Journal of Geochemical Exploration 172 (2017) 142–150

Contents lists available at ScienceDirect

Journal of Geochemical Exploration

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

Impact of a zinc processing factory on surrounding surficial soil contamination

D. Dumoulin [a], G. Billon [a,*], N. Proix [b], H. Frérot [c], M. Pauwels [c], P. Saumitou-Laprade [c]

[a] Laboratoire de Spectrochimie Infrarouge et Raman (LASIR) – UMR CNRS 8516, Université Lille 1, 59655 Villeneuve d'Ascq, France
[b] Institut National de la Recherche Agronomique (INRA), Laboratoire d'Analyses des Sols, 273, rue de Cambrai, 62000 Arras, France
[c] Laboratoire Evolution, Ecologie et Paléontologie (EEP) – UMR CNRS 8198, Université Lille 1, 59655 Villeneuve d'Ascq, France

ARTICLE INFO

Article history:
Received 30 May 2016
Revised 8 September 2016
Accepted 15 October 2016
Available online 17 October 2016

Keywords:
Zinc smelter
Soil pollution
Speciation
Metal mobility

ABSTRACT

Zn smelting plants located at Auby (Northern France) have strongly polluted the surroundings through dust emissions, storage of ores and slag without strong environmental concerns. Although highly contaminated surficial soils have been removed in the private and public gardens to safeguard health of the inhabitants, one small public area, called the Peru Park, has not been treated because of the presence of peculiar calamine grasslands. Our investigations in the soils of this park clearly evidenced a very strong contamination by several metals with concentrations up to 21,000 mg kg^{-1} for Zn, 3500 mg kg^{-1} for Pb and 160 mg kg^{-1} for Cd. Additionally, the mobility of these metals is important in soils and increases with the pollution level. In the pore waters of strongly polluted zones, our findings are more contrasted with high concentrations of dissolved Zn (3.6–32 mg L^{-1}) and to a lesser extent Cd (0.02–0.25 mg L^{-1}), whereas dissolved Pb remains at low concentrations (0.0001–0.021 mg L^{-1}) and, according to calculations, is quite exclusively bound to humic substances. Finally, this study obviously underlines that this severe pollution and the high mobility of Zn and Cd could strongly impact the surficial aquifer and the trophic chain present in this area.

1. Introduction

For centuries, landscapes of Hauts-de-France Region (France) have been deeply impacted by intense coal mine and metallurgic activities. For nearly a century and a half, three multinational companies produced tons of zinc and lead ores: The Mining and Metallurgic Society of Peñarroya-Metaleurop at Noyelles-Godault built in 1893 and closed in 2003, and two factories of The Royal Mining Company of Nyrstar-Umicore, the first one at Mortagne-du-Nord built in 1901 and closed in 1963, and the second one at Auby, still in activity and presently international leader for zinc production. Therefore, the vicinity of these industrial sites has become highly contaminated wastelands. In addition to waste deposits, some atmospheric fall-out has also contributed to spread pollution over thousands hectares around industrial sites. Trace metallic elements like zinc (Zn), lead (Pb) and cadmium (Cd) are the main contaminants. Pollution with these elements results in the formation of the so-called calamine soils, with strong element enrichment in comparison to normal bedrock concentrations (Douay et al., 2008). Metal contaminants, are they essential (*e.g.* Zn) or not (*e.g.* Cd or Pb), can become toxic to living organisms when present at high concentrations in the environment. Accordingly, calamine soils represent extremely harmful conditions for living organisms. Most local species of plants and animals cannot survive in such environments, leading to a drastic decrease of specific richness. However, rare organisms evolved the ability to survive and develop on calamine soils. When present on polluted soils, metal-adapted plant species form specific habitats that, although species-poor, participate to the local biodiversity. In the Nord-Pas de Calais-Picardie Region, calamine soils are covered with calaminarian grasslands including some Angiosperms plant species, such as *Arabidopsis halleri* (Brassicaceae), *Armeria maritima* subsp. *halleri* (Plumbaginaceae) and *Viola calaminaria* (Violaceae), whose distribution is locally restricted to calamine soils (metallo-endemics). Due to their rarity, calaminarian grasslands represent protected habitats listed in the Annex I of European Habitat Directive (Natura 2000 code 6130) and benefit from management program (Natura 2000 sites FR3100504 and FR3100505). The dynamic of this particular flora, as well as the general capacity of metals to enter trophic chains, depend on the variability in time and space of soil metal concentrations. It also depends on metal bioavailability, although there is still a debate on the precise definition of bioavailability and on the methods for its measurement (Kim et al., 2015).

In this context, the present paper addresses the following issues: (i) Are Zn, Cd and Pb concentrations spatially heterogeneous on a typical

* Corresponding author.
E-mail address: gabriel.billon@univ-lille1.fr (G. Billon).

http://dx.doi.org/10.1016/j.gexplo.2016.10.005
0375-6742/

calamine grassland? (ii) What is the mobility of these metals in such a soil? (iii) What are the explaining factors of metal mobility? (iv) What can we infer about the bioavailability, and thus the toxicity, of these metals?

