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ScienceDirect
Procedia Earth and Planetary Science 10 (2014) 100 – 103
Procedia
Earth and Planetary Science

Geochemistry of the Earth's Surface meeting, GES-10

Temporal variability of groundwater chemistry and relationship with water-table fluctuation in the Jianghan Plain, central China

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Abstract

Samples were collected every month from 39 monitoring wells over a period of 1 year and three months (from Jan 2013 to Mar 2014) in the Jianghan alluvial plain in the middle reaches of the Yangtze river, central China, to evaluate the temporal variability of groundwater composition for As and other constituents. The concentrations of K,Na,Ca,Mg in groundwater generally varied less than 30%, whereas concentrations of the redox-sensitive components (Fe,NH_4-N,S and As) varied greater over time. In wells tapping the confined aquifers with depth of 25m, concentrations of groundwater As were much higher and ranged up to760 ±320 μg/L seasonally. Higher As concentration were associated with an increasing percentage of As(III) in rainy season and a decrease towards the end of dry season, indicating a reductive mobilization responding to groundwater level fluctuation.

Peer-review under responsibility of the Scientific Committee of GES-10
Keywords: arsenic; temporal variability; redox; water level; Jianghan Plain

1. Introduction

Naturally arsenic enrichment of groundwater is a subject of great concern, which has been reported from numerous countries worldwide[1-2]. China is one of the most serious waterborne endemic arsenicosis affected area. Typical cases of endemic arsenic poisoning have been reported in two kinds of regions in China[3-4]: Hetao Basin, Huhhot Basin, and Datong Basin were selected as arid inland basins in Northern China; Jianghan Plain is a newly discovered arsenic affected area in Southern China, which is one of the typical humid river deltas. Differences in climate, geological background and anthropogenic activities make investigations of high As groundwater in the

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Peer-review under responsibility of the Scientific Committee of GES-10
doi:10.1016/j.proeps.2014.08.018

Jianghan Plain different from those in northern China[5]. Temporal change of As concentrations in groundwater has been reported in Bangladesh and China[6-8].There is growing evidence that temporal changes of As concentration can be attributed to seasonal fluctuation of water-levels and its effect on redox condition or groundwater flow pattern.

In this paper, we present the results of 15 months groundwater monitoring data, from 39 monitoring wells installed in endemic arsenicosis area in Jianghan Plain. These observations not only fill a gap in our understanding of seasonal variation in groundwater arsenic concentrations, they also help us to figure out the mechanisms of As transformation and the relation to water-level fluctuation during pre-monsoon , monsoon and post-monsoon seasons.

2. Materials and methods

2.1. Study area

Jianghan alluvial plain in Central China is located in the middle Reaches of the Yangtze River, formed by Yangtze River and its largest tributary Han River (Fig.1a). It is well known as the beautiful and rich land of fish and rice. It has a sub-tropical monsoonal climate with an annual precipitation and evaporation of about 1200 mm and 1378 mm, respectively. Annual average temperature is 16.8°C. The monitoring field site was constructed in Shahu Original Farm, where the first case of arsenic poisoning was reported in Jianghan Plain[5]. The field site with an area of 10 km^2 lies in the hinterland of eastern Jianghan Plain in Xiantao City, surrounded by Tongshun River, Dongjing River, Kuige River, and Lvfeng River (Fig.1b), and covered by other abundant surface water bodies such as ponds, irrigation channel. The Quaternary groundwater systems can be divided into two groups of aquifers. The first group is composed of Holocene alluvial and lacustrine deposits (clay, silt and fine sand) with the thickness of 3-10m. The second group is composed of late and middle Pleistocence alluvial sediment (medium–coarse sand and gravel, interlaced clay lenses in local area) with the thickness of 30 m, which is the main aquifer for water supply. A total of 39 monitoring wells with three different depths were installed at 13 sites (Fig.1b). At each site, three monitoring wells with 10 m(A), 25 m(B), and 50 m(C) deep tapped shallow aquifers composed of Quaternary deposits.

