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Accumulation, transfer, and potential sources of mercury in the soil-wheat system under field conditions over the Loess Plateau, northwest China

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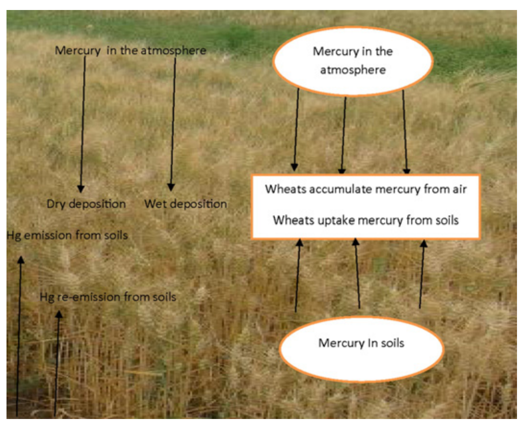
HIGHLIGHTS

- Hg concentrations in wheats and corresponding soils from loess plateau, northwest China.
- Spatial distribution pattern of Hg in wheat grains different from that of soils.
- Major source of Hg in soils was probably local sources.
- Principle source of Hg in wheat roots was probably soils.

GRAPHICAL ABSTRACT



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ABSTRACT

There is limited information on accumulation, transfer, and source of mercury in wheats under field conditions over the Loess Plateau, northwest China. The present study collected 26 pairs of topsoil and whole wheat samples (roots, stems, leaves, shells, and grains) from Dongdagou stream watershed and upper Xidagou stream watershed, Baiyin City, northwest China. Hg concentrations from these samples were used to identify their relationships with soil properties, interactions with other metals, localization of Hg in the different wheat tissues, bioconcentration and transfer of Hg, and major sources of Hg in wheat. Results show that Hg levels in 11 out of 26 sampled soils (42.3% of soil samples) exceeded Hg limit of grade II soil environmental quality standards in China (1.0 mg·kg^{-1}). Likewise, it was also found that Hg in over 50% of wheat grain samples reached or exceeded the maximum permissible food safety levels (0.02 mg·kg^{-1}) according to the General Standard of Contaminants in Food in China (GB 2762-2012). The spatial distribution pattern of Hg in wheats grains was different from that

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Hg
Wheat
Loess plateau

in the sampled soils. Hg concentrations in different wheat tissues were highest in roots, followed by leaves, stalks, shells, and grains, respectively. Bio-concentration factors (BCF) of Hg in almost all grains samples were one or two orders of magnitude lower than that in roots, except for two wheat samples. The translocation factors (TF) of Hg in wheat tissues on average were leaves > stems > shells > grains. The spatial distribution of Hg and its correlation with other heavy metal detected simultaneously in the soil samples suggested that the Hg soil contamination was probably caused by past sewage irrigation practices and atmospheric deposition. Correlation analysis revealed that the principle source of Hg in wheat roots was very likely from Hg contaminated soils.

1. Introduction

Mercury (Hg) is a pollutant of global concern owing to its long-range atmospheric transport, persistence, bioaccumulation, and significant adverse effects on human health and the environment. Hg may be methylated to extremely toxic methylmercury (MeHg) under certain environmental conditions. MeHg is more toxic and mobile than the inorganic form and is readily bioaccumulated and biomagnified in food chains (Peng et al., 2012). Coal combustion, Hg, Au, Ag, Cu and Zn mining and smelting activities, sewage irrigation, and industrial and agricultural uses of Hg have led to rising mercury contamination in soils (Du et al., 2005; Clarkson, 2002).

The contamination of soil and food crops by mercury is also an environmental and health concern because it can readily be untaken by plants and accumulated in the body where it poses a direct threat to human health (Wang et al., 2012a). It has been reported that in Guizhou Province, China, the main exposure pathway of MeHg to local residents was the consumption of contaminated rice grown near Hg mining areas, sometimes reaching levels as high as 145 μg/kg. (Zhang et al., 2010, Horvat et al., 2003). Meng et al. (2014) measured Hg soil concentrations in four mining districts and found that the mean total mercury concentrations in soils ranged from 2287.7 ± 1466.5 μg/kg in Fankou to 101,734.3 ± 60,220.7 μg/kg in Wanshan. Significant correlations were found between concentrations of total mercury and MeHg in rice plants and Hg levels in soils (Meng et al., 2014). Hg concentrations in wheat foliage were significantly correlated with Hg in air but not with Hg in soil, indicating that Hg in crop foliage was mainly from the air (Niu et al., 2011). It remains uncertain whether the primary source of mercury in plants is from the atmosphere or soil (Meng et al., 2014; Niu et al., 2011; Patra and Sharma, 2000). This poses a key question in the cycling of Hg concerning which sources contribute most significantly to Hg accumulation in plants (Ericksen et al., 2003; Niu et al., 2011).

