

Challenges of sustainable water quality management in rural India

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High rates of mortality and morbidity due to water-borne diseases are well known in India. Serious degradation of water quality in urban India has often been attributed to indiscriminate disposal of sewage and industrial effluents into surface water bodies. Although some degree of intervention in terms of chlorination and monitoring of water quality exists in major cities and towns, rural India, which constitutes the bulk (70%) of the population, is usually deprived of such interventions. The population in rural India is mainly dependent on the groundwater as a source of drinking water. As a quality concern the groundwater is often found to be contaminated with fluoride, arsenic, iron and salts. In recent years, fluorosis has emerged as major public health issue in rural India.

At the technical level, some progress has been made in the development and use of field-level diagnostic kits. Decentralization of health-related monitoring at the villages needs to be institutionalized and this requires capacity development at all levels.

This article discusses the various components that impact effective water quality management in rural India. Experience suggests that redesigning of data management programme at village, district and at national level, upgradation of district-level laboratories and addressing technical, legal and institutional components should become the first steps in achieving effective water-quality management and providing better health to millions of people living in rural India.

Keywords: Data management, rural India, water quality monitoring, water quality standards.

ACCESS to safe drinking water remains an urgent necessity, as 30% of urban and 90% of rural households still depend completely on untreated surface or groundwater¹. While access to drinking water in India has increased over the past decade, the tremendous adverse impact of unsafe water on health continues². It is estimated that about 21% of communicable diseases in India is water-related³. The highest mortality from diarrhoea is said to be among children under the age of five, highlighting an urgent need for focused interventions to prevent diarrhoeal disease in this age group⁴. The diarrhoeal and other water-borne diseases in India are given in Table 1.

Despite investments in water and sanitation infrastructure, many low-income communities in India and in other developing countries continue to be bereft of safe drinking water⁵. Regardless of the initial water quality, widespread unhygienic practices during water collection, storage and consumption, overcrowded living conditions and limited access to sanitation facilities perpetuate the transmission of diarrhoea-causing germs through the faecal-oral route (Table 1)⁶. A majority of inland rivers which are

the sources of drinking water in urban India are also contaminated (Table 2)⁷.

While the shift in usage from surface water to groundwater has undoubtedly controlled microbiological problems in rural India⁸, the same has however, led to newer problems of fluorosis and arsenicosis^{9,10}. Excess iron is an endemic water quality problem in many parts of eastern India¹¹. In 2002, 17 states were affected by severe fluorosis¹² and now the problem exists in 20 states, indicating that endemic fluorosis has emerged as one of the most alarming public health problems of the country¹³. About 62 million people are suffering from various levels of fluorosis, of which 6 million are children below the age of 14 years; they suffer from dental, skeletal and/or non-skeletal fluorosis¹⁴.

A survey carried out by the Rajiv Gandhi National Drinking Water Mission (RGNDWM), a nodal agency responsible for setting up systems of monitoring rural drinking water in India, indicated in its report during 1993 (based on 1% random sampling) that 217,211 inhabitants had water-quality problems in rural India¹⁵ (Table 3).

Water quality is now being recognized in India as a major crisis. Any sustainable water quality management plan has to have a policy that addresses technical, institutional and legal components, so that the management itself becomes effective.

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Table 1. Incidence of diseases in major states of India

