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Influence of Particle Size in the Characterization of Street Dust by Proximal Soil Sensing †

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Abstract: Urban road dust can be enriched in different elements and hence it can pose a threat to human and environmental health. Proximal soil sensing allows the swift monitoring of such particles in order to drive attention to any possible risks. The goal of this study is to find the variation in concentrations found when using a portable X-ray fluorescence (XRF) proximal sensor for the determination of metals in road dust with different degrees of sample pretreatment. In general, although results are element dependent, sieving samples to a particle size of < 250 μm is recommended. This study can help field workers to define an expected accuracy when using sensors in street dust analysis.

Keywords: Street dust; XRF; proximal soil sensor; soil; characterization; particle size; pretreatment

1. Introduction

Environmental analyses can be carried out by using different types of sensors and methodologies. Diverse variables such as molecule identification, carbon monoxide detection, or compounds speciation can be studied by using biosensors, chemical, or physical sensors [1–3]. A particular type of instrument that can be placed within two meters of a soil sample is called proximal soil sensor. These kind of devices are considered effective since many readings can be taken in the field [4,5].

A specific type of proximal soil sensor, portable X-ray fluorescence (XRF) devices, use a spectrometric technique that measure, compare and contrast the energy emitted by the elements in the sample after excitation by a source of X-rays in order to quantify the relative concentrations of the elements [4,6,7]. Portable XRF devices have been used in the analysis of soil, sediments and road dust, either as the main analytical technique or as part of a compound method [8–11].

Determining contamination or human health risk in a specific area can be done by identifying contaminants in street dust [12]. Road dust is a collection of particles from both natural and anthropogenic sources that settle down on the streets and sidewalks. Such particles can become resuspended by the wind and traffic conditions, and reach humans in the vicinity [13,14].

This work describes the influence of particle size in the characterization of street dust by proximal soil sensing. Contrasting the results of a homogenized sample with those of a sieved sample (<250 μm) allows to exemplify the importance of applying pretreatment to street dust when analyzing metals.

2. Methods

A total of 44 road dust samples were collected from streets in Monterrey, Mexico from a mix of commercial areas, residential streets and roads with different traffic volumes. Sampling was carried out in August 2017 during a period without any rain for at least seven days. Plastic brushes and pan were used to collect the samples from an area of one squared meter. Any vegetation and gravel was removed before analysis. Plastic bags were used to store the samples at room temperature.

Each sample was kept in its plastic bag and homogenized (i.e. mixed by stirring and rotating the bag thoroughly) before the first measuring process. For the second measuring process, each sample was placed into a < 250 μm sieve and the resulting portion was similarly homogenized and measured. Metals were determined by using a portable XRF device (Olympus 6000 Delta Premium) placing the sensor on top of the plastic bag for both kind of samples in order to simulate field work conditions. Count time for each reading was 90 s in regular soil mode. To test the reliability of the XRF device, blank samples and certified reference material (CRMs) obtained from NIST® (2710a and 2711a) were measured repeatedly. RSDs calculated showed ranges between 1-10% for all the studied elements. Mean recoveries calculated ranged between 110-135%.

Additionally, regressions analysis between the data obtained from both kind of samples was carried out to test the influence of sieving the samples to a particle size of < 250 μm. Statistical analysis was performed by using XLSTAT software (Addinsoft, Paris, France 2017).

3. Results and Discussion

Even though the 44 road dust samples were collected from similar areas, the available amount of dust ranged from 147 to 643 gr with a mean of 366 gr (see Fig. 1) denoting that locations have different characteristics due to different traffic and wind conditions. The quantities that correspond to the fine portion of the sample (< 250 μm) ranged from 35 to 95% with a mean of 65% indicating that the general composition of the samples varies greatly in relation to particle size.

