Access, monitoring and intervention challenges in the provision of safe drinking water in rural Bihar, India

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ABSTRACT

This practical paper addresses the vital gap in water quality monitoring in Bihar. The study addresses an institutional weakness in the area of water quality management in rural Bihar, India. The study focuses on the role of access as a vital component in addressing water quality monitoring and interventions that has a huge impact on protecting community health in areas severely contaminated with arsenic and fluoride. The study calls for a drastic shift in the monitoring and intervention strategy to address safe water provision for rural Bihar.

Key words | access, arsenic, fluoride, rural Bihar, technological intervention, water quality monitoring

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INTRODUCTION

Access to safe water is a prerequisite to good health. Located in the eastern part of India, (Figure 1) the state of Bihar faces tremendous challenges in ensuring access to safe water for its population of 83 million (Das 1999). Frequent breakdown of old assets, lack of repairs and maintenance, and irregular power supply prevents the sustainability of various technologies in rural Bihar for the provision of safe drinking water (State draft water policy of Bihar 2010). The arsenic and fluoride contamination of ground water poses a serious water quality problem (Srikanth 2009a). As many as 22 of the 39 districts have either arsenic or fluoride in excess in the drinking water above the permissible level of Indian drinking water standards (Bureau of Indian Standards (BIS) 1983).

The alluvial formations constitute prolific aquifers where a ‘tubewell with motorized pump’ could yield between 120 and 247 m^3/day (Saha *et al.* 2007). This has led to a proliferation of shallow boreholes with hand pumps in rural Bihar (Saha 1999; Mishra 2009). At government level, emphasis is laid on the physical coverage of the habitations with water supply schemes being undertaken on a yearly basis. However, site selection based on geology and water quality parameters are largely ignored. This has resulted in widespread occurrence of fluoride, arsenic and iron in the drinking water (Ghosh *et al.* 2007). It is said that Bihar has the largest number of hand pumps (both shallow ones and deep ones) promoted by government agencies. About 600,000 hand pumps have been installed by the state agencies alone (Table 1).

According to the ‘Public Health Engineering Department’ 13 districts are affected by elevated concentrations of arsenic of more than 50 ppb in drinking water and 11 districts by high levels of fluoride above permissible limits of 1.5 ppm set by the Bureau of Indian Standards (Tables 2 and 3). Many of the drinking water sources that are contaminated by arsenic also contain high concentrations of iron.

Considering the magnitude of the problem, an attempt has been made to understand the critical elements involved in the overall drinking water management in rural Bihar by assessing:

- The number of private drinking water sources and government-created sources and their relative ratio in the arsenic-, fluoride- and iron-contaminated villages in each administrative unit (panchayat).
- The number of dysfunctional hand pumps and operation and maintenance mechanisms available at community levels in the sample villages.

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Figure 1 | Map showing the state of Bihar.

Table 2 | List of districts and habitations contaminated by arsenic in Bihar state (*Source*: Public Health Engineering Department, Bihar)

Sl. No.	District name	Total number of blocks[a]	Total number of affected blocks	Total number of affected habitations
1	Begusarai	18	4	84
2	Bhagalpur	16	4	159
3	Bhojpur	14	4	31
4	Buxar	11	4	385
5	Darbhanga	18	1	5
6	Katihar	16	5	26
7	Khagaria	7	4	246
8	Lakhisarai	7	3	204
9	Munger	9	4	118
10	Patna	23	4	65
11	Samastipur	20	4	154
12	Saran	20	4	37
13	Vaishali	16	5	76
Total :		195	50	1,590

[a]Block is an administrative unit constituting a cluster of villages with over 100,000 inhabitants.

Table 1 | Status of drinking water sources created by Government of Bihar (Department of Public Health Engineering)

Sr No.	Description	Number
1.	Total no. of hand pumps across the state (Bihar)	656,048
2.	Total no. of dysfunctional hand pumps	71,419
3.	New hand pumps installed in the year 2010–2011	61,796
4.	Hand pumps repaired during 2010–2011	16,554

Source: Public Health Engineering Department, Bihar.