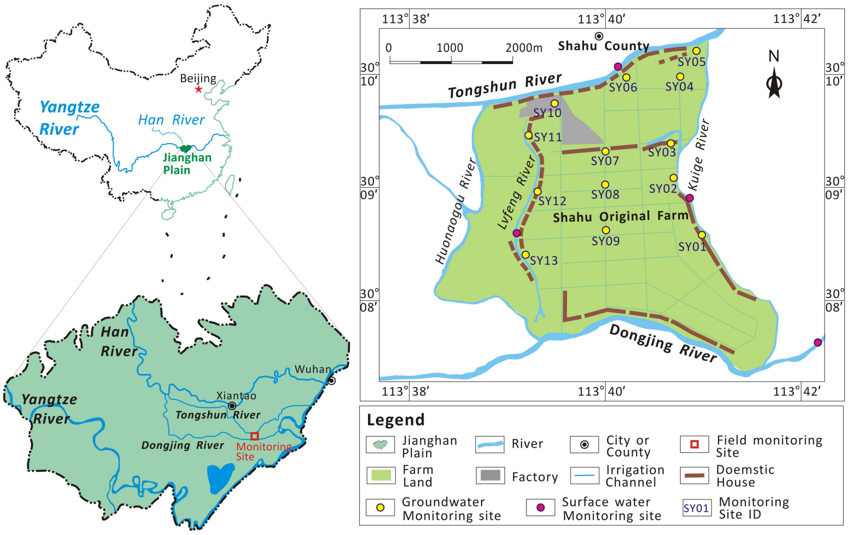

Fig.1 Maps showing the locations of field monitoring site in Jianghan Plain, as well as the distribution of groundwater and surface water monitoing sites.

2.2. Sampling and analysis

Groundwater samples were collected monthly from Jan 2013 to Mar 2014 in Shahu monitoring field site of Jianghan Plain. Temperature, pH, EC, and Eh were measured on site using a portable pH, EC, and Eh meter in situ(HACH HQ40D,USA). NH_4-N, Fe^{2+} and sulfide were measured on site using a portable spectrophotometer

(HACH 2800, USA). Concentrations of HCO_3^- were measured within 24 hours using acid-base titration methods. The total concentration of dissolved ions (Ca, Mg, Na, K, Fe, and Mn) was determined using an inductively coupled plasma atomic emission spectrometer (ICP-AES) (IRIS Intrepid II XSP, USA). Anions such as Cl^-, NO_3^-, and SO_4^{2-} were determined using an ion chromatograph (Dionex 2500, USA). Total dissolved As was determined using a hydride generation-atomic fluorescence spectrometer (HG-AFS, 930, Titan, China).

3. Results and discussion

3.1. Temporal water-level fluctuation and groundwater chemistry variation

Water levels of unconfined aquifer (well A with 10m depth) rose from 21.6 to 23.7 m abl during the wet season (Jun-Sep), drastically declined to 20.1m abl during the dry season (Nov-Mar). Water levels of confined aquifers varied from 21.3-22.3 m abl (well B with 25 m depth) and 21.5-22.3 m abl (well C with 50 m depth) during the wet season to 19.3-21.0 m abl and 19.0-20.9 m abl during the dry season, respectively.

Slight temporal variations in Na, K, Ca, Mg, and HCO_3 concentrations in groundwater were observed, with RSDs less than 30%. In comparison, seasonal variability of the concentrations of redox sensitive constitutes (NH_4-N, S^{2-}, Fe, Mn, SO_4, As) were much greater (Table 1).

Table 1 Temporal variations of redox-sensitive components in groundwater at different depths at field monitoring site in the Jianghan Plain

