first level (good air quality) are 50 and 25 $\mu g\ m^{-3}$ (24-hour means), respectively. These values are higher than the WHO (45 and 15 $\mu g\ m^{-3}$, respectively). The lag between Brazilian legislation and WHO guidelines and the accumulated evidence of significant risks to health, mainly considering $PM_{2.5}$, supports the urgency of a new revision and improvement of Brazilian NAQS, extensive air quality monitoring in Brazilian cities and the implementation of a plan to manage air quality and emission control (DANTAS et al., 2021).

Resolution 491/2018 stipulates that the Ministry of the Environment and the environmental agencies of each State (and the Federal District) should perform the air quality monitoring and draw up a plan to control pollutant emissions considering the NAQS and the economic and geographical features of each state. The plan should have been implemented by November 2021 and should have identified the main pollution sources, the priority areas, the goals and strategies to meet the NAQS (CONAMA, 2018). Air quality management is a great challenge in middle-income countries (DANTAS et al., 2021), but it is also a key step to ensure people´s right to health.

According to the 2018 Report of the State Environmental Institute (*Instituto Estadual do Ambiente*, INEA), the first monitoring measurements in the State of Rio de Janeiro were performed in 1967 (INEA, 2018). INEA, which was created in 2009, has an automatic monitoring network with 58 stations based in the Metropolitan Region of Rio de Janeiro (MRRJ), Meio Paraíba Region and Norte Fluminense Region, and a semiautomatic network with 116 stations monitoring particulate matter every six days (INEA, 2022). The last air quality report was published in 2018 (INEA, 2018) and the last emission inventory, collected data for the MRRJ in 2013 (INEA, 2016). Since the daily air quality report is limited to a few stations, the population has no access to recent complete air quality data. The Energy and Environment Institute (*Instituto de Energia e Meio Ambiente, IEMA*), a non-profit organization founded in 2006, collect and organize air quality data determined by the state environmental agencies and has a national platform updated until December 2020, where INEA data can be found (IEMA, 2021).

In the city of Rio the Janeiro, the Municipal Department of the Environment (*Secretaria Municipal do Meio Ambiente*, SMAC) has also conducted a monitoring program. Since 2012, eight fixed-site and one mobile automatic air quality monitoring stations have been operating (DATA RIO, 2022a) and the IQA Report is published daily (SMAC, 2022). $PM_{2.5}$ is only determined in Irajá station, in the north of the city. Data obtained by the mobile station in the period 2010-2018 showed that the northern and western areas of the city have the worst IQA and ozone and $PM_{2.5}$ are the pollutants of major concern (DATA RIO, 2022a). Although initiatives carried by the municipal governments are welcome, it is worth noting that, according to the national legislation, the air quality monitoring is mandatory for the governments of the States and the Federal District.

Clearly, other solutions are required to obtain air pollution data and identify the impact of different sources of air pollution and the areas and pollutants of major concern. Monitoring air pollution levels and constructing an air quality network could help the identification of possible risks to human health. Moreover, these data should be widely shared to raise society's awareness of the risks it is facing and to ensure people´s right to health. According to the IEMA Annual Report 2019, the WHO guidelines and the NAQS are systematically violated and the death associated with air pollution increased by 14% between 2006 and 2016, accounting for an important fraction of deaths from noncommunicable diseases (IEMA, 2019).

This study presents, as an alternative, the use of low-cost air quality monitors for the determination of $PM_{2.5}$. Data are shared on a global web platform which can be free accessed through computers and smartphones. This study is part of the project "Clean air for a good start" (*Aires Nuevos para la Primera Infancia*) managed by the Horizon Citizen Foundation (HORIZONTE CIUDADANO, 2021), with the goal of obtaining evidence to set a plan to reduce children exposition to air pollution. The collaborative network covers 33 cities in Chile, Argentine, Mexico, Uruguay, Peru, Brazil, Colombia, Nicaragua, El Salvador and Equator, including 14 universities and local governments.

The project is related to the SDGs: a) Goal 3 (ensure healthy lives and promote well-being for all ages) and the associated targets (reduce the global maternal mortality ratio, end preventable deaths of newborns and children and reduce the number of deaths and illnesses from hazardous chemicals and pollution); b) Goal 11 (make cities and human settlements inclusive, safe, resilient and sustainable) and c) Goal 17 (strengthen the means of implementation and revitalize the global partnership for sustainable development) (SDGs, 2022). The project acknowledges the effects of pollution in early childhood which leads to an increased risk of disease, death and developmental disruptions and impacts the life and future of children, mainly those under five years.