- Implication of unmonitored private drinking water sources on community health
- The overall impact of government water quality monitoring and intervention programmes in Bihar.

Table 3 | List of fluoride-affected districts and habitations in Bihar state (*Source*: Public Health Engineering, Bihar)

Sl. No.	District name	Total number of blocks	Total number of affected blocks	Total number of affected habitations
1	Nalanda	20	20	213
2	Aurangabad	11	8	37
3	Bhagalpur	16	1	224
4	Nawada	14	5	108
5	Rohtas	19	6	106
6	Kaimur	11	11	81
7	Gaya	24	24	129
8	Munger	9	9	101
9	Banka	11	6	1,812
10	Jamui	10	10	1,153
11	Sheikhpura	6	6	193
Total :		151	98	4,381

Importance of this study

This study focuses on the role of access as a vital component in addressing successful water quality monitoring and interventions. So far all efforts in monitoring and intervention strategy undertaken by the government in India have been based on monitoring of government drinking water sources and setting up community treatment systems without giving much importance to the access to the drinking water sources within the community and this remains a major gap in the provision of safe water to the communities affected by arsenic and fluoride. This study would contribute to a new line of thinking which is largely overlooked in the overall context of water quality management programme in the country which should differ state to state based on local ground realities.

METHODOLOGY

A survey-cum-study was undertaken in one village per panchayat (a panchayat is an administrative unit comprising a number of villages with population less than 10,000) spread across 30 districts of Bihar. Stress was laid on identifying quality-affected villages in each district especially those affected by arsenic, fluoride and iron. The data was collected through close-ended questionnaires as well as personal interviews with the village head. Cross verification of secondary data given by the state agencies was done on a sample basis.

Questionnaires

A detailed close-ended questionnaire was developed that included details regarding the total number of households, number of shallow private hand pumps, total number of government hand pumps, income status of the families and existence of operation and maintenance plans for hand pump maintenance. The questionnaire was administered to almost all households in the sample village to get a comprehensive picture.

Personal interview

A personal interview was conducted with each village head regarding the quality of the drinking water source, household details, etc. All the information given by the village head was cross validated with government records and site visits.

Area of the study

The sample included nine arsenic-affected districts, eight fluoride-affected districts and seven iron-affected districts (Table 4).

RESULTS

The results from the study indicate that hand pumps are the major source of drinking water in almost all districts of Bihar. The total number of hand pumps at households was found to be higher in contaminated habitations than in the districts that were relatively free from major contaminants (Table 4). Further, it is observed, that the number of shallow hand pumps at households (private) outnumber the government-created sources (Figure 2). Districts affected by iron and arsenic contamination had a greater number of hand pumps at household level when compared to the fluoride-affected districts which fall under water-stressed areas. Unlike the government-created sources, the private hand pumps are set at lesser depths, i.e. around 18–24 m.

Access to the drinking water

The percentage of population with access to drinking water sources via hand pumps in arsenic, fluoride and iron-contaminated habitations is given in Figure 3(a,b,c,d). The study revealed that access to the drinking water through hand pumps is higher in the arsenic and iron-contaminated belt, compared with the uncontaminated sites. This is probably due to hydro-geological conditions and population density. The sites contaminated with arsenic and iron fall under a high water table zone, therefore there is a proliferation of shallow hand pumps at household level leading to an increase in access.