State	Number of incidences reported						
	Diarrhoea (1998)	Cholera (2000)	Malaria (2001)	Japanese encephalitis (2002)	Hepatitis (2000–01)	Dengue (2001)*	Enteric fever (1998)*
Andhra Pradesh	1,852,642	2	57,735	22	27,595	1	53,252
Assam	596,176	–	95,142	472	–	–	15,330
Bihar	NR	–	4,108	8	–	–	NR
Delhi	133,089	903	1,484	1	4,007	322	3,219
Gujarat	207,027	185	81,347	0	3,982	69	3,617
Haryana	375,113	1	1,202	59	1,086	260	988
Jharkhand	–	–	130,784	–	–	–	–
Karnataka	674,805	354	197,625	152	24,571	202	5,296
Kerala	550,768	146	2,289	0	5,521	41	9,817
Madhya Pradesh	479,073	NR	183,118	–	6,620	NR	39,084
Maharashtra	1,098,750	778	56,043	119	40,962	54	16,004
Orissa	793,442	0	454,541	–	14,011	0	35,084
Punjab	196,398	14	604	10	1,796	49	2,827
Rajasthan	211,710	13	129,233	–	1,601	1452	8,113
Tamil Nadu	47,367	1248	31,551	0	1,740	816	9,067
Uttar Pradesh	564,587	0	94,524	604	988	11	20,929
Uttarakhand	–	–	1,196	–	–	–	–
West Bengal	7,20,352	150	145,053	0	5,831	NR	7,414
India	8,904,597	3807	2,085,484	1464	153,034	3278	318,510

*Source: ref. 60.

Table 2. Water quality of Indian rivers

	Observed bacterial quality of Indian rivers	
	Total coliform (MPN/100 ml)	Faecal coliform (MPN/100 ml)
Ganga	300–25 × 10 ⁵	20–11 × 10 ⁵
Yamuna	27–26.3 × 10 ⁶	11–17.2 × 10 ⁵
Sabarmati	210–28 × 10 ⁵	28–28 × 10 ⁵
Mahi	3–2400	3–75
Tapi	40–2100	2–210
Narmada	9–2400	2–64
Godavari	8–5260	2–3640
Krishna	17–33,300	3–10,000
Cauvery	39–160,000	2–28,000
Mahanadi	15–30,000	50–17,000
Brahmani	80–90,000	40–60,000
Baitarni	900–22,000	700–11,000
Subarnrekha	150–1800	70–540
Brahmaputra	360–240,000	300–24,000
Satluj	8–35,000	2–3500

Source: ref. 7.

Table 3. Water quality problem in rural areas

Nature of problem	Number of habitations affected
Excess fluoride	36,988
Excess arsenic	3553
Excess salinity	32,597
Excess iron	138,670
Excess nitrate	40,003
Other reasons	1400
Total	217,211

Source: ref. 15.

Drinking water quality in national context

Ensuring the supply of safe drinking water in India is a constitutional mandate, with the Article 47 conferring the duty of providing clean drinking water and improving public health standards to the state. In recent years High Courts around the country have been recognizing the right to safe drinking water as a fundamental right. According to the Constitution of India, water supply is a State subject. The Union Government is only responsible for setting water quality standards. State Governments have established departments or special agencies for supply of domestic water in urban and rural areas. These agencies are also responsible for monitoring the quality of the water supplied (Figure 1).

The National Water Policy (2002) of India also emphasizes through a generic statement – ‘Both surface water and ground water should be regularly monitored for quality. A phased programme should be undertaken for improvements in water quality’¹⁶.

Since the First Five-Year Plan in 1951, investments made in water and sanitation have been estimated at Rs 1105 billion. Yet, it has been estimated that around 37.7 million Indians are affected by water-borne diseases annually, 1.5 million children are estimated to die of diarrhoea alone and 73 million working days are lost due to water-borne diseases each year¹⁷. The resulting economic burden is estimated at US\$ 600 million a year¹⁸. Clearly, the health benefits in terms of reduction in water-borne diseases have not been commensurate with the investments made¹⁹. Planned expenditure for the water supply sector reforms under the various five-year plans has also

increased drastically from the First to the Tenth Five-Year Plan²⁰ (Figure 2).

So far Rs 735.67 crores has been released during 2006–07 to tackle water quality problems (up to 20% of accelerated rural water supply programme fund) under Sub Mission of Department of Drinking Water Supply (DDWS). An additional Rs 160.19 crore has been released under the national drinking water and surveillance programme to envisage water quality testing of all drinking water sources, including private source by the community with the help of user-friendly kits²¹.