The main goals of this article are: a) evaluate the quality of data obtained with the low-cost instrument in comparison with data obtained by the SMAC automatic monitoring station; b) report the data obtained during the first monitoring period; c) present the perspectives of this project and the possibility of using this kind of monitoring as an alternative for a preliminary analysis of air quality and the discussion of an air quality plan focused in the children's well-fare and health.

Experimental method

Studied area

The MRRJ has been previously described by Silva et al. (2017). It has a population of approximately 13 million people and 7,535 km^2. The city of Rio de Janeiro is one of the 22 municipalities of the MRRJ and it is the capital of the state.

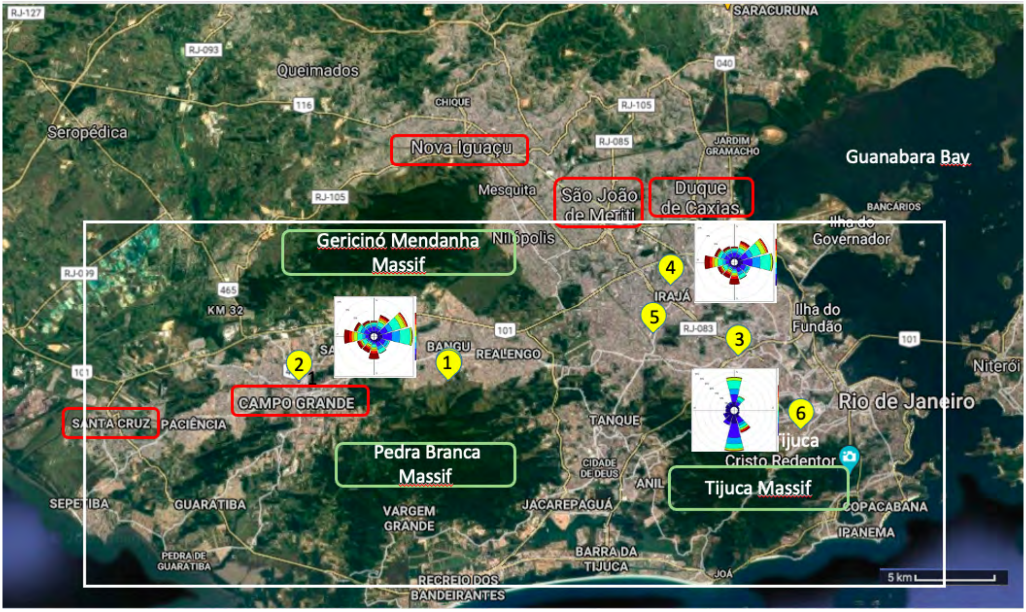
More than 35% of the MRRJ is covered by the Atlantic Forest (*Mata Atlântica*). The main vegetated areas are the Tijuca Forest, Pedra Branca and Gericinó-Mendanha Parks. The Tijuca Forest (with an area of 39.52 km^2) is the largest secondary urban forest in the world (CUSTODIO et al., 2010) and divides the city of Rio de Janeiro in the southern and northern areas. The mountainous regions as well as the Atlantic Ocean and the Guanabara and Sepetiba Bays control the wind patterns and air circulation.

According to the Köppen climate classification, the climate condition is Aw (tropical savanna with dry-winter characteristics), with a dry season (from April to September) and the lower and higher precipitation values in August and January, respectively. The mean annual temperature is 29.0 ^{o}C, with maximum and minimum mean values of 32.2 ^{o}C (February) and 26.4 ^{o}C (July) (DANTAS et al., 2021).

The main industries, located in the northern and western areas, were described by Dantas et al. (2021) and include the chemical, petrochemical, pharmaceutical, food, metallurgic and steel sectors, electricity production, mining, agriculture, and livestock farming. The northern and western areas are characterized by mixed emission sources (vehicular, industrial and biogenic), while the south of the city is a typical urban area impacted by vehicular emissions.