Homogenized samples without any sieving showed the following statistics: Rb ranged from 4.2 to 39.6 ppm with a mean of 19.7 ppm; Zr ranged from 33.0 to 334.0 ppm with a mean of 138.6 ppm; Zn ranged from 109.0 to 1,180.0 ppm with a mean of 642.3 ppm; Ti ranged from 325.0 to 2,710.0 ppm with a mean of 1,237.8 ppm; Hg ranged from 4.9 to 15.0 ppm with a mean of 7.7 ppm; Sr ranged from 235.0 to 1,586 ppm with a mean of 436.6 ppm; Mn ranged from 151.0 to 957.0 ppm with a mean of 355.3 ppm; K ranged from 4,704.0 to 11,984.0 ppm with a mean of 8,638.7 ppm; Ni ranged from 26.0 to 110.0 ppm with a mean of 52.4 ppm; Ba ranged from 101.0 to 652.0 ppm with a mean of 248.4 ppm; Cr ranged from 30.0 to 545.0 ppm with a mean of 103.2 ppm; and Pb ranged from 10.2 to 712.0 ppm with a mean of 242.1 ppm. On the other hand, samples that were sieved to < 250 μm and homogenized showed the following statistics: Rb ranged from 7.8 to 34.1 ppm with a mean of 22.5 ppm; Zr ranged from 71.5 to 310.5 ppm with a mean of 173.4 ppm; Zn ranged from 103.5 to 1,134.5 ppm with a mean of 584.1 ppm; Ti ranged from 478.5 to 3,674.0 ppm with a mean of 7,992.7 ppm; Hg ranged from 4.8 to 16.3 ppm with a mean of 8.1 ppm; Sr ranged from 255.0 to 1,856.5 ppm with a mean of 442.3 ppm; Mn ranged from 188.0 to 1,226.0 ppm with a mean of 366.9 ppm; K ranged from 3,738.0 to 10,983.0 ppm with a mean of 7,992.7 ppm; Ni ranged from 30.0 to 126.0 ppm with a mean of 49.1 ppm; Ba ranged from 142.5 to 400.5 ppm with a mean of 248.5 ppm; Cr ranged from 34.5 to 225.5 ppm with a mean of 91.5 ppm; and Pb ranged from 35.8 to 388.5 ppm with a mean of 201.8 ppm.

Regressions between the two measurements obtained by metal can be seen in Figure 2. It can be noted that a systematic underestimation generally happens on measurements taken on homogenized samples without any sieving. Namely, Pb shows a slope smaller than 0.80; Cr, Ba, and Ni show a slope from 0.80 to 0.90; K, Mn, Sr, and Hg show a slope from 0.9 to 1.00; and Ti, Zn, Zr, and Rb show a slope greater than 1.00. Additionally, the coefficient of determination is greater than 0.8 for Cr and Sr; greater than 0.60 for Pb, K, Ti, Zn, Zr, Rb; and smaller for Ba, Ni, Mn, Hg. The linearity and correlation between measurements are element dependent and hence any analysis should be carried out independently. It can be suggested that correction methodologies could adjust the accuracy for measurements with underestimation.

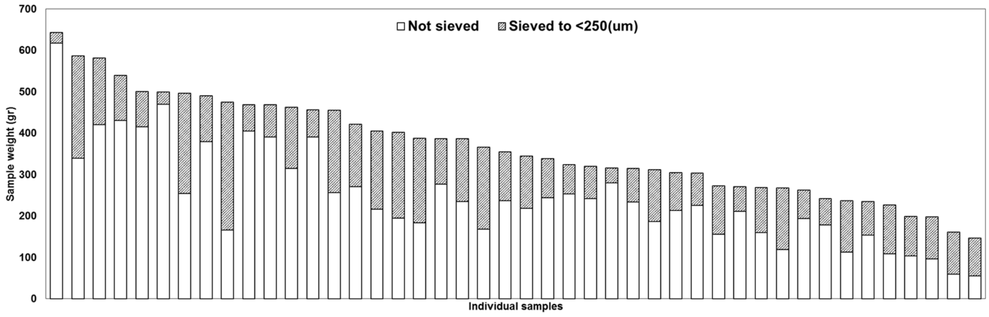

Figure 1. Weight of samples distribution from largest to smallest. Two portions can be seen: The first after homogenization, and the second after sieving to < 250 μm.