Groundwater quality – a major concern in rural India

Groundwater accounts for more than 80% of the rural domestic water supply in India²². Data collected in 1998

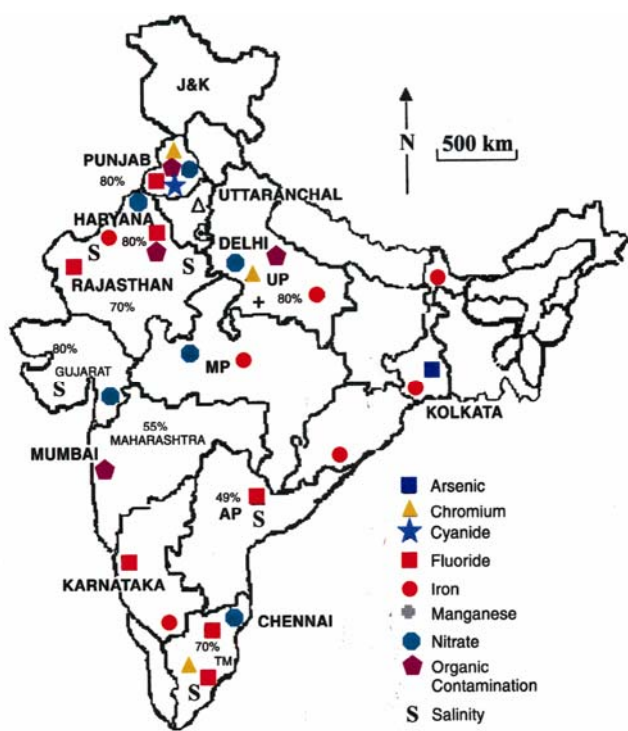


Figure 1. Groundwater quality map of India. Source: ref. 24.

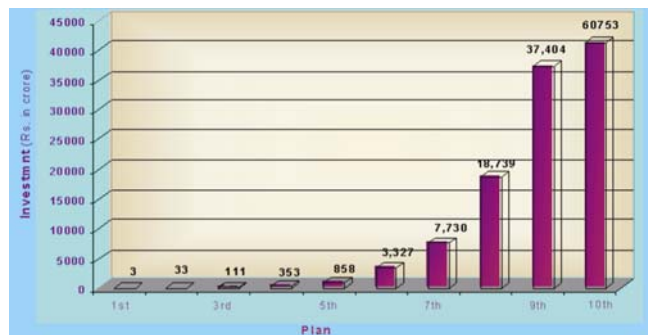


Figure 2. Planned expenditure for the water and sanitation sector reforms.

for the 54th round of the National Sample Survey showed that 50% of rural households were served by a tube well/hand pump, 26% by a well, and 19% by tap²³. In most parts of the country, however, the water supplied through groundwater is beset with problems of quality²⁴ (Figure 1). The over-dependency on groundwater has led to 66 million people in 22 states at risk due to excessive fluoride and around 10 million at risk due to arsenic in six states²⁵. In addition, there are problems due to excessive salinity, especially in coastal areas, iron, nitrates and others²⁶. Around 195,813 habitations are affected by poor water quality due to chemical parameters²⁷.

Major groundwater contaminants

India’s Tenth Five-Year Plan lists excess fluoride concentration as one of the three major hurdles to the sustainable supply of safe water for domestic use²⁸. Twenty Indian states have excess fluorides in the groundwater²⁹ (Figure 3). Nearly 6 million children below the age of 14 suffer from dental, skeletal and non-skeletal fluorosis¹³. A national-wide survey of habitations with drinking water problem was undertaken in 1991 by the Ministry of Rural Development based on 1% sampling, which was later validated and updated (Table 3).

In India high arsenic (As) contents have been reported from West Bengal, from the districts of Nadia, Murshidabad, Malda, Bardhaman, North and South Parganas³⁰.