The low-cost instruments were installed in five locations (Figure 1), in the northern and western areas, with schools and day care centers in the vicinity. Another instrument was set at Irajá air quality monitoring station to compare data obtained by the low-cost equipment with those determined according to the Brazilian legislation (MMA, 2019). The selected areas are characterized by poor air quality (DATA RIO, 2022a), low and medium human development indexes (DATA RIO, 2022b) and also for inequalities and poverty.

Figure 1 – Studied locations in the city of Rio de Janeiro (yellow points): 1-Bangu, 2-Campo Grande, 3-Irajá, 4-Madureira, 5-Del Castilho and 6-Tijuca. The approximate area of the city of Rio de Janeiro is within the white rectangle. The main industrial areas are indicated in red (Santa Cruz, Campo Grande and the cities of Duque de Caxias, São João de Meriti, and Nova Iguaçu). The main mountains areas are indicated in green (Tijuca, Pedra Branca and Gericinó-Mendanha). Wind roses were calculated for the studied areas.



Source: Adapted from Google Maps, 2022.

The main characteristics of each location and the studied period (in parenthesis) are described in the following paragraphs.

1. *Bangu* (04/23/2021-11/17/2021)

The district, surrounded by the Gericinó and Pedra Branca mountains, is crossed by the largest source of mobile emissions in the city, Brasil Avenue, and Santa Cruz Avenue (approximately 3 and 1.5 km away from the monitoring location, respectively). The main local emission sources are vehicular (mainly cars, motorcycles, trucks and buses) and natural sources (dust and vegetation). Winds flow from the west and east transporting air masses originating in the western industrial areas and other urban districts in the east and west (vehicular emissions). The equipment was installed in a residential area with houses, moderate light vehicular flow and several day cares, kindergartens and schools (Rei Leão Daycare School, Waldir Azevedo Municipal School, Nações Unidas Municipal School, Bonequinho Doce Kindergarten, Os Cordeirinhos Educational Center) and leisure areas.

2. *Campo Grande* (03/27/2021-11/17/2021)

Campo Grande is the largest district in the western area of the city, with houses and low buildings. The district has several commercial, agricultural, livestock and industrial activities (metallurgy, electrical, food and pharmaceutical). It is also surrounded by the Gericinó and Pedra Branca Massifs with the Atlantic Ocean in the southwest (approximately 15 km). The monitor was installed in a residential area with low vehicular flux, two schools (Rainha Victória Municipal School, Embaixador Araújo Castro Municipal School), a hospital and pediatric center (CEMERU Health Clinic) and a leisure area (Jarici Square).

3. *Del Castilho* (01/22/2021-11/17/2021)

Del Castilho is an urban district in the north of the city with commercial and service activities. The main local emission sources are vehicular (both light and heavy duty) circulating in the main highways (Linha Amarela and Brazil Avenue) and avenues (Dom Helder Câmara). Winds from the north and northeast transport pollutants originating in the industrial area. The monitor was installed in a residential area with residential buildings, high vehicular flux (cars, buses and trucks), commercial activity, several day cares, kindergartens and schools (Plantando o amanhã Kindergarten, Legião da Boa Vontade Kindergarten and Educational Center), hospitals and pediatric centers (Bárbara Starfield Family Hospital, Sérgio Nicolau Amin Family Hospital).

4. *Irajá* (02/18/2021-08/24/2021)

Irajá is an urban area, in the north of the city, with commercial activities. Winds from the north and northeast (night and morning) and from the south and west (afternoon and evening). The main local pollutant sources are vehicular emissions (mainly cars, motorcycles, trucks and buses) and natural sources (dust and vegetation). The district also receives air masses originating in the northern industrial areas and air masses originating in downtown and other urban districts in the south (vehicular emissions). The monitoring station is located in Nossa Senhora da Apresentação Square, a leisure and open walking area, approximately 100 m away from two main streets with high flow of cars and buses. It is also close to Irajá Cemetery, a taxi station and by the entrance of the trucks' parking area of a supermarket. The square is also approximately 100 m away from another market, Água Grande Road, a high-traffic street, and less than 1 km away from the Central Food Supply (CEASA). Near the monitoring location there are day cares, kindergartens and schools (Jeciá de Freitas Ferreira Municipal Kindergarten, Tia Dida Kindergarten, CIEP Maria Werneck de Castro School, Mario Paulo de Brito Municipal School), hospitals and pediatric centers (Deputado Pedro F. Filho Family Hospital, Municipal Health Center).

