

Groundwater quality in India

Distribution, Social burden and Mitigation Options

Sunderrajan Krishnan
INREM Foundation

ABSTRACT

A variety of quality issues affect groundwater in India. The reasons for these quality problems are rooted to groundwater exploitation, external contamination from point/non-point sources and natural geogenic processes. Biological and chemical contamination of water account for a massive disease burden on society leading to child mortality, labour loss due to recurring disease, chronic ailments, etc. The impact of some of these problems is exacerbated due to current hygiene, malnutrition and poverty status of the people.

The key problems can be pointed out as – Biological contamination, Fluoride, Salinity, Nitrate and Iron problems; and Industrial contamination. Apart from these other quality problems such as Strontium, Heavy elements etc. also exist and interact with these wider spread problems. One of the main challenges we face is the lack of good and vast geological understanding of the distribution of these contaminants. Since the current network of quality measurements is highly insufficient, numerous civil society initiatives have emerged attempting to involve community in monitoring water quality. Some understanding has emerged out of this, but the quality of these measurements and kits are some times in question.

The social burden of some of these quality problems have been documented by research studies. Problems such as Fluorosis impose a massive social cost which can be a significant part of the income. On an already malnourished population, Fluorosis and Arsenicosis add to health complication leading to severity which otherwise would not be observed in healthy individuals. The loss to agricultural productivity from water quality problems arises especially in salinity affected areas. In Iron affected areas, pipes and wells can be affected. Kidney stones, a root cause of which is poor hydration, is also a major health burden.

Mitigation measures are possible for each of these quality problems. In many cases, however, there is interaction between quality problems such as those with Iron-Arsenic-Fluoride (Assam), Salinity-Fluoride (Saurashtra, Gujarat) and say, Biological-Arsenic (WB). Therefore, we need a region specific typological approach that considers the particular characteristic problem of the area. There are good successful cases for several of these mitigation issues – watershed based measures along the coast for Salinity in Saurashtra, RO plants in affluent areas across the country, rain water harvesting for assuring safe drinking water, referral hospitals for particular problems such as Fluorosis, low cost filters for Fluoride and Arsenic etc.

As a good response to all these problems, what we need is integration of efforts – across different disciplines such as Geology, Health, Technology and Management; across

different departments such as Public health, water supply, education, rural development; across tiers of the government and Panchayati Raj Institutions (PRIs); across public and private institutions. Water quality management needs to enter into every aspect of governance in order to achieve an overall impact.

1. Distribution and Social Burden

Contamination of groundwater occurs due to naturally existing geogenic sources as well as substances that infiltrate into aquifers. The existence of contaminants and also transport of substances are highly site-dependant. Still, there are some regional variations that are broadly known, but few good synthesis are available (Kumar and Shah, 2003)

- a) Vast tracts of Rajasthan, Gujarat and Andhra Pradesh are affected by groundwater with Fluoride concentrations of greater than 1 mg/l. Fluorosis can lead to varying degree of afflictions: from dental problems to severe musculo-skeletal deformity. The contaminant is found naturally in the rocks and sediments of aquifers and the depths of its occurrence vary with the formation. For example, in Mehsana district of Gujarat, high Fluoride concentrations are found in aquifer layers deeper than 100m, whereas in Vishakhapatnam, high Fluoride is found in shallow groundwater at depth less than 15m (Rao et al, 1998). Smaller areas of several other states like Punjab, UP, Karnataka, Maharashtra and MP also exhibit high Fluoride concentrations in groundwater.
- b) High Arsenic content (greater than 0.05 mg/l) is found primarily in sediments of the Alluvial Indo-Gangetic-Brahmaputra basins (Chowdhury et al, 1999). Initially observed in high concentration only in Bangladesh and West Bengal, now the contaminant is reported from Assam and Nepal to parts of Pakistan. Newer areas are being discovered every year. Symptoms of Arsenic poisoning range from Diffuse Melanosis (darkening of skin) to Spotted Melanosis (pigmentation) and finally to Keratosis. In the final stage, the affliction can reach up to the stage of Skin Carcinoma.
- c) Coastal and inland salinity are found in large tracts of the country. Saurashtra and Kutch in Gujarat and parts of Andhra Pradesh, Orissa and West Bengal show intrusion of sea water into coastal aquifers. Inland salinity is present in the states of Punjab, Haryana, Rajasthan, Gujarat, MP, Maharashtra, UP and some pockets of other states. Apart from being harmful to the productivity of crops and soil quality, high salinity can cause ailments such as Kidney Stone (Indu and Rawal, 2007).
- d) High Iron concentration in groundwater is found in Eastern parts of the country, especially in Assam, Bihar, Uttar Pradesh and West Bengal. Prolonged intake of high Iron content water can cause Homochromatosis.
- e) Increasing use of Nitrogenous fertilizers in India has led to Nitrate contamination of aquifers at levels greater than 40mg/l in many parts of the country (Agrawal et

