Evaluation of sampling inhalable PM10 particulate matter (≤ 10 µm) using co-located high volume samplers

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Abstract. This paper presents the results of the determination of the concentrations of atmospheric particulate matter ≤ 10 µm (PM10), collected simultaneously by six PM10 high volume samplers from two different manufacturers installed in the same location. Fifteen samples of 24 h were obtained with each equipment at a selected urban area of Rio de Janeiro city. The concentration of PM10 ranged between 10.73 and 54.04 µg m⁻³. The samplers were considered comparable to each other, as the adopted methodology presented good repeatability.

1. Introduction

Aerosol may be defined as a stable suspension of solid and liquid particles in a gas. The atmospheric aerosol is formed by particles with a wide range of aerodynamic diameters (10⁻³ to 10² µm) [1]. These particles result from innumerable sources and processes; therefore, the atmospheric particulate matter (APM) is a complex mixture containing a large number of organic and inorganic species, belonging to a broad variety of families of chemical compounds [2].

A well accepted classification of atmospheric particles employs the aerodynamic diameters as a parameter. This classification takes into consideration the penetration of the particles with 50% efficiency through inlets with cut points of 2.5 and 10 µm, so that two fractions results: PM2.5 and PM10, respectively. This classification procedure considers that the smaller the particle the greater will be their ability to penetrate deeper in the human respiratory tract, where they remaining for long periods, thereby causing high impacts on the human health [1].

The standards for ambient air quality (in terms of µg m⁻³) were defined for some atmospheric pollutants in Brazil, by the Resolution number 3 of the Brazilian CONAMA (Conselho Nacional do Meio Ambiente) [3]. These standards include total suspended particles (TSP) and inhalable particles (PM10). This Resolution also states that the sampling method for the PM10 sampling should be “the high volume method coupled to a system for inertial separation of particles”. The high volume sampler described in the method is non-automatic and contains a specially designed inlet with a cut point of 10 µm.[4] There are equivalent methods, and only those approved in compliance with criteria of the US EPA (Environmental Protection Agency of the US) are considered.

This study aimed obtaining metrological data of PM10. With this purpose, six PM10 samplers were located in the same area and operated simultaneously, for the same period. Therefore, this study allowed obtaining a broader knowledge of the process as well as of the variables, which mostly...
influence the measurements of PM10 concentrations. Although the study was not intended to assess the air quality in the sampling region, the obtained results can be used with this purpose, although they represent a short period campaign.

2. Materials and methods

2.1. PM10 samplers
Six PM10 high volume samplers were used in this study. Three samplers consisted of Thermo Scientific® PM10 inlets mounted on Energética® bases (motors) and three samplers consisted of Energética® PM10 inlet and bases. The inlet is the component through which air enters the sampler and where the particles carried by the air flow are fractioned by inertia at the design cut point of the inlet (i.e. 10 µm). The inlet contains several jet nozzles with appropriate inside diameter and an impaction plate for the retention of particles larger than 10 µm (Figure 1). The base contains – following the direction of the air flow – a filter holder, a Venturi type volumetric flow rate controller, and a motor blower for suctioning the air through the sampler.

2.2. Sampling site description
The six samplers were installed in an open urban area in the neighborhood of Jacaré, in Rio de Janeiro City, Rio de Janeiro State, Brazil (22°53'30.S 43°15'04.W). The samplers were installed on wooden platforms (50 cm high), and distributed in a circular form, with a distance of approximately 2 meters from each other (Figure 2), without physical obstacles such as buildings within a radius of 2 m. In such way, the effects of sampling site differences and wind direction were minimized, following the recommendations of US EPA [5].

2.3. Sample collection
The samples were simultaneously collected between October 16 and November 29 of 2009, on glass fiber filters (Energética E558X10IN), previously equilibrated during 24 h in conditioning chamber
with controlled temperature and humidity. They were weighed using an analytical balance with a sensitivity of 0.0001 g (Shimadzu, model AX200). The samplers were calibrated and operated according to the ABNT standard method (NBR 9547:1997) [6]. The samples were collected during 24 h periods. The meteorological data were obtained at every hour using a meteorological station installed near the sampling site (Met One Instruments, model 466A).

