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Suburban air quality: Human health hazard assessment of potentially toxic elements in PM10

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HIGHLIGHTS

- Health risk due to PM10 was assessed for children and adults at two suburban sites.
- Health risk was higher for residents at the industrial site than at the traffic site.
- Cancer and non-cancer risks were below the safe limit for adults.
- As, Pb and Zn in PM10 posed higher potential health risk for children than adults.

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ABSTRACT

PM10 samples were collected at two suburban locations in northern Spain, a traffic-industrial suburban (TIS) station located in the coastal city of Gijón and an industrial suburban (IS) station in Langreo, about 25 km inland. The aerosol samples were chemically analysed to determine ambient air concentrations of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, V and Zn. The results showed that the mean levels of As, Co, Cu, Fe, Mn, Ni, Pb and Se recorded at the IS location were higher than those at the TIS station. Mean levels of Fe and Zn in PM10 were higher than all other species at both the TIS and IS sampling sites (467 and 353 ng Fe/m^3 and 46 and 282 ng Zn/m^3, respectively). Human exposure to these twelve potentially toxic elements through PM10 was assessed for both children and adults using the U.S.EPA method, considering three pathways: ingestion, dermal contact and inhalation. In general, the IS location presented higher non-cancer risks than the TIS site. However, at both suburban locations, cancer and non-cancer risk values were in the acceptable range for adults, some exceptions being found. Greater health risk was estimated in the case of children. For this sector of the population, ingestion, dermal contact and/or inhalation of As, Pb and Zn in PM10 may pose a health hazard owing to possible carcinogenic/non-carcinogenic effects.

1. Introduction

Air pollution may be the cause of a variety of adverse effects on human health, such as heart disease, lung cancer, acute respiratory infections in children and chronic bronchitis in adults. Air pollution can also aggravate pre-existing heart and lung disease and trigger asthmatic attacks (Kampa and Castanas, 2008; Peled, 2011). Furthermore, the International Agency for Research on Cancer (IARC), which is the specialized cancer agency of the World Health Organization (WHO), classified outdoor air pollution as group-1 carcinogenic to humans. Outdoor air pollution has also been linked with non-carcinogenic effects, which range in terms of severity from subclinical physiological changes to mortality (IARC, 2016a).

Van Den Heuvel et al. (2016) found that the biological effects induced by PM10 were dependent on the properties of the particles, metals being among the main determinants for the observed biological responses. Further research is needed concerning the

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chemical characteristics of aerosol from different sources and the associated health risks for the population exposed to this air pollutant. To the best of our knowledge, few studies have examined the health risks for children and adults associated with suburban air quality due to ingestion, dermal contact and inhalation of PM10. This paper intends to broaden scientific knowledge of the potential risks associated with human exposure to toxic elements in PM10 sampled in suburban areas.

In the present study, PM10 samples were collected from two suburban sites in northern Spain, influenced by traffic and nearby industrial activities. The main objective of this research was to assess the human health hazards associated with As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, V and Zn in PM10 via ingestion, dermal contact and inhalation. The assessment was carried out independently for children and adults. Results were compared to examine how traffic and industry could affect both subpopulations in these suburban settings.

2. Methodology

2.1. Location description

Sampling was carried out at two suburban locations in Asturias (northern Spain) about 25 km from each other (Supplementary Material). One sampling station was in the eastern part of Gijón (43°31′23″N 5°37′16″W), a city with substantial maritime traffic in goods and industrial activities (primarily steelworks, thermal power plant, coal depot and cement plant). This station was near a trunk road (N-632) with irregular traffic intensity and a motorway (A-8). Hereinafter it is referred to as the traffic-industrial suburban (TIS) station. The other sampling station was located in Langreo (43°18′33″N 5°42′21″W), an inland borough of Asturias. This station is classified as industrial suburban (IS) given that it is surrounded by numerous industrial activities, such as a thermal power plant, marble and granite construction and repair shops, a concrete, artificial stone and ceramic pavement factory, a machined and forged parts factory, an automotive spare parts industry, boiler making and recycling of metal waste, smelting of materials (ferroalloys, scrap metals) and a coking plant. Traffic from a nearby regional road (AS-117) also influenced this station.

2.2. Sampling and chemical analysis

Using a high-volume sampler, daily PM10 samples were collected over filters composed of quartz microfibers, 90% being nanofibers (Suárez-Peña et al., 2016). During 2013–2014, fifty-two PM10 samples were obtained at each sampling station. The samples were chemically digested and analysed, As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, Se, V and Zn being determined. Further details are provided in the Supplementary Material.

