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Assessing the human health risk for aluminium, zinc and lead in outdoor dusts collected in recreational sites used by children at an industrial area in the western part of the Bassin Minier de Provence, France

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ABSTRACT

The Western part of the "Bassin Minier de Provence", a former coal mining area, is still occupied by old polluting industries such as a coal-fired power plant and an alumina factory. In 2011 a preliminary outdoor dust survey was carried out in the area as the first step to an exposure and health risk assessment study. Dust samples were taken at 19 sites distributed across the study area, depending on the location of recreational areas used by children to play outdoors. Pseudo-total concentrations of Al, Zn and Pb were determined by ICP-MS and bioaccessible concentrations were estimated using the Unified BARGE Method. Exposure was calculated according to a scenario evaluation approach for dust ingestion and dermal contact routes. Estimation of health risk for exposure to Al, Zn and Pb in outdoor dust was based on the summation of individual risks for the oral and dermal routes. Results show that Al occurs in very high concentrations but mainly innon-bioaccessible forms, especially near the alumina plant. Zinc and Pb occur in low-average levels but mainly in bioaccessible forms. The estimated potential risk decreases according to Pb ≫ Al > Zn and is lower for the ingestion route. The preliminary results presented in this study indicate that, for Al and Zn, the outdoor dusts of the BMP represent an acceptable risk to children's health. However, the estimated hazard quotients suggest that there is some health risk associated to environmental Pb.

1. Introduction

In the context of this study, risk to an individual or population (receptors) can be described as beginning with a chemical released from a source into the environment where it is transported via air, water, soil, dust, and diet (i.e., exposure pathway). Contaminant fate combined with exposure pathway determine chemical concentrations with which individuals may come in contact, either through inhalation, ingestion, or skin/eye contact (i.e., exposure route). The receptor's characteristics (behavioural and physiological) as well as the concentration of the agent will determine the magnitude, frequency, and duration of the exposure (U.S. EPA, 2011). The exposure becomes an absorbed dose (also referred in the literature as bioavailable dose or bioavailable fraction) when the contaminant crosses an absorption barrier (e.g., skin, lungs, gut). But bioavailability depends on metal species, dust organic content andparticle sizes (Rasmussen et al., 2008), and determining total metal concentrations may not be sufficient to allow an estimate of the actual health risk. In vitro tests have been developed to measure bioaccessibility as a surrogate of bioavailability. Bioaccessibility is a measure of the amount of contaminant that may be solubilised in human gastrointestinal fluids (Ruby et al., 1999). Different types of tests have been developed to estimate oral bioaccessibility, especially for soil in Europe (Oomen et al., 2002; Wragg et al., 2011). The considerable amount of research that has being carried out on oral bioaccessibility is partly due to the fact that a number of studies (DeKom et al., 1997; Laidlaw and Taylor, 2011; Morrison et al., 2012) have beenindicating soil and dust ingestion as the most important route of exposure to environmental chemicals. Children, in particular, may ingest soil

Abbreviations: *DAD*, dermal absorbed dose; *ADI*, average daily intake; *AF*, adherence factor; *AT*, averaging time; Bf%, bioaccessible fraction; BMP, Basin Minier de Provence; *BW*, body weight; *C*, pseudo-total concentration; DHQ, dermal hazard quotient; *ED*, exposure duration; *EF*, exposure frequency; G, gastric; GI, gastrointestinal; *HQ*, hazard quotient; *IR*, intake rate; OM, organic matter; PHE, potentially harmful elements; RfD_{ABS}, absorbed reference dose; RfD_o, oral reference dose; UBM, Unified BARGE Method.

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and dust through deliberate hand-to-mouth or object-to-mouth movements, or unintentionally by eating food that has dropped on the floor (U.S. EPA, 2011; Bacigalupo and Hale, 2012). Over the last decade a number of studies have investigated the exposure of children to urban particulate materials in playgrounds (De Miguel et al., 2007; Ottesen et al., 2008; Okorie et al., 2011; Costa et al., 2012; Glorennec et al., 2012), since the probability of exposure to potentially harmful elements (PHE) in these recreational areas is particularly high (during games at school breaks or in public playgrounds after school). Thus identifying the importance of this exposureroute is necessary for evaluation, in terms of potential health effects by means of a risk assessment. Dermal exposure is most likely to occur through contact with chemically contaminated surfaces, soil, dust, sediment, liquids, and water (U.S. EPA, 2011).

