Physics and Chemistry of the Earth 36 (2011) 1353–1362

Contents lists available at ScienceDirect

Physics and Chemistry of the Earth

journal homepage: www.elsevier.com/locate/pce

Geophysical exploration for lithological control of arsenic contamination in groundwater in Middle Ganga Plains, India

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ARTICLE INFO

Article history:
Received 30 April 2010
Received in revised form 6 April 2011
Accepted 12 May 2011
Available online 24 May 2011

Keywords:
Groundwater
Arsenic contamination
Claybarrier
Geophysical surveys
ERT
TEM

ABSTRACT

A hydrogeochemical analysis of water samples in Middle Ganga Plains (MGP) revealed patchy occurrence of arsenic contamination in groundwater with high spatial variability. An integrated study consists of hydrochemical, 2-d DC resistivity and IP chargeability, and 1-d transient electromagnetic measurements (TEM) was carried out in the Ganga–Son interfluves region, which helped in identifying the contrast in lithological set up in the form of low resistivity (10–25 Ωm) and high chargeability (5–20 mV/V) clay deposits between the arsenic contaminated and arsenic free aquifers. It revealed that the clay acts as controlling factor to the arsenic contamination in the groundwater regime. Knowledge of impermeable clay barrier helps in reducing the uncertainties that exist in the hypothesis of arsenic in groundwater in the MGP, as the clay boundaries inferred from the geophysical interpretations coincide very closely with the boundary of arsenic free and arsenic contaminated groundwater obtained from the water quality analysis.

1. Introduction

Arsenic (As) contamination in groundwater is of increasing concern due to its high toxicity. The first arsenic-caused skin problem was diagnosed in Bangladesh in 1995 (Das et al., 1995). Later on many cases of acute and chronic arsenic poisoning were reported in various parts of the world (Gray et al., 1989; WHO, 1993; Senesse et al., 1999; Saha, 2003). The deep (~100 m or more) aquifers in southern Bangladesh (initially free from arsenic contamination, where arsenic in solid phase was not available) started picking up with time and became arsenicferous with accelerated groundwater extraction (Muralidharan, 1998; Acharyya et al., 2000; Sambu and Wilson, 2008). Slowly, after Bangladesh, the adjacent areas such as West Bengal in India also switched their water supply from surface water to groundwater. Around 10 million additional domestic wells were installed to provide potable water to over 100 million people (Harvey et al., 2005). The excessive pumping of deep aquifers caused imbalance in the groundwater dynamics and resulted induced leakage of arsenic contamination from shallow aquifers to the deep aquifers. Muralidharan (1998) advocated for construction of deep wells only in areas with thick clay layer overlying the deeper aquifer to avoid any vertical leakage and also optimization of the groundwater withdrawal.

Subsequently, As contaminations in the groundwater were reported from the Middle Ganga Plains (MGP) falling in Jharkhand, Bihar and Uttar Pradesh (UP) states of India (Chakraborti et al., 2003; Bhattacharjee et al., 2005; Acharyya and Shah, 2007; Shah, 2008; Chandra et al., 2009). UP Jal Nigam, Public Health Engineering Departments of Bihar and Jharkhand states and other Ground Water Agencies have done extensive work analyzing water samples for arsenic content in 30 districts of Uttar Pradesh and 15 districts of Bihar. In several areas of these districts, As concentration in groundwater has been found exceeding the Indian permissible limit of 50 μg/l. As per the recommendation of WHO (1993), the required permissible limit of As concentration in potable water is reduced to 10 μg/l. However in absence of an alternate source, the permissible limits has been relaxed to 50 μg/l in India (BIS, 2003).

The above fact drew attention of the geoscientists to look into the probable reasons responsible and provide a sustainable solution for mitigation. There are number of studies in this direction mostly dealing with geochemical aspects of the contamination and designing of various filters for removal of arsenic (Shen, 1973; Cheng et al., 1994; Hering et al., 1996; Joshi and Chaudhuri, 2001; Ning, 2002; Hug and Leupin, 2003; Wickramasinghe et al., 2004; Shih, 2005). The sludge coming out of the filter became a matter of great concern as it goes again into the subsurface and adds to the contamination of groundwater regime in the surroundings. There is a need of a dependable solution to sustainably provide potable water in the arsenic affected regions. It requires a

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doi:10.1016/j.pce.2011.05.009

Table 1
Hydrochemical data analyzed from Balia–Patna sector of Middle Ganga Plains.

