Decoding Metal Associations in an Arid Urban Environment with Active and Legacy Mining: the Case of Copiapó, Chile

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Decoding Metal Associations in an Arid Urban Environment with Active and Legacy Mining: the Case of Copiapó, Chile

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Introduction:

Copiapó city in the arid Atacama desert has **more than 30 abandoned mine tailings** (Fig. 1) and one **active copper smelter** (Fig. 2).

Soils and street dust could be enriched in **heavy metals** due to different dispersion mechanisms, such as **wind, rain and landslides**, leaving the population exposed to high **health risk**.

In March of this year **many landslide happened** in Copiapó city affecting tailings and cover with muds part of the city.

It is vital to learn **what sources are affecting the city**, **which ones are the most dangerous** and **what is their range of dispersion.**

Study Site: Copiapó, Atacama Region, Chile
Population: 166.751 inhabitants
Area: 47,77 km^2
Rainfalll: 28 mm annual mean
Mean temperature: 15,2 ºC annual mean
Main economic activity: Mining and agriculture
Number of Tailings in the region: 164

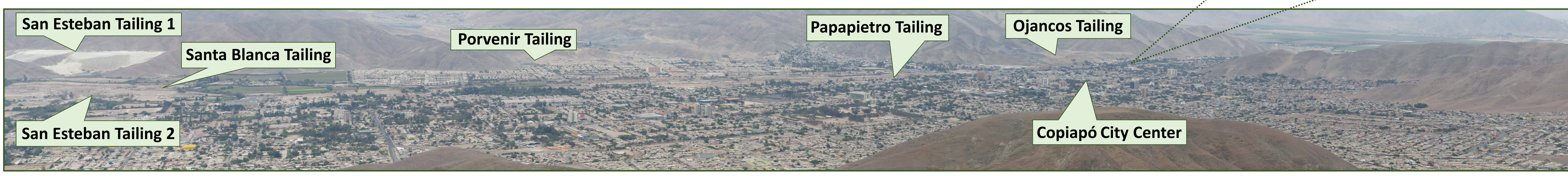

Fig. 1: Location of some of the mine tailings in Copiapó

Methodology:

- **71 street dust, 42 soils, 41 mud (transect method after landslides), 83 tailings** in two samples campaigns.
- Samples were dried (40 °C) and sieved (< 2 mm). Elemental composition was determined by **pXRF**. Measures was validated with ICP-MS comparison (replicated and reference material).
- Values of **As**, **Co**, **Cu**, **Fe**, **Mn**, **Pb** and **Zn** were considered valid for the pXRF method.
- **Positive Matrix Factorization (PMF)** is a model that uses the concentration and uncertainty of each sample to determine the **source's fingerprint** and the **apportionment to these samples** [1,2]: Was used with the **pXRF measurements of the street dust** samples.
- The **source contribution** was represented spatially and graphically using the **Kriging** method.