2.3. Health risk assessment

The model used to estimate the potential human exposure to the twelve aforementioned elements in PM10 and their carcinogen/non-carcinogen effects was developed by the United States Environmental Protection Agency (U.S.EPA). EPA Human Health Risk Assessment Guidance[1] provides information and methodologies for assessing the impact on human health of toxic substances released into the environment, based on data of the contaminant concentrations in the media of interest.

The present study was based on the following assumptions: 1) The potentially exposed population was the residents in the sampling locations; 2) The target subjects were divided in two groups: children (≤6 years) and adults (≥21 years) (U.S.EPA, 2014); 3) Three possible exposure pathways were considered: direct inhalation through the mouth and nose, dermal absorption, and indirect ingestion via food and drinks containing deposited particles; 4) Intake rates were approximated by those developed for soil (Shi et al., 2011).

Furthermore, Cr is a ubiquitous element that can be found in the environment in several oxidation states (from Cr(II) to Cr(VI)), Cr(III) being a stable form and Cr(VI), the second-most stable (Tchounwou et al., 2012). Anthropogenic activities mainly release this metal in the hexavalent form, which is the most toxic form and has been classified as a human carcinogen (Hu et al., 2012; Tchounwou et al., 2012). To study the carcinogen/non-carcinogen effects of Cr by means of the U.S.EPA model, a seventh of the total Cr concentration determined in PM10 was considered Cr(VI). This assumption was based on the concentration ratio of carcinogenic Cr(VI) to non-carcinogenic Cr(III), which is about 1:6 (Izhar et al., 2016; Massey et al., 2013).

2.3.1. Human exposure: ingestion, dermal contact and inhalation

The chemical daily intake (ingestion), CDI_{ing} (mg/kg·day), the dermal absorbed dose, DAD_{derm} (mg/kg·day) and the exposure concentration (inhalation), EC_{inh} (μg/m^3), were estimated for each element in PM10 using the following expressions (U.S.EPA, 1989; 2004, 2009):

$$CDI_{ing} = \frac{C \cdot IngR}{BW} \cdot \frac{EF \cdot ED}{AT} \cdot CF \quad (1)$$

$$DAD_{derm} = \frac{C \cdot SA \cdot AF \cdot ABS}{BW} \cdot \frac{EF \cdot ED}{AT} \cdot CF \quad (2)$$

$$EC_{inh} = C \cdot ET \cdot \frac{EF \cdot ED}{AT_n} \quad (3)$$

where,

C: 95% upper confidence limit (UCL) on the arithmetic mean metal PM10 chosen as the exposure point concentration; *IngR*: ingestion rate (in accordance to Hu et al. (2012), Keshavarzi et al. (2015), Shi et al. (2011) and Sun et al. (2014), in the present study, the values used for *IngR* were those provided in U.S.EPA (1989) for the risk assessment of ingestion of soil/dust, i.e., 200 mg/day for children and 100 mg/day for adults); *BW:* average body weight (15 kg for children and 70 kg for adults (U.S.EPA, 1989)); *EF*: exposure rate (350 days/year for local residents); *ED*: exposure duration (the recommended default values of U.S.EPA (2014) were used, i.e., 6 years for children and 24 years for adults); *AT*: averaging time (for carcinogens, $AT = 70$ years·365 day/year; for non-carcinogens, $AT = ED \cdot 365$ days/year); *CF*: conversion factor (10^{-6} kg/mg); *SA*: surface area of skin that comes into contact with airborne particulates (2800 cm^2 for children and 5700 cm^2 for adults, as in recent studies (Keshavarzi et al., 2015; Izhar et al., 2016)); *AF*: skin adherence factor for airborne particulates (0.2 mg/cm^2·day for children and 0.07 mg/cm^2·day for adults (U.S.EPA, 2004)); *ABS*: dermal absorption factor (the *ABS* values for As and Cd were 0.03 and 0.001 (U.S.EPA, 2016), respectively; as no values were available for the rest of the elements analysed in PM10, 0.01 was used in this study, as in Hu et al. (2012) and Shi et al. (2011)); *ET*: exposure time (24 h/day); and *ATn* is the average time (for carcinogens $ATn = 70$ years·365 days/year·24 h/day; for non-carcinogens, $ATn = ED \cdot 365$ days/year·24 h/day).

[1] Available at: https://rais.ornl.gov/guidance/epa_hh.html.