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Iodine speciation and its potential influence on iodine enrichment in groundwater from North China Plain

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Abstract

In order to reveal the pattern of spatial distribution of iodine in groundwater at North China Plain (NCP), a total of 136 groundwater samples were collected along the regional groundwater flow paths. The results showed that groundwater iodine ranged from 1.51 to 1106 µg/L, and 31.4% of the samples have iodine concentrations higher than 150 µg/L. High iodine groundwater samples are mainly observed in the coastal area of Bohai sea, and well depths greater than 350 m. The results of iodine speciation analysis showed that groundwater iodide, iodate and organic iodine had the ranges of <0.025~854 µg/L, <0.035~293 µg/L and <10~296 µg/L, respectively, indicating that iodide is the dominant species of iodine in groundwater at NCP. Iodate is only observed in groundwater with Eh values higher than 0 mV, suggesting that groundwater redox condition is the main factor controlling iodine speciation. The widespread sub-reducing/reducing condition and low affinity of iodide are the two main factors promoting the iodine enrichment in groundwater.

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1. Introduction

Iodine is an essential trace element for human thyroid hormones thyroxine (T₄) and triiodothyronine (T₃). However, excessive intake of iodine can cause serious health problems such as thyroiditis and thyroid papillary cancer. Residents in North China Plain (NCP) have been suffering both from high iodine groundwater and the exposure to iodine-enriched food chain¹. Groundwater accounts for approximately 86% of annual water supply at NCP. To avoid abstracting shallow saline and contaminated water for safe water supply, deep wells with depths

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greater than 300 m have been installed to meet the demand for water of domestic use and agricultural activities. Unfortunately, deep groundwater often contains high concentrations of iodine, especially in the coastal areas. Additionally, our previous studies suggested that iodine in solution can exist in several species, which exhibit different environmental and biological behaviors, for instance, the relatively higher affinities for iodate on iron oxides compared to iodide². Therefore, the main objectives of this study are (1) to investigate the spatial distribution of groundwater iodine at NCP, (2) to understand the iodine speciation and its controlling factors, and (3) to reveal the main factors affecting the iodine enrichment in groundwater from NCP.

2. Methods

A total of 136 groundwater samples from NCP were collected in July 2015 (Fig. 1). When sampling, total dissolved solid (TDS), redox potential (Eh), temperature (T) and pH were monitored using calibrated HACH Instruments' portable meters. Water samples were filtered on site through 0.45 μm membrane filters and stored in pre-cleaned 50 mL polypropylene bottles. Samples for total iodine, iodine species, bromine and total organic carbon (TOC) analysis were collected in pre-cleaned amber glass sampler vials without headspace, and stored in the dark until analysis. Total iodine and bromine were determined using ICP-MS (PE ELAN DRC-e). Inorganic iodine speciation analysis was conducted within a week after sampling using high performance liquid chromatography-inductively coupled plasma-mass spectrometry (HPLC-ICP-MS; AS14 analytical column, ICS-1500, Dionex; PE ELAN DRC-e), with the detection limits for iodate and iodide of 0.035 $\mu\text{g/L}$ and 0.025 $\mu\text{g/L}$, respectively. Organic iodine concentrations were calculated using the difference between total iodine and inorganic iodine. All the hydrochemical parameters were measured at the State Key Laboratory of Biogeology and Environmental Geology, China University of Geosciences in Wuhan.

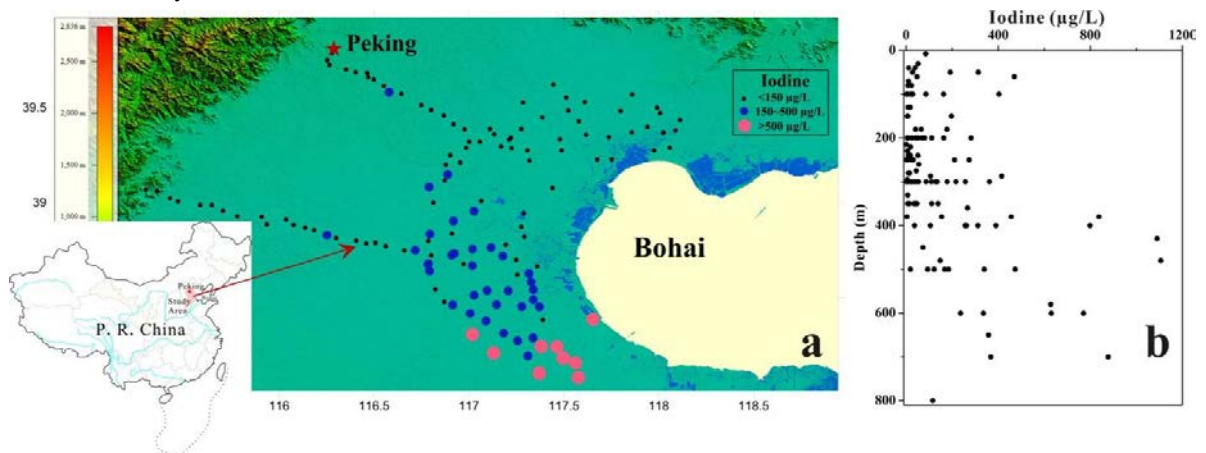


Fig. 1 Horizontal (a) and vertical (b) distribution of groundwater iodine at NCP.

3. Results and Discussion

3.1. Spatial distribution of groundwater iodine

Groundwater iodine at NCP ranged between 1.51 and 1106 $\mu\text{g/L}$ with the median value of 51.73 $\mu\text{g/L}$, and 31.4% of groundwater iodine exceeds the Chinese government recommended value of 150 $\mu\text{g/L}$ for drinking water. The spatial distribution of groundwater iodine is shown in Fig. 1. It indicates that in the northern part of NCP near Tangshan city, the groundwater generally had iodine concentrations lower than 150 $\mu\text{g/L}$, and high iodine concentrations (> 150 $\mu\text{g/L}$) are mainly observed in the coastal area of Bohai sea, especially near Cangzhou city. Vertically, although high iodine groundwater occurred in all sampled well depth from 8 to 800 m, iodine concentrations higher than 500 $\mu\text{g/L}$ were only observed in the well depth higher than 350 m.

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