5. *Madureira* (02/18/2021-08/04/2021)

Madureira district is characterized by commercial, cultural and leisure activities and a high flow of vehicles. The main pollutant sources are local, mainly vehicular emissions (cars, motorcycles, trucks, and buses), and transported air pollutants originating in the northern industrial areas, downtown and other urban districts in the south (vehicular emissions). The equipment was installed in a building, at Madureira Park, where an environmental education project, for approximately 1000 kids, was being performed. Madureira Park is a leisure area (3,800 m^2) including bike lanes, speedway, sport courts, children's play areas and educational activities. Nearby there are schools (Astolfo Rezende Municipal School and Pedro Faria Educational Center), a day care (São Miguel Arcanjo Municipal Daycare) and a hospital (UPA Rocha Miranda Hospital). In August 2021 the environmental education project was deactivated and the equipment was moved to Tijuca district.

6. *Tijuca* (08/17/2021-11/17/2021)

Tijuca district is characterized by commercial activities and a high flow of vehicles (mainly cars and buses) as well as many restaurants, bars and leisure activities. The area predominately receives mountain breeze from the south. The main emission sources are vehicles and natural input (dust and vegetation). The equipment was installed in a residential area with moderate vehicular flux (buses and cars), near a gasoline station and approximately 200 m from Sumaré Massif which is covered by Atlantic rainforest vegetation. In the vicinity there are school (Casa de Jacira School), a day care center (Sonhos Municipal Daycare), two hospitals (Aeronautic Hospital and Casa de Portugal Hospital) and a karate training center for children.

Experimental data

$PM_{2.5}$ concentrations were determined using low-cost air quality monitors (Air Visual Pro). AirVisual uses light-scattering to measure particles. It converts the signal to a particle mass concentration and stores the data on the device memory. Real-time measurements are displayed on the device and transmitted via Wi-Fi connection. These values and 1-hour means are shared globally through the Air Visual app and dashboard (IQAir, 2022). Initially, the monitors were installed in the same location, during four days, and results were compared showing a difference $< 17\%$ between individual values and the mean. The price of this kind of low-cost particulate matter monitor is approximately 1-10% of the cost of reference (or equivalent) equipment recommended in the Environmental Technical Guide edited by the Ministry of Environment (MMA, 2019) depending on the equipment configuration.

Experimental data were initially analyzed to identify spurious values and organized in spread sheets as 1-hour means. Statistical analysis was performed using free software (R, 2022) and current algorithms, recommended in the literature, to calculate and represent the boxplots, as implemented in OpenAir package (OPENAIR, 2022).

Results and Discussion

Comparison with the air quality monitoring station

According to Brazilian legislation (CONAMA, 2018), $PM_{2.5}$ determined at the automatic air quality monitoring station in Irajá are reported as 24-hour means (DATA RIO, 2022a; SMAC, 2022) using a continuous particulate monitor (Met One Instruments Inc., model BAM-1020 Continuous Particulate Monitor, Washington, USA). These results were compared with 24-hour means determined using the low-cost monitor installed at the station (Air Visual Pro). Data were obtained in the period 02/18/2021-08/24/2021. Individual values differ in approximately 20% and median values were 13.2 and 15.8 $\mu g\ m^{-3}$ for the low-cost monitor and the SMAC's equipment (difference 19.7%).

These results show that low-cost monitors reproduce the general behavior of $PM_{2.5}$ levels and can initially be used to evaluate the status of the atmosphere as compared to clean air standards and to other urban areas and to identify areas which require a detailed ambient air quality monitoring using a reference instrument according to Resolution 491/2018 (CONAMA, 2018). In Brazilian and other Latin American cities, where resources are limited and urgent studies are necessary to protect public health, this kind of measurements could provide a first insight into the priority areas.

