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Arsenic levels in human hair, Kandal Province, Cambodia: The influences of groundwater arsenic, consumption period, age and gender

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ABSTRACT

This study focused on the analysis of As levels in human hair samples collected from six villages in the Kandal Province of Cambodia. Of interest were the influence of, and interactions among, certain factors affecting As intake into the human body: As concentrations in groundwater, period of groundwater consumption, age and gender. The results revealed As levels in human hair ranging from 0.06 to 30 μg g^{-1} with median and arithmetic mean values of 0.61 and 3.20 μg g^{-1} ($n = 68$), respectively. Furthermore, a linear relationship was found between As concentrations in human hair and in the local groundwater. Arsenic (III) is the dominant species in Kandal groundwater, constituting in most cases at least 60% of the total As. Arsenic concentration ranged from 5 to 1543 μg L^{-1}, with the median value 348 μg L^{-1} and arithmetic mean 454 μg L^{-1}. In large rural, poor areas holding most of Kandal's 1.1 million people, up to 2 in 1000 people are believed to be at risk of cancer through the As-enriched water they drink. A toxicity risk assessment provides a hazard quotient (HQ) equaling 5.12, also a clear indication of non-carcinogenic exposure risk. On the authors' visit to Kampong Kong commune, Kandal Province, cases of arsenicosis were diagnosed in patients as a result of drinking As-enriched groundwater.

1. Introduction

Groundwater resources are a very important component of drinking water supplies for Cambodia (Berg et al., 2007; Federicks, 2004). Comprehensive groundwater surveys have been conducted by Buschmann et al. (2007, 2008) in the Mekong River floodplain and Rowland et al. (2008) in Kandal Province, Cambodia; both reported high-As concentrations in the groundwater. Sthiannopkao et al. (2008) sampled tube well water in the Prey Veng and Kandal Provinces of Cambodia. The concentration of total As in both provinces ranged from non-detectable (ND) up to about 900 μg L^{-1}, with 54% of all collected samples exceeding the WHO drinking water guide value (10 μg L^{-1}) (Allan et al., 2002). In Kandal, there have been many reports of As enrichment of groundwater (Polya et al., 2003, 2005; Buschmann et al., 2007; Kocar et al., 2008; Rowland et al., 2008; Benner et al., 2008; Luu et al., 2008). According to Buschmann et al. (2008), the mean As content of Kandal groundwater was 233 μg L^{-1}. Rowland et al. (2008) reported that the range of As concentrations was 0–855 μg L^{-1}. Kocar et al. (2008) reported, in addition, that dissolved As concentrations varied spatially, ranging up to 1300 μg L^{-1} in aquifer groundwater and up to 600 μg L^{-1} in surficial clay pore water. Benner et al. (2008) concluded that a unique combination of biogeochemical and physical-hydrologic properties of abandoned channel ponds may conspire to produce both high rates of As release and high rates of recharge, potentially delivering much of the As observed in the subsurface. According to Luu et al. (2008) about 86% of groundwater samples collected from three villages (PT, POT and CHL) in the Kandal Province of Cambodia contained As concentrations above the WHO drinking water guidelines. In addition, As (III) was found to be the dominant species (Polya et al., 2003; Rowland et al., 2008; Luu et al., 2008). The release of As into the groundwater is seen to result from microbial reductive dissolution of hydrated ferric oxides (Polya et al., 2003; Rowland et al., 2008; Polizzotto et al., 2008). In Cambodia, As-enriched groundwaters are situated in the Mekong floodplain, where young alluvium sediments dominate. According to Polya et al. (2003, 2005) and Buschmann et al. (2007), these young alluvium sediments have abundant hydrated ferric oxides in which As has been sorbed. That the groundwater in Kandal Province is under reducing conditions has been confirmed by the data from on-site measurements of low Eh, high NH_4^+ and Fe^{2+}, and low SO_4^{2+} and NO_3^- (Luu et al., 2008). Feldman

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