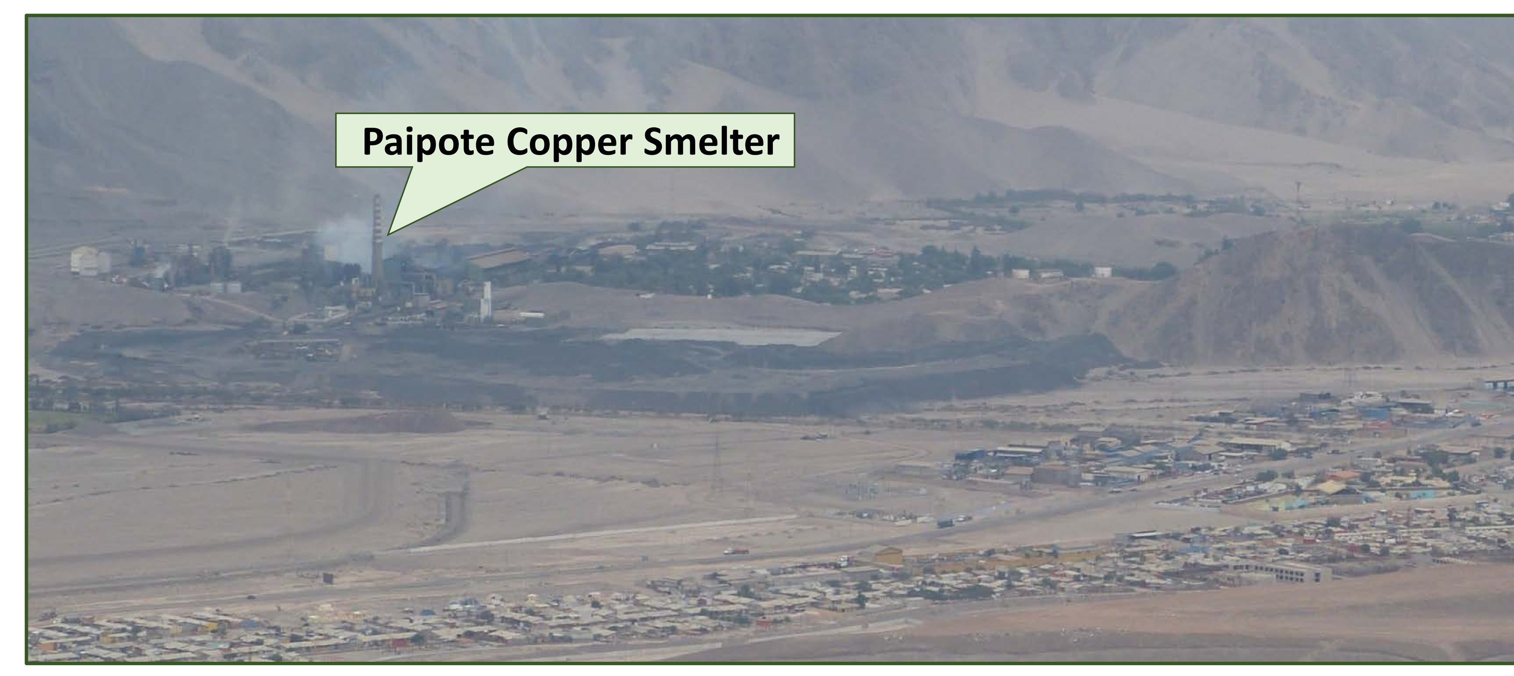

Fig. 2: Paipote Copper Smelter nearby population

Results:

PMF model identified four main factors or sources (Fig. 3) related to:

- **Industries emission:** 87% of Cu variation (copper smelter and industries).
- **Traffic emission:** 85% of Pb variation.
- **Crustal:** 55% of Co variation and 45% of Fe variation, but Co concentration were very low so its considered not enriched by anthropogenic activities.
- **Tailings:** 67% of Mn, 59% of As and 52% of Zn variations.

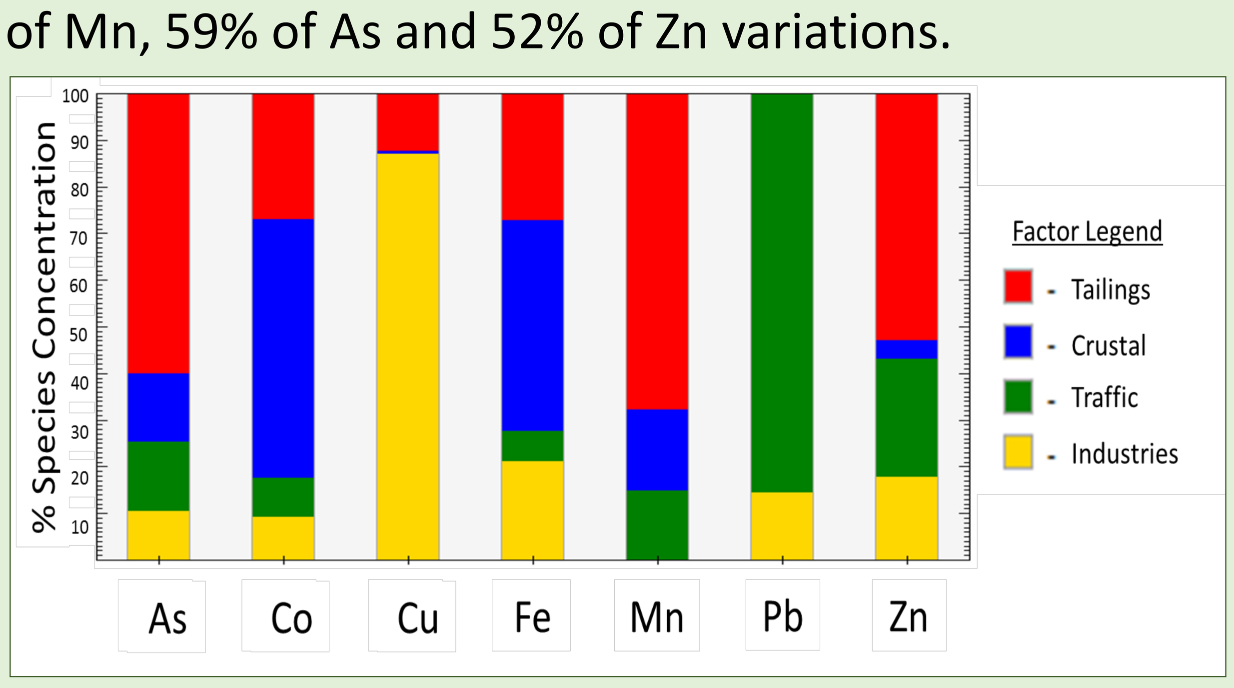

Fig. 3: Source's fingerprint related to street dust pXRF measurements

Two zones had been **contributed by the industrial factor** (Fig. 4), one is **nearby the copper smelter** and the second one is the **industrial zone of Copiapó** in the southwest of the city.