2. Material and methods

2.1. Presentation of the sampling site

The sampling site is a small public park, called Peru Park, located in the city of Auby (Northern France) and situated close to the Zn smelter Nyrstar (Fig. 1), one of the largest factories in Europe and still in activity. Founded in 1869, it produces nowadays approximately 220,000 t of Zn per year. The atmospheric metal emissions released in the past by this factory have contributed to a severe contamination of the surrounding soils (Douay et al., 2008; Sterckeman et al., 2000). The Peru Park has the particularity of combining an outdoor playground in its north part and a protected area in the South due to the presence of calamine grassland. Contaminated topsoil was indeed partially removed in the North and replaced to accommodate a playground area whereas the rest of the park remains highly contaminated. The contaminated soil presents a 1–2 cm thick holorganic top horizon made of weakly degraded plant litter and roots that can result from the resistance of metal-rich plant debris to microbial attack and from the low faunal activity. It can be defined as loamy soil with a quite neutral pH (mean of 7.1) containing in average 20% of clays, 31% of sands and 49% of silts (internal report).

2.2. Samplings and pretreatments of the samples

Several sampling campaigns have been scheduled from the year 2012. The first one took place on 04 April 2012 to map the contamination of the whole park's topsoil (Fig. 1). For that purpose, 26 samples of soils were collected using a manual 6 cm-internal diameter stainless steel auger that permits to collect approximately the 20 first cm of the soils. The second campaign was conducted on 21 May 2012 on a very restricted area of 71 m^2 in the south of the park, in close proximity to the pits where porous candles were deployed (Fig. 1). However, as the biologists monitored also this site, it was not possible to dig pits within this area. 16 samples of surface soils (A1–A16) were collected with the manual auger in order to well characterize the pollution of the soil in which the candles have been placed. After each campaign, soil samples were prepared according to the standard ISO 11464 (AFNOR, 2006). Each

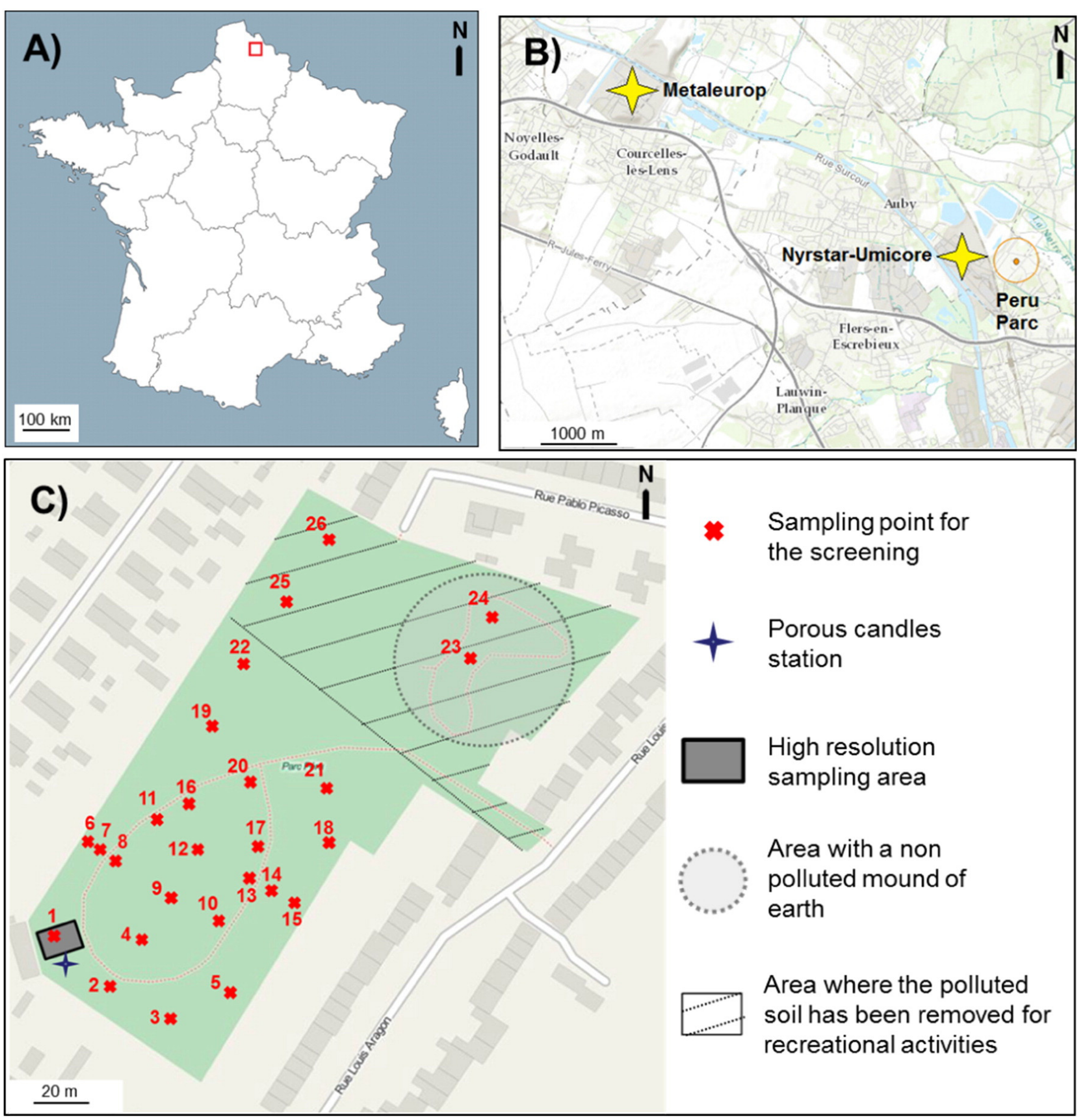

Fig. 1. Location of the study site. A) in France; B) in the city of Auby; C) detailed map of the Peru Park with the sampling points.