$PM_{2.5}$ levels determined in this project

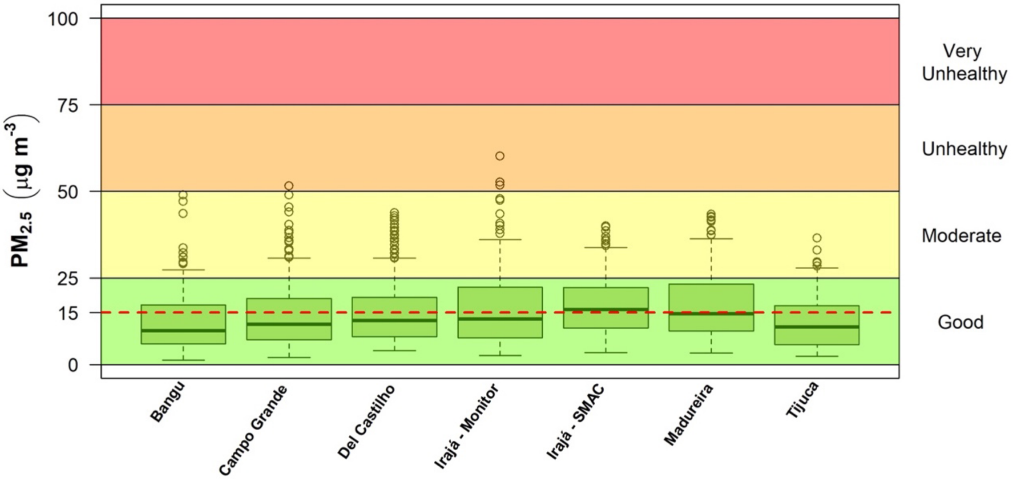
According to the Brazilian legislation 24-hour means in the interval 0-25 $\mu g\ m^{-3}$ represent "good" AQI, while the intervals >25-50 $\mu g\ m^{-3}$, >50-75 $\mu g\ m^{-3}$ and >75-100 $\mu g\ m^{-3}$ correspond to "moderate", "unhealthy" and "very unhealthy" categories, respectively. These values are indicated in Table 1. 24-hours $PM_{2.5}$ concentration means are presented in Figure 2. Values determined by the automatic monitoring station (SMAC), in the same period, are shown for comparison.

Table 1 – AQI intervals according to Brazilian legislation

AQI	$PM_{2.5}$ concentrations ($\mu g\ m^{-3}$)
Good	0-25
Moderate	>25-50
Unhealthy	>50-75
Very unhealthy	>75-100

Source: Adapted from MMA, 2019.

Figure 2 – 24-hour mean concentrations in the studied locations. According to the Brazilian legislation 24-hour means in the interval 0-25 μg m^{-3}, >25-50 μg m^{-3} and >50-75 μg m^{-3} correspond to "good", "moderate" and "unhealthy" categories, respectively. Values determined by the automatic monitoring station (Irajá SMAC) are shown for comparison. The limit 15 μg m^{-3}, according to the WHO, is also shown.



Source: Authors, 2022.

According to the boxplots shown in Figure 2, all median values correspond a "good" air quality, considering the Brazilian legislation. However, approximately 40% of values are > 15 μg m^{-3} (the value indicated by the WHO in 2021).

For a better understanding of these results, in Figure 3 the AQI are shown, calculated on the basis of $PM_{2.5}$. Since AQI should be calculate using all criteria pollutants, values represented in Figure 3 are a lower limit and other AQI could be higher, mainly for ozone and PM_{10} (SMAC, 2022). Concentrations > 15 μg m^{-3} are indicated in purple. The relative number of days in each interval ("good", "moderate", "unhealthy") is shown in Table 2.

Figure 3 – AQI calculated for $PM_{2.5}$ on the basis of Brazilian legislation: "good" (green), "moderate" (yellow), "unhealthy" (orange). The numbers in each box are $PM_{2.5}$ 24-hour means (in μg m^{-3}). Concentrations > 15 μg m^{-3} are indicated in purple.

Source: Authors, 2022.

Table 2 – Relative number of days (%) with AQI "good", "moderate" and "unhealthy", $PM_{2.5}$ levels > 15 μg m^{-3} and median concentration determined for the sampling period

Location	Days	IQA good 0-25 µg m^{-3}	IQA moderate >25-50 µg m^{-3}	IQA unhealthy >50-75 µg m^{-3}	> 15 µg m^{-3}	Median (µg m^{-3})
Bangu	211	89.57%	10.43%	0%	31.75%	8.9
Campo Grande	232	84.48%	15.09%	0.43%	34.00%	11.6
Del Castilho	303	86.14%	13.86%	0%	39.60%	12.7
Irajá	185	80.00%	18.38%	1.62%	43.24%	13.2
Madureira	146	80.82%	19.18%	0%	47.26%	14.7
Tijuca	95	92.63%	7.37%	0%	26.31%	10.9

Source: Authors, 2022.