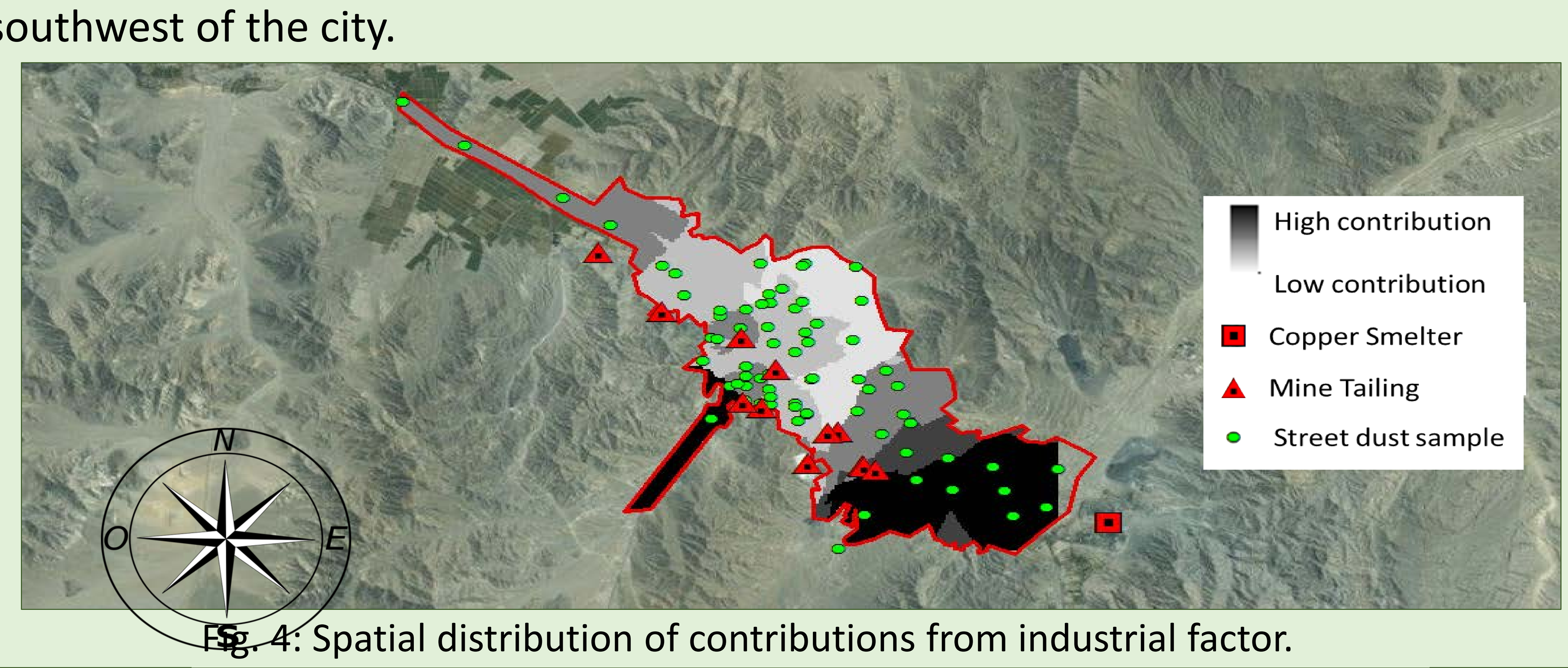

Fig. 4: Spatial distribution of contributions from industrial factor.

Landslides (March, 2015):

Heavy rains were the cause of many landslides in Atacama region. In the city the landslide went through the riverbed of Copiapó river and through the Paipote ravine, covering **40% of the urban area** with muds (Fig. 5).

The main concern was that some **tailings could be dragged by the landslide** and could be deposited in the streets of Copiapó, exposing the population to a high health risk.

Fig. 5: Copiapó's street after the landslides

- Some muds samples were above the Brazilian and Canada intervention limit for Cu, Zn, Hg,As and Pb in soils. Muds were taken off as soon as possible.
- **Two tailings were affected by the landslide**.
- Fig. 6 shows that **Cu and Zn** concentration rises while the muds go trough the city and the river bed, suggesting a process of **enrichment.** Also the **fine fraction** shows a tendency to **decrease**.

