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Traffic signatures in suspended dust at pedestrian levels in semiarid zones: Implications for human exposure

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HIGHLIGHTS

- Dust suspension of coarse particles affecting pedestrian.
- Pixel counting showing metal-enriched agglomerates.
- Coarse particles act as main carriers for emergent pollutants.
- Traffic geochemical signatures dominate dust at pedestrian level.
- Underestimation of human health impact by dust suspension.

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ABSTRACT

Deeper knowledge on dust suspension processes along semiarid zones is critical for understanding potential impacts on human health. Hermosillo city, located in the heart of the Sonoran Desert was chosen to evaluate such impacts. A one-year survey of Total Suspended Particulate Matter (TSPM) was conducted at two different heights (pedestrian and rooftop level). The minimum values of TSPM were reported during monsoon season and winter. Maximum values showed a bimodal distribution, with major peaks associated with increase and decrease of temperature, as well as decreasing humidity. Concentrations of TSPM were significantly exceeded at pedestrian level (~44% of analyzed days) when compared to roof level (~18% of analyzed days). Metal concentrations of As, Pb, Cu, Sb, Be, Mg, Ni, and Co were higher at pedestrian level than at roof level. Pixel counting and interpretations based on scanning electron microscopy of dust filters showed a higher percentage of fine particulate fractions at pedestrian level. These fractions occur mainly as metal-enriched agglomerates resembling coarser particles. According to worldwide guidelines, particulate matter sampling should be conducted by monitoring particle sizes equal and inferior to PM_{10}. However, this work suggests that such procedures may compromise risk assessment in semiarid environments, where coarse particles act as main carriers for emergent contaminants related to traffic. This effect is especially concerning at pedestrian level, leading to an underestimation of potential impacts of human exposure. This study brings forward novel aspects that are of relevance for those concerned with dust suspension processes across semiarid regions and related impact on human health.

1. Introduction

Human exposure to metals in dust-rich atmospheric systems remains poorly understood. In recent years, studies related to impact of fine particles (aerodynamic diameter size smaller than

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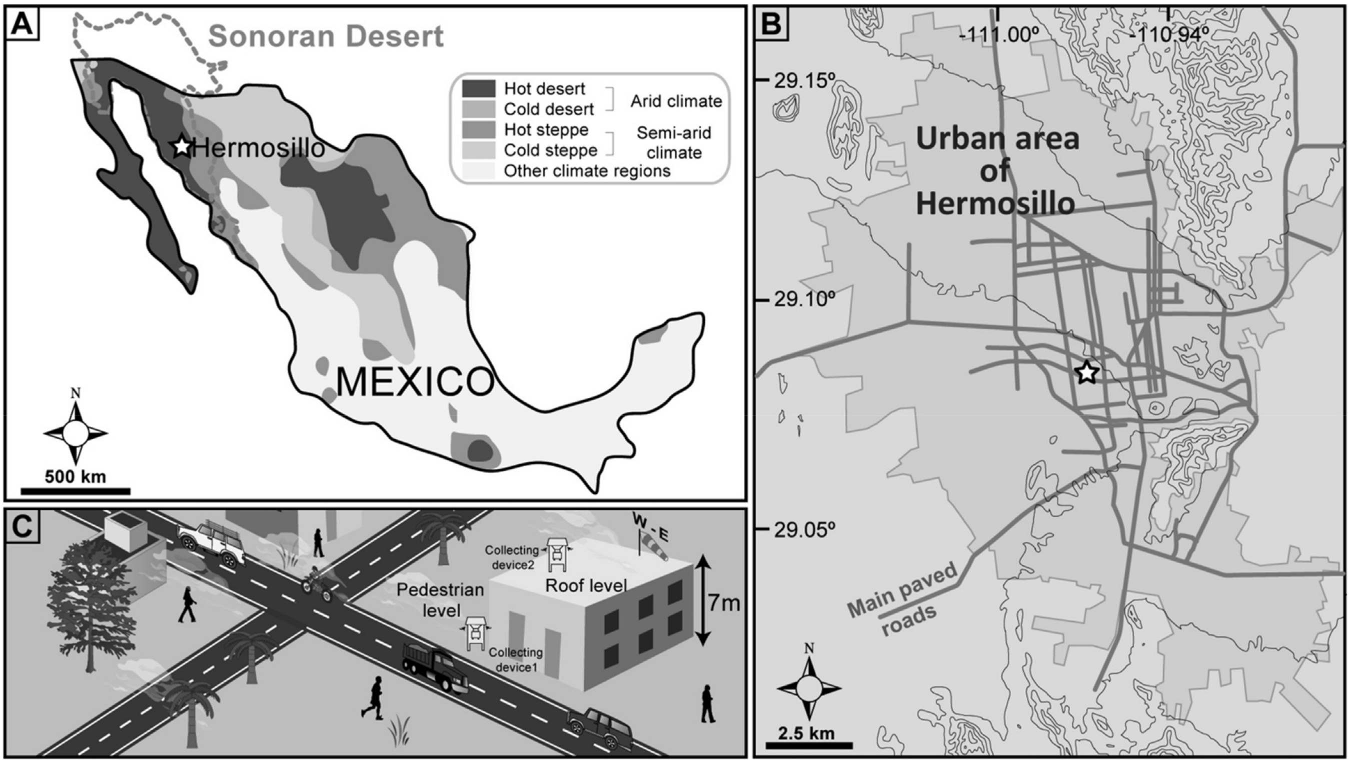

Fig. 1. Geographic location of the study area and sampling strategy. A) Distribution of arid and semi-arid regions across Mexico (after the Köppen-Geiger climate classification, adapted from Peel et al., 2007) and delimitation of the Sonoran Desert, where the studied area is located, at the city of Hermosillo (indicated by star); B) Simplified morphologic and road map within the urban area of Hermosillo. C) Schematic representation of the selected sampling sites, with two dust collecting devices positioned at pedestrian and roof level.