S. No.	Latitude (°)	Longitude (°)	Samples	Depth (m)	As (μg/l)	ORP (mV)
1	25.75810	84.17097	HP-1	30	25	–
2	25.74437	84.13388	HP-2	14	10	–
3	25.74437	84.13388	HP-3	24	10	–
4	25.76701	84.35279	HP-4	18	10	–
5	25.76701	84.35279	HP-5	40	25	–
6	25.77891	84.39862	HP-6	76	25	–
7	25.78020	84.40014	HP-7	61	25	–
8	25.78020	84.40014	HP-8	18	100	–
9	25.78297	84.40127	DW-1	5	0	–
10	25.78297	84.40127	HP-9	18	100	–
11	25.78053	84.40259	HP-10	21	500	–
12	25.77486	84.41674	HP-11	24	10	–
13	25.77452	84.41693	HP-12	27	0	–
14	25.73707	84.46534	HP-13	41	100	–
15	25.73744	84.46548	HP-14	76	500	–
16	25.78053	84.40259	HP-15	24	500	–
17	25.76666	84.47217	HP-16	23	0	–
18	25.74011	84.61835	HP-17	24	0	–
19	25.74127	84.62528	HP-18	18	10	–
20	25.74121	84.62548	HP-19	27	50	–
21	25.74112	84.62521	HP-20	27	50	–
22	25.73977	84.62855	HP-21	27	50	–
23	25.69005	85.12746	HP-22	12	10	–
24	25.69508	85.13375	HP-23	30	500	–
25	25.69588	85.13425	DW-2	5	0	–
26	25.69005	85.12746	HP-24	12	10	–
27	25.69508	85.13375	HP-25	30	500	–
28	25.69414	85.13114	HP-26	38	20	–
29	25.64768	84.88523	HP-27	200	0	–
30	25.68517	84.87275	HP-28	30	300	–
31	25.68556	84.87287	HP-29	9	0	–
32	25.68300	84.87296	HP-30	24	300	–
33	25.68279	84.87378	HP-31	8	0	–
34	25.67472	84.72386	HP-32	21	10	–
35	25.68210	84.73315	HP-33	34	0	–
36	25.68237	84.73368	HP-34	24	0	–
37	25.68237	84.73368	HP-35	32	0	–
38	25.68312	84.78383	HP-36	30	0	–
39	25.68329	84.78332	HP-37	27	0	–
40	25.71217	84.79242	HP-38	24	10	–
41	25.65087	85.09019	HP-39	85	0	–
42	25.70396	84.8275	HP-40	12	0	44
43	25.70454	84.82724	HP-41	12	0	43
44	25.70435	84.82807	HP-42	24	0	64
45	25.70579	84.82812	HP-43	12	500	-85
46	25.70622	84.82825	HP-44	12	0	-33
47	25.70332	84.82828	HP-45	15	0	30
48	25.70663	84.82870	HP-46	–	0	72
49	25.70634	84.82877	HP-47	9	0	55
50	25.70666	84.82854	HP-48	12	0	−45
51	25.70663	84.82921	HP-49	14	0	46
52	25.70676	84.82918	HP-50	12	0	43
53	25.70633	84.82921	HP-51	12	0	79
54	25.70645	84.82941	HP-52	12	10	64
55	25.70548	84.83033	HP-53	12	0	98
56	25.70550	84.82970	HP-54	18	0	83
57	25.70483	84.82986	HP-55	18	0	88
58	25.70469	84.83058	HP-56	21	0	68
59	25.70416	84.83048	HP-57	18	0	109
60	25.70417	84.82947	HP-58	15	400	−99
61	25.70436	84.82941	HP-59	15	0	57
62	25.70446	84.82939	HP-60	24	0	111
63	25.70365	84.82922	HP-61	12	800	−65
64	25.70424	84.82919	HP-62	15	400	−3
65	25.70422	84.82876	HP-63	12	900	−57
66	25.70523	84.82890	HP-64	26	10	−55
67	25.70445	84.82830	HP-65	15	400	−72
68	25.70475	84.82829	HP-66	14	700	−59
69	25.70515	84.82826	HP-67	12	600	−63
70	25.70535	84.82834	HP-68	18	200	21
71	25.70563	84.82812	HP-69	12	400	−51
72	25.70533	84.82443	HP-70	12	350	−71
73	25.70575	84.82401	HP-71	–	350	−97
74	25.70569	84.82424	HP-72	12	100	−28