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Toxicity and metal content of organic solvent extracts from airborne particulate matter in Puerto Rico ☆

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Abstract

The importance of airborne particulate matter (PM) in causing increases in morbidity and mortality in humans has been confirmed by numerous epidemiological and laboratory studies. It has been proposed that PM might deliver transition metals to the airways were they react and generate reactive oxygen species (ROS), thus promoting the expression of inflammatory mediators, and cytotoxicity. In Puerto Rico (PR), the northern Guaynabo area is a US EPA non-attainment zone for PM_{10} (PM with a mass median aerodynamic diameter $\leqslant 10\,\mu m$), and a previous study found that organic PM_{10} extracts from this area were cytotoxic. The purpose of this research project is to compare the toxicity between organic PM extracts from Guaynabo (a coastal urban site) and Fajardo (a coastal rural town) based on their polarity, collection season, and geographical location. We will also evaluate if the metal content of such extracts is associated with their biological activity. PM_{10} filters from both locations were subjected to a sequential Soxhlet extraction using hexane and acetone. Normal and transformed bronchial epithelial cells were then exposed to the extracts. Using the neutral red assay to measure cell viability we found that coastal urban PM from PR generally exhibits higher cytotoxicity than coastal rural PM. However, this effect is dependent on the polarity of the extracts and the collection season (in winter hexane PM_{10} is more toxic, whereas during the summer acetone PM_{10} is more toxic). We also found that non-polar organic constituents in PM from PR are generally more toxic than the polar organic constituents. The main conclusion from this work is that the metal contents of the organic PM extracts from PR could play a minor role in the cytotoxicity observed. This is supported by the findings of elements such as As, V, Ni, and Cu in the most cytotoxic extracts. However, organic compounds probably play the major role. The presence of bioactive fractions of PM underscores the importance of conducting more detailed studies.

Keywords: Particulate matter; Cytotoxicity; Organic extracts; Human cells; Puerto Rico

1. Introduction

During the last decade, the importance of airborne particulate matter (PM) in inducing increases in morbidity and mortality in humans has been confirmed by numerous epidemiological studies showing an association of PM concentration with these two health effects. Human exposure to elevated PM levels can induce airway inflammation leading to airway hyperreactivity (Ghio and Samet, 1999), airway and nasal damage (Gavett et al.,

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1997; Calderón-Garcidueñas et al., 2001), and predisposition to infection (Florey et al., 1979). These responses, observed to occur under controlled exposure conditions in vivo, may also occur in susceptible individuals exposed to ambient PM and could play a role in the associated increases in morbidity and mortality (Ghio and Devlin, 2001; Zanobetti et al., 2000). Laboratory studies have demonstrated that PM can alter the expression of multiple inflammatory mediators, up-regulate the expression of adhesion molecules on inflammatory cells (Salvi et al., 1999), and cause lipid peroxidation (Madden et al., 1999; reviewed in Ghio and Huang, 2004).

It is hypothesized that the toxicity of PM might be due to its organic content (Hannigan et al., 1998), its metal content (Ghio et al., 1996), the presence of endotoxins or other biologicals (Monn and Becker, 1999), the presence of acidic particles (Bascom et al., 1996), or its ultrafine components (Oberdörster et al., 1992). Recent research has focused the attention on PM metal content. It has been proposed that PM might deliver transition metals to the airways with subsequent reaction and generation of reactive oxygen species (ROS), thus promoting the expression of inflammatory mediators, and cytotoxicity (Frampton et al., 1999).

In the island of Puerto Rico (PR) the ambient air of the northern Guaynabo and Cataño area (Fig. 1) has historically been perceived as polluted by its residents. This stems from the presence of heavy industrial activity and vehicle traffic. Furthermore, for several years this area has been designated by the US EPA as a non-attainment zone for PM_{10} (PM with a mass median aerodynamic diameter $\leqslant 10\,\mu m$) (Puerto Rico Environmental Quality Board (PREQB), 1994; United States Environmental Protection Agency (US EPA), 2005). Epidemiological data from PR