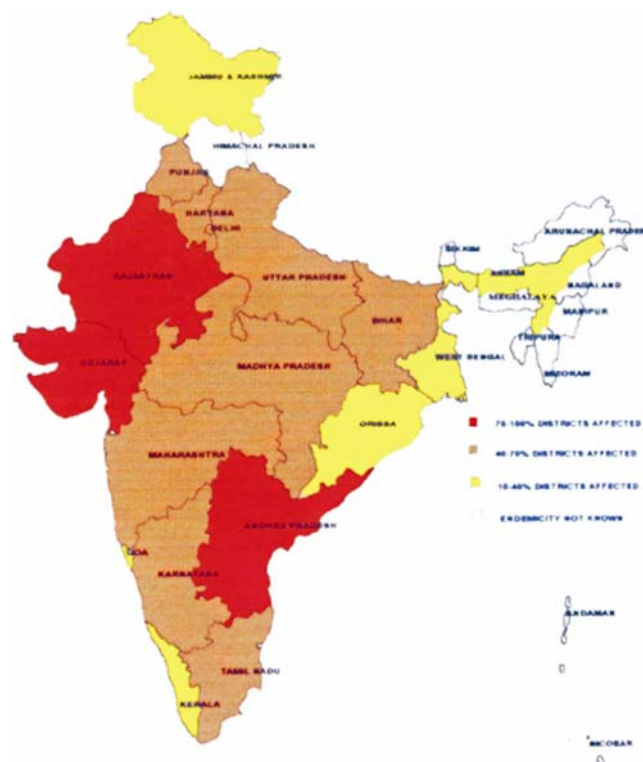


Figure 3. Fluoride endemicity in India. Source: ref. 30.

The presence of arsenic in water is geogenic. The entire Gangetic delta plain, which consists of alluvial soil, contains arsenic in the deeper aquifers. It causes skin lesions and can lead to arsenicosis at a later stage³¹. In recent years high arsenic contamination has also been reported from different parts of eastern UP, Bihar and Jharkhand³².

Bacteriological contamination, especially faecal coliform, is the most widespread groundwater pollution problem in India²⁷. Groundwater itself does not inherently contain faecal coliform. Most of the groundwater coliforms come from the leaching of solid (human and animal excreta) and liquid wastes. The presence of faecal coliforms and related pathogens accounts for a number of water-borne diseases like diarrhoea, gastroenteritis, jaundice, hepatitis, cholera, typhoid, polio, etc.³³. Sanitary risk of locating a drinking water source (hand pump) close to household toilets and accumulation of animal excreta near a drinking water source are the major risks in a typical rural settings³⁴ (Figure 4).

Iron, hardness and salinity impart an unpalatable taste to water, making it unfit for drinking. Many coastal districts in India suffer from excess salinity in groundwater³⁵. Hardness is mainly caused by the presence of carbonate, bicarbonate, chloride and sulphate salts of calcium and magnesium in water. Iron is found in parts of Madhya Pradesh, Uttar Pradesh, coastal Orissa, Andhra Pradesh and Tamil Nadu³⁶.

Water quality monitoring and assessment in India

The first step towards ensuring safe drinking water is to generate reliable and accurate information about water quality. Several government institutions and departments are involved in water quality monitoring, leading to overlapping of functional areas and duplication of efforts. While the State Pollution Control Board laboratories and the Central Pollution Control Board (CPCB) regularly monitor surface water bodies, the Central Ground Water Board is primarily responsible for monitoring groundwater quality along with the State Drinking Water Mission under the respective public health engineering de-



Figure 4. Sanitary risk: accumulation of animal waste near the source and badly maintained hand pump.

partments. In order to monitor the surface water quality, the CPCB started a national water quality monitoring programme in 1978 under the Global Environmental Monitoring System (GEMS). It started with monitoring 24 surface water and 11 groundwater sampling stations across India. Parallel to GEMS, a National Programme on Monitoring of Indian National Aquatic Resources (MINARS) began in 1984. At present, a network comprising 870 stations on rivers, water bodies and subsurface water (Central Pollution Control Board 2003) is in place.