Dysfunctional hand pump

Our study has shown that the total number of dysfunctional hand pumps varied from 24 to 31% in different sample villages in the state of Bihar (Figure 4). A significant number of dysfunctional hand pumps were observed in fluoride-affected areas. Since fluoride contamination goes hand in hand with water stress, the hand pumps in fluoride-affected areas are subjected to more wear and tear (Srikanth 2009b). The number of dysfunctional hand pumps of private sources was insignificant, when compared with government-created hand pump sources. This

Table 4 | Total number of drinking water sources in the sample village affected by arsenic, fluoride and iron (deep and shallow hand pumps)

					Total no. of sources (A) + (B)		
Sr No	District	Block	Panchayat	Arsenic	Govt (Deep hand pump)	Pvt (shallow hand pump)	Population exposed to contaminants from shallow water sources
1	Saran	Chapra Sadar	Mushepur	Arsenic	564	657	4,050
2	Buxar	Chaki	Arak	Arsenic	64	1,350	6,750
3	Patna	Maner	Singhara	Arsenic	29	112	672
4	Khagaria	Rahimpur	N. Rahimpur	Arsenic	210	1,500	9,000
5	Vaishali	Bidupur	Rahimpur	Arsenic	45	150	900
6	Samastipur	Mohanpur	Dumri Uttar	Arsenic	80	620	3,720
7	Bhagalpur	Nathnagar	Gosaipur	Arsenic	65	550	3,300
8	Darbhanga	Alinagar	–	Arsenic	82	856	5,136
9	Bhojpur	Shahpur	Simaria	Arsenic	3	950	5,700
Total					**1,142**	**6,745**	**39,228**
1	Aurangabad	Deo	Pawai	Fluoride	9	40	360
2	Kaimur	Bhabua	Akahlaashpur	Fluoride	102	750	4,500
3	Rohtas	Sheo-sagar	Naad	Fluoride	5	107	642
4	Munger	Haveili Kharagpur		Fluoride	181	685	4,110
5	Jamui	Jamui	Manjhwe	Fluoride	69	45	270
6	Gaya	Nagar Prakhand Chanduati Block	Churi	Fluoride	243	692	4,152
7	Nalanda	Asthanwa	Nowanwra	Fluoride	25	300	1,800
8	Banka	Amarpur	Bishanpur	Fluoride	112	1,042	6,240
Total					**746**	**3,361**	**15,794**
1	Araria	Raniganj	Hasanpur	Iron	720	1,080	**6,480**
2	Saharsa	Sour bazar	Sour bazaar Purvi	Iron	100	577	3,462
3	Kishan ganj	Kishan ganj	Zinga kata	Iron	36	2,689	16,134
4	Madhepura	Kumar khand	Tengraha Siklyaha	Iron	336	1,377	8,262
5	Gopal ganj	Manjha	Gausia	Iron	59	16	96
6	Purnia	K. Nagar	Ganeshpur	Iron	186	3,278	19,668
7	Siwan	Hussain ganj	Gopalpur	Iron	12	1,518	9,100
Total					**1,429**	**10,535**	**63,202**
1	Sitamarhi	Baja patti	Rudauli	None	118	99	594
2	W.Champaran	Majhauliya	Bkhariya	None	50	222	1,332
3	Madhubani	Madhepur	Sunder virajeet	None	201	461	2,766
4	Muzaffarpur	Muraul	Mirapur	None	80	305	1,830
5	Arwal	Arwal	Arwal Sipah	None	534	150	900
Total					**983**	**1,237**	**6,090**

is because of increased ownership of hand pumps at household level which addresses better operation and maintenance than the community or public sources created by the state agency and therefore the number of dysfunctional hand pumps created by the government is increasing.