- al, 1999). The states of Punjab and Haryana are in high risk from Nitrate contamination. Other states with areas showing high Nitrate levels are Gujarat, Tamil Nadu, West Bengal and Uttar Pradesh. Consumption of water containing high levels of Nitrate can be a cause for some types of Cancer. It can also cause the Blue baby syndrome which affects new born babies.
- f) Pesticide contamination of groundwater has raised alarm in recent times. High pesticide content in groundwater has been reported in the agricultural intensive regions such as Punjab and Haryana.
 - g) Many regions of the country have been marked as having aquifers polluted by industrial chemicals. These include areas in and around the towns in rural areas where industrial units are often located. Ankleshwar (South Gujarat), Chembur (Mumbai), Patancheru (Hyderabad), Tiruppur (Tamil Nadu), Behala (West Bengal) are some examples. These aquifers show high concentrations of substance such as Chromium, Mercury, Lead etc., the effects of which can range from minor skin diseases to being carcinogenic and in some cases, directly life-threatening. Apart from these, there are numerous instances where effluents from small industries are released in unlined channels or dumped directly into borewells, as reported recently in South Gujarat and also in cities like Kanpur and Kolkata.
 - h) Groundwater acts as a conduit for various viral and bacterial diseases especially in shallow aquifers through mixing of sewage and infiltration from latrine pits. Since shallow groundwater is used for drinking in much of the Eastern Gangetic plains, this is a common problem in this region. The gastroenteric epidemics generally peak during the time of monsoon. Some other regions such as South Gujarat figure high on this list. Diseases include minor afflictions such as Diarrhoeal, Viral and Ameobal infections to more severe diseases such as Cholera.

Salinity

One of the major health crisis from poor water quality is that of high Salinity in drinking water mostly in coastal areas, but in many inland areas also, especially in western India (Indu and Rawal, 2007). The fluid intake and volume of urine is the key factors for composition of renal stone and its prevention (Siener, R and A. Hesse, 2003). Looking from an epidemiological perspective, 'adequate intake of fluid is the most important therapeutic measure irrespective of stone composition or the cause stone formation' (Siener, R and A. Hesse, 2003, pp S50). Brikowski et al (2008) attribute the mean annual temperature and consequently high rate of perspiration, lower urine volume, to be the primary control on patterns of Kidney stones. The south-eastern US which is also considered as a kidney-stone belt is cited as an example to support this observation. High Fluoride in water is also considered to be one possible contributor to formation of stones (Singh et al, 2001). Evidences are given to show presence of Fluoride in stones, but how strong a role Fluoride plays in stone formation is currently being studied.

It has been shown that high Salinity along with high Calcium in drinking water are also areas with statistically higher incidences of kidney stone problems. A census of affected villages of Junagadh district in Gujarat revealed that 7.9 percent of the population in fully saline villages and 3.2 percent in non-saline villages had at least one of the five symptoms for Kidney Stone. In these saline villages, the average treatment expense incurred by an affected person was Rs 5,790 and average wage loss was Rs 3,520. Urologists say that about 80 percent of kidney stone cases have a chance of recurrence, raising the expenses incurred on treatment even further.