Monitoring of groundwater quality in rural India – a major challenge

Monitoring groundwater quality remains a prime concern and a major challenge in rural India since it is the predominant source of drinking water³⁷. It remains a major monitoring challenge considering the geographical spread of Indian villages and the fact that many of the remote villages are not accessible to regular monitoring by central agencies due to transportation and communication problems. Hence it is the rural population that suffers the most from problems related to fluoride, arsenic as well as microbial contamination³⁸.

State drinking water mission under the Rajiv Gandhi National Drinking Water Mission (RGNDWM) and sanitation department through the public health engineering division is mandated to undertake the assessment of all drinking water sources. The National Rural Drinking Water Quality Monitoring and Surveillance Programme was launched in February 2006. The components of the programme are IEC, HRD, Monitoring and Surveillance activities, which include field testing kits (chemical and bacteriological), and strengthening of district level laboratories.

The objectives of the programme are as follows:

- Monitoring and surveillance of all drinking water sources in the country by the community.
- Decentralization of water quality monitoring and surveillance of all rural drinking water sources in the country.
- Institutionalization of community participation and involvement of local village institutions (Panchayat raj) for water quality monitoring and surveillance (WQM&S).
- Generation of awareness among the rural masses about water quality and water-borne diseases.
- Building capacity of panchayats/village institutions to own the field testing kit and take up full operation and maintenance (O&M) for WQM&S of all drinking water sources.

However, as on date less than 50% of all the rural water sources were analysed by the district laboratories in many states of India due to lack of adequate manpower³⁹.

The enormous task of collecting water samples from remote sources and transporting them to district laboratories often becomes a tedious task, as they are usually situated hundreds of kilometres away from the source. The Public Health Engineering Department (PHED) runs district laboratories in every district, which are entrusted with the task of collecting and analysing the samples. However, these laboratories are inadequately equipped both in terms of manpower and infrastructure when compared to the scale of required operation. It has been estimated that 16 million samples need to be tested annually following a norm of one sample for every 200 persons⁴⁰. Even a basic requirement like the capacity to monitor bacteriological quality of water is grossly inadequate in some states. The district-level laboratories are mostly understaffed and hence standard norms of sample collection, storage and analysis are grossly violated³⁹. Thus monitoring is the weakest link in the system that works to provide safe water in rural India.

Data management and information flow

No system has yet been devised or put in place that is able to consolidate the water quality data generated by district laboratories to convey meaningful village/source-level information on water quality at the national level. Most of the data generated are chemistry-driven and are not correlated to the disease burden in the communities. The utility of these data for any desired intervention, therefore, is significantly low. As a matter of fact any information about contaminated sources and its subsequent disease burden in the affected villages is generally culled out from newspaper reports or from activist NGOs rather than a scientific monitoring relating the cause to the effect⁴¹.

Many institutions in India are involved in the management of water quality data. But there is a lack of coordination among the various institutions involved in water quality monitoring. Although plenty of data are available on chemical contamination, they are seldom well documented. There are few defined data users resulting in a colossal public expenditure. Very little information is also available on the relative significance and adverse impacts of different types of pollution resulting from agriculture, industries, animal waste, etc.²⁰.

Thus water quality monitoring by government agencies has always faced problems related to the science, technology and information flow and this understandably have not produced the desired results. Hence, the present line of thinking is to decentralize water quality monitoring and management by involving the rural community in every stage of the process of 'community-based water quality management'.

Community-based water quality management based on decentralized water quality monitoring systems (using

field test kits) is also fraught with many difficulties. Some of the major challenges in this area are capacity development and building awareness at the grassroots level. Our experience shows that the IEC material developed by voluntary organizations, government agencies, etc. has many technical elements that are beyond the understanding of grassroots level rural communities. Therefore, the first step towards community-based water quality management is to develop appropriate IEC material in regional languages.

