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Heavy metal distribution in dust from elementary schools in Hermosillo, Sonora, México

Diana Meza-Figueroa*, Margarita De la O-Villanueva, Maria Luisa De la Parra

Department of Geology, University of Sonora, Rosales y Encinas, Hermosillo, Sonora, Mexico 83000, Mexico

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Abstract

The city of Hermosillo, Sonora in northern Mexico was investigated for its heavy metals content. Samples of sedimented dust in roofs from 25 elementary schools were analyzed for their contents of Ni, Cr, Zn, Cd, Co, Ba, V, Pb, Fe and Cu after digestion with nitric acid. The results of the analysis were used to determine spatial distribution and magnitude of heavy metals pollution. The results of this study reveal that heavy metals distribution is different in two areas of the city. The southern area contains higher concentrations of heavy metals than the northcentral area. The mean level of Cd in exterior dust is 5.65 mg kg^{-1} in the southern area whereas the mean level of Cd is 2.83 mg kg^{-1} in the northcentral area. Elevated concentrations of Zn (2012 mg kg^{-1}), Pb (101.88 mg kg^{-1}), Cr (38.13 mg kg^{-1}) and Cd (28.38 mg kg^{-1}) in roof dust were found in samples located near industrial areas. Principal component analysis (PCA) was applied to the data matrix to evaluate the analytical results and to identify the possible pollution sources of metals. PCA shows two main sources: (1) Pb, Cd, Cr and Zn are mainly derived from industrial sources, combined with traffic sources; (2) Fe, Co and Ba are mainly derived from natural sources. V and Ni are highly correlated and possibly related to fuel combustion processes. Enrichment factors were calculated, which in turn further confirms the source identification. Ba and Co are dominantly crustal. Anthropogenically added Cd, Pb, Zn and Cr show maximum enrichment relative to the upper continental crustal component. The distribution of the heavy metals in dust does not seem to be controlled only by the topography of the city, but also by the location of the emission sources.

Keywords: Dust; Roofs; Heavy metals; Mexico

1. Introduction

Particulate matter emitted from the geologic media pose threats to human health and the environment due to expansion of infrastructure development to serve increasing population. Natural particles derive primarily from soil minerals, while anthropogenic particles derive from road construction (asphalt, concrete and road paint), automobiles (tire dust, brake dust), industrial inputs or atmospheric depositions (Adachi and Tainosho, 2005). Apart from the intrinsic geochemistry of earthen dust materials, anthropogenic activities have introduced contaminants in topsoil from atmospheric deposition by sedimentation, impaction and interception (Li et al., 2001). Soil particles are subsequently entrained into the atmosphere as

*Corresponding author. Tel.: +52 6622 139307; fax: +52 6622 592111.
E-mail address: dmeza@ciencias.uson.mx (D. Meza-Figueroa).

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dust. Particulate matter, commonly referred to as dust, can range in size from 1 to 10 000 μm. Dust can be generated through civil construction operations, farming activities and vehicle operations on un-surfaced roads. Upon generation, dust can be carried by wind into sensitive environments. Lead and a variety of other metals from automobile exhaust have been found to contaminate roadway and parking site dust sampled in Palermo, Italy (Varrica et al., 2003) and Kayseri, Turkey (Tokalioglu and Kartal, 2006). Key heavy metals are thereby Pb from leaded gasoline, Cu, Zn and Cd from car components, tyre abrasion, lubricants and industrial and incinerator emissions (Markus and McBratney, 1996; Thornton, 1991; Wilcke et al., 1998). Contamination of roadway topsoil material from which dust may be generated by vehicular and wind action is particularly prevalent in developing countries, where most roads are un-surfaced and in some cases leaded gasoline has been in use.

Though there are numerous studies of heavy metal contamination of urban dusts in developed countries, little information is available on heavy metals of urban dusts in developing countries (Banerjee, 2003). Mexican legislation does not consider heavy metal concentration (except by Pb) in dusts. In developed countries, most of these studies of heavy metal contamination in dusts focused on Pb, Cu and Zn (Charlesworth et al., 2003) and little attention has been paid to other trace elements, such as As, Hg, Sb, Cr, Mn, Ag, etc. In addition, the atmospheric particulate standards of most developing countries are based on the mass concentration measurement of the total suspended particles (TSP), including Mexico. Because the relationship between health effects (respiratory and cardiovascular diseases) and TSP levels was found to be much lower than the levels of atmospheric particulates finer than 10, 2.5 or 1 μm (PM10, PM2.5 and PM1, respectively), the ambient air quality standards are currently based on the measurements of PM10 and PM2.5 (USEPA, 2006; Querol et al., 2001). Consequently, most studies are focused on suspended atmospheric particulates (e.g., Querol et al., 2002; Artiñano et al., 2003: Alastuey et al., 2004; Salvador et al., 2004; Shah et al., 2006; Viana et al., 2006; Yadav and Rajamani, 2006).

In recent decades, there has been a growing concern for the potential contribution of ingested dust to metal toxicity in humans (Chirenje et al., 2006; Inyang and Bae, 2006). Some trace metals (such as Cu and Zn) at small amounts are harmless, but some (notably Pb and Cd) even at extremely low concentrations are toxic and are potential cofactors, initiators or promoters in many diseases including cardiovascular diseases and cancer (Dockery and Pope, 1996; Willers et al. 2005). Young children are more likely to ingest significant quantities of dust than adults because of the behavior of mouthing non-food objects and repetitive hand/finger sucking. Secondly, children have a much higher absorption rate of heavy metals from digestion system and higher hemoglobin sensitivity to heavy metals than adults (Hammond, 1982). Because of their ubiquitous distribution, non-degradable persistence and deadly nature, heavy metal poisoning is one of the most widespread pediatric health problems regardless of gender, race, ethnic origin and socioeconomic status (Casey et al., 1994). Sedimented dust on roofs in schools and in buildings near playgrounds could be one of the major pathways of childhood exposure. Of particular interest are the sources and pathways of hazardous particles that enter and deposit in a classroom environment and thus expose the occupants, particularly children, in the dwelling to levels of contaminants above safe limits. Components and quantity of dust deposited in roofs at schools could provide an indirect measurement of air pollution integrated over varying time periods. However, there is a lack of information on sedimented dust and consequently, most developing countries do not have regulations, guidelines, or standard tests for heavy metal contamination in schools.

The city of Hermosillo, in northwestern Mexico was chosen for this study. This city is a rapidly developing area in a desertic environment where long periods of no precipitation are common and atmospheric dry deposition occurs. Hermosillo contains a poor soil cover that allows re-suspension of soil particles and 20% of the city's surface remains un-surfaced. A recent study (Cruz, 2005) characterizes the air quality in Hermosillo as bad or not satisfactory for the studied period (June 2001–May 2002), indicating that the TSP commonly exceeds maximum levels of 260 $\mu g\,m^{-3}$ for 24 h. Yearly maximum allowable limit of 75 $\mu g\,m^{-3}$ of TSP (According to Mexican official standards: NOM-025-SSAI-1993) was also out of compliance for the northcentral area of the city (Fig. 1). While this city contains a large industrial and agricultural activity in northwestern Mexico, no work, to our knowledge, has been undertaken to investigate the heavy metal accumulation in this area. Therefore,