Fluoride

Water induced Fluorosis is expected to have around 60 million patients exposed to risk in India. The main symptoms are those of Dental and Skeletal Fluorosis, and then allied diseases. On a secondary level, different other Fluoride related disorders include Kidney stones, risk to pregnancy etc. Generally, the WHO standard of 1.5 mg/l is an exposure limit, but lower degree of symptoms are present in even more patients in areas with lesser Fluoride than 1.5 mg/l. Apart from water, people residing in Fluoride affected areas are exposed to risk also from food-crops that are irrigated with Fluoride rich groundwater. There is also consumption of Fluoride from some common food items such as tea, rock salt etc., but Fluorosis resulting from such a route is not that widespread. Almost every state in India has some Fluoride affected villages, but the main affected states are Rajasthan, Andhra Pradesh, Maharashtra, Karnataka, Gujarat, Tamil Nadu and MP. States like UP and WB are also revealing more areas with high Fluoride. As groundwater use for drinking develops and newer sources of groundwater tapped, the prevalence is just increasing constantly. Some places are just few steps into the disease with only very young children affected, eg. Jhabua in western MP, but other places like say, Anantapur in southern AP have several generations of affected patients. In such places, the problem has become part of folklore, a gradual fact of life.

.A study of the socioeconomic impact of Fluorosis was conducted in 25 villages of North Gujarat by surveying a total number of 28,425 respondents (Shah and Indu, 2004). Of these surveyed people, nearly 36% people were affected by Dental Fluorosis (DF) and 16% were suffering from at least one of the symptoms of Fluorosis. About 70 % of the severely afflicted people were from the monthly income group of Rs 500 to Rs. 3500 with an average cost (medicinal + wage loss) of Rs. 5,500 per person per year. The proportion of Fluoride debility cases declined with rising income. Better nourishment, using packaged drinking water and better medical care could explain this decline. This hints that, in general, higher income group people could escape the ill-effects of poor quality groundwater and that these effects are distributed inequitably within society.

A field research study conducted at 5 Fluoride affected areas of Rajasthan, Karnataka and Andhra Pradesh shows that affordability of safer drinking water is related with higher income level and that the severity of Fluorosis affliction is higher for lower income levels (Indu et al, 2007). The cost incurred from medicines and loss of wages is a significant proportion (5%-25%) of the family earnings and has a general debilitating impact on the affected families. The per capita annual medical cost due to Fluorosis

ranges from Rs 800 to Rs. 2800 and the wage loss due to loss of labour days ranges from Rs. 4500 to Rs 12000 annually.

Iron

Iron in groundwater is present mainly in the reduced Ferrous form within groundwater originating from Iron Pyrites – mineral which is mainly Iron Sulphide FeS_2 and in oxides such as Ferrous Hydroxide. Iron is recognized as an essential trace element for humans. Due to Iron deficiency, there is practice of Iron supplements and in western countries Iron fortification within certain cereal products. Dietary sources of Iron can be through water, food (1.68 mg/ for fruits, vegetables; 4.8 mg/MJ for green vegetables, fish and tomatoes.

The WHO does not recommend a health based guideline for Iron in drinking water. However, it follows a recommendation based on provisional maximum tolerable daily intake (PMTDI) of 0.8mg/kg of body weight (WHO, 2003; JECFA, 1983). The assumption they make is that 10% of Iron intake is through water and recommend the limit as 2 mg/l. One can complete this link in reasoning by assuming a human being of 50 kg weight and consumption of 2 litres/day i.e.

$$\begin{aligned}\text{Safe Iron concentration} &= \text{PMTDI} * \text{Body weight} * \text{percentage from water/water consumption} \\ &= 0.8 \text{ mg/kg} * 50 \text{ kg} * 0.1 / 2 \text{ litres} \\ &= 2 \text{ mg/l}\end{aligned}$$

However, the Food and Nutrition Board of Institute of Medicine (of US) in recommending the Tolerable Upper Intake Levels Iron (UL) point out that Gastro-Intestinal (GI) problems are the primary proven health related risks from intake of Iron, especially when Iron intake is in empty stomach which is especially possible with water (NAP, 2000). Experiments performed using intake of Ferrous Sulphate has shown increasing levels of abdominal pain, diarrhea, constipation, bloating and nausea with increasing the dosage amongst subjects. The UL levels based upon only GI symptoms is placed at 45 mg/day for healthy adults.