Index	Well Depth	unit	Pre-monsoon (May, 2013)			Monsoon (Aug, 2013)			Post-monsoon(Nov,2013)		
			Max	Min	Mean	Max	Min	Mean	Max	Min	Mean
Eh	10m	mV	-15.0	-125	-81.7	-132	-170	-153	-62.1	-151	-112
	25m		-46.0	-171	-89.6	-145	-190	-168	-135	-171	-148
	50m		-59.9	-177	-115	-95.5	-211.3	-164	-117	-146	-132
NH_4-N	10m	mg/L	11.0	0.20	2.64	11.1	0.15	3.45	10.4	0.26	3.22
	25m		11.3	0.55	3.11	10.9	0.60	3.75	10.9	0.50	4.03
	50m		3.03	0.85	2.19	2.80	1.05	2.09	2.88	1.13	2.15
S^{2-}	10m	μg/L	89	--	15	163	7.0	38.4	44.0	2.00	12.7
	25m		121	2	16	62.0	5.0	29.4	34.0	2.00	15.6
	50m		133	2	34	230	1.0	72.2	258	1.00	88.2
SO_4^{2-}	10m	mg/L	43.5	4.47	11.0	51.0	4.42	14.4	19.8	<0.01	8.54
	25m		8.95	4.09	4.74	6.20	4.15	4.64	5.52	<0.01	4.18
	50m		20.0	4.13	6.40	18.1	4.25	6.52	10.4	<0.01	5.69
Fe	10m	mg/L	17.5	0.32	7.86	33.3	3.11	14.1	33.7	1.93	12.5
	25m		5.40	1.07	2.97	13.5	1.79	7.62	12.5	0.15	6.30
	50m		5.98	0.72	2.43	7.02	2.03	3.70	4.94	1.97	3.49
Mn	10m	mg/L	5.43	0.54	1.89	5.43	0.57	2.19	4.89	0.26	2.03
	25m		5.70	0.60	1.60	6.42	0.29	1.86	6.54	0.17	1.80
	50m		4.06	0.17	0.67	3.83	0.19	0.84	3.30	2.57	0.75
As	10m	μg/L	65.5	2.70	20.3	182	23.6	48.0	105	2.57	33.1
	25m		122	5.46	48.0	1003	11.1	236	947	10.2	234
	50m		52.7	15.3	31.7	76.6	4.24	46.9	75.4	25.5	49.1

3.2. Seasonal variation of arsenic and the relation to water-level fluctuation

Seasonal variation in As concentration was observed in both unconfined aquifer and confined aquifer. Concentrations of total As in groundwaters from 39 wells in the monitoring field site ranged from 3.6±3μg/L to 760 ±320 μg/L during the monitoring period (Fig.2). Arsenic concentration was generally higher in August than in May. Seasonal variation in redox potential and concentrations of Fe in groundwater was consistent with that in As. Higher As concentration was observed in wells at 25 m. Temproal variations of arsenic concentration related to groundwater levels, with lower concentration corresponding to lower water level (during dry season) and higher concentration corresponding to higher water level (during wet season). Higher As concentration were associated with an increasing percentage of As(III) in rainy season and a decrease towards the end of dry season, indicating a reductive mobilization responding to groundwater level fluctuation. Reductive dissolution of Fe oxides and reductive desorption have been widely accepted as the major mechanisms for As release and mobilization in reducing conditions [2,7-8].

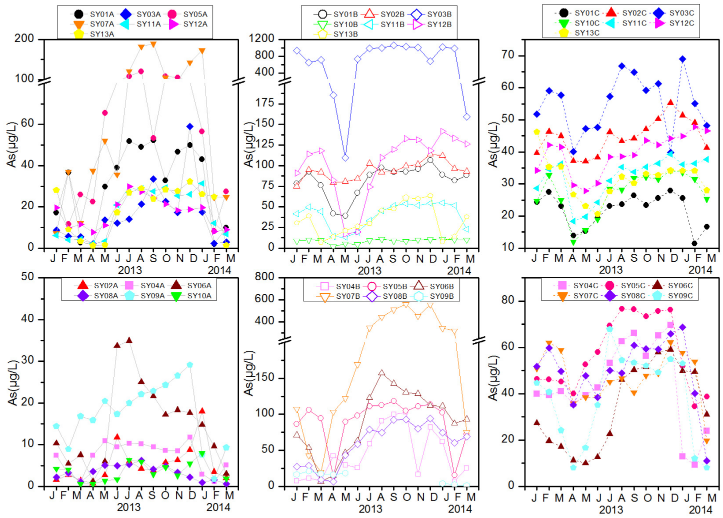

Fig.2 Temporal variation of arsenic concentration in groundwater at different depths in field monitoring site from Jan, 2013 to Mar, 2014.

4. Conclusions

Seasonal variation in As concentration was observed in both unconfined aquifer and confined aquifer in the Jianghan alluvial plain in the middle reaches of the Yangtze river, central China. Concentrations of total As in groundwaters from 39 wells in the monitoring field site ranged from 3.6±3μg/L to 760 ±320 μg/L over a period from Jan 2013 to Mar 2014. Higher As concentration were associated with an increasing percentage of As(III) in rainy season and a decrease towards the end of dry season, indicating a reductive mobilization responding to groundwater level fluctuation.

Acknowledgements

The research work was financially supported jointly by National Natural Science Foundation of China (41102153, 41120124003), the Fundamental Research Funds for the Central Universities (CUGL140412), and Program of International S&T Cooperation (No. 2014DFA20720) supported by Ministry of Science and Technology of China.

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