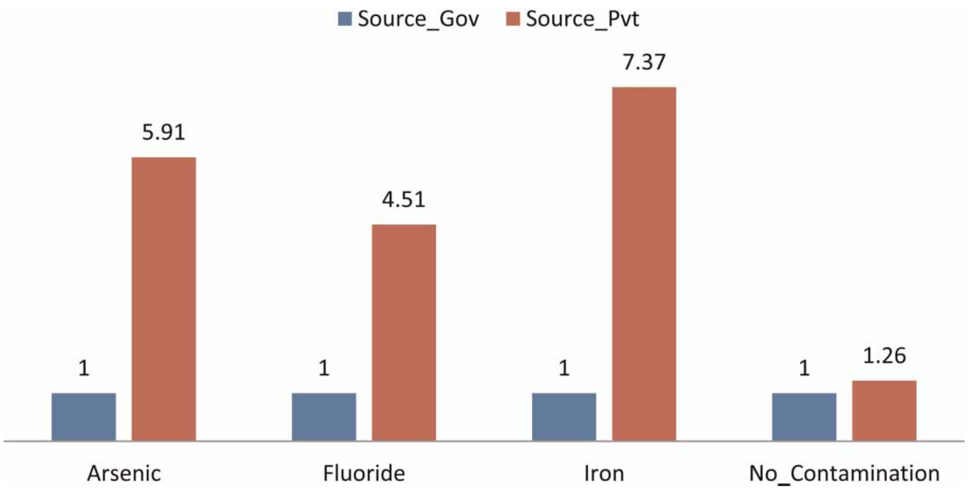

Figure 2 | Ratio of government deep source and private shallow water sources.

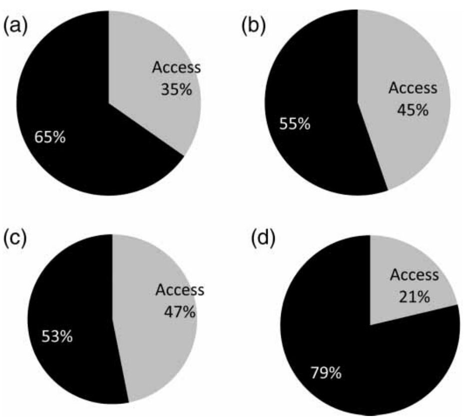

Figure 3 | (a) Access to water sources in arsenic-contaminated habitations, (b) Access to water sources in fluoride-contaminated habitations, (c) Access to water sources in iron-contaminated habitations, (d) Access to water in non-contaminated habitations.

DISCUSSIONS

Risk of exposure to arsenic, iron and fluoride from shallow and unmonitored hand pumps

The shift from traditional unprotected wells that were microbiologically unsafe but offered relative safety from geogenic chemicals, like arsenic, fluoride and iron, has led to a proliferation of shallow hand pumps in the state of Bihar. The rapid proliferation of shallow hand pumps is related to hydrological features which are similar to the situation prevailing in Uttar Pradesh, West Bengal and Bangladesh that lie across the Indo-Gangetic plain (Chakraborty *et al.* 2004). Many of the districts affected by water quality fall along the Indo-Gangetic plains that are in high water table zones. The shallow hand pumps yield water from a depth of 30 feet and the majority of the hand pumps are local versions and their depth varies from 30 to 50 feet. Many local versions of the hand pumps are affordable for the rural poor in Bihar. The arsenic and iron contamination is confined within a younger alluvial belt along the River Ganges, representing the reducing environment resulting in mobilization of arsenic in ground water. The affected aquifer is the main supplier of drinking water in rural Bihar through shallow hand pumps. Over 6,500 shallow hand pumps are found at household levels (private) in the sample villages in seven districts of Bihar, as against 1,142 deep hand pumps. Over 39,228 of the population are at risk of arsenic exposure through the shallow source in the sample villages, about 15,794 are at risk from fluoride and over 63,202 at risk of iron contamination (Table 4). Therefore, the risk of exposure to arsenic is considerable through these shallow sources (Table 4). In other words increased access to water through shallow sources is directly responsible for arsenic exposure among the community.

Similarly, unmonitored household sources serve as the major route for exposure to fluoride. Over 3,000 unmonitored sources are located in sample villages in eight districts that are classified under fluoride contamination.