Another fundamental problem in water quality management in India is the development and implementation of the analysis tools. One has to perform a series of steps such as data mining, map generation, and simulating and interpreting models.

Web-based Geographical Information System (GIS) provides an option to visualize and assess water quality over the web for an end-user with minimum knowledge and computing experience. Water quality data for the study region from various sources can be obtained and stored in a relational database management system (RDBMS). The stored data can be provided over the web using a graphical user interface with water quality assessment tools to identify different management options⁴². The availability of data and assessment tools over the web is expected to increase public participation in the decision-making process and effectiveness of water quality assessment over the web (Figure 5).

Utility of field-testing water-quality kits at community level and their limitations

The utility of field-testing kits in community-based water quality monitoring and management is to give a quick and initial assessment of water quality. Various state departments have procured these field-testing kits under the Rajiv Gandhi drinking water mission on water quality programme²¹. However, one of the major challenges in this front is the lack of regular supply of reagents in remote rural areas for performing water quality tests on a periodic basis. In the absence of a supply chain, many

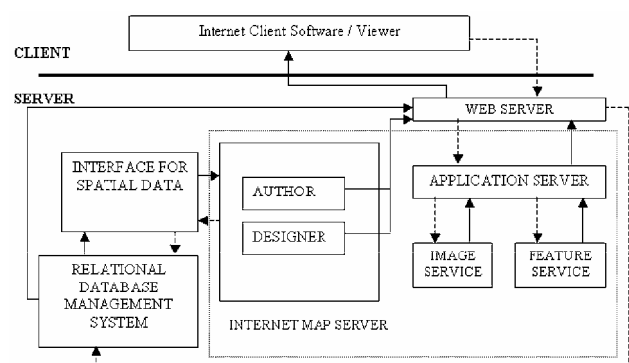


Figure 5. Client and server architecture. Source: ref. 42.



Figure 6. Handpump attached defluoridation plant lying dysfunctional due to absence of O&M in Palamau district of Jharkhand state.

portable field-testing kits remain unutilized, rendering the whole programme at the national level likely to be ineffective⁴³. Community-based water quality management gets acceptability among the rural communities only when the awareness and testing is backed by sound water treatment interventions⁴⁴. However, the national water quality programme is slow on the issue of intervention. The emphasis is on locating alternate safe sources in the case of fluoride and arsenic contamination.

However, in reality it is seen that the safe source often turns unsafe because of over abstraction of groundwater and the rural community is often seen drinking unsafe water in the absence of regular preventive monitoring and awareness.

Need for integration of hygiene, sanitation and water quality intervention

Although the burden of diarrhoeal disease resulting from inadequate water quality, sanitation practice and hygiene remains high, there is little understanding of the integration of these environmental control strategies⁴⁵. Sanitation and hygiene are often perceived as social and behavioural issues, and water quality as a technical issue requiring technical intervention. In the absence of common verifiable indicators for both water quality, and hygiene and sanitation at the community level, the outcomes of various interventions are seldom quantifiable.

Moreover, sanitation is often perceived by both the government agencies as toilet coverage at household level, but seldom emphasis is laid on treating the water emanating from these facilities leading to gross contamination of water sources. Although open defecation remains a major problem in rural India and responsible for contamination of surface water, animal wastes (cattle excreta) also play a significant role in groundwater con-

tamination in rural India in the absence of effective animal waste management³⁴.

Technological options for treating drinking water in rural India

Technological options for treating drinking water by the community in rural India should go hand in hand with social and behavioural issues like sanitation and hygiene. When centralized treatment systems are absent or inadequate, the responsibility for making drinking water safe falls back on community by default.