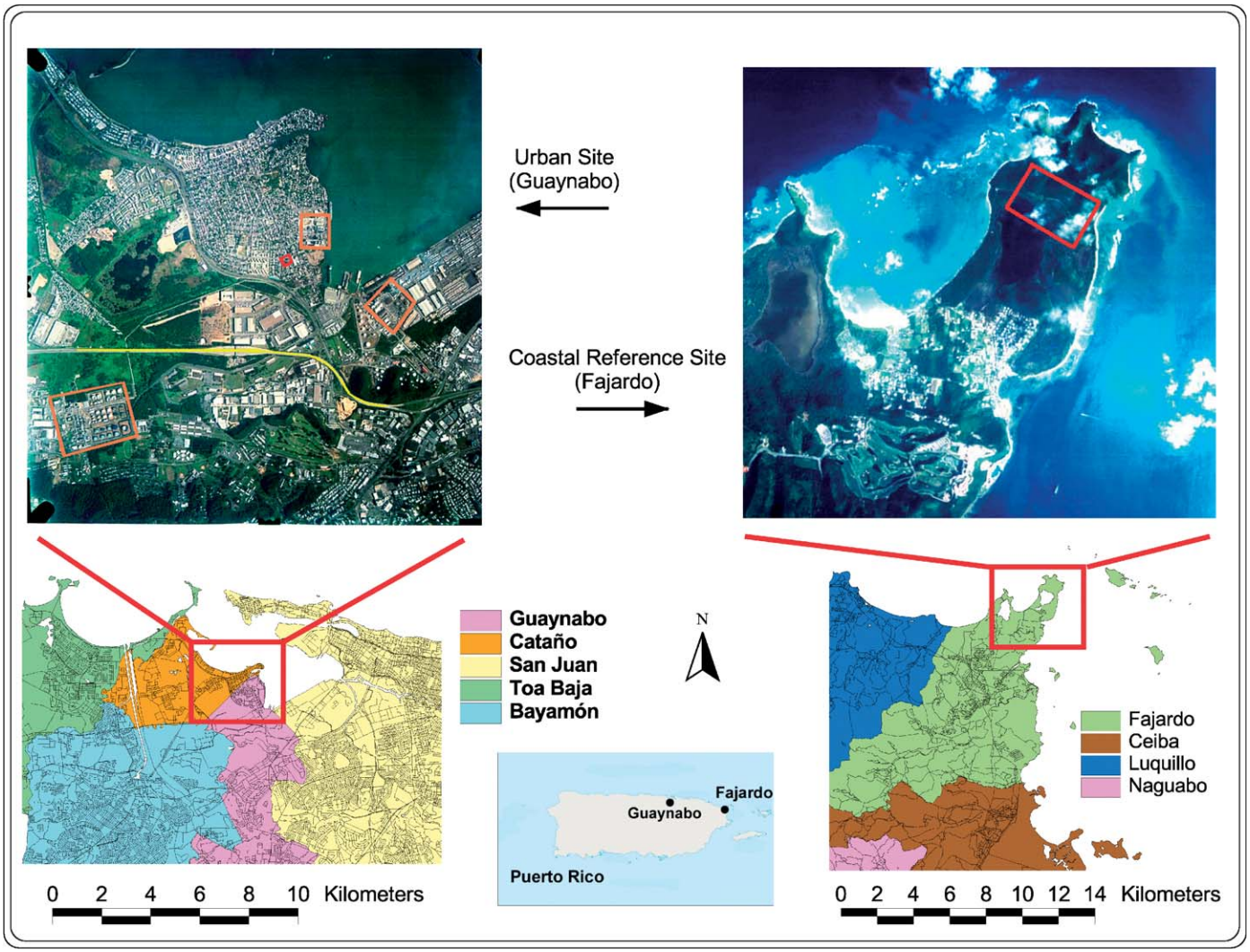

Fig. 1. *Left*: Overview and air photograph of the San Juan Bay area including the northern Guaynabo (urban) site. Red square in photograph represents PM monitor location, yellow line highlights major 8-lane highway with toll booth station, and orange squares represent major industrial activities. Clockwise from top, squares delimit a grain mill, an oil-burning power plant, and a petroleum refinery. *Center inset*: Map of Puerto Rico showing the location of both PM stations. *Right*: Overview of the northeastern tip of Puerto Rico and air photograph of Fajardo. Red square in photograph represents general location of the PM monitor (Scale of photos: 1:20,000).