Steps in soil pollution by the toxic spill of a pyrite mine (Aznalcóllar, Spain)

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Introduction

On 25 April 1998, the walls of two contiguous ponds containing the coagulating residues from a pyrite mine located in Aznalcóllar (southwestern Spain) broke open (Figure 1), and toxic waste and tailings were spilled into the Añapo and Guadímar River basins, affecting some 40 km². The tailings spread as a dehydrated dense water layer 15 cm from the water line, forming a toxic spill. The polluted water contained some 10 km/m and reached the Guadalquivir River, affecting the National Park of Doñana (proclaimed by UNESCO in 1984 as a part of World Heritage). Nevertheless, a rehabilitation was rapidly conducted, minimizing the damage of the toxic wastes in the wildlife reserve. The aim of this work is to describe the steps in soil pollution over time.

Materials and Methods

On 5 May 1998, with a little rainfall, four sectors in the affected area were studied along the basins of the Añapo and Guadímar Rivers, analyzing tailings, polluted water and contaminated soils as well as uncontaminated soils; near the mine (M), at the point of the spill (Sp), 10 km from the spill, Punte de las Dolinas (P), 12 km Amalia, and (A) at 21 km; Quema (Q), at 29 km; Los Pobres (LP), at 34 km from the Quema point and Pozo Cañada (P), at 36 km (Figure 2). In each sector, a square plot was laid out (25 m x 25 m). At each corner of the plot, samples were taken of tailings as well as at the surface (0-10 cm) in depth, in order to monitor the contamination over time. Each plot was sampled on 3 more dates: 20 May, 4 June and 22 July 1998. However, in two sectors (Q and LP), the tailings were removed before 4 June. In Quema, two plots with tailings (250 m²) were left untouched for scientific study and additionally a third sample was taken on 13 May 1998 (405 days after the spill). Soil samples were taken on procedures of the Soil Survey Staff (1951). In all soils, physical, chemical, and physico-chemical properties were determined (Table 1): particle size, pH, bulk density, electrical conductivity, total carbon, organic carbon, equivalent carbon content, carbon exchange capacity (CEC), exchangeable bases (Ca, Mg, K, Na), iron oxides (Fe₂O₃), iron oxide-amorphous forms (Fe₃O₄), and total sulphur. A saturated extract of the tailings was prepared and the elements were precipitated as CaCO₃ (samples of tailings and soils, finely ground (0.001 mm)), digested in strong acids (HNO₃, H₂O₂, HCl) and the elements were precipitated as CaCO₃ and total sulphur. A saturated extract of the tailings was prepared and the elements were precipitated as CaCO₃ (samples of tailings and soils, finely ground (0.001 mm)), digested in strong acids (HNO₃, H₂O₂, HCl) and the elements were precipitated as CaCO₃ and total sulphur.

Results and Discussion

First Step

Toxic waste and tailings penetrated the soils (Figure 3).

The total concentration of each element was directly related to the square root of the time elapsed after the spill (Figure 9).

The soluble elements infiltrated the soils with the rainwater, swiftly augmenting the soil pollution (Figure 6).

These processes were more pronounced in the middle and lower sectors of the basin, where the particle size was finer, the sulphur content higher and the bulk density less.

The pollution tended to acidify the soils, although this trend was not strongly evident apparently due to the buffering effect of the CaCO₃ in most of the soils.

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Second Step

Drying and consequent aeration of the tailings that remained on the surface of the soils rapidly oxidized sulphides to sulphates, lowered the pH and solubilized part of the formerly insoluble pollutants (Figure 7).

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Given that no rain fell for a long time after the spill, the solubilized elements remained in the solution phase of the tailings and, with evaporation, rose by capillary action to the surface, forming a white salty crust (Figure 8).

The mobility rates of the elements in the tailings increased with time and those in the soils diminished.

The pollutants tended to concentrate in the first 10 cm of the soils without seriously contaminating the groundwater, at least in the carbonate soils.

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This results underscore the urgency of removing the tailings from the soil surface.

References