Utilizing both these levels of 0.8 mg/kg of body weight and 45 mg/day, one can arrive at a standard for drinking water. The WHO assumes that 10% of Iron enters the body through water and utilizes the PMTDI value to arrive at 2 mg/l as the safe limit for Iron. It does not use the UL levels which were recommended later in 2001, whereas the WHO limits were imposed in 1983.

$$\begin{aligned}\text{Safe Iron concentration} &= \text{UL} * \text{percentage from water /water consumption} \\ &= 45 \text{ mg} * 0.1 / 2 \text{ litres} \\ &= 2.5 \text{ mg/l}\end{aligned}$$

One can expect according to this limit that gastro-intestinal problems can be caused by drinking water with Iron greater than 2.5 mg/l.

Apart from concerns on GI through, excess Iron is suspected to be related to the following conditions:

1. Iron overload

Iron overload is a condition when the body iron stores increases as a result of iron administration, repeated blood transfusions or disorders that increase the rate of iron absorption within the body. The known impacts of iron overload are mainly Cirrhosis (a liver disease which leads to a progressive loss of liver function), and some types of carcinoma, tuberculosis and other infections. In Indian populations, there have not been any links established as yet to detect Iron overload (Poddar, 2006), but there needs to be studies using results from the Human genome project and epidemiological studies to explore such links.

2. Cardio-vascular disease

There are studies to indicate positive relationship between higher serum ferritin concentrations and risk of greater CHD. However, no conclusive evidence has been yet shown to link high Iron stores and Iron intake to risk from CHD. The current understanding is that there is not enough evidence to either attribute or exclude Iron from risk to CHD (NAP, 2000; JECFA, 1983).

3. Iron-Zinc interactions

High Iron intake is linked with lowering on Zinc absorption in the body, especially when both are taken in an empty stomach. Zinc is essential for many enzymatic functions of the body and Zinc deficiency exhibits itself in problems with cell growth and repair. However, since there are no severe adverse impacts of Iron-Zinc interactions observed in clinical trials, this factor is not used to furnish a health based guideline for Iron (NAP, 2000).

4. Cancer

Liver cancer as a consequence of Cirrhosis is well established. For other general cancers, there have been several epidemiological studies that have indicated higher Cancer incidence in populations with greater Iron exposure. The current understanding is that though the link between Iron overload and Liver cancer is well established, the relationship between dietary Iron intake and other types of Cancer especially Colon cancer, is inconclusive (NAP, 2000).

Agrochemicals and Nitrates

Pesticides and other chemicals used in agriculture such as Nitrates seep into groundwater and can be the cause for public health concerns. Since even low pesticide levels can be harmful and currently available instrumentation in district laboratories are not equipped well enough, the impact of these problems lies un-addressed. However, Nitrate

distribution is relatively better monitored, even though it is highly dynamic. High amount of Nitrates ingestion can lead to methaemoglobinemia, and could be triggers for cancer, increased infant mortality, abortions, birth defects, recurrent diarrhoea, changes in cardiac muscles, alveoli of lungs and adrenal glands (Gupta et al, 2008). When inhaled, Nitrates can cause unconsciousness, vomiting and nausea. Many of these effects lie undetected due to problems in causation and good epidemiological studies.