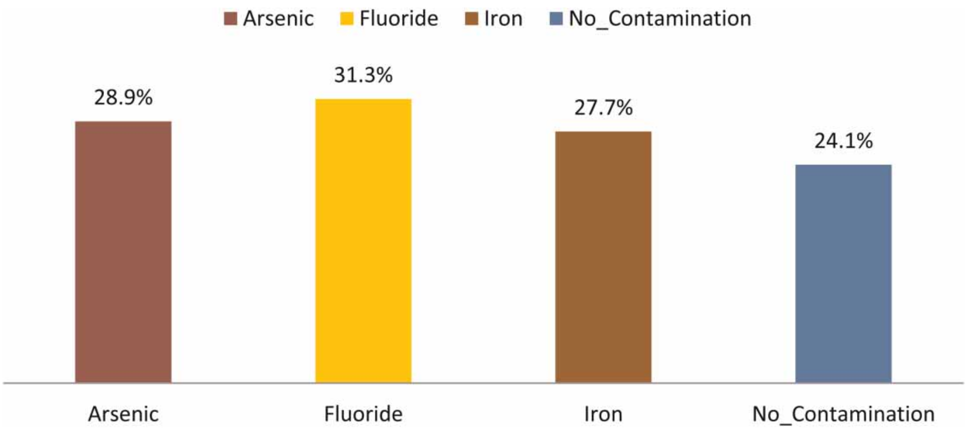

Figure 4 | Dysfunctional government drinking water sources (deep hand pumps).

Further, there appears to be enormous risk of more habitations and communities coming under the risk of arsenic and fluoride exposure if the present trend of usage of unmonitored household water sources remains unabated. There is a need for an effective information education and communication strategy that discourages the use of shallow hand pumps in arsenic- and iron-affected habitations and prevents usage of unmonitored water sources in districts that are endemic to fluoride contamination.

Further it was found that the majority of government hand pumps are based on deeper aquifers that are free from arsenic contamination (Ghosh 2007). However, in the absence of operation and maintenance being in place, the majority of hand pumps based on safer aquifers, that are developed by state agencies, are worn out depriving the community of accessing safe water (Figure 4).

Monitoring and mapping challenges

One major issue emerging from this study is how far the present water quality monitoring and mapping, undertaken by the state agency, is valid in the given situation. The mandate of the state agency is to create and monitor government-created drinking water sources and water supply schemes. The mandate restricts water quality monitoring to government-created sources only, whereas the study clearly suggests that the private hand pumps clearly outnumber the government-created drinking water sources (Table 4). Therefore, monitoring of water quality and mapping of water contamination based on the government-created sources is grossly inadequate and does not reflect the ground reality.

In fact, the government-created sources in Bihar are usually based at a greater depth range of 80–120 feet. This would render the government sources relatively free from contamination in the arsenic-prone areas whereas the private sources, which are in significant numbers, are at risk of arsenic contamination and pose immediate public health concern from contamination. Therefore, classification of the affected habitations and mapping based on government sources, where at least 30% of these sources are dysfunctional sources, would lead to erroneous conclusions.

Therefore, it can be argued that unless 20–30% of privately held sources are analyzed it is difficult to draw a meaningful conclusion resulting from the monitoring and mapping exercise undertaken presently. In the existing institutional system, there is no provision for such monitoring, unless the community pay for getting their water tested, therefore this would remain untested, exposing the population to arsenic-, iron- and fluoride-contaminated water. The study calls for mandatory testing of private sources as well. Blanket testing confined to government sources is inadequate in terms of public health perspective.

A better mechanism that could be advanced for monitoring of water quality would involve outsourcing water quality testing to private/non-governmental organization (NGO) agency at district level as part of a private–public partnership by contracting services and utilizing the government infrastructure (laboratory) in areas where sources are very high and therefore difficult to monitor with the available infrastructure and human resource available from the state agency. An exercise undertaken recently by us revealed an attractive business option for building up of the private–public participation concept in the area of water quality monitoring (Srikanth 2011).

Intervention challenges

Interventions for arsenic, fluoride and iron removal are undertaken by the Government of Bihar by the Public Health Engineering Department under various central and state government schemes (Table 5). These include installation of community level centralized treatment plants for removal of arsenic, fluoride and iron.