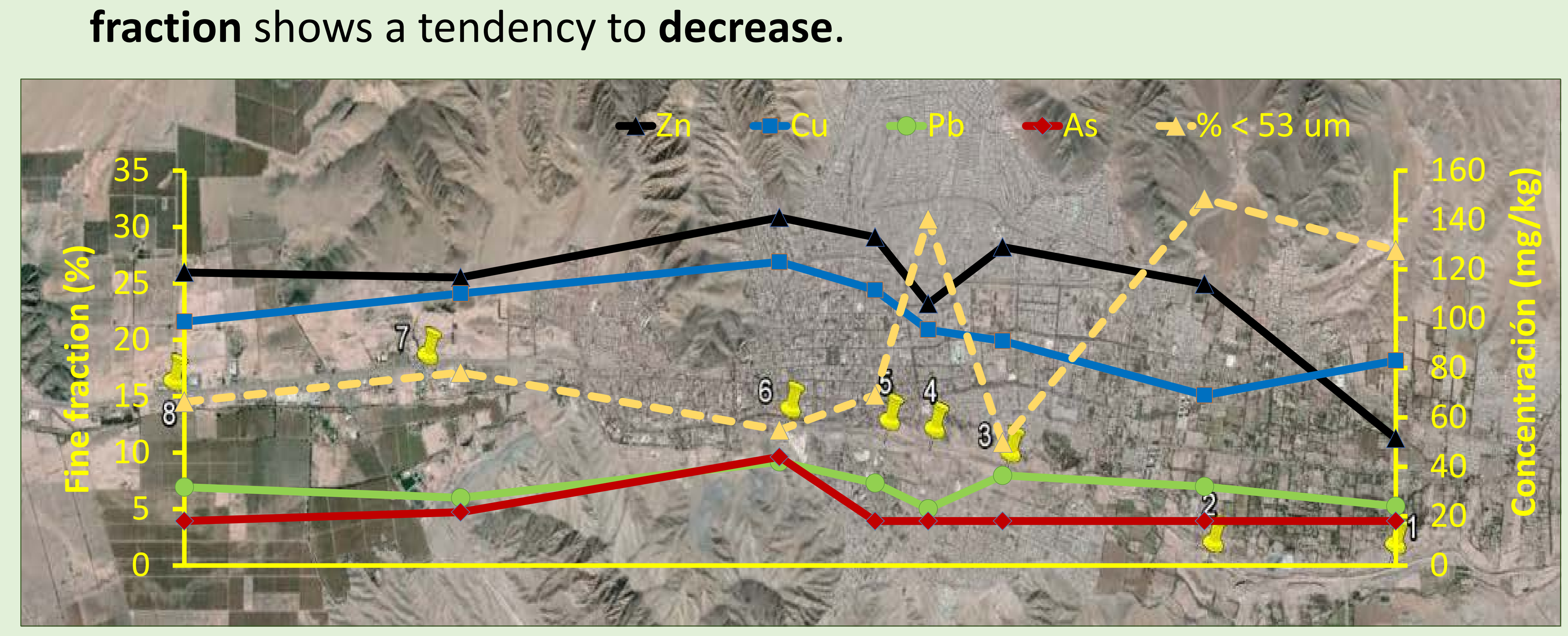

Fig. 6: As, Cu, Pb and Zn concentration obtained by pXRF on muds of the Copiapó river axis

Conclusions:

- Two contaminating sources were clearly identified, **traffic emissions and the industrial emissions**.
- The muds that pass trough Copiapó City and Copiapó riverbed **were enriched by Zn and Cu**.
- The dragged tailings material was diluted **without changing the concentration of elements on muds**.
- The **pXRF technique has limitations** on the quantity of elements correctly measured and in limits of quantification.

Further work and perspectives:

- **Other techniques** such as X-ray diffraction, Cluster and Principal Component Analysis, ratios of elements and increase the elements measured could **reinforce the identification of sources**.
- Analyze the effect of the **change on percentage of finest fraction in the element concentrations** from the landslide muds.
- We hope that this work can help **planners and regulators** to make better decisions considering the zones that are affected by anthropogenic contamination.

References:
[1] Paatero, P. and Tapper, U. (1994) Positive matrix factorization: a non-negative factor model with optimal utilization of error estimates of data values. Environmetrics, 5 , pp. 111–126.
[2]Norris et al., 2014G. Norris, R. Duvall, S. Brown, S. BaiEPA Positive Matrix Factorization (PMF) 5.0 Fundamentals and User Guide.

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