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Land use and air quality in urban environments: Human health risk assessment due to inhalation of airborne particles

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ABSTRACT

Particle matter (PM) and its associated compounds are a serious problem for urban air quality and a threat to human health. In the present study, we assessed the intraurban variation of PM, and characterized the human health risk associated to the inhalation of particles measured on PM filters, considering different land use areas in the urban area of Cordoba city (Argentina) and different age groups. To assess the intraurban variation of PM, a biomonitoring network of *T. capillaris* was established in 15 sampling sites with different land use and the bioaccumulation of Co, Cu, Fe, Mn, Ni, Pb and Zn was quantified. After that, particles were collected by instrumental monitors placed at the most representative sampling sites of each land use category and an inhalation risk was calculated. A remarkable intraurban difference in the heavy metals content measured in the biomonitors was observed, in relation with the sampling site land use. The higher content was detected at industrial areas as well as in sites with intense vehicular traffic. Mean PM_{10} levels exceeded the standard suggested by the U.S. EPA in all land use areas, except for the downtown. Hazard Index values were below EPA's safe limit in all land use areas and in the different age groups. In contrast, the carcinogenic risk analysis showed that all urban areas exceeded the acceptable limit (1×10^{-6}), while the industrial sampling sites and the elder group presented a carcinogenic risk higher that the unacceptable limit. These findings validate the use of *T. capillaris* to assess intraurban air quality and also show there is an important intraurban variation in human health risk associated to different land use.

1. Introduction

Air pollution is considered one of the biggest environmental problems, particularly in urban environments where the population is constantly growing and the air quality decreases proportionally to this population increase (WHO, 2013). Since the 90's, quantification of particle matter (PM), either PM_{10} or $PM_{2.5}$, increased exponentially due to many studies showing that high PM concentrations were associated to adverse human health outcomes (Pirani et al., 2015). Particles consist of a core whose composition depends on their emission source and a large number of adsorbed substances, such as heavy metals, organic compounds, biological material, ions, reactive gases and mineral components (Valavanidis et al., 2006). In urban environments, the presence of metals in the inorganic fraction of airborne particles comes mainly from metal processing activities, road dust, cement production, soil resuspension, waste incinerators and sometimes coal burning (Mugica et al., 2002; He et al., 2016; Izhar et al., 2016). Vehicles are another major emission source of metal particles through combustion processes, transportation, corrosion of metallic parts and motor vehicle exhaust (Karagulian et al., 2015; Pernigotti et al., 2016).

Several studies confirmed the relationship between human exposure to particles and increased mortality rate (WHO, 2016). In addition, toxicological and epidemiological studies over the last years presented strong evidence of an association between particles bound metals and potential toxicological health effects (Castillo, 2016; Izhar et al., 2016; Li et al., 2016). Indeed, PM bound metals were associated to adverse health effects such as lung cancer (Chen et al., 2016), cardiovascular damage (Zhang et al., 2016), arteriosclerosis, hypertension (Fang and Zheng, 2014), among others. Therefore, in urban environments it is important to perform a careful monitoring of particle bound metals in order to get information related to population exposure. Thus, for the preliminary assessment of potential health effects of this pollutants, risk assessment strategies are an interesting approach (Romanazzi et al., 2014), considering pollutants toxicity as well as different exposure routes. Indeed, risk assessment strategies have been extensively used by government authorities to define guideline values in developed countries (Ferreira-Baptista and De Miguel, 2005).

