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Health benefit from decreasing exposure to heavy metals and metalloid after strict pollution control measures near a typical river basin area in China

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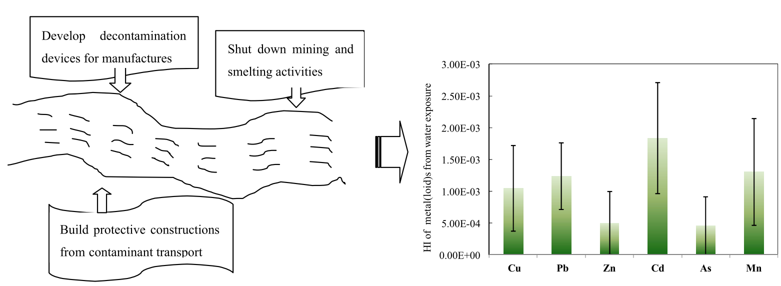
HIGHLIGHTS

- The contents of heavy metal(loid)s in various sites are observed along a typical river basin.
- The health risk assessments of local children and adult are analyzed.
- The water quality is not heavily polluted by heavy metal(loid)s.
- Ingestion exposure is the predominant pathway for the local population exposed to metal(loid)s.
- Health risks are generally acceptable, but risks were highest for the children (0–5 yrs).

GRAPHICAL ABSTRACT



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ABSTRACT

The metal(loid) pollution still is a great concern due to the effects from urbanization and industrialization. While, the health risks from the toxic metal(loid)s could decrease if strict pollution control measures were adopted. However, few studies to date investigate the health risks of heavy metal(loid)s in a systematic river basin for the dependent residents, after taking pollution control measures. Thus, the contents of metal(loid)s (Cu, Pb, Zn, Cd, Mn, As) in surface water along a typical river basin were investigated in this study, and the potential non-carcinogenic and carcinogenic health risks posed to the residents were assessed. Although the soluble contents of Cu, Pb, Zn and Cd exceeded the respective thresholds in two sites located downstream the mine area, they were greatly decreased in comparison with previous contamination levels, and the soluble concentrations of all the metal(loid)s were within the relevant thresholds in the sites far away from the mining area. Moreover, the closer to the mining area, the higher the pollution levels of metal(loid)s. The total hazard index for non-carcinogenic risks of metal(loid)s were basically lower than the threshold (1) for the local population. Whereas, although the content of metal(loid)s were low (such as As), they could pose relative higher non-carcinogenic health risks. The result illustrated that pollution levels, toxicity of the contaminants and exposure behavior patterns all could contribute to the potential detrimental health risks. Additionally, the non-carcinogenic

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and carcinogenic risks from ingestion exposure were ~2–~4 orders of magnitude higher than those from dermal contact. The total carcinogenic risks were basically lower than the maximum tolerable levels (1.0×10^{-4}), indicating carcinogenic risks from most areas of the river could also be accepted. Among different population groups, heavy metal(loid)s posed relative higher non-carcinogenic and carcinogenic risks to the children in 0–5 years old. Fortunately, the surface water in most area of this basin is safe in usage for the local population and the health risks were basically acceptable in case exposed to the target metal(loid)s, after the river basin was in the charge of strict pollution control measures.

1. Introduction

It is well known that safety of drinking water is of great concerns all over the world, especially for the developing countries like China. China's water resources are distributed quite unevenly. The northern river basins containing 44% of the national population have no more than 13% of the water supply (Xie et al., 2009). On the one hand, less than half of China's major rivers, lakes and reservoirs are suitable for use as drinking water after treatment (MEP, 2009), on the other hand, water shortage compel population to use contaminated sources (Wu et al., 2008). Nationwide, lots of households do not have access to a centralized public water supply and rely on untreated hand pump, well, or surface-water sources (Duan et al., 2014; Zhang et al., 2009; Zhao et al., 2016). These resulted in considerable association between water scarcity and adverse health outcomes, such as oesophageal cancer (Wu et al., 2008), liver cancer (Christoffersen and Kaas, 2000).