The mass of PM10 was determined as the difference between the average weights of each filter before and after the sample collection. The average weights were obtained from three repeated weight measurements and the volumes of sampled air were determined according to NBR 9547. The concentrations of PM10 were calculated by dividing the net weight of particulate by the volume of sampled air.

3. Results and discussions

3.1. PM10 concentration

The concentrations of PM10 during the studied period varied from 10.73 to 54.04 µg m⁻³. The individual measurements obtained with the 6 samplers were always below the daily average primary standard (240 µg m⁻³) and the daily average secondary standard (150 µg m⁻³), adopted by the Brazilian CONAMA. These results indicate that, as far as PM10 is concerned, the sampling site is submitted to a little impact by particulate pollutants. The concentrations of PM10 measured with the samplers and in the different sampling dates are shown in figure 3. The result of November 2nd for sampler identified as 3-TS was considered an outlier, and, this data was excluded from the subsequent statistical analysis.

The PM10 concentrations measured with the six samplers were quite similar in the different days and showed the same pattern of variation throughout the period of testing (Figure 3). This demonstrated that the sampling process is repetitive, even in the different conditions (different days) that take place at the testing site, especially taking into account that the PM10 concentration can only be assessed with the different samplers when the environmental conditions remain unchanged.

The results obtained are fundamentally important as they indicate that the sampling tests with only one sampler at the site, as it is commonly done, may lead to reliable results.

3.2. Comparison among the PM10 samplers

The performances of the two groups of equipment were verified using parameters established by the US EPA [5]. In such comparison, the instruments manufactured by Thermo Scientific® (designated as TS) were considered as reference, since they are certified by the US EPA, and those manufactured by Energética® (designated as E), as candidate.

The results obtained for both groups of equipments are presented and compared in figure 4. The values of the slope (a), the intercept (b) and the determination coefficient (R²) comply with the prerequisites (a = 1 ± 0.1; b = 0 ± 5; R² > 0.97), thus indicating that there is no difference in the results obtained with the two sets of samplers.
The study was conducted in only one site due the difficulty of finding appropriate and safe locations, thereby limiting the range of concentration measurements. However, since the lower concentrations of particulate matter are more affected by the variability of the sampling systems and of the collection procedure, it was inferred that the resulting range of concentrations have actually strengthened the adequacy of the procedures. Therefore, it was concluded that the measurements with reference group and those with the candidate group turned out on equivalent results.

3.3. Comparison among the dates of sampling tests

Considering that the samplers provide equivalent results, these results were then compared by a single factor analysis of variance (ANOVA), in which the tested factor was the difference between the dates. The value obtained for the calculated F (1344.2) turned out to be larger than the tabulated F (1.86), thus indicating that the results between the dates are different. This outcome was expected as there is variation in the environmental conditions along the days of sampling tests. The relative standard deviation of each sampling day varied from 1.25 to 6.18%, thereby remaining below the maximum value established by the US EPA (7%). This indicated that the results are repetitive on each sampling day, when the non-homogeneous factors of the sampled environment and the variations inherent to the operator are not significant, and that the differences detected by ANOVA among the sampling days ensue from the differences taking place among the concentration values.

4. Conclusions

The results obtained in this study indicate variations among the data of PM10 during the collection days in a short period of time (15 days), since the environmental conditions undergo variation. However, an evaluation of this parameter at a particular point of collection, with six samplers, indicated good repeatability of the results, and, thus, the adequacy of the methodology used for the sampling of this pollutant, as well as the little influence of the operator. This study serves as a support for the estimation of uncertainties in sampling tests using high volume samplers with inertial separation, thus helping researchers and other professionals in the area. Furthermore, it shows that the results are highly comparable on every day, indicating that the results obtained with a single sampler may be considered reliable. Finally, the study demonstrates that the domestic sampling equipment lead to data comparable to those obtained using a certified and imported equipment.

References

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