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Risk assessment and management of arsenic in source water in China

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ABSTRACT

As part of our efforts to identify effective ways and means to keep source water safe, the concept of risk assessment and management is introduced in this paper to address the issue of risk assessment and management of arsenic in source water in China. Carcinogenic and non-carcinogenic risk are calculated for different concentrations of arsenic in source water using the corrective equation between potential health risk and concentration of arsenic in source water with purification process taken into consideration. It is justified through analyses that risk assessment and management is suitable for China to control pollution of source water. The permissible content of arsenic in source water should be set at 0.01 mg/L at present in China, and necessary risk management measures include control contaminated sources and improvement of purification efficiency.

1. Introduction

Source water quality is deteriorating rapidly for water pollution and human activities throughout the world as more and more domestic and industrial wastewater are discharged into source water [1–3], and it is therefore very difficult to keep drinking water sources safe enough to ensure the health of human being [4]. So much work has been done to find effective ways and means to keep high quality of source water. For example, it is clearly stated in the amendments of Safe Drinking Water Act in USA that each state is required to develop a Source Water Assessment and Protection Program (SWAP) in 1996 to protect public water systems from being contaminated by identifying and analyzing potential contaminant sources [5]. Sound policies were formulated in British Columbia, Canada to identify, document, and reduce watershed risks and to sustain clean and safe drinking water sources [6]. As the results of risk assessment, stakeholders and governments have worked out effective protection plans and management strategies.

The quality of drinking water sources in China is also deteriorating fast, and has caused some problems. All the governments at different levels are trying very hard to take various measures to control water pollution and protect drinking water sources in recent years. They adopted the Water Pollution Prevention and Control Law, delineated source water protection areas, worked out national environmental protection plan, implemented water pollution control programs etc. The concept of risk assessment and management has been gradually introduced into the source water protection system of China.

According to the source water quality monitoring data published by Ministry of Environmental Protection (MEP) of China, arsenic has a very high detectable rate in source water. It has been proved through extensive research that arsenic is a toxic substance with adverse effects on human health [7]. In new *Water Quality Standards for Drinking Water* (GB5749-2006), the Ministry of Healthy in China lowered the permissible content of arsenic from 0.05 mg/L to 0.01 mg/L for centralized water supply.

The potential health risk caused by arsenic in China has been evaluated in this paper on the basis of background data of arsenic in source water and the arsenic removal efficiency of traditional purification processes, and then, the risk management measures has been suggested as the results of risk assessment and cost-effectiveness analysis.

2. Human health risk assessment method for pollutants in source water

The method developed by USEPA was used in this study to estimate the lifetime health risk of pollutants through oral ingestion [8]. The following are the basic equations used for lifetime cancer risk assessment and hazard index (*HI*) of pollutant *i* in drinking water:

$$\text{cancer risk}_i = CDI_i \times SF_i \quad (1)$$

$$HI_i = \frac{CDI_i}{RfD_i} \quad (2)$$

where cancer risk_i is the carcinogenic risk of pollutant *i* in drinking water (unitless); HI_i is the hazard index of pollutant *i* in drinking

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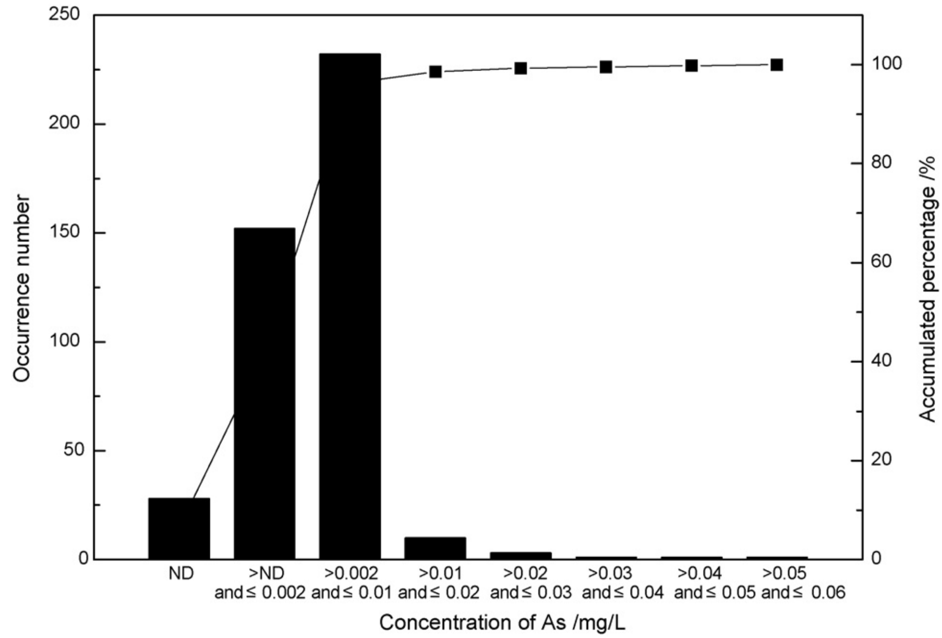