Many inorganic elements are potentially harmful, so it is important to understand their source-transport-fate in the environment and pathways through which they may be transferred to humans. Identifying the main sources and routes of human exposure to PHE is essential for effective risk assessment. For instance, elements such as Al, Zn and Pb are constituents, in major or trace amounts, of raw materials and wastes associated with the production of alumina (Harford et al., 2010). Another major environmental source of these PHE is coal combustion (Huggins et al., 2009). A coal-fired power plant and an alumina factory are major industries in the Western part of the Bassin Minier de Provence, in France. Since these are pollutant industries, it is important to assess their impact on the environment and human health.

To this end, we here report the results of a preliminary dust survey carried out at the BMP to assess the health risk posed by PHE in outdoor dusts, collected at ground-level in urban recreational areas used by children to play. The main objectives of this study are: (i) interpreting results of the oral bioaccessibility testing for Al, Zn and Pb in dusts; and (ii) assessing potential exposure and non-carcinogenic risk for children while playing outdoors.

2. The study area

The BMP is located in the south of France, between Marseille and Aix-en-Provence, in the Provence-Alpes-Côte-d'Azur region (Fig. 1). It is a 300 km^2 depression drained by the Arc River, where the exploitation of coal began in the XVth century. The last mine pit closed in 2003, near the city of Gardanne (OHM, 2012) that has 20,000 people. The Western part of the basin is still occupied by old polluting industries such as a coal-fired power plant and an alumina factory (Fig. 1). The alumina plant extracts aluminium from bauxite to produce alumina (Al_2O_3) used in cosmetics and electronic components. At the end of the manufacturing process, the residue is in suspension in water and is dischargedin a conventional lagoon-type Red Mud disposal unit (Martinent-Catalot et al., 2002).

At the moment, the coal-fired power plant uses coals from South Africa, Russia and Colombia that arrive to the city by train or trucks.

The municipality of Gardanne has been dealing with a heavy mining legacy superimposed by the industrial activities previously described. Coal heaps composed of mine tailings spread over a large area, either within the city or its surroundings. Nowadays, the identified pollution sources that raise more concern in the population are the emission of gases and dusts, as well as the storage of raw and transformed materials. Nevertheless, whatever this industrial legacy, the BMP has been affected by the dynamics of the Aix-Marseille metropolitan area, due to the economic development of the region and to new residential practices. As a result, urbanization has been spreading over forest and agricultural areas and urban pollution is becoming an environmental issue among new residents (Reis et al., in press).

The study area stands in the western part of the BMP and includes two small cities: Gardanne and Bouc-bel-Air (Fig. 1). The urban area is settled along a NE–SW valley surrounded by forest and agricultural fields. In the area, the main wind directions are approximately N–S.

3. Materials and methods

3.1. Sampling and sample preparation

In this study, the designation of outdoor dust refers to a mixture of materials such as displaced urban soil, pavement debris and airborne particles that settle at ground-level.

Dust samples were taken at 19 sites distributed across the study area, depending on the location of public parks, public gardens, sport facilities, playgrounds and schools (Fig. 1). These urban recreational areas frequently used by children were selected as sampling sites since they are possible places where dust ingestion might occur while children play.

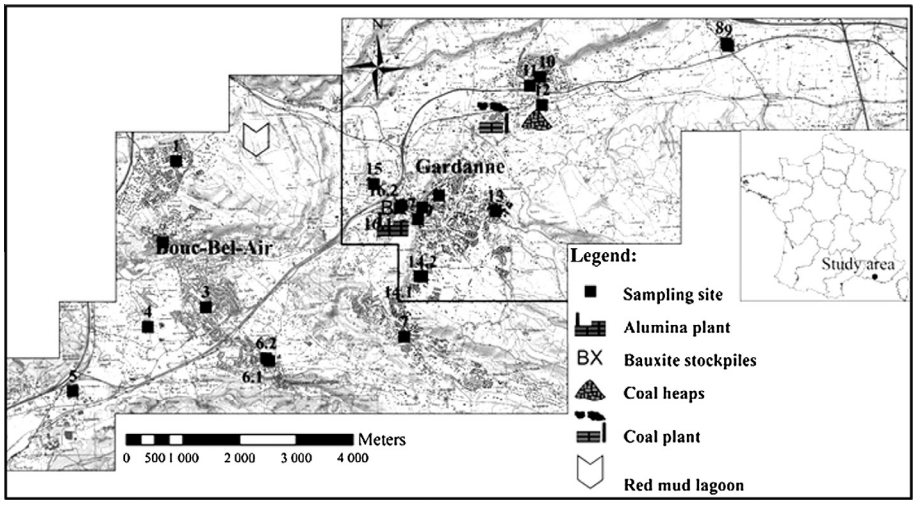

Fig. 1. The western part of the Provence coal basin: topographic map of the study area with the location of the main anthropogenic sources (power plant, alumina plant); the black squares locate the dust sampling sites and the black dots locate the two main cities inside the study area.

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