Ecotoxicology and Environmental Safety 159 (2018) 198–204

Contents lists available at ScienceDirect

Ecotoxicology and Environmental Safety

journal homepage: www.elsevier.com/locate/ecoenv

# Street dust from a heavily-populated and industrialized city: Evaluation of spatial distribution, origins, pollution, ecological risks and human health repercussions

R. Urrutia-Goyes[a], N. Hernandez[b], O. Carrillo-Gamboa[b], K.D.P. Nigam[b,c], N. Ornelas-Soto[b,*]

[a] *Departamento de Ciencias de la Energía y Mecánica, Universidad de las Fuerzas Armadas ESPE, Av. Gral. Rumiñahui s/n, P.O. Box 171-5-231B, Sangolqui 171103, Ecuador*

[b] *Laboratorio de Nanotecnología Ambiental, Tecnologico de Monterrey, Escuela de Ingeniería y Ciencias, Ave. Eugenio Garza Sada 2501, Monterrey, N.L. 64849, México*

[c] *Department of Chemical Engineering at Indian Institute of Technology, Delhi, India*

ARTICLE INFO

*Keywords:*
Street dust
Heavy metals
XRF
Human health
Risk assessment

ABSTRACT

Emissions from vehicles include particles from tire and brake wearing that can settle down and join industrial discharges into street dust. Metals present in street dust may create ecological and health threats and their analysis is of great environmental relevance. The city of Monterrey, Mexico is an industrial pillar of the country and shows an increasing fleet during the last years, which has yielded higher traffic and emissions. This study analyzes 44 street dust samples taken across the city for total element concentrations by using X-ray fluorescence. Associations and indicators are calculated to define possible origins, levels of pollution, natural or anthropogenic sources, and ecological and human health risks. High concentrations of As, Ba, Cu, Fe, Mo, Ni, Pb, Ti, and Zn were found. Main sources of metals were defined as: tire wearing for Zn and Fe; brake wearing for Ba, Cu, Fe, Pb and Zr; additional industrial sources for Mo, Ni, Pb, and Ti; and other natural sources for As. Ecological risk was found to be moderate across the city and risk due to Pb concentrations was established for children.

## 1. Introduction

Emissions due to traffic is a recurrent concern for both developed and in-development cities since an increase in population and industrial activities yields higher traffic and hence higher emissions (Carrera et al., 2015; Xing and Brimblecombe, 2018). Many adverse effects have been associated with tailpipe emissions and thus, the majority of international regulations point to this specific type of production (Buzzard et al., 2009; Morin et al., 2016). However, there are other discharges from automobiles that may create ecological and human health risks that are worth revising. Additional emissions from vehicles include particles resulting from tires treads and tire dust, brake dust and brake pads, and general parts wear. Such particles may become street dust and join industrial emissions in the area creating a threat once they are exposed to humans (Adamiec et al., 2016; Apeagyei et al., 2011; Thorpe and Harrison, 2008).

Monterrey, with dry but extreme temperature conditions, is the third largest urban center in Mexico with more than 4 million inhabitants and 5 million expected for 2030. Its economy is based among others, on manufacturing, metallurgy, and food and beverages production. With a contribution of ~9% to the gross domestic product (GDP) of the country and a GDP per capita only second to Mexico City, Monterrey is considered the most important industrial region of the whole country. The fleet of the city was 1.7 million in 2008 an over 2 million in 2015, with an estimated 8 million of daily trips (GMM, 2015; INEGI, 2016).

Previous studies have found the city to have high levels of fine organic aerosols in the air, and defined the exhaust from motors as the main air pollutant (Carrera et al., 2015; González et al., 2017; Mancilla et al., 2016). However, no studies have been carried out in street dusts across the region. Since street dust has been reported to have enriched concentrations of heavy metals compared to soils, and that vehicle emissions, aside from tailpipe, may contain high amounts of Zn, Fe, Cu, Pb, among others, an evaluation of the street dust in Monterrey is necessary to define its metal content, origin, and possible pollution effects on ecological and human health (Apeagyei et al., 2011; Charlesworth et al., 2011). In addition, some metals may be bioavailable in ecosystems as toxins, and some of the adverse effects related to exposure and inhalation of particulate matter include respiratory illnesses, neurological complications, digestive diseases, etc.

* Corresponding author.
*E-mail addresses:* erurrutia@espe.edu.ec (R. Urrutia-Goyes), ornel@itesm.mx (N. Ornelas-Soto).

https://doi.org/10.1016/j.ecoenv.2018.04.054
Received 13 March 2018; Received in revised form 20 April 2018; Accepted 26 April 2018

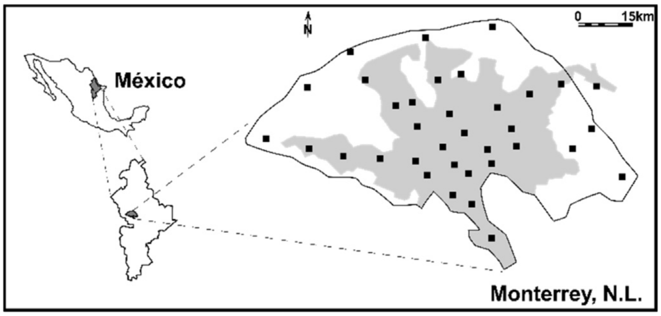


**Fig. 1.** Sampling locations in Monterrey, Mexico. Referenced on the field with a GPS. Greyed-out area denotes densely populated areas.

