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Human health risk assessment from arsenic exposures in Bangladesh

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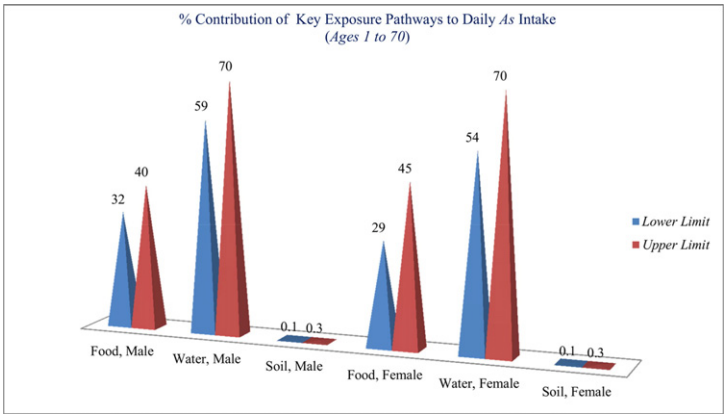
HIGHLIGHTS

- A health risk assessment from arsenic exposure for the people in Bangladesh was developed.
- 98% of daily arsenic intake in Bangladesh is through food and water consumption.
- Lifetime excess risk of cancer cases in Bangladesh is estimated as 1.15 million people.

GRAPHICAL ABSTRACT



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ABSTRACT

High arsenic exposures, prevalent through dietary and non-dietary sources in Bangladesh, present a major health risk to the public. A quantitative human health risk assessment is described as a result of arsenic exposure through food and water intake, tea intake, accidental soil ingestion, and chewing of betel quid, while people meet their desirable dietary intake requirements throughout their lifetime. In evaluating the contribution of each intake pathway to average daily arsenic intake, the results show that food and water intake combined, makes up approximately 98% of the daily arsenic intake with the balance contributed to by intake pathways such as tea consumption, soil ingestion, and quid consumption. Under an exposure scenario where arsenic concentration in water is at the WHO guideline (0.01 mg/L), food intake is the major arsenic intake pathway ranging from 67% to 80% of the average daily arsenic intake. However, the contribution from food drops to a range of 29% to 45% for an exposure scenario where arsenic in water is at the Bangladesh standard (0.05 mg/L). The lifetime excess risk of cancer occurrence from chronic arsenic exposure, considering a population of 160 million people, based on an exposure scenario with 85 million people at the WHO guideline value and 75 million people at the Bangladesh standard, and assuming that 35 million people are associated with a heavy activity level, is estimated as 1.15 million cases.

1. Introduction

The International Agency for Research on Cancer (IARC) classifies arsenic (*As*) and *As* compounds as a Group 1 carcinogen based on

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epidemiological studies where human exposure to inorganic arsenic (iAs) was found to increase the risk of cancer. The US Environmental Protection Agency (US EPA) lists iAs as a Group A, or known carcinogen. The carcinogenic potential of iAs is thus well established, manifesting itself in many types of cancers. As a carcinogen, *As* causes skin cancer (the most common cancer type associated with *As*), and/or can lead to internal cancers affecting the bladder and lung (ATSDR, 2007; Naujokas et al., 2013; Yoshida et al., 2004). A positive correlation has also been observed between *As* exposure and cancers of the kidney, liver, and prostrate (IARC, 2012). The most characteristic effect of chronic oral *As* exposure is skin disorders such as hyperkeratinization, hyper/hypo-pigmentation, and dermatitis. Other non-cancer health effects of *As* include vascular diseases, respiratory diseases, neurological effects such as peripheral neuropathy, neurobehavioral alterations, and cognitive impairment, higher risk of adverse effects in pregnancy, and anemia (ATSDR, 2007; IARC, 2004; Milton et al., 2005; Yoshida et al., 2004).

Bangladesh is located in the Bengal basin where the shallow aquifer is severely contaminated with *As*. Groundwater is the major source of water for human consumption and crop irrigation in Bangladesh. Among the rural populace, this source dependency is greater than 90%. The authors' companion review paper, '*A Critical Review of Arsenic Exposures for Bangladeshi Adults*', highlighted the consumption of *As*-contaminated food, consumption of *As*-contaminated beverages, accidental soil ingestion, betel quid chewing, tobacco smoking, and inhalation of *As*-contaminated air, in addition to uptake of *As*-contaminated water, as relevant *As* intake pathways for the adult population in Bangladesh (Fig. 1). The potential of human *As* intake through these dietary and non-dietary sources is a major public health concern in Bangladesh. Studies from Bangladesh have reported a correlation between human *As* exposure and non-accidental deaths, with greater *As* exposure associated with a higher risk of non-accidental deaths including death from cancer (Argos et al., 2010; Rahman et al., 2006; Sohel et al., 2009). A risk estimation by Argos et al. (2010), based on their prospective cohort study in Bangladesh (study period from 2000 to 2009 and covering 11,746 adults), reported that more than 20% of deaths in the cohort population over the period of investigation could be ascribed to *As* exposure (>0.01 mg/L) in drinking water. Against this backdrop, a human health risk assessment (HHRA) for Bangladesh, based on the significant *As* intake pathways identified in our companion review paper and focusing on carcinogenic effects owing to chronic *As* exposure, is developed in this paper.

2. Speciation of *As* in dietary & non-dietary sources

As, heavily influenced by conditions in the ambient environment, may occur in four different oxidation states: −III, 0, +III, and +V (Smedley and Kinniburgh, 2002; Wang and Mulligan, 2006). However, the inorganic *As* (iAs) forms trivalent arsenite (As(III)) and pentavalent arsenate (As(V)), predominate in water, soil and air (Smith et al., 1998). Other *As* forms include monomethylarsonate (MMA(V)), dimethylarsinate (DMA(V)), monomethylarsonite (MMA(III)), dimethylarsinite (DMA(III)), arsenobetaine (AsB), arsenocholine (AsC), trimethylarsine oxide (TMAO), tetramethylarsonium ion (TMA+), arsenolipids, and arsenosugars. The toxicity of *As* depends on its chemical form. In general, organic *As* species are considered either non-toxic or less toxic than iAs compounds which are known carcinogens. AsB is considered non-toxic to humans (Francesconi, 2010). According to IARC, DMA and MMA are 'possibly carcinogenic to humans' (Straif et al., 2009). AsC, TMAO, and TMA+ are not considered to be of toxicological significance (ATSDR, 2007; Lynch et al., 2014). Organic arsenicals like arsenosugars and

Fig. 1. *As* intake sources for Bangladeshi adults.