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Review

Arsenic in the human food chain: the Latin American perspective

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ABSTRACT

Many regions of Latin America are widely reported for the occurrence of high arsenic (As) in groundwater and surface water due to a combination of geological processes and/or anthropogenic activities. In this paper, we review the available literature (both in English and Spanish languages) to delineate human As exposure pathways through the food chain. Numerous studies show that As accumulations in edible plants and crops are mainly associated with the presence of high As in soils and irrigation waters. However, factors such as As speciation, type and composition of soil, and plant species have a major control on the amount of As uptake. Areas of high As concentrations in surface water and groundwater show high As accumulations in plants, fish/shellfish, livestock meat, milk and cheese. Such elevated As concentrations in food may result in widespread health risks to local inhabitants, including health of indigenous populations and residents living close to mining industries. Some studies show that As can be transferred from the water to prepared meals, thereby magnifying the As content in the human diet. Arsenic speciation might also change during food preparation, especially during high temperature cooking, such as grilling and frying. Finally, the review of the available literature demonstrates the necessity of more rigorous studies in evaluating pathways of As exposure through the human food chain in Latin America.

Contents

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1. Introduction

Arsenic (As) is a ubiquitous element that can pollute soil, water, and plants including other compartments of the ecosystem and the environment, and ultimately affects human health and well being. The sources of As in the environment are mainly geogenic, i.e. naturally occurring (Bhattacharya et al., 2002; Smedley and Kinniburgh, 2002; Nriagu et al., 2007). In Latin America, naturally occurring As is commonly observed in the volcanic ash deposits, and volcanic rocks, predominantly of rhyolitic to intermediate composition. Arsenic is also observed to be associated with metal oxides as adsorbed phases, especially in iron oxides, clay particles, sulfide minerals and organic materials (Welch et al., 1988; Bundschuh et al., 2000, 2004; Bhattacharya et al., 2006). The release of As in the hydrosphere, pedosphere, biosphere and atmosphere is mainly associated with natural rock or mineral weathering processes and anthropogenic activities such as mining (discussed in detail by Bundschuh et al., 2011—this issue). Arsenic can be taken up by the terrestrial and aquatic biota which are either consumed by humans or incorporated into fodder for livestock. Although As can also be accumulated in animal tissues, the accumulated As in animal tissues can be partly transformed into organic As (o-As) through biomethylation processes (Centeno et al., 2002). In this paper we review the existing literature dealing with the occurrence of As in Latin America. Firstly, we synthesize the uptake of As from the soil and water by edible plants and animals, and their products, especially in the human food chain. Arsenic in processed foods and prepared meals is also reviewed and finally the biotransfer of As into the human diet is highlighted. Such critical synthesis of the available literature will assist us in evaluating pathways of human As exposure in Latin America that will also form a basis for risk assessment.

2. Arsenic in the human food chain

2.1. Arsenic uptake by the edible plants and crops

There are indications that the use of As-contaminated water for irrigation has led to accumulations of As in surface soils which further lead to bio-accumulations of As in edible plants and crops.

Based on the available literature, we have detailed here the country-specific information on As uptake by edible plants and crops from a Latin American perspective to evaluate pathways of As accumulation.

2.1.1. Mexico

Castro-Larragoitia et al. (1997) measured As content in corn (*Zea mais*) and chili (*Capsicum*) grown in the mining district of Santa Maria de La Paz (~500 km NNW of Mexico City, San Luis Potosí state, Fig. 1), where mining activities (Ag–Pb–Zn–Cu–Au) were active for the last 200 years. The climate of the area is semi-arid. The study showed that mine tailings (mean As concentration: 4000 mg/kg) are dispersed by the wind and surface water runoff during occasional heavy rainfalls and thereby contaminated the surface soils of the region. The As concentration in the grains of corn ranged between 0.05 and 0.55 mg/kg (dry weight, dw), but on the leaves used for livestock fodder, rose to between 2.1 and 33 mg/kg, dw (Castro-Larragoitia et al., 1997). The concentration of As in the stem was one-fold lower than in leaves (range 0.28–3.9 mg/kg, dw). The uptake of As from soils (top soil As was up to 300 mg/kg) was considered as the most prevalent accumulation process, supported by the decrease in As content from the bottom to the top of the leaves. However, adsorption of soluble As on the dust particles adhered to the leaves could be another reason for the observation of high As concentrations in some of the leaf samples.

At Zimapán, another historical semi-arid mining district in the Hidalgo province of central Mexico (Fig. 1), groundwater containing As concentrations above Mexican drinking water standards (25 μg/L) was consumed for more than a decade, affecting the health of thousands of inhabitants (Armienta et al., 1997a,b; Valenzuela et al., 2005). The studies suggested that the oxidation and dissolution of As-bearing minerals within a deep fractured limestone aquifer was the main As release mechanism (Armienta et al., 2001; Sracek et al., 2010). However, leaching of As from mine tailings may have also caused As pollution in shallow wells (Ongley et al., 2007). In this region, due to lack of exploitable surface water sources, the cultivated land primarily relies on irrigation water produced mainly from the As-enriched shallow groundwater. Prieto-García et al. (2005) studied As bio-accumulation in edible parts of plants/fruits in the cultivated