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The hydrogeochemical characteristics of high iodine and fluoride groundwater in the Hetao Plain, Inner Mongolia

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Abstract

Twenty groundwater samples and two surface water samples were collected to determine the occurrence and distribution of iodine and fluoride in groundwater in the area of Hangjinhouqi, the Hetao Plain, Inner Mongolia. Currently, 65% and 50% of samples exceeded the Chinese standard (I=150μg/L, F=1mg/L) for drinking water for iodine and fluoride, respectively. No correlation has been shown between I and F, although the spatial distribution of high iodine and high fluoride groundwater samples overlaps, with 80% of the high fluoride groundwater samples located in the high iodine areas. Different enrichment mechanisms of fluoride and iodine are involved. Water-rock interaction processes are at the origin of fluoride rich-groundwater, whereas evaporation of shallow groundwater and the oxidation by microorganisms of elevated organic matter content in deep groundwater contribute to the enrichment of iodine.

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Keywords: high iodine; high fluoride; groundwater; Hetao Plain; correlation anlysis; hydrogeochemical characteristics.

1. Introduction

Mainly derived from natural sources, high concentrations of iodine and fluoride in groundwater pose potential health problems. Iodine is an essential micronutrient for synthesis of thyroid hormones in human body and animals; low iodine level (<5μg/L) results in iodine deficiency disorders (IDD), while high level (>150μg/L) of iodine causes iodine excess disorders (IED), and both deficiencies and excesses can lead to severe metabolic disorders, such as endemic goiter [1,2]. Similarly, small amounts of fluoride are

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essential for humans, it has an important role in forming dental enamel and minerals in bones, but at high concentrations can cause dental fluorosis and harm the central nervous system and bones [3].

The Hetao Plain, Inner Mongolia is a typical high fluoride area in China, where more than 5.7 million residents suffer from fluorosis due to long-term intake of high F^- groundwater [4]. It is also one of the regions in China with iodine excessive concentrations. In the past years, much attention has been paid to endemic fluorosis, and only little work has been done on the problem of high iodine groundwater. The main objective of this study was to delineate the spatial distribution of both I and F enrichments in the groundwater in this region, in addition, to analyze the relationship between the high iodine groundwater and the high fluoride groundwater, which will provide scientific basis for safety and water resource management in this area.

2. Sampling and analytical methods

Water samples were collected during August 2010 from 22 sites across Hangjinhouqi, including twenty groundwater and two surface water samples. All the groundwater samples were collected from the shallow aquifer with groundwater table ranging between 2.0 to 5.4 meters. Parameters including water temperature and pH were measured on site by using a Hach sension2 portable pH/ISE meter. Alkalinity was determined on the sampling day and equivalent volume was determined from a Gran titration. Water samples were also collected for subsequent laboratory analysis. Water samples for cation and trace elements analysis were immediately filtered and preserved with 6M HNO_3, while anion samples were not acidified. Samples for total iodine analysis were alkalized with 1% KOH. All samples were subsequently stored in a cool box until analysis. Major cations were determined by ICP-AES (IRIS Intrepid ⅡXSP). Anions F^-, Cl^-, NO_3^- and SO_4^{2-} were determined by ion chromatography (Dionex-DX-120). Concentration of total iodine was determined by ICP-MS. In most cases, analytical charge imbalances were less than 5%. All analyses were accomplished at the State Key Laboratory of Biogeology and Environmental Geology of China University of Geoscience in Wuhan.

3. Results and discussion

3.1. Water chemistry

All the water samples were plotted onto Piper's diagram (Fig.1 (a)), it shows that the water types are variable, between HCO_3-(Ca,Mg), HCO_3-Na, (Cl, SO_4)-Na and (Mg,Ca)-Cl types, only sulphated waters are missing. Most water samples have high TDS, with bicarbonate and chloride as the dominant anions and sodium as the dominant cation. The groundwater temperature ranges between10.1 and 23.8, and the groundwater is circum-neutral to slightly alkaline, with pH values ranging from 7.2 to 8.5.

3.2. Distribution of Iodine and fluoride

The concentrations of iodine in groundwater ranged from 27.3 to 1638 μg/L, with 65% of samples exceeding the Chinese standard of 150μg/L for drinking water. High iodine groundwater mostly belongs to the Cl-Na and (Cl, HCO_3)-Na types. Fluoride concentration was high up to 2.79 mg/L, with 50% of samples exceeding the Chinese standard of 1mg/L for drinking water. The spatial distribution of iodine and fluoride illustrated in Fig. 1(b), with delineation and of areas characteristic by high iodine and high fluoride concentrations. It is worth noticing that the spatial distribution of high iodine (>150μg/L) and high fluoride (>1mg/L) groundwater overlaps, with 80% of the high fluoride groundwater samples located in the high iodine areas.

