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Accuracy and reliability of Chile's National Air Quality Information System for measuring particulate matter: Beta attenuation monitoring issue

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ABSTRACT

A critical analysis of Chile's National Air Quality Information System (NAQIS) is presented, focusing on particulate matter (PM) measurement. This paper examines the complexity, availability and reliability of monitoring station information, the implementation of control systems, the quality assurance protocols of the monitoring station data and the reliability of the measurement systems in areas highly polluted by particulate matter. From information available on the NAQIS website, it is possible to confirm that the $PM_{2.5}$ (PM_{10}) data available on the site correspond to 30.8% (69.2%) of the total information available from the monitoring stations. There is a lack of information regarding the measurement systems used to quantify air pollutants, most of the available data registers contain gaps, almost all of the information is categorized as "preliminary information" and neither standard operating procedures (operational and validation) nor assurance audits or quality control of the measurements are reported. In contrast, events that cause saturation of the monitoring detectors located in northern and southern Chile have been observed using beta attenuation monitoring. In these cases, it can only be concluded that the PM content is equal to or greater than the saturation concentration registered by the monitors and that the air quality indexes obtained from these measurements are underestimated. This occurrence has been observed in 12 (20) public and private stations where $PM_{2.5}$ (PM_{10}) is measured. The shortcomings of the NAQIS data have important repercussions for the conclusions obtained from the data and for how the data are used. However, these issues represent opportunities for improving the system to widen its use, incorporate comparison protocols between equipment, install new stations and standardize the control system and quality assurance.

1. Background

In recent decades, a global tendency toward air quality degradation has been observed in several urban areas of the world (Folberth et al., 2014; Parrish et al., 2011; Vallero, 2014), which has been attributed to high concentrations of particulate matter (PM). Of these urban areas, cities such as Sao Paulo, Mexico City, Lima, Buenos Aires and Santiago experience air pollution related to PM (Molina and Molina, 2004; WHO, 2014; Zereini and Wiseman, 2010) that poses a risk to human health (Kampa and Castanas, 2008; Kim et al., 2015; Leiva G et al., 2013). Studies performed by the World Health Organization (WHO) show that air pollution causes cancer in humans; in particular, PM is the air pollutant responsible for the most cases of cancer, especially lung cancer (IARC/WHO, 2013). It was estimated that by the year 2012, 3.7 million people worldwide had died prematurely due to exposure to particles with aerodynamic diameters less than 10 μm (PM_{10}) (WHO, 2014).

In most cities in Chile, there are air quality problems related to the presence of high levels of PM_{10} and $PM_{2.5}$ (particulate matter with an aerodynamic diameter under 2.5 μm) (Díaz-Robles et al., 2011; MMA, 2013). The annual average concentration for PM_{10} and $PM_{2.5}$ exceeds the guidelines established by the WHO for PM_{10} and $PM_{2.5}$, as well as the air quality national standard of Chile, in several cities in Chile (see Fig. 1). Moreover, the official 2011 Report of the State of the Environment in Chile, developed by Chile's Environment Ministry (MMA), highlighted that at least 10 million people (60% of the country's population) are exposed to an average annual concentration of $PM_{2.5}$ higher than the national standard (20 μg m^{-3}) (MMA, 2011). Additionally, it was estimated that at least 4000 deaths every year are caused by chronic exposure to $PM_{2.5}$ (MMA, 2011).

Air quality monitoring stations have been installed in Chile since the 1990s (Morales and Leiva G., 2006; Ulriksen, 1993). Initially, the responsibility for monitoring the air quality was shared by several institutions in the country: the Ministry of Health, the Farming and Livestock Service, the MMA, private companies and NGOs. However, since 1 January 2012 the MMA is solely responsible for the administration and implementation of public stations and networks to monitor the air quality.