As expected, the higher values and worst AQI were registered in autumn and winter (mainly in July), during the dry season. In 2021, the rainy period began in October (approximately 110 mm) and fine particulate matter concentrations decreased as a consequence of the precipitation scavenges effect. Unfortunately, due to the difficulties in the implementation of the project, the studied periods are different. Nevertheless, Figure 3 shows that in July, when comparing Bangu, Campo Grande, Del Castilho, Madureira and Irajá, the higher concentrations were determined in Irajá (3 values > 50 μg m^{-3}) and Campo Grande (1 value > 50 μg m^{-3}). In July, values > 15 μg m^{-3} were determined 22 times (71% of values) in Campo Grande, Del Castilho, Madureira and Irajá and 16 times (52% of values) in Bangu.

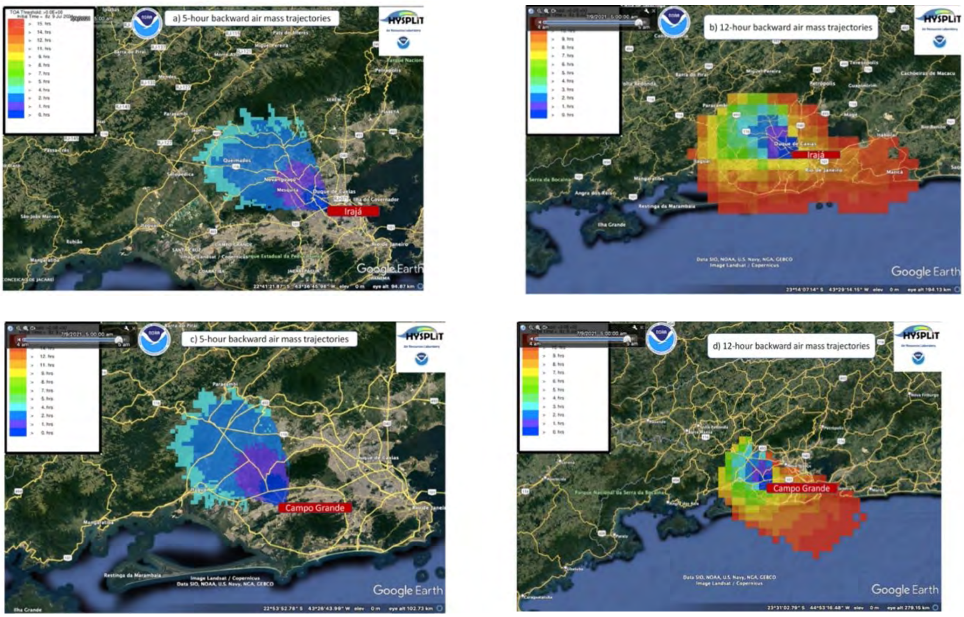
Table 2 shows that > 80% of days met the CONAMA 2018 standard (24 hours mean < 25 μg m^{-3}) in all the studied locations. However, the WHO limit (15 μg m^{-3}) was exceeded in more that 30% of days and, in winter, more than 50% of days. Moreover, according to the more recent WHO guidelines (WHO, 2021b), the limit of 15 μg m^{-3} should not be exceeded more than 3-4 times per year. When the annual means are considered, the Brazilian legislation and WHO established the means 10 μg m^{-3} and 5 μg m^{-3}, respectively. These means cannot be calculated since the monitors were installed a few months ago, but results in Figure 2 and the Table suggest that the 5 μg m^{-3} limit would be certainly exceeded.