To ensure drinking water quality in terms of microbial contamination, one needs to consider point of use disinfection as an ideal choice and in the case of chemical pollution/contaminants, the interim solution like defluoridation and arsenic removal plants need to be promoted along with long-term solutions like rainwater harvesting, artificial recharge and restoration, and protection, of tanks, lakes, etc. Promotion of traditional structures like open wells and sanitized dug wells is effective in tackling the problems related to iron and to some extent in the case of arsenic and fluoride⁴⁶. Household ceramic filters are effective in prevention of diarrhoea in many developing countries⁴⁷. More effort is needed to promote these filters through village entrepreneurship.

Point of use disinfection

At present the central and state agencies promote chlorine bleach (bleaching powder) for disinfection of community water sources, including wells on an ad-hoc basis and therefore, no guidelines have been adopted for regulating dosage and contact time of chlorination. Bleaching powder is often seen dumped indiscriminately into the large water-storage tanks/wells, leading to excess residual chlorine⁴⁸. Under the present circumstances, one of the ideal ways to obtain safe water for the community is to promote point of use disinfection along with hygienic water-storage practices. This may prove to be a viable option and would cost less than 5 dollars a year per household⁴⁹. Point of use disinfection is promoted on an experimental basis in Indian slums and initial studies show that this programme requires extensive awareness campaign and IEC strategies⁵⁰.

Problems of multiple contaminations

In many parts of rural India, water is contaminated by bacteria as well as by various inorganic chemicals, rendering it non-potable. In such cases, the technological option is to look for a combination of salts, zeolite and chlorine bleach for treating turbidity, suspended solids

and low level concoction of fluoride and arsenic simultaneously at the point of use.

Operation and maintenance of defluoridation and arsenic removal plants

Perhaps one of the major handicaps in the promotion and installation of defluoridation and arsenic removal plants at the household and community levels is the absence of community involvement in the government rural water supply/intervention programmes. Defluoridation plants based on activated alumina techniques and arsenic filters set up by the government and other agencies are lying defunct because of operation and maintenance problems leading to wastage of millions of rupees. Affected communities are not trained on recharging the filters on a regular basis resulting in total failure of these plants⁵¹. Institutionalizing operation and maintenance of the treatment plant at community level and willingness to pay for treated water covering at least operation and maintenance component is vital for sustainability of any meaningful intervention. Perhaps one of the positive features that emerged from a recent World Bank review of drinking water in 10 states of India is the willingness to pay among the rural communities. The survey covered 40,000 rural households across ten states and covered more than 600 drinking water supply schemes. The study showed that the average spending on water by a rural household is Rs 81 per month, and the 'willingness to pay' survey (which is part of the study) shows that they are quite open to spending up to Rs 60 a month on just 'operating and maintaining' a water scheme, provided they are assured regular and dependable supply of safe water. This is one of the positive developments that can be tapped to ensure supply of safe water for rural communities⁵².

Legal issues

Need for revised national drinking water quality standards for India

The recently revised guidelines of WHO² speak about preventive approach towards water-borne diseases⁵³. Further, WHO guidelines state that the national drinking water standard needs to be developed based on country geography, and climatic conditions. Therefore, the major challenge confronting water quality management is to establish a realistic national drinking water standard based on scientific research, which should take various contributing factors such as nutrition, local climatic conditions and occupation into consideration. The Bureau of Indian Standards (BIS), an agency responsible for developing guidelines for drinking water quality standards in India, has more or less adopted WHO guidelines for

drinking water without making the necessary modifications for Indian conditions. The permissible level of fluoride in drinking water in India is 1.5 mg/l and for arsenic⁴⁶ it is 50 µg/l (ref. 54). Further, WHO permissible limit of fluoride and arsenic is not area-specific and does not justify the local elevated levels of water consumption in South Asia. It has been confirmed that this increased ingestion also intake of arsenic in babies⁵⁵. In India the insidious routes intake is mainly through contaminated food chain where contaminated aquifers are being tapped for obtaining irrigation water⁵⁶. With emerging adverse health impacts, the permissible limit of arsenic in drinking water has been further lowered in developed countries (7 µg/l in Australia).