In order to analyze the concentration of metals in street dust and soil, techniques such as inductively coupled mass spectrometry, X-ray fluorescence (XRF), and atomic absorption have been used (OSHA, 2014; USEPA, 2014). The advantages of using a portable XRF device include multi-element analysis, immediate results, simple sample preparation, and the ability to take non-destructive measurements in the field. The technique is based on the release of energy produced by the interaction between electrons and a radiation applied to the atoms of the sample. Such energy is detected and matched to signature spectrums that are element-dependent (USEPA, 2015; Weindorf et al., 2014).

The aim of this study is to characterize street dust from an overpopulated city in Mexico by using portable XRF to assess any association to natural or anthropogenic sources such as traffic or industry emissions, and to find any possible risks posed to the environment and human health. To the best of our knowledge, the present study would be first of its kind to intertwine sources, sinks, and repercussions in a city from Mexico. This work can serve as a multidisciplinary example of the sources and effects of pollution present in highly populated and industrialized cities across the globe.

## 2. Methods

### 2.1. Study area

Monterrey belongs to the state of Nuevo León, Mexico and is located ~700 km to the north of Mexico City. The city is divided by Santa Catarina River and comprises several districts into one major urban zone referred to as Monterrey Metropolitan Area –MMA. Monterrey is considered a developed industrial city with a mix of commercial streets and residential areas. Street dust samples were collected from high traffic roadways across both densely populated areas and peripheral zones. In total, samples were obtained from 44 locations according to Fig. 1 and analyzed for metal concentrations.

### 2.2. Sampling

Street dust samples were collected in August 2017. The sampling process was completed throughout the day (20–30 °C), within one week after several without any rain during the dry season. Specific locations can be seen in Fig. 1. Two plastic brushes (with thick and thin bristles respectively) were used to sweep street dust up onto a flat piece of paper and then placed into a zip locked plastic bag. Water and a cloth were used to clean tools after sampling to avoid cross contamination. Each sample represents 400–800 g of dust from an area of approximately one square meter on road shoulders, at a distance of few centimeters away from the curb or gutter. Subsequently, samples were disaggregated, air-dried and stored in the laboratory at room temperature.

### 2.3. Analysis

Any vegetation and gravel-sized particles were removed from every street dust sample collected. Plastic bags were then poured out onto a 250 μm sieve. Samples were sieved and the resulting subsamples were placed into plastic bags (100 μm thickness) before homogenizing by mixing and rotating at 45 degrees. Shaking of the subsamples was avoided since it produces stratification. The subsample in the bag was then flattened to form a uniform layer of approx. 3 cm thickness. Loss of

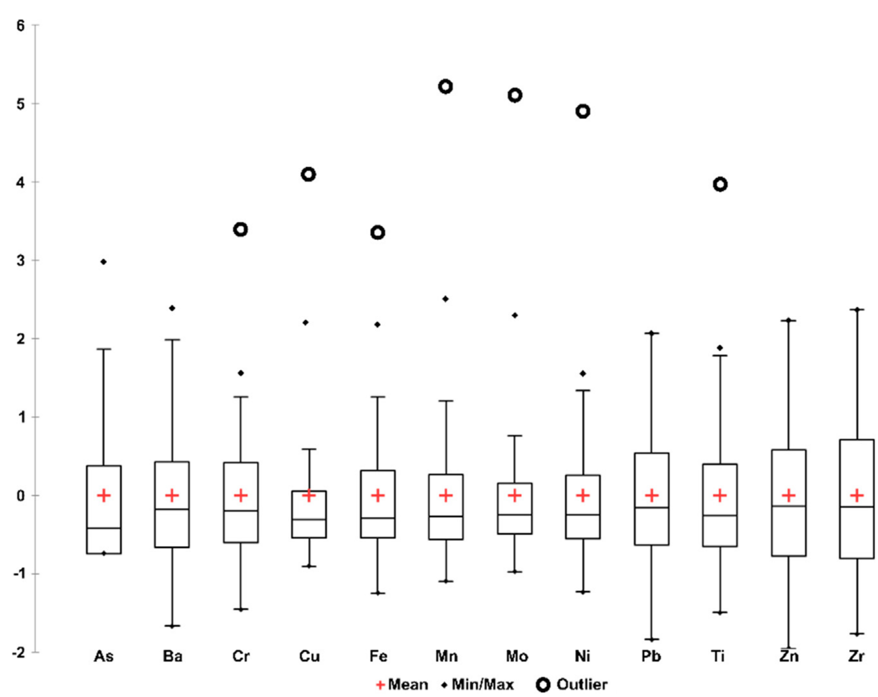


**Fig. 2.** Box plots of (standardized) concentrations (in mg/kg) of the elements present in street dust in Monterrey.