Simulation of pollutant's transport

Air masses arriving at the studied locations were simulated using the dispersion model HYSPLIT as implemented by the Air Resources Laboratory (NOAA) and Australian Bureau of Meteorology (HYSPLIT, 2022; ROLPH; STEIN; STUNDER, 2017). The higher $PM_{2.5}$ concentrations were determined on July 9, 2021. In Irajá and Campo Grande the 24-hours means were 52.7 and 51.6 $\mu g\ m^{-3}$, respectively, and in the other locations values were > 30 $\mu g\ m^{-3}$. Using the dispersion model, air masses arriving at Irajá and Campo Grande sites were simulated. Since maximum values were observed at 5:00 a.m. (local time), simulations were performed considering the arriving time 5:00 a.m. and a total simulation time of 5 (Figures 4a and 4c) and 12 hours (Figures 4b and 4d). Figure 4a shows that air masses arriving in Irajá during the night hours originated in the industrial areas in the north and southeast of the Metropolitan Region of Rio de Janeiro (Duque de Caxias, Nova Iguaçu, Belford Roxo and other cities in the chemical and petrochemical complex; see Figure 1). Figure 4b shows that in the previous evening (July 8), air masses were originated in the south and southeast, an urban area characterized by vehicular emissions (light and heavy-duty vehicles).

Similar results were obtained for Campo Grande (Figure 4c and 4d), where the air masses arriving at night were originated in the city of Seropédica (where extractive activities are practiced by several mining companies) and the western industrial area.

Figure 4 – Air masses arriving in Irajá and Campo Grande on July 9, 2021 at 5:00 a.m. (local time): a and c) last 5 hours, b and d) last 12 hours



Source: Authors and HYSPLIT, 2022.

Figure 4 reinforces the complexity of emission sources in the city of Rio de Janeiro and the key role of pollutants originated in other cities of the metropolitan region. Then, any air quality plan to control emissions and improve air quality should consider not only the local sources but also the surroundings, changes in land use, populational growth, green urban areas, transport matrix and main highways and avenues. Emission inventories for stationary sources in the MRRJ are incomplete, limited and with low resolution. For mobile sources (vehicles), the last inventory (2013 base year), published by INEA (INEA, 2016), shows that the main particulate matter emissions are due to vehicles powered by diesel (97%), mainly trucks (60%) and urban buses (approximately 13%). The city of Rio de Janeiro contributes approximately half of the exhaust emissions. Godoy et al. (2018) determined that the vehicular contribution to fine particulate matter was 48% in Duque de Caxias and 70% in Tijuca, with a mean value of 59% for four sampling points within the MRRJ. Recently Dantas et al. (2021) have compiled the main emission sources affecting the city of Rio de Janeiro. Also, Andreão et al. (2020) used the Brazilian top-down vehicular emission inventory of 2012 and the PREP-CHEM-SRC processor tool for air quality modeling in four metropolitan areas of Brazilian southeast, including Rio de Janeiro.

While these are primary emissions, fine particulate matter also has secondary origin which depends on physicochemical processes and emission of precursors (such as volatile organic compounds and nitrogen oxides). Both secondary aerosol precursors and primary aerosols have local origin and are also transported from other areas. The complexity of ozone and $PM_{2.5}$ formation and transport and the nonlinear relation between primary emissions and secondary pollutant concentrations was evident during the lockdown due to COVID-19 pandemic (SICILIANO et al., 2020; CAZORLA et al., 2020). Also, in a recent study, Chiquetto et al. (2020) showed that, in the megacity of São Paulo, high ozone concentrations (which is also a secondary pollutant) are associated to poor urban mobility conditions and suggested that emission restrictions can affect locations tens of km downwind due to atmospheric transport.

The COVID-19 pandemic also raised a new debate about the causal relationship between poor air quality and the incidence or lethality of the virus (GOUVEIA; KANAI, 2020) and also about the pandemic as a consequence of urbanization, globalization and human interactions with the environment (SILVA; ARBILLA, 2020). Investments in education, urban planning, and transportation lead to the reduction of air pollution, a better quality of life for the population, the reduction of epidemics and a healthier future for incoming generations.

As previously discussed (ANDREÃO; ALBUQUERQUE, 2021; DANTAS et al., 2020; GIODA et al., 2021), air quality management involves the identification of concern areas and pollutants and the assessment of human exposure and health effects. In this context, the project “Clean air for a good start” could improve the generation, exchange and accessibility of information on air quality through the participation of universities, municipalities and communities and suggest and implement actions to reduce exposure to air pollution with focus on early childhood. The first stage in the program is particulate matter monitoring and the construction of an open database as well as the interpretation of results. In a second stage, the impact of air pollution on children, mainly those under five years, will be investigated. Finally, results will be discussed with local governments. The project aims to raise awareness and influence to offer new generations a safe environment and a sustainable planet, to reduce mortality rates and improve the wellbeing of future citizens. Results presented in this study are part of the first stage of the project which was continued in 2022.