The water resources without treated would contain untreated sewage, fecal, microbial pollutants (Chorus and Bartram, 1999), and heavy metals from different natural sources (i.e., erosion of bed rocks, ore deposits and volcanic activities) and anthropogenic activities (i.e., mining, smelting and industrial influx, etc.) (Wilson and Pyatt, 2007; Shah et al., 2012). Particularly from mining activities, tailings which contain large amounts of heavy metals could cause contamination in nearby and downstream areas for rivers, lakes and reservoirs (Sarmiento et al., 2009; Kim et al., 2009). This contamination is mainly because of the wet precipitations like rainwater circulations, erosion and tailing debris transportation (Luis et al., 2011; Reis et al., 2007). Inevitably, the metal pollution of aquatic ecosystems is increasing due to the effects from urbanization and industrialization (Martin et al., 2015; Bai et al., 2011; Zhang et al., 2011). Thus, contamination of heavy metals in the aquatic environmental such as surface water has attracted great attention, and heavy metals are considered as priority pollutants owning to their abundance, persistence nature, bioaccumulation capacity and environmental toxicity (Ahmed et al., 2015a; Fu et al., 2014).

Excessive accumulation of toxic heavy metals in water may not only threaten the safety of ecosystems such as invertebrates and fish (Ahmed et al., 2015b; Islam et al., 2015), but also pose serious health effects to humans (Gutiérrez et al., 2008; Ahmed et al., 2015b; Martin et al., 2015; Saha et al., 2016). Although some heavy metals such as copper (Cu), znic (Zn) and manganese (Mn) are essential elements for human, high exposure or long-term low exposure may pose detrimental effects to health (Armendáriz et al., 2015; Espín et al., 2014). Moreover, some heavy metals, like lead (Pb), arsenic (As) and cadmium (Cd) are highly toxic at very low concentration (Kavcar et al., 2009; Saha and Zaman, 2013). High exposure to Pb can seriously damage the kidney, liver, central nervous and hematologic systems (Counter et al., 2008; Huang et al., 2012b; Sun et al., 2006). While, low dose exposure could also exert negative health effects (ATSDR, 2007; Grandjean, 2010; Jusko et al., 2008). Furthermore, it is reported that there is no safe level for Pb exposure (Koller et al., 2004; Lanphear et al., 2005), and Pb exposure is one of the important 67 risk factors contributing to the global burden of disease (Lim et al., 2012). Similarly, long-term exposure to As can result in a chronic systemic disease called arsenicosis, and cognitive function injury during childhood (Sun et al., 2015; Cordeiro et al., 2016) and in adults and elders (Liu et al., 2017). Also, more and more researches increasingly suggest that there may be no dose threshold for As, any low exposure could boost risks for diabetes, heart disease, immunological problems and cancer (Navas-Acien et al., 2008; Dangleben et al., 2013; Gilbert-Diamond et al., 2013). While, intake high level of Cd could lead to harm to kidney, lung, liver, bone and exert reproductive effects and cancer (Nordberg, 2003; He et al., 2013). Additionally, it is reported that Cd is a nephrotoxic metal with no known biological function in human (Akesson, 2011). Thus, the heavy metal(loid)s exposure is still regarded as a great concern.

Exposure to heavy metals via drinking water remains a present health threat to populations, particularly in areas of the developing countries (Fox et al., 2012). In recent years, numerous health-related pollution incidents associated with heavy metals in drinking water source have been widely reported in China, such as arsenic contamination of the drinking water source and, lately, cadmium pollution in Guangxi and Guangdong provinces (Huang et al., 2012a). Thus, the protection of water quality for the drinking water source has become a prime concern for the policy makers, especially for the developing countries like China. Therefore, analysis of heavy metals distribution in drinking water source is useful to identify the magnitude of contamination induced by anthropogenic pressure (Alves et al., 2014), while, estimation of potential health risk associated with the contaminated water exposure could be an important practice (Alves et al., 2014; Amaya et al., 2013). However, most studies associated with heavy metal(-loid) pollution in water focused on the magnitude and distribution of heavy metals in the aquatic environment (Miller et al., 2004) or pollution levels and human health risks of heavy metal(loid)s in certain industrial areas (Ji et al., 2013; Sipter et al., 2008). There are few researches to date pay attention to the health risks due to expose to drinking water source for the general residents, after adopting strict pollution control measures. Additionally, mining activities have resulted in the contamination of a considerable number of rivers with heavy metal(loid)s in China (Zhuang et al., 2009). Nonetheless, little information is available concerning the effects of mining pollution and the health benefit from strict pollution control measures for mining activities, on the population who lives beside the rivers and relies on them for food and livelihood. Whether the metal(loid) contamination in drinking water source would still pose health risks to the dependent residents after pollution control measures? What is the magnitude of health risks to the residents because of metal(loid) exposure from water, still need to be assessed in the drinking water source areas.

As risk assessment is the essential foundation of risk management (AS/NZS, 2009), quantitatively assessing the risks posed by