Targeting uncontaminated deep aquifers is considered as an attractive option and has been adopted in Bihar and Uttar Pradesh although the long-term impact is not known. However, recent scientific evidence emerging from other parts of the world, like Vietnam, shows increasing risk of exposure due to leaching when large-scale abstraction is adopted (Michael & Voss 2008; Winkel *et al.* 2011). Further research is required to understand the risk of arsenic exposure from deeper aquifers through motorized extraction of water in large quantities for village drinking water supply and agriculture in Bihar based on ground water.

A close look at the community level water treatment facility revealed that less than 50% of households access safe water from community sources, although the state and the centre incur huge expenditure on a yearly basis for the

Table 5 | Mitigation measures undertaken by Government of Bihar in the districts affected by contaminants

		Arsenic		Fluoride		Mitigation measures	
S.no.	**District**	**Arsenic (ppb)**	**Affected population**	**Fluoride (ppm)**	**Affected population**	**Treatment plants**	**Alternate measures**
1	Begusarai	321	210,013			9	
2	Bhagalpur	267	39,737	5.5	135,013	2	
3	Bhojpur	987	211,340			2	
4	Chapra	120	79,840			1	
5	Darbhanga	124	27,602			2	
6	Katihar	187	218,939			8	
7	Khagaria	250	133,343			4	
8	Samastipur	298	66,641			3	
9	Lakhisarai	254	14,531				
10	Buxar	256	198,867			3	Multi-village water supply project
11	Patna	765	76,500			2	
12	Vaishali	156	132,788			2	
13	Aurangabad			3.7	12,495		
14	Jamui			6.0	69,950	1	
15	Gaya			6.4	223,727	5	
16	Rohtas			5.0	34,591		
17	Sheikhpura			6.7	23,925		
18	Nawada			4.3	299,424	2	
19	Nalanda			5.6	42,000		
20	Banka			7.6	21,000		Hand pump attachments
21	Munger	149	27,872	10.8	51,716	3	
22	Bhabhua			3.2	190,000		

Table 6 | Reasons for not accessing safe water from WTP

Reasons	Community (%)
Plant too far from home	16.2
Timings not convenient	18.9
Takes too long to reach the water treatment plant	5.4
Plant is difficult to reach	18.9

installation of water treatment plants (WTP) for removal of contaminants (Table 6). The study reveals that the need to collect water from the treatment facility is the primary reason for not using the service properly.

Access to safe water is very much interlinked to interventions. Table 6 gives reasons for not accessing water from a treatment plant. Site selection remained arbitrary and the community were seldom consulted or involved in the government schemes, which are largely contractually driven. Other constraints for use of treatment plant water were the presence of a water source within the household, perception that own source is better than the community source including the treatment plant and inclement weather conditions. Perhaps one of the practical approaches in arsenic-contaminated areas would be to facilitate deepening of shallow hand pumps at household levels by adopting some financial mechanism including microfinance as one of the viable approaches in the provision of safe water. Point of use filter can be an interim measure to combat the drinking water contamination.

CONCLUSIONS

The following conclusions are reached from the study:

1. Government hand pumps are probably safer (due to greater depth of abstraction) but a large number of them are dysfunctional and they are fewer in number when compared to private shallow boreholes.
2. Private shallow boreholes are more likely to be affected by arsenic, iron and fluoride in the affected blocks and serve as major sources of exposure to contaminants especially arsenic.
3. Current water quality testing does not cover private hand pumps and is therefore not very relevant to public health.
4. Targeting uncontaminated deep aquifers is a popular option although the long-term impacts are not known.
5. Community water treatment does not resolve the problems, as access to safe drinking water remains unresolved in reality in the affected blocks.
6. Promotion of affordable 'Point of use filters' as an interim measure for arsenic and fluoride management should be encouraged.
7. Deepening of shallow hand pumps at households may be considered as one practical option using micro financial institutions.
8. Research needs to be undertaken to understand the future risk of exposure to arsenic due to large-scale motorized abstraction for water village supply and tube well-based agriculture across the Indo-Gangetic plain in Bihar.

DISCLAIMER

The views and opinion expressed in this article are based on the author's own experience gained from the field and in no way represent those of his organization.

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