A MEASURING INSTRUMENT SELECTION CHECKLIST FOR INDOOR PARTICLE POLLUTION STUDIES

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Abstract. *The possibility of acquiring real-time concentration data is leading many indoor air quality and health researchers to the use of particle measuring instruments instead of the classic filtration approach. This paper summarized a checklist of characteristics that have to be considered on the selection of such instruments and checked the compliance of a popular air monitoring device among environmental exposure researchers. Technical, economic and logistics aspects have to be considered. Suitability, measurement range, accuracy, resolution and robustness are indispensable metrological characteristics. The air monitoring device failed the accuracy check. Tests showed no stability in results, their reliability cannot be assured. A good starting point for the selection of manufacturers of such instruments is US Environmental Protection Agency's list of designated reference and equivalent methods for specified air pollutants, which includes particle pollution instrumentation.*

Keywords*: indoor air quality, particle pollution, metrology*

1. INTRODUCTION

Particle pollution is a complex mixture of extremely small solid particles and liquid droplets found in the air. It is made up of a number of components, including acids, organic chemicals, metals, and soil or dust particles. Particulate matter includes inhalable coarse particles, with diameters between 2.5 and 10 micrometers (PM_{10}), and fine particles, with diameters smaller than 2.5 micrometers ($PM_{2.5}$) (EPA, 2009). Indoor sources include human occupants (skin, hair) and activities (cooking, cleaning, smoking, candle and incense burning), plants, pets, appliances (combustion appliances, unvented heaters, printers and photocopiers) and building materials (EPA, 2007; Morawska and Salthammer, 2003). The size of particles is directly related to their potential for causing health problems. Particulate matter, especially fine particles, generally pass through the throat and nose and can get deep into the lungs and even the bloodstream. Once inhaled, these particles can affect the heart and lungs and cause serious health effects, from irritation of the airways, coughing, and difficult breathing, to decreased lung function and irregular heartbeats (EPA, 2009).

In Brazil, the National Health Surveillance Agency (Anvisa) is responsible for the establishment of national norms and standards regarding restrictions on contaminants and other materials which constitute a risk to health. There is a technical orientation with reference standards on indoor air quality with specification for particulate matter (aerodispersoids, 80 $\mu g/m^3$ limit, technical standard 004) (ANVISA, 2003). Sampling method is the collection of aerodispersoids by filtration, sampling protocol ABNT MB–3422, with calibration protocol ABNT NBR–10.562 and laboratory protocol Fundacentro NHO 17. Basically, air is driven by a sampling pump through a filter, which retains the particles and must be weighted in an analytical balance (active sampling, gravimetric analysis, accuracy of measurement 5%). Concentration is determined by dividing the amount of particles retained in the filter by the volume of air that has passed through it. Each filter gives one value of concentration for the entire sampling duration.

The possibility of acquiring real-time concentration data is leading many indoor air quality and health researchers to the use of particle measuring instruments instead of the classic filtration approach. This paper summarizes a checklist of characteristics that have to be considered on the selection of such instruments and checks the compliance of a popular air monitoring device among environmental exposure researchers.

2. SELECTION CHECKLIST

When measuring a physical quantity, it is mandatory to give an indication of the quality of the result in order to assure its reliability. Unless measurements are made with a perfectly accurate instrument under a completely controlled and stable environment and by a flawless operator, the results will have some degree of error. The indication given by the instrument is only an estimate of the result of the measurement, and it is complete only with a statement of the uncertainty of that estimate (Albertazzi and Sousa, 2008; ISO, 1995).

When selecting an instrument for a study, technical, economic and logistics aspects have to be considered. Albertazzi and Sousa (2008) have compiled an evaluation table with desirable characteristics, summarized in the checklist below (Fig. 1). Technical aspects (metrological characteristics) have to be verified at first. Suitability, measurement range, accuracy, resolution and robustness are indispensable. The selection of an instrument must consider the overall performance.

Technical aspects	Economic aspects	Logistics aspects
Suitability Measurement range Accuracy Resolution Velocity Measurement rate Robustness Usability Automation level Data processing resources	Initial investment Operating costs	Delivery conditions Post-sale support Updates

Figure 1. Measuring instrument selection checklist (Albertazzi and Sousa, 2008, adapted)

3. COMPLIANCE CHECK

The TSI SidePak AM510 Personal Aerosol Monitor is a popular air monitoring instrument among environmental exposure researchers (Exposure Science, 2007). Mass concentration of particles is determined in real-time by the use of light scattering technology: mass is determined from the intensity of light scattered by the aerosol within a fixed sensing volume, and the information is converted to units of mass per unit volume (mg/m^3) (TSI, 2006, 2008).