2.5 μm) have increased and received more attention than those related to coarse particles (aerodynamic diameter size larger than 2.5 μm). This is because fine particles are potentially more harmfull, as only these may reach the alveoli of the lungs (Lippmann and Chen, 2009).

Coarse particulate matter is less commonly taken into account, since their emission and transport is related to mechanical processes including wind erosion and wind-blown soil. Health impact is thereby presumably lower due to the short residence time in atmosphere because of gravitational settling (Zheng et al., 2010; Pasha and Alharbi, 2015). However, areas with continuous vehicular movement are highly prone to dust suspension processes by means of traffic-related atmospheric contamination (Fujiwara et al., 2011). This local source represents a potentially dangerous chronic pedestrian exposure.

Rapidly growing cities in semiarid zones face a particular environmental dynamics mainly driven by dust transport processes linked to climate and traffic sources (Fenger, 1999; Moreno-Rodríguez et al., 2015). Soil suspension, surface runoff, and aeolian erosion are the dominant promoting processes of dust emission in these climates. Such processes are particularly enhanced in developing countries like Mexico, where public transportation service is poorly managed, forcing citizens to an overuse of vehicles for daily transportation. In an effort for reduction of dust emission to atmosphere, concreted paved surface percentage has noticeable increased in cities located in desertic zones along Mexico (Moreno-Rodríguez et al., 2015). But this mitigation solution has only a limited effectiveness.

The environmental impact of traffic emissions in urban areas is strongly related to transport demand, climate conditions, and road physical conditions (Barrios et al., 2012). The interaction between turbulence and suspension of road dust can be particularly complex during dry periods, because high evapotranspiration could act as a driver for contaminated particulate matter loading in urban

Table 1
Descriptive statistics of trace metals analyzed from filters at pedestrian and roof-levels. Concentrations in mg kg^{-1} for all elements, except when marked * (ng g^{-1}); sd: standard deviation; dl: detection limit.

	dl	Pedestrian level		Roof level	
		Min–max	Mean ± sd	Min–max	Mean ± sd
Be	0.005	0.1–0.3	0.2 ± 0.1	0.06–0.15	0.09 ± 0.04
Mg	0.270	450–1840	985 ± 326	374–1400	799 ± 252
Ca	4.730	4780–22,725	13,561 ± 3065	610–20,615	13,797 ± 3359
Cu	0.012	26–317	73 ± 38	23–143	65.7 ± 24.3
V	0.010	5–160	86 ± 42	5.5–149	87.4 ± 39.09
Cr	0.018	4.4–407	262 ± 107	2–347	264 ± 108
Ti	8.110	24–101	51 ± 18	28–67	38 ± 9.8
Fe	0.160	494–4745	1735 ± 745	561–3310	1768 ± 669
Co	0.001	0.5–64	18 ± 22	0.6–60	24 ± 20
Na	2.710	9005–24,487	16,573 ± 4634	6305–2002	12,026 ± 4882
Al	0.580	1680–5506	3514 ± 1233	1430–4722	2445 ± 1199
K	8.110	3318–20,750	16,567 ± 3710	2700–19,013	16,123 ± 4545
Ba	0.003	2080–17,227	7657 ± 5030	865–12,097	4847 ± 4138
Ce	99*	505.6–4244	1923 ± 1025	622–3023	1651 ± 823
As	0.015	1.7–15.5	4 ± 1.6	1.7–9.7	3.9 ± 1.4
Se	0.003	0.2–15.9	1.5 ± 0.4	0.2–1	0.5 ± 0.2
Mo	0.031	0.5–17	3 ± 4	0.4–2	0.8 ± 0.4
Ag	0.002	0.1–0.5	0.2 ± 0.1	0.1–0.3	0.1 ± 0.1
Cd	0.023	0.1–0.5	0.3 ± 0.1	0.2–0.7	0.3 ± 0.1
Sn	0.017	1.4–4	2.5 ± 1	0.9–4	2.3 ± 1
Sb	0.005	0.5–8	3 ± 2.1	1–6	2.8 ± 1.8
Pb	0.003	2–25	10 ± 6.6	3.3–24	9.8 ± 6.1
Ni	0.052	2–38	18.7 ± 10	2–37	18.8 ± 9
Mn	0.023	34–6681	528 ± 843	33–528	376 ± 137
Zn	0.134	28.15–62,209	12,842 ± 6380	1870–18,411	12,569 ± 4077
Sr	0.100	65–755	138 ± 79	65–209	130 ± 33
La	91*	256–2143	986 ± 539	310–1510	842 ± 447