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Metal contamination of soils and crops affected by the Chenzhou lead/zinc mine spill (Hunan, China)

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Abstract

In 1985, the collapse of the tailing dam in Chenzhou lead/zinc mine (Hunan, southern China) led to the spread of mining waste spills on the farmland along the Dong River. After the accident, an urgent soil cleaning up was carried out in some places. Seventeen years later, cereal (rice, maize, and sorghum), pulses (soybean, Adzuki bean, mung bean and peanut), vegetables (ipomoea, capsicum, taro and string bean) and the rooted soils were sampled at four sites: (1) the mining area (SZY), (2) the area still covered with the mining tailing spills (GYB), (3) the cleaned area from mining tailing spills (JTC), and (4) a background site (REF). Metal concentrations in the crops and soils were analyzed to evaluate the long-term effects of the spilled waste on the soil and the potential human exposure through food chains. The results showed that the physical–chemical properties of the soils obviously changed due to the different farming styles used by each individual farmer. Leaching effects and plant extraction of metals from some soils were quite weak. Certain soils were still heavily polluted with As, Cd, Zn, Pb and Cu. The contamination levels were in the order of GYB>SZY>JTC showing that the clean-up treatment was effective. The maximum allowable concentration (MAC) levels for Chinese agricultural soils were still highly exceeded, particularly for As and Cd (followed by Zn, Pb and Cu), with mean concentrations of 709 and 7.6 mg kg^{-1}, respectively. These concentrations exceed the MAC levels by 24 times for As and 13 times for Cd at GYB. Generally, the edible leaves or stems of crops were more heavily contaminated than seeds or fruits. Ipomoea was the most severely contaminated crop. The concentrations of Cd and Pb were 3.30 and 76.9 mg kg^{-1} in ipomoea leaves at GYB, which exceeded the maximum permit levels (0.5 mg kg^{-1} for Cd and 9 mg kg^{-1} for Pb) by 6.6 and 8.5 times, respectively. Taro (+skin) could accumulate high concentrations of Zn and Cd in the edible stem, and rice and capsicum had high Cd concentration in the edible parts. However, the toxic element concentrations in maize, sorghum, Adzuki bean, soybean and mung bean remained lower than the threshold levels. The bio-accumulation factors (BAFs) of crops were in the order: Cd>Zn>Cu>Pb>As. BAF was typically lower in the edible seeds or fruits than in stems and leaves. The accumulation effect strongly depends on the crop's physiological properties, the mobility of the metals, and the availability of metals in soils but not entirely on the total element concentrations in the soils.

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Even so, the estimated daily intake amount of Cu, Zn, Cd, and Pb from the crops grown in the affected three sites and arsenic at SZY and GYB exceeded the RDA (Recommended dietary allowance) levels. Subsequently, the crops grown in Chenzhou Pb/Zn mine waste affected area might have a hazardous effect on the consumer's health. This area still needs effective measures to cure the As, Cd, Pb, Zn and Cu contamination.

Keywords: Heavy metals; Arsenic; Soil; Crop; Contamination; Lead/zinc mine; China

1. Introduction

Mining activity is a chief source of metals entering into the environment. In the process of mining exploitation and ore concentrating, mine tailing and wastewaters are created, and dust is emitted. This results in the surrounding environment being severely polluted. The most serious problem is that of spilled mine tailing. Since 1970, there have been 35 reported major mine tailing dam failures around the world resulting in significant soil and river pollution and the loss of more than 500 lives (Macklin et al., 2003). In 2000 alone, there were a total of five reported accidents (in China, Romania, Sweden, and USA; Macklin et al., 2003).

In China, on August 25th, 1985, the mine tailing dam of Chenzhou lead/zinc mine (Hunan, southern China) collapsed because of heavy rain. In that disaster, a strip of farmland about 400 m in wide on both sides of the Dong River channel was covered with an about 15-cm-thick layer of black sludge. After the collapse of the dam, an emergency soil clean-up procedure was quickly carried out in some places. The toxic sludge and a major portion of the contaminated soil surface were mechanically removed. Nevertheless, most of the contaminated farmlands are still covered with spills and a part of these contaminated farmlands are cultivated at present.

Crops can uptake toxic elements through their roots from contaminated soils, and even leaves can absorb toxic elements deposited on the leaf surface. Queirolo et al. (2000) found that corn and potatoes (+skin), growing in a volcano-influenced location of Talabre (Northern Chile), contain very high arsenic concentration in the edible parts (1.85 and 0.86 mg kg^{-1} fresh weight, respectively), exceeding the National Standard of Chile for arsenic (0.5 mg kg^{-1}) by approximately 400% and 180%, respectively.

Chronic lower level intakes of toxic elements have damaging effects on human beings and other animals (Ikeda et al., 2000), since there is no efficient mechanism for their elimination, and the detrimental impact becomes apparent only after several years of exposure (Bahemuka and Mubofu, 1999). Consuming food contaminated by Pb, Hg, As, Cd and other metals can seriously deplete body stores of Fe, vitamin C and other essential nutrients, leading to decreased immunological defenses, intrauterine growth retardation, impaired psycho-social faculties and disabilities associated with malnutrition (Iyengar and Nair, 2000). Türkdogan et al. (2003) found that the high concentrations of metals (Co, Cd, Pb, Mn, Ni and Cu) in fruit and vegetables in Van region of Eastern Turkey are related to the high prevalence of upper gastrointestinal (GI) cancer rates. Lacatusu et al. (1996) reported that the soil and vegetables polluted with Pb and Cd in Copsa Mica and Baia Mare, Romania, significantly contributed to decreased human life expectancy within the affected areas, reducing average age at death by 9–10 years.

In Chenzhou Pb/Zn mine area (Fig. 1), previous investigations have shown that soil and waters were severely polluted by heavy metals (Zeng et al., 1995, 1997). It is therefore anticipated that crops grown in this area cannot be free from metals pollution. Thus far, there still has been very little published information on the uptake of toxic elements by cereal, vegetables and pulses in the Chenzhou Pb/Zn mine affected area after the mine tailing dam collapse. The objective of this paper is; (1) to quantify the content of metal in soil and crops; (2) to investigate the degree of pollution and the daily intake amount of toxic