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Enrichment of heavy metals in surface layers of urban soils

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For the last forty years (from 1974 to present), a ferroalloy industry has been working in Bagnolo Mella (85 m a.s.l.), a small city in the province of Brescia, Northern Italy. The factory produced, as a byproduct of the industrial process, particulate matter emissions enriched in heavy metals: particularly manganese (Mn), and also lead (Pb), iron (Fe), nickel (Ni), copper (Cu), zinc (Zn) and arsenic (As). All these elements lead to potential toxic effects as they contaminate life and work environments of the exposed population. Moreover, the active factory is located near residential areas in a vast plain characterized by little wind (dominated by the East–West feature) and shallow water table with a great number of water resurgences, thus threatening surface soil and water resources as well as the population.

Aiming at contributing to quantify the exposure of the population to environmental heavy metal–pollution near the factory, and the heavy metals proneness to migrate through the soil, we report the results of an investigation of metals concentrations and speciation within the uppermost layers of the Earth Critical Zone of the study area.

Four sites – where lawns have been maintained at least for some decades – were identified as representative of the plant influence, on the basis of data collected during a previous experimental field campaign and of the local wind rose: three sites were chosen among the most prone ones to particulate matter deposition and one was chosen as a control site, in an upwind area, with respect to the plant. In the four sites, total soil metal concentrations were measured by means of a portable X-Ray fluorescence device (pXRF) along the soil profiles, down to the depth of 30 cm from the soil surface. Four loose soil samples were also collected at each site at different depths, and they were subjected to a sequential extraction procedure. Their heavy metal content was measured by inductively coupled plasma–mass spectrometry (ICP–MS). Data were analyzed both in their raw form and by applying the compositional data analysis (CoDA) approach, the analysis of variance (ANOVA), and principal component analysis (PCA).

The profiles of the total metal concentration showed a metal accumulation in surface and subsurface soil layers, and gave evidence of the plant activity consequences on the nearest and downwind sites. The recognized patterns are statistically meaningful (with $p < 0.01$) according to ANOVA, and PCA highlighted the predominant role of Mn in explaining most of the variability across the four sites. The speciation profiles, besides describing loosely the same observed patterns, show how the amorphous oxides species is always prevalent for Mn and Pb along the whole profile, while for Fe and As the species associated with crystalline oxides are always the prevalent ones. Finally it was observed that, when total Mn content is great, i.e. in the most enriched sites, sequential extractions cannot dissolve most of it.