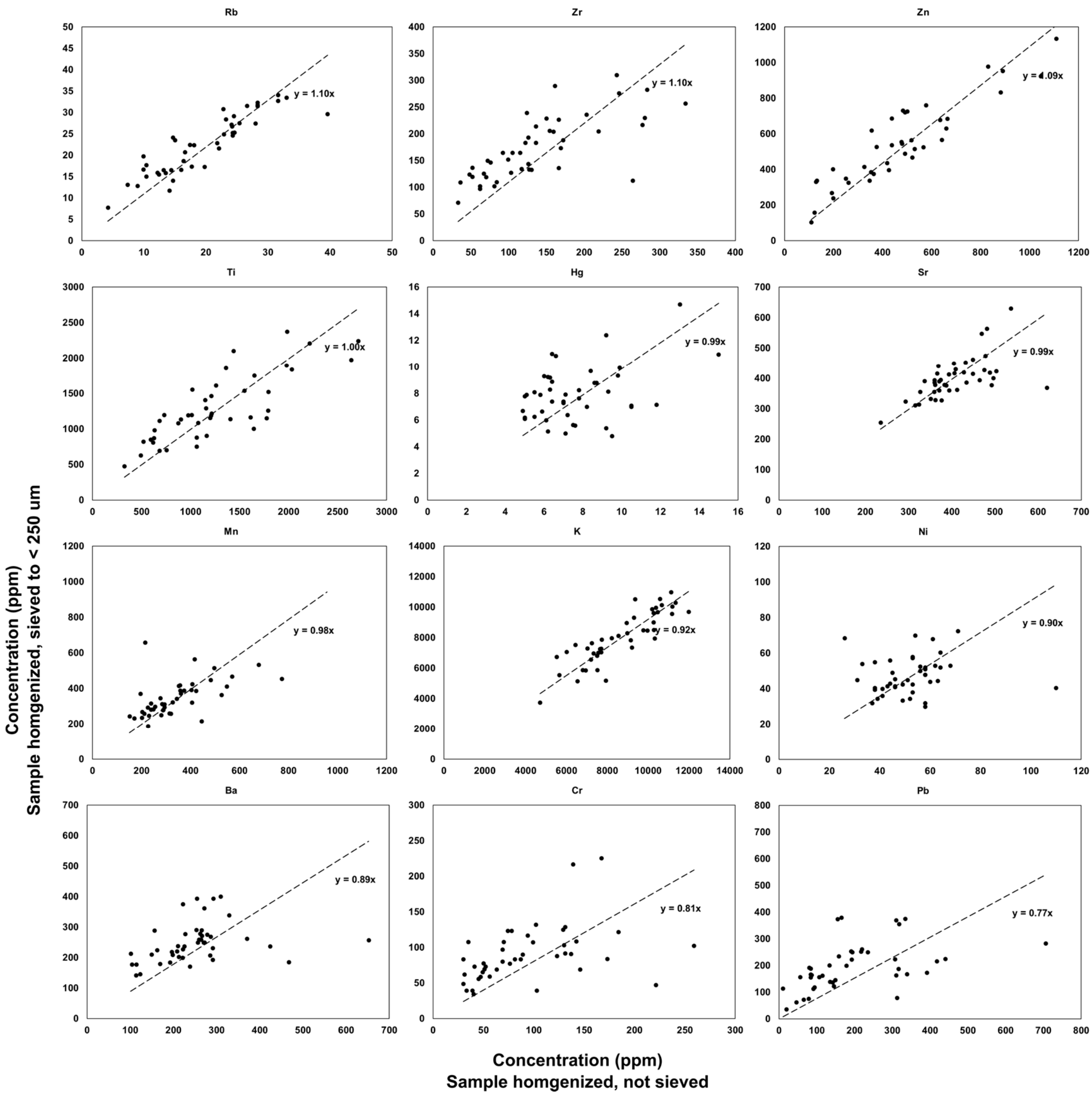

Figure 2. Regressions of portable XRF measurements on samples sieved to < 250 μm against measurements on samples homogenized only. Dashed black line represents linear trend. Elements sorted by slope in descendent order.

4. Conclusions

Road dust samples have been collected and analyzed for metals by using XRF. Great variability has been found both in the available amount of dust per area and in the proportional composition of fine portions. Wind and traffic conditions are suggested as the main cause for such behavior. Regression analysis for measurements taken on samples homogenized without any sieving and samples sieved to < 250 μm with additional homogenization has led to the conclusion that sample pretreatment improves the results obtained when analyzing metals in street dust.

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Conflicts of Interest: The authors declare no conflict of interest.

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