In the case of fluoride, symptoms of dental and skeletal fluorosis are even seen among the communities in southern India, where fluoride ranges between 0.5 and 0.08 mg/l (ref. 57) as against 1 mg/l set by the WHO guidelines. Moreover, poor socio-economic conditions resulting in malnutrition also play a significant role in aggravating the disorder. Therefore, the adoption of lowered drinking water standard in case of fluoride and arsenic compared to WHO guidelines is highly desirable in the Indian context. The revised standard should also consider the fact that the consumption of water is high in India due to the tropical climate compared to the West. The occupation of majority of the people living in rural India is agriculture. And it is the same community which is mostly dependent on groundwater and on an average consume 4–5 l of water per day and suffers from various forms of fluorosis and arsenicosis⁵⁸. The traditional Indian food is semi-solid and contains more water and therefore, increases the probability of body burden due to fluoride and arsenic. Focused epidemiological research, therefore, is required to fix a desirable standard and arrive at a realistic national drinking water standard⁵⁹.

Institutional issues

Apart from monitoring and managing water quality, that needs to be matched with the management needs of developing countries, there are also other institutional needs to be overcome. The principle institutional issues include the following:

- Data collecting agencies and users of water quality data should not be the same. At present, the CPCB which is a regulating agency, also monitors surface and inland waters in India.
- Lack of coordination among various agencies working on water quality management and public health institutions.
- Absence of a single nodal agency at the state level that can serve as a repository of water quality data for coordinated intervention.

- Inadequately trained manpower to carry out systematic monitoring, data interpretation and data management at district level across the country.
- Lack of epidemiological research related to water quality and water-borne diseases. At present, this is mostly chemistry-driven and not related to disease burden. Therefore, the impact of water quality on health is seldom well documented.
- Lack of strict enforcement of regulatory guidelines, especially those related to industrial waste due to political and economic reasons.

Limitations of human resources

Perhaps one of the major lacunae in this sector is that there are few institutions/universities in India that offer specialized integrated courses in environmental health. Therefore, there is a dearth of trained professionals dealing in water and sanitation issues related to health. Institutions dealing with water and sanitation are often seen headed by administrators and managerial specialists who have little formal or scientific training in these issues.

Sustainability

Financial, institutional and technical sustainability are the key elements for successful implementation of water quality management programme at the community level. This requires capacity building at the community level, so that services are profitably rendered. It requires the following considerations.

Public-private partnership: Contracting out water quality monitoring and analytical services to private sector/technical NGOs can be seen as one of the alternative mechanisms to bring greater efficiency of water quality monitoring and ease the burden of sample collection and water quality monitoring by the state in rural India. Alternatively, operation and maintenance of government laboratory at district level can be leased out to private agencies under a government contract. The government can then function as an enforcing agency to oversee quality control and quality assurance of the laboratory instead of running the laboratory, which is often seen burdensome in terms of manpower and other resources.

Data management of the sources can also be outsourced for generating high quality data incorporating source data using latest software and GIS-based maps. However, more informed debate is needed to assess the pros and cons of these alternative mechanisms.

Conclusion

Water quality monitoring and management model for India needs to be quite different than that of the West.

Institutional change that advocates decentralized monitoring and intervention at community level offers cost savings and community involvement in the process. Integration of water quality, sanitation and hygiene with positive outcome of intervention process is vital in bridging the existing gap. Community participation in operation and maintenance of the water treatment structure is vital in addressing the gaps in the sector. Research and review of national drinking standards taking into consideration the local condition, especially with regard to critical parameters like fluoride and arsenic is vital for preserving public health. Citizen action groups and civil societies should be increasingly engaged in making the government accountable in enforcing regulation with regard to industrial effluent and sewage treatment plant for preventing surface and groundwater contamination. Outsourcing water quality data management and sample collection and monitoring could be an alternative mechanism that can be explored, which would ease the burden on the state and bring better efficiency and sustainability. More scientific debate on privatization of water quality management in India needs to be considered.

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

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