Fig. 1. Frequency distribution of annual average arsenic content in surface water sources measured at 428 centralized drinking water sources in 2006 in China (ND: not detected).

water (unitless); SF_i is the slope factor for pollutant i (kg d/mg); RfD_i is the reference dose for pollutant i (mg/kg d); CDI_i is the chronic daily intake (mg/kg d) for pollutant i.

The equation for CDI_i is:

$$CDI_i = \frac{C_i \times L \times EF \times ED}{BW \times AT} \tag{3}$$

where C_i is the concentration of pollutant i in drinking water (mg/L); L is the daily water ingestion rate (L/day), taken as 2L/day; EF is the exposure frequency (days/year), taken as 365days/year; ED is the exposure duration (year), taken as 30 years for non-carcinogens and 70 years for carcinogens; BW is the body weight (kg), taken as 70 kg; AT is the average exposure time (in day), 30 years × 365 days/year for non-carcinogens and 70 years × 365 days/year for carcinogens.

Source water can be drunk as drinking water only after being purified. If the removal efficiency for pollutant i is R (%), the relationship between the concentration of pollutant i in source water (C_{i0}) and C_i can be expressed as:

$$C_{i0} \times (1 - R) = C_i \tag{4}$$

Therefore, the relationship between the concentration of pollutant i in source water and the lifetime health risk by drinking water containing pollutant i can be established using the following

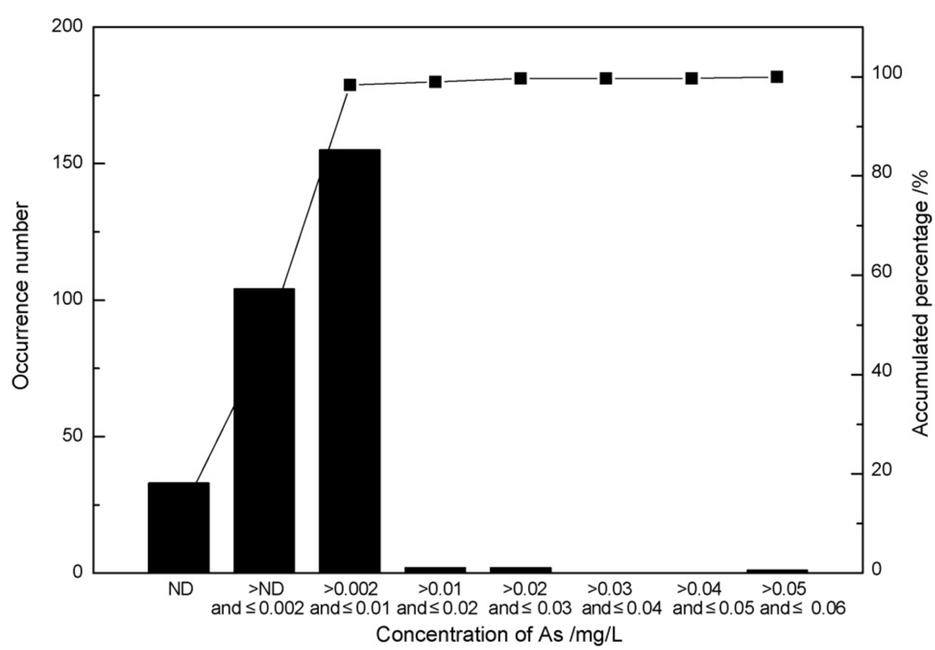

Fig. 2. Frequency distribution of annual average arsenic content in ground water sources measured at 297 centralized drinking water sources in 2006 in China (ND: not detected).