The first characteristic that has to be considered when choosing an instrument for a particle pollution study is its suitability to measure the pollutant. The aerosol monitor identifies particulate matter with diameters between 0.1 and 10 micrometers and is portable, therefore is suitable for indoor particle pollution studies. The measurement range is 0.001 to 20 mg/m^3, which is adequate as the reference outdoor air quality index particulate matter table goes up to 604 µg/m^3 (0.604 mg/m^3) (EPA, 1999). Resolution (1 µg/m^3) and robustness (compact portable system, operating range 0–50°C) are also adequate. However, there’s no specification on accuracy. Without an accuracy specification, there’s no information on the closeness of the agreement between the indication given by the instrument and the real value of particle concentration: there’s no indication on the quality of the result, and its reliability cannot be assured.

Analyzing its calibration certificate, one might notice that there is a remark stating that there is no standard from the US National Institute of Standards and Technology for optical mass measurements, and that the calibration has been done using emery oil and has been nominally adjusted to the respirable mass of standard ISO 12103-1 (A1 test dust, Arizona dust), with calibration ratio greater than 1.2:1. Figure 2 shows environmental conditions and the linearity plot of two calibration certificates. One might notice that the four calibration points were measured under extremely low relative humidity conditions: 22 and 19%, when environmental humidity below 30% is not recommended (EPA, 2008a). These environmental conditions will hardly be found in normal indoor environments. There is no information on the effect of relative humidity on the performance of the monitor on the calibration certificate or even in the user guide, but there is a suggested correction factor at the service and support website which indicates that the performance is affected above 60% RH (TSI, 2009). Also, barometric pressure was below one standard atmosphere (1013.25 hPa), which is the usual for the calibration of instruments (Finnemore and Franzini, 2001; ISO, 1975).

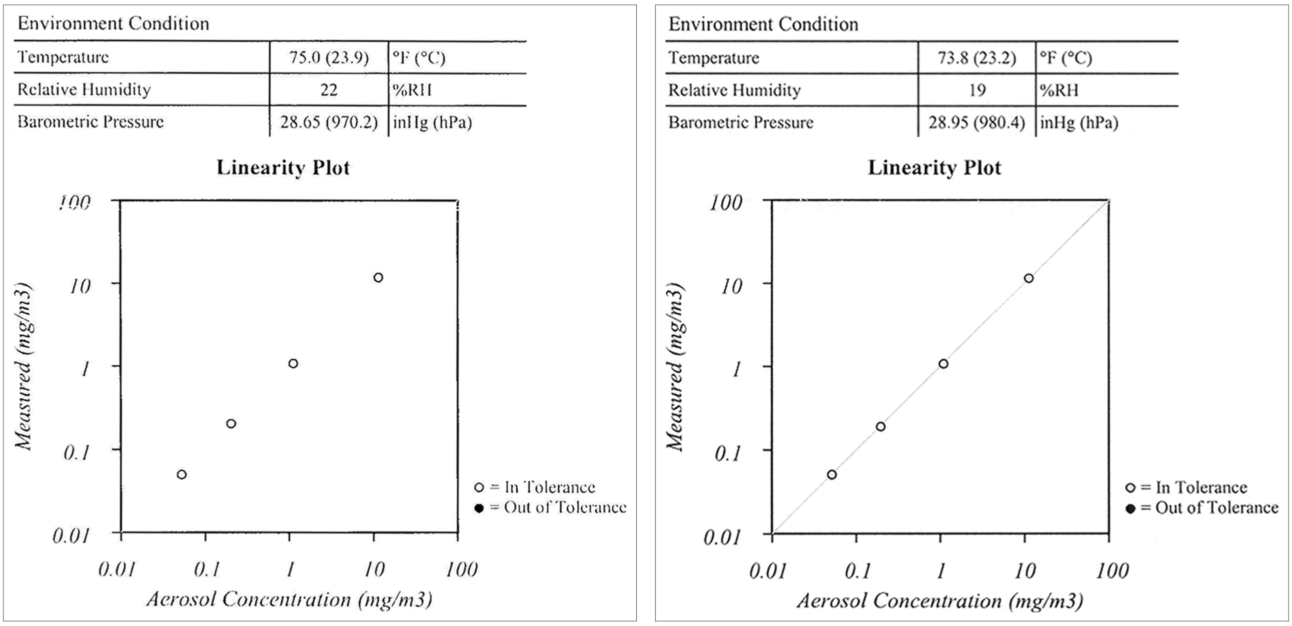

Figure 2. Detail of two calibration certificates (10801009 01/2008, 10711003 11/2007)