Located in the Loess Plateau of Gansu province, Baiyin City is situated west of the Dongdagou and Xidagou stream basins and is a hub for industrial Hg pollution (Fig. 1). Various mining, smelting and industrial plants are located along both streams are both designated sinks for domestic wastewater and industrial sewage (Nan and Zhao, 2000). The average mercury content of coal used and exploited in Gansu Province is about 0.15 ~ 0.20 μg/g (EPIAGP and SWMCGP, 2012), higher than the world average of 0.10 μg/g (Srivastava et al., 2006), and slightly lower than the mean average concentration of 0.19 μg/g Hg in coal used in China (Zheng et al., 2007). Due to the shortage of fresh water for irrigation and improper land and water treatment over the past 40 years, local farmers have been using industrial and domestic wastewater to

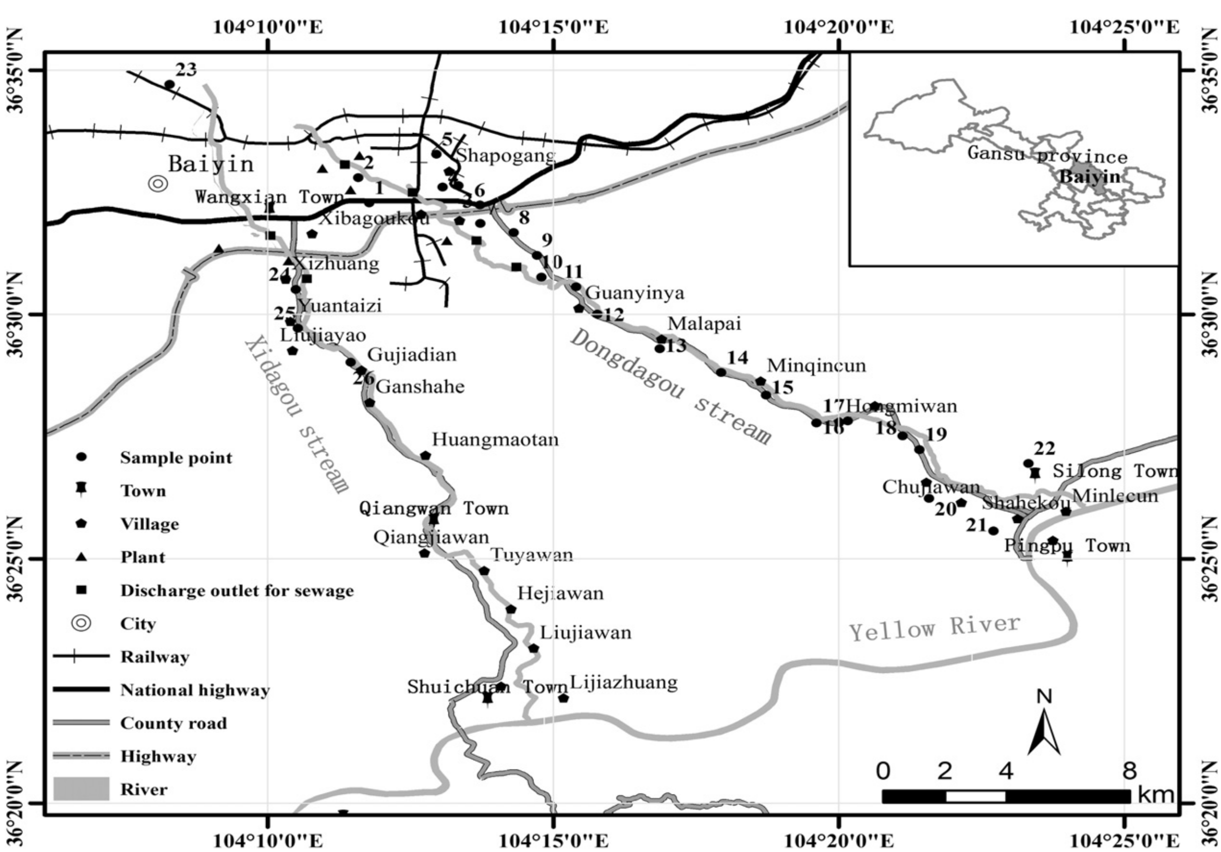

Fig. 1. Sampling sites in the farmland from the Dongdagou stream and Xidagou stream basins, Baiyin City, Gansu province, China.