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Geochemistry and risk assessment of street dust in Luanda, Angola: A tropical urban environment

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Abstract

A total of 92 samples of street dust were collected in Luanda, Angola, were sieved below 100 μm, and analysed by ICP-MS for 35 elements after an aqua-regia digestion. The concentration and spatial heterogeneity of trace elements in the street dust of Luanda are generally lower than in most industrialized cities in the Northern hemisphere. These observations reveal a predominantly "natural" origin for the street dust in Luanda, which is also manifested in that some geochemical processes that occur in natural soils are preserved in street dust: the separation of uranium from thorium, and the retention of the former by carbonate materials, or the high correlation between arsenic and vanadium due to their common mode of adsorption on solid particles in the form of oxyanions. The only distinct anthropogenic fingerprint in the composition of Luanda's street dust is the association Pb–Cd–Sb–Cu (and to a lesser extent, Ba–Cr–Zn). The use of risk assessment strategies has proved helpful in identifying the routes of exposure to street dust and the trace elements therein of most concern in terms of potential adverse health effects. In Luanda the highest levels of risk seem to be associated (a) with the presence of As and Pb in the street dust and (b) with the route of ingestion of dust particles, for all the elements included in the study except Hg, for which inhalation of vapours presents a slightly higher risk than ingestion. However, given the large uncertainties associated with the estimates of toxicity values and exposure factors, and the absence of site-specific biometric factors, these results should be regarded as preliminary and further research should be undertaken before any definite conclusions regarding potential health effects are drawn.

Keywords: Risk; Exposure; Trace elements; Urban; Children

1. Introduction

Solid particles that accumulate on outdoor, impervious materials in urban environments are collectively referred to as "street dust". The two main sources of street dust, and consequently of the trace elements found therein, are deposition of previously suspended particles (atmospheric aerosol) and displaced urban soil. Additionally, the emissions from several point-sources (vehicular traffic, heating systems, building deterioration, construction and renovation, corrosion of galvanized metal structures, etc.) contribute directly to the street-dust load in their proximity (Harrison, 1979; Hopke et al., 1980; Schwar et al., 1988). Street dust does not remain deposited in place for long. It is easily resuspended back into the atmospheric aerosol, to which it contributes a significant amount of trace elements (Maxwell and Nelson, 1978), or precipitation washes it

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away becoming an important component of the suspended and dissolved solids in street run-off and in receiving water bodies (Vermette et al., 1991, and references therein).

The ultimate reason behind the large body of research on street dust that has accumulated in the last three decades—at least in the developed regions of the world—is the concern over the potential effects of exposure to this material through inhalation, ingestion and dermal contact. Numerous studies have tried to ascertain various aspects of this problem, both for house and street dust: amount and size of dust particles in the home/outdoor environment, rate of deposition onto household /urban surfaces, rate of transfer to the human organism, sources and chemical composition of house/street dust, behavioural effects on children living in urban areas with high levels of toxic chemicals, etc. (Day et al., 1975; Harrison, 1979; Fergusson et al., 1986; Davies et al., 1987; Fergusson and Kim, 1991; Akhter and Madany, 1993; Edwards et al., 1998; Gulson et al., 1998). The fact that different investigations often arrive at inconclusive and sometimes contradictory results only reflect the enormous difficulties involved in evaluating all the factors previously mentioned for a material whose properties are highly variable in time and space, and for which even the choice of a sampling procedure can pose a serious problem (Archer and Barrat, 1976; Bris et al., 1999). Probably, the most difficult question regarding the potential adverse health effects of street dust is the quantitative evaluation of the rates of exposure. These have only been extensively researched for children and hand-to-mouth activity during games and for the habit of "pica", i.e. mouthing of non-food objects (Biggins and Harrison, 1980, and references therein; Rundle et al., 1985; Watt et al., 1993). For example, Evans et al. (1992) refer to a model in which children are assumed to ingest 60 mg day^{-1} of dirt, and where 30% of the ingested lead is bioavailable (other researchers, like Claeys et al., 1993, place this figure at 50%). With exceptions like those just discussed, most studies have either established an inferred link between elevated concentrations of toxic elements in street dust and the observed incidence of a given effect in a population, or have directly equated risk with predominance of bioavailable or mobile chemical species, as determined in sequential or selective extraction protocols (Banerjee, 2003; Robertson et al., 2003). Some authors have tried a more direct approach, assessing the ecotoxicological significance of trace elements in street dust by means of bioassays (Wang et al., 1998).

Risk assessment strategies constitute an alternative approach to evaluate the potential health effects of trace elements in street dust. These strategies are based on the separate assessment of (a) the toxicity of the chemicals included in the analysis by exposure route (i.e., inhalation, ingestion, and dermal contact), and (b) the levels of exposure to those chemicals for the potential receptors. For non-carcinogenic toxicants, a range of exposures from zero to some finite value (reference dose or acceptable/tolerable daily intake) are assumed to be tolerated by the organism with essentially no chance of expression of the toxic effect. If the daily dose to which a receptor is exposed exceeds the corresponding reference dose, the receptor is considered to be potentially at risk. On the other hand, there is no level of exposure to a genotoxic carcinogen that does not pose a small but finite probability of generating a carcinogenic response. Risk to the exposed individual is measured as the product of the lifetime-average daily dose times a "slope factor", defined as the incremental probability of developing cancer during a lifetime due to chronic exposure to a unit dose of contaminant. This probability must not exceed a subjective level of risk (in the range 10^{-4}–10^{-6}) deemed acceptable by the corresponding regulatory authorities. Risk assessment tools have been extensively employed by regulatory authorities to define soil screening levels or soil guideline values. However, only a few research studies have attempted to use these same tools to evaluate the risk from exposure to toxic elements and radionuclides in urban environments (Boyd et al., 1999; Crick et al., 1987; Nadal et al., 2004).

This paper presents the main findings of a study carried out in Luanda (Angola), during the dry months of August and September 2002 with two purposes: to discuss the differences in the geochemical nature between street dust in a tropical environment and that found in cities of developed regions; and to evaluate, by means of risk assessment strategies, the potential adverse health effects of the exposure of children living in Luanda to street dust.

1.1. Description of the study area

Luanda, the capital city of Angola, is located on the inner side and to the South of the Bay of Luanda, on the Atlantic coast of Africa (Fig. 1). The climate is tropical (average temperature and precipitation: 26 °C and 350–400 mm yr^{-1}, respectively) with two seasons: the warm and rainy season which lasts 8–9 months, and the dry and relatively cold season, known locally as "cacimbo", which extends between June and September. The population of Luanda has grown rapidly in the last 10 years and had reached approximately 2.5 million at the time of this study. Luanda's commercial and residential centre occupies the inner part of the city around the harbour. It is surrounded by a succession of residential districts which are, in turn, encircled by the "muceques" or "shanty-towns" in the outskirts of Luanda. An industrial belt, which includes an oil refinery, a cement plant, a zinc smelter, and an iron foundry, extends outside the muceques, from North to East. Two geologic formations occur predominantly in