An experiment was designed to assess the stability of the aerosol monitor. The concentration curve of clean air in a filter test bench was analyzed. Confined air was filtered by two high efficiency particulate air filters. Data was registered for three hours. Tests were repeated three times with and without the monitor’s built-in filter for zero calibration attached (Fig. 3a, 3b). Figures 4 and 5 show the concentration curves. Under that clean filtered environment, it was expected concentration indications to be near zero $\mu g/m^3$, but graphics show great variation. After the preliminary results the monitor was substituted for a new one in order to test the hypothesis of instrumental failure, but the variation remained.

Figure 3. Filter test bench
(1 aerosol monitor, 2 T and RH transmitter, 3 acquisition points, 4 monitor with built-in filter)

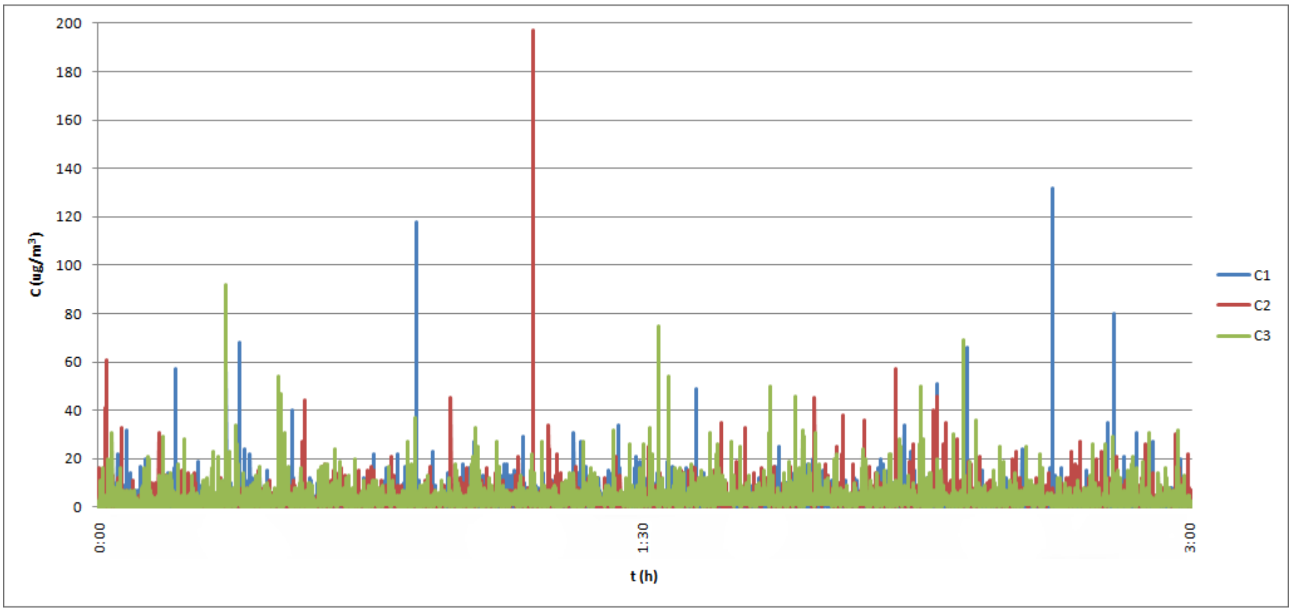

Figure 4. Measured concentration for three independent runs (C1, C2 and C3) under the filter test bench