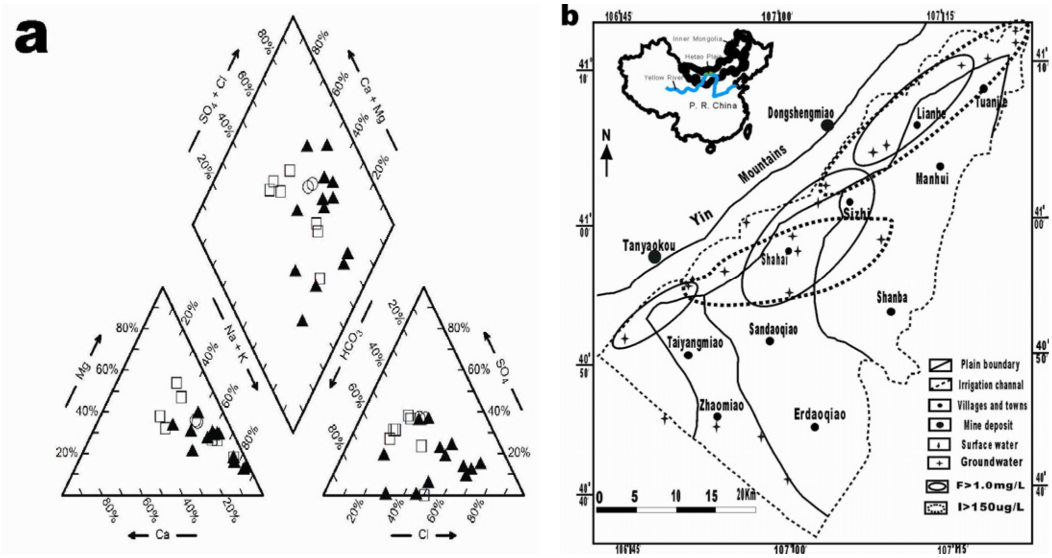

Fig. 1 (a) Piper diagram of groundwater and surface water in Hangjinhouqi (▲ I > 150μg/L □ I < 150μg/L ○ surface water); (b) The spatial distribution of iodine and fluoride in the area of Hangjinhouqi

3.3. Correlation analysis

Spearman's correlation coefficient has been calculated to examine possible relationships among the physicochemical parameters. The concentrations of iodine in groundwater have a positive correlation with HCO_3^- and TOC, with correlation coefficient of 0.668 and 0.832 respectively. The concentrations of fluoride in groundwater have a negative correlation with Ca and Mg, with correlation coefficient of -0.553 and -0.476, respectively. Correlation analysis showed that there was no obvious correlation between I and F. However, the spatial distribution of high iodine groundwater and high fluoride groundwater were similarly, these finding may be due to different enrichment mechanisms of fluoride and iodine in this area.

The study area is a typical sediment-filled basin, groundwater is recharged by vertically infiltrating meteoric water in the basin and laterally penetrating fracture water from marble, slate and gneiss along the mountain front, as well as drainage from natural lakes and canal. It is also impacted by evapotranspiration and irrigation return flow induced by agricultural activities and artificial extraction [5] is the main process of discharge. Two parameters are expected to contribute to the enrichment of iodine in groundwater in this region: the evaporation of shallow groundwater and the occurrence of the microorganisms in reducing and organic matter-rich deep groundwater. The latter process is the more contributive although the former is more common [6]. As far as F is concerned, the widely distributed hypo-metamorphic rocks may be the primary sources of F in the groundwater [7]. The saturation indices calculated for all the water samples using the computer program PHREEQC 2.18 indicates that all the waters are unsaturated with respect to fluorite, with saturation indices (SI) ranging from -0.51 to -1.85. Therefore, water-rock interactions between groundwater and minerals lead to the enrichment of fluoride in groundwater without any limitation by fluorite precipitation.

4. Conclusion

This study presents the occurrence and distribution of iodine and fluoride in groundwater in the area of Hangjinhouqi, the Hetao Plain, Inner Mongolia. The concentration of iodine in groundwater ranged from 27.3 to 1638.0μg/L, with 65% of water samples exceeding the Chinese standard of 150μg/L for drinking water, additionally, the concentration of fluoride was up to 2.79mg/L, with 50% of samples exceeding the Chinese standard of 1mg/L for drinking water.

Although, the spatial distribution of high iodine and high fluoride groundwater samples overlaps, with 80% of the high fluoride groundwater samples within the area of high iodine groundwater samples, correlation analysis have not shown any relation between I and F. This may be due to different enrichment mechanisms for fluoride and iodine. Fluoride is accumulated in groundwater through water-rock interactions, while evaporation of shallow groundwater and oxidation by microorganisms of organic matter in reducing deep groundwater and contribute to the enrichment of iodine in groundwater in this region.

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