World population is concentrated in urban areas suggesting the

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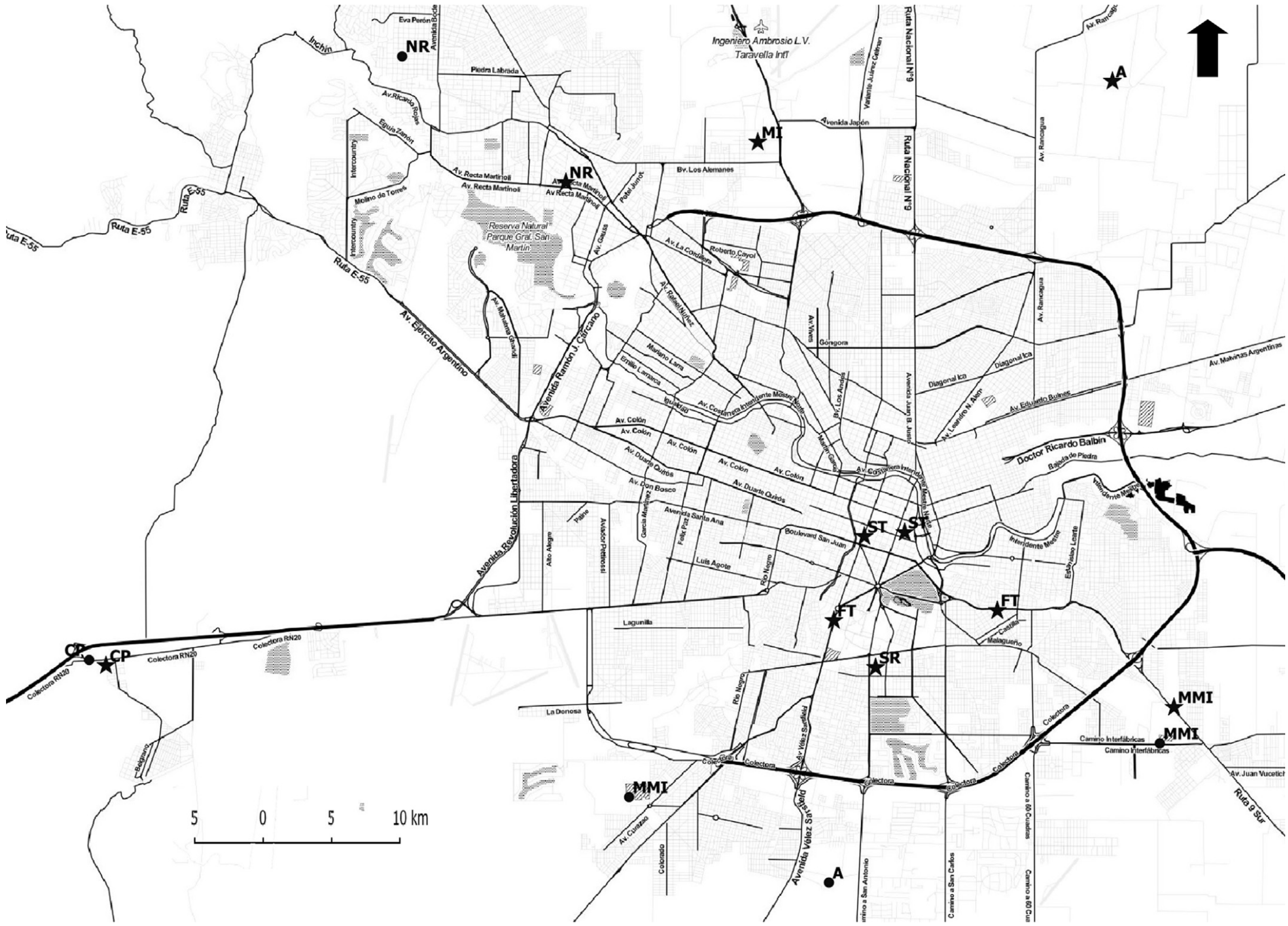

Fig. 1. Location of sampling sites (n = 15 sites) in the city of Córdoba, Argentina. Sites with ★ are biomonitoring and instrumental monitors sampling sites, and sites with • only biomonitors sites.

Table 1
Reference Dose expressed as Reference Concentration (RfC) and Cancer Potency Factor expressed as Inhalation Unit Risk (IUR) for elements determined in PM_{10}. *Ferreira-Baptista and De Miguel (2005); **Zhou et al. (2014).

Element	RfC [ppm/day]	IUR [$m^3/\mu g$]
Cr	2.86×10^{-5}*	3.36×10^{-2}*
Mn	1.43×10^{-5}*	
Co	5.71×10^{-6}*	7.84×10^{-3}*
Ni		6.72×10^{-4}*
Cu	4.02×10^{-2}**	
Zn	3×10^{-1}**	
As		1.21×10^{-4}*
Ba	1.43×10^{-4}*	
Pb	3.52×10^{-3}**	

Table 2
Parameters employed for non-cancer and cancer risk assessment in different age groups.

Age group	IRa (m^3/h)	IRb (m^3/day)	ET (h/day)	EF (days/year)	ED (years)	BW (kg)	AT (days)
Children	0.43	10.3	1.81	365.25[a]	5.7	23.15	28,489.5[b]
Youth	0.66	15.8	1.68		16	64.2	
Adults	0.66	15.8	4.68		41	80	
Elder	0.56	13.6	4.90		71	80	

Ira,b: inhalation rate; ET: time of exposure; EF: frequency of exposure; ED: duration of exposure; BW: body weight; AT: Average exposure time throughout life.
[a] It is considered that people are exposed to air pollutants every day of the year.
[b] Average life expectancy for men and women.

need to monitor air pollutants in such environments. However, the availability of instrumental monitors in developing countries is sometimes scarce, due mainly to their high cost (Monaci et al., 2000; Olcese and Toselli, 2004; Mateos and González, 2016). An alternative to instrumental monitoring is the use of biomonitors, that is, to get information on pollutants levels and their effects using living organisms (Nimis et al., 2000; González et al., 2003; Smodis, 2008; Van Dijk et al., 2015). Moreover, the use of active biomonitoring and the identification of efficient biomarkers have been suggested as a necessary complementary tool for instrumental monitoring (EuroBionet, 2000). In addition, biomonitoring has many advantages compared to instrumental monitoring: it is possible to assess many different sampling sites simultaneously, biomonitors are extremely low-cost and they provide information about pollutant effects on a living organism (Augusto et al., 2010; Wannaz et al., 2013; de Paula et al., 2015; Capozzi et al., 2016; Giampaoli et al., 2016). Epiphytic plants are one of the most frequently used atmospheric biomonitors, since they obtain their nutrients from the atmosphere, avoiding the influence of soil pollutants. Particularly, species from the *Tillandsia* genus demonstrated to be suitable biomonitors of heavy metals associated to airborne particles over vast areas in Argentina (Pignata et al., 2002; Wannaz et al., 2006, 2012; Bermudez et al., 2009; Abril et al., 2014), however these biomonitors have never been employed on a local scale.

Despite the fact that vehicle exhausts have been acknowledged as