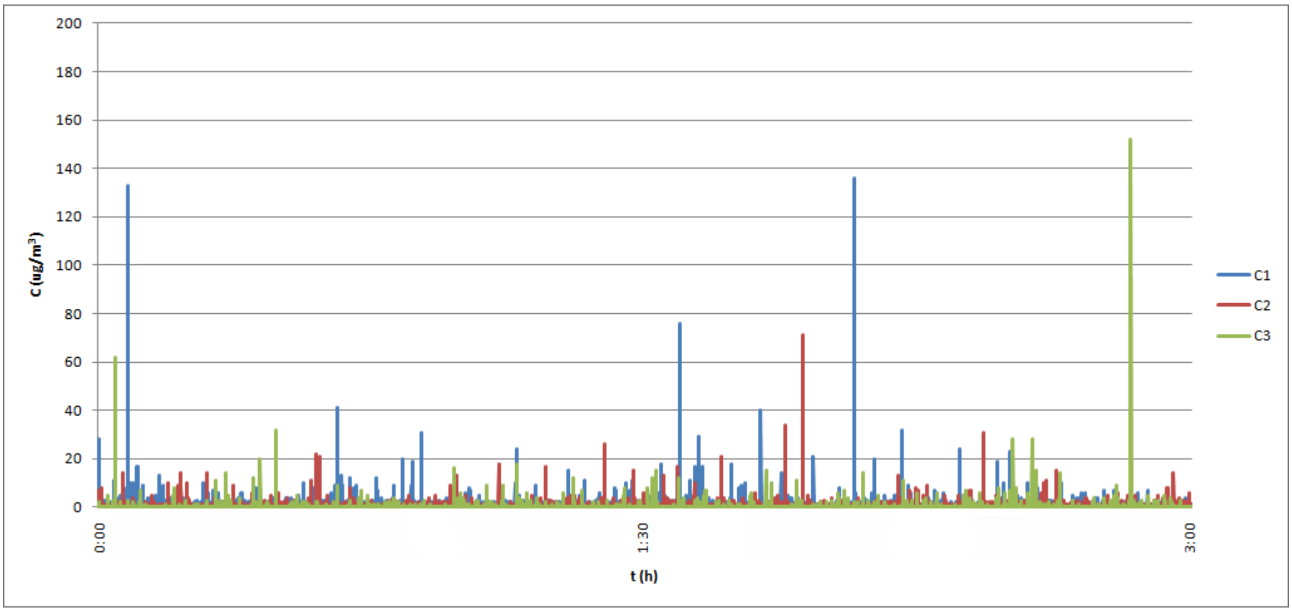

Figure 5. Measured concentration for three independent runs (C1, C2 and C3) under the filter test bench, built-in filter attached

Figure 4 shows concentration indications under the filter test bench. As confined air was filtered by two high efficiency particulate air filters, concentration indications were expected to be near zero µg/m^3, but there was great variation: values up to 197 µg/m^3 were registered. The coefficient of variation for the tests was calculated. The coefficient of variation is the ratio between the standard deviation and the average of a sample, and indicates the dispersion of data: results below 0.2 indicate low dispersion, results above 1 indicate extreme dispersion (Bastos and Duquia, 2007). Results for the tests were all above 1 (1.88, 1.50 and 1.38, respectively), indicating great data dispersion. As tests were ran under the same stable conditions, it was expected a low data dispersion. These results indicate that instrument's repeatability isn't fine. Values above 3 µg/m^3 were considered spurious, and its percentage was above 10% in all three tests (11.12%, 13.30% and 17.30%, respectively), which is a high percentage.

Figure 5 shows concentration indications with the monitor's built-in filter for zero calibration attached. Under this circumstance, with another high efficiency particulate air filters right at monitor's air inlet, concentration indications were expected to be zero µg/m^3, but there was also great variation: values up to 152 µg/m^3 were registered. The coefficient of variation of tests were all above 5 (5.72, 5.88 and 15.20, respectively), indicating extreme data dispersion.

These results again indicate that instrument's repeatability isn't fine. Values above 1 μg/m^3 were considered spurious, and its percentage was above 1% in all three tests (5.56%, 3.19% and 1.81%, respectively).

Without an accuracy specification of the monitor, there's no indication on the quality of concentration results, and its reliability cannot be assured. This would be enough to not consider this instrument for a study. With tests showing no stability in results and no fine repeatability, its reliability cannot be assured at all.

The US Environmental Protection Agency maintains a list of designated reference and equivalent methods for specified air pollutants, including particulate matter (EPA, 2008b). It is a good starting point for the selection of manufacturers of such instruments.

4. SUMMARY

A checklist of characteristics that have to be considered on the selection of measuring instruments was summarized. Technical, economic and logistics aspects have to be considered. Suitability, measurement range, accuracy, resolution and robustness are indispensable metrological characteristics.

The compliance of a popular air monitoring device among environmental exposure researchers was checked and it failed the accuracy check. Tests showed no stability in results, their reliability cannot be assured.

A good starting point for the selection of manufacturers of such instruments is US Environmental Protection Agency's list of designated reference and equivalent methods for specified air pollutants, which includes particle pollution instrumentation.

5. ACKNOWLEDGEMENTS

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7. RESPONSIBILITY NOTICE

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