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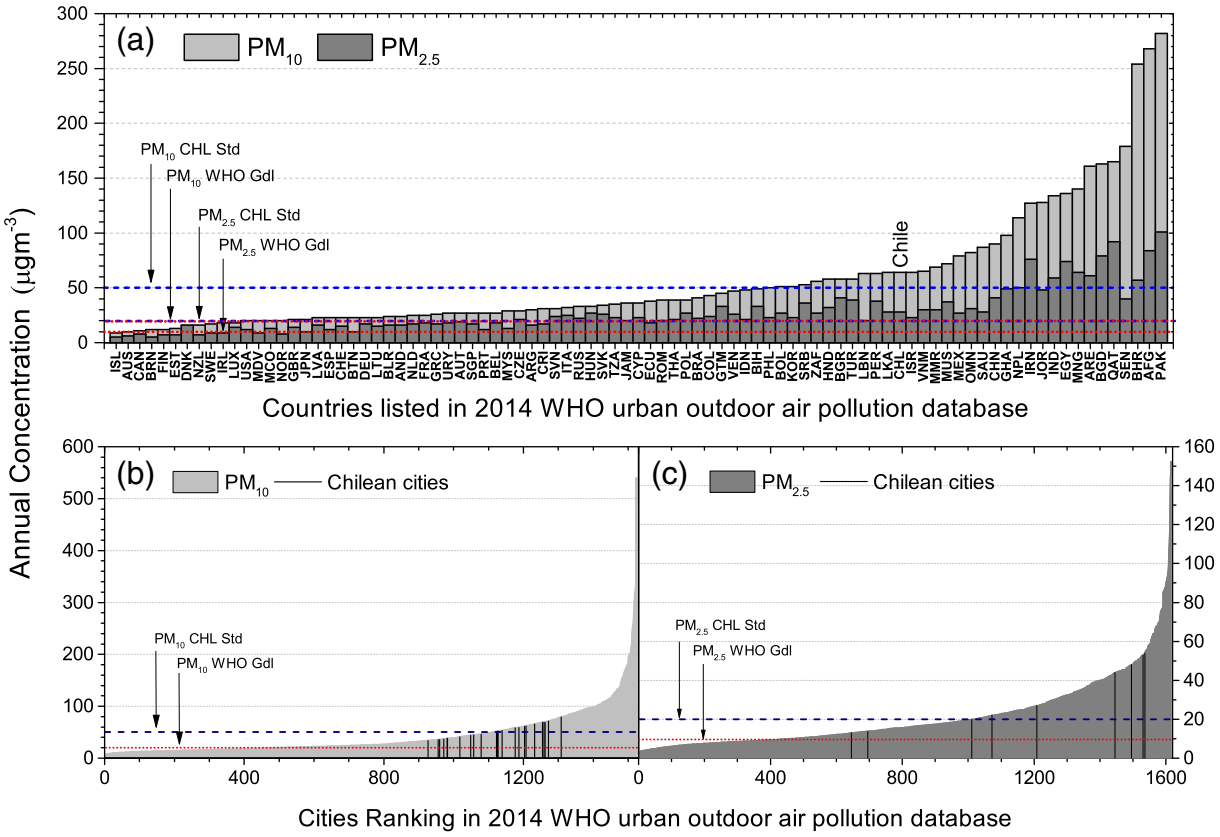

Fig. 1. Ranking of concentrations of particulate matter in different counties (a) and cities around the world for PM_{10} (b) and $PM_{2.5}$ (c) (WHO, 2014). Black line are chilean cities listed in *Database of Atmospheric (outdoor) air pollution in cities*, (WHO, 2014). Blue dash line is a Chilean air quality standard (PM_x Cl STd) and red dot lines is the WHO air quality guideline (PM_x WHO-Gdl).

The air quality information in Chile is obtained from public and private monitoring networks. This information is centralized at the National Air Quality Information System (NAQIS) that is currently managed by the MMA (SINCA, 2015). Through the NAQIS, the MMA, provides viable and reliable access to air quality information, assesses compliance with standards, proposes measures to prevent and control pollution, implements measures to protect public health as specified in the law, provides reliable data for scientific research, optimizes available resources, avoids loss of resources and avoids task duplication (SINCA, 2015).

Information about air pollutant concentrations in the environment is available to the public at the NAQIS website (SINCA, 2015). This site is widely used to develop several official reports as well as scientific studies about the state of the air quality, especially regarding PM concentrations. This information has been used in epidemiological studies (Díaz-Robles et al., 2014; Leiva G et al., 2013; Sanhueza et al., 2009), high pollution events forecasting (Cassmassi, 1999; Díaz-Robles et al., 2008; Perez and Reyes, 2006), studies concerning the relation between the chemical and physical compositions of PM (Morales and Leiva G., 2006; Morata et al., 2007; Toro A. et al., 2014), analyses of spatial and temporal trends (Gramsh et al., 2006; Morales and Leiva G., 2006; Toro A. et al., 2014), assessments of the cost and efficacy of prevention and decontamination measures (Silva and Quiroz, 2003; Toro A. et al., 2014). At a governmental level, the reports regarding the state of the air quality in Chile are noteworthy because the government's main objective is the enforcement of regulations, laws or international treaties signed by Chile. Examples of these noteworthy reports include the Official Environment Status Report 2011 (Chapter 1) (MMA, 2011), First Report about the State of the Environment 2013 (MMA, 2013), OECD Environmental Performance Reviews: Chile 2005 (OECD, 2005), and Database of Atmospheric (outdoor) air pollution in cities, 2014 (WHO, 2014).

To properly assess air quality standards, implement prevention and decontamination policies and develop scientific research using the information available at the NAQIS, the information must be reliable (MMA, 2014). For this reason, this paper presents a critical analysis of the information available at the NAQIS. This paper examines the reliability and completeness of the information, the characteristics of the equipment used in the measurements and the implementation of quality assurance and quality control (QA/QC) programs. Additionally, this paper discusses the repercussions of using beta attenuation monitoring (BAM) detectors, which has been proven to underestimate the 24-hour standard in some areas of the country highly polluted with PM_{10} and $PM_{2.5}$, in monitoring networks. Finally, this paper highlights the need for the relevant authorities to implement constant improvements to the NAQIS systems.

2. Materials and methods

2.1. National Air Quality Information System website

The NAQIS can be accessed via a website maintained by the MMA (SINCA, 2015). The information comes from public stations administered by the state (mainly by the MMA) and from private stations operated by private and/or state-owned companies to meet the requirements of environmental regulations (SINCA, 2015). The NAQIS website uses the Airviro software application developed by the Swedish Meteorological and Hydrological Institute (SMHI), Norrköping, Sweden (SMHI, http://www.smhi.se/airviro/). This software assists in handling high volumes of information and connecting with other systems and monitoring networks. The information from public and private monitoring stations is sent to the NAQIS portal (SINCA, 2015).