Conclusions

In Brazil, $PM_{2.5}$ was included as criteria pollutant in 2018. However, fine particulate monitoring is still limited and restricted to a few cities. The lack of resources to install and maintain monitoring equipment and the low number of technicians and monitoring stations are a consequence of the public programs which fail to protect the unalienable rights of citizens related to health and welfare. Project "Clean air for a good start" is the first network joining the efforts of scientists, municipal governments and citizens to implement a regional observatory of air quality and early childhood and support the design of low cost and high impact local action plans, the exchange of experiences and the scaling of initiatives to protect the development and wellbeing of children.

In this study, the first results of the project are presented and show that low-cost monitors could contribute to a preliminary survey of air quality and the identification of areas which require the investments on automatic monitoring stations. Clearly, particulate matter levels are high when compared with WHO guidelines and coordinated actions would be needed to decrease emissions of primary pollutants and secondary aerosol's precursors.

As has been pointed out by WHO, it is not possible to determine a minimum limit in particulate matter, mainly $PM_{2.5}$, below which no harmful effects to health would occur. Childhood is a period extremely sensitive to air pollution and the impacts can go on a lifetime. Then, NAQS should be as low as possible and the governments should implement effective and urgent control plans. Initiatives of universities and civil organizations, like those participating in this project, are welcome and may contribute to raise awareness about air pollution and the related effects on health.

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AMBIENTE & SOCIEDADE 25 anos años years

Ares novos para a primeira infância: as crianças são o futuro do planeta

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João Rogério Borges de Amorim Rodrigues
Bruno Siciliano
Graciela Arbilla

São Paulo. Vol. 26, 2023
Artigo Original

Resumo: Na primeira infância, a poluição do ar leva a um aumento das doenças, mortes prematuras e perturbações no desenvolvimento. O material particulado fino ($MP_{2,5}$) é considerado o poluente clássico de maior importância. No entanto, no Brasil, o monitoramento de material particulado fino é limitado e restrito a poucas cidades. Na cidade do Rio de Janeiro, apenas uma estação registra as concentrações de $MP_{2,5}$ e divulga diariamente os índices de qualidade do ar. Este estudo é parte do projeto "Ares Novos para a Primeira Infância" coordenado pela Fundação Horizonte Cidadão, com o objetivo de obter evidências para estabelecer um plano para reduzir a exposição das crianças à poluição do ar. Os dados são compartilhados numa plataforma virtual global. Os resultados mostram níveis de $MP_{2,5}$ altos quando comparados com as recomendações da OMS e a necessidade de ações coordenadas para reduzir as emissões de poluentes primários e de precursores de poluentes secundários.

***Palavras-chave*:** Saúde infantil; material particulado fino; monitores de baixo custo; rede cooperativa; poluição do ar e saúde.

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Aires nuevos para la primera infancia: los niños son el futuro del planeta

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Bruno Siciliano
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São Paulo. Vol. 26, 2023
Artículo Original

Resumen: En la niñez, la contaminación del aire lleva a un aumento de las enfermedades, muerte prematura y problemas en el desarrollo. El material particulado fino ($MP_{2,5}$) es considerado un contaminante clásico de mayor importancia. Sin embargo, en Brasil, el monitoreo de material particulado es limitado y restringido a pocas ciudades. En la ciudad de Rio de Janeiro, solamente una estación registra las concentraciones de $MP_{2,5}$ y publica diariamente los índices de calidad del aire. Este estudio es parte del proyecto "Aires Nuevos para la Primera Infancia" coordenado por la Fundación Horizonte Ciudadano, con el objetivo de generar evidencias para proponer un plan para reducir la exposición de los niños a la contaminación del aire. Los datos son compartidos en una plataforma virtual. Los resultados muestran niveles de $MP_{2,5}$ altos en comparación con las recomendaciones de la OMS y la necesidad de acciones coordenadas para disminuir las emisiones de contaminantes.

Palabras-clave: Salud infantil; material particulado fino; monitores de bajo costo; red cooperativa; contaminación del aire y salud.