Arsenic

Arsenic in groundwater is emerging as a widespread problem in the floodplains of the Ganges and Brahmaputra. In India, many areas from West Bengal have been shown to be affected whereas Bihar is an emerging area with high Arsenic contamination (Chakraborti et al, 2003). Newer areas are suspected to be Assam, Arunachal Pradesh, Bihar, Manipur, Meghalaya, Nagaland, Uttar Pradesh and Tripura. Outside of India within the Ganges-Meghna-Brahmaputra (GMB) basins, the southern parts of Bangladesh are long affected from Arsenic just as in West Bengal. Some reports of Arsenic in Nepal Terai are also accumulating (Shreshtra et al, 2004). Within this larger region, there are pockets of villages that show very high concentration of Arsenic, much above the WHO recommended safety limit of 10 micro g/l (micrograms/litre also some times called parts per billion, (ppb)). The Indian safety standard for Arsenic is 50 micro g/l which is adopted by several other countries partly due to the possible perceived magnitude of the problem otherwise. A matter of possible surprise is that density of Arsenic present in soil is not much above that present in other regions of the world. It is the specific geochemical conditions that aid in the release of As(III) into groundwater. Arsenic release from sediments in South Asia is attributed mainly to desorption or dissolution of Arsenic from iron oxides. This happens mainly due to reducing conditions in aquifers below the so-called redox zone or transition between oxidizing and reducing conditions a few metres below the water table. Here, the higher oxidized As(V) reduces to As(III) which is released into groundwater. The reasons for onset of reducing conditions are several: rapid burial of organic matter, high microbial activity or recent anthropogenic carbon. Some or all of these contribute to the reduction process and mobilization of As(III) which is then released into the relatively deeper groundwater that has low flow rates due to the poor hydraulic gradients in the Bengal basin. Other factors contributing to the release of As(III) is the possible competition faced by As(III) from high level of phosphates present in groundwater towards adsorption on the surface of Iron oxide. Such adsorption would demobilize the released As(III), otherwise. An excellent summary of current knowledge on Arsenic geochemistry in South Asia is given in a World Bank summary report (WB, 2005b).

After several years of low level Arsenic exposure, various skin lesions appear. These are manifested by hyper-pigmentation (dark spots like rain drops), hypo-pigmentation (white spots) and keratosis (hardening of skin) of the palm of hands and soles of feet. After a dozen or so years, skin cancers are expected. Arsenic can be transmitted not just by drinking water, but also by direct exposure to skin and hair (GoWB and UNICEF, 2004). It also transmits through food grains and the possible transmit of Arsenic

through summer (Boro) rice grown in the Bengal is an issue of debate (Duxbury et al, 2003).

2. Current responses: an example of Fluorosis

A variety of factors add challenges to the problem of addressing solutions to water quality and health issues:

1. The nature of quality problems – Salinity, Fluoride, Biological, Arsenic, Iron – and their combinations require different technologies for water treatment. Also, we keep coming across newer problems such as increasing agrochemicals presence in drinking water of some areas.
2. The variable affordability of households to water treatment technology within any village means that not all households would be willing to shell out equally for a commonly owned treatment system, especially since the best techniques of treatment such as Reverse Osmosis (RO) also cost considerably as compared to saving levels of rural poor,
3. The variable quality of water of different sources at different times of the year means that one needs to employ the proper treatment depending upon source and particular time of the year
4. Adaptation of the technology to different needs – i) taking into account that many farmers drink water from bore-wells in the fields, ii) single common source of drinking water for several villages, iii) cultural beliefs eg. drinking water that is freshly supplied every day, iv) catering to old, disabled and remotely located inhabitants

We take an example of Fluorosis to understand historically the programs conducted in India for defluoridation. Note that Defluoridation is not just entirely Fluorosis mitigation – which is a health concern. Apart from removal of Fluoride, focus must be also on nutrition and other preventive and palliative aspects.

Historic development of Defluoridation programs

The Nalgonda mechanism was popularized through efforts of NEERI starting from the 1970s (Nawalakhe et al, 1975). It requires adding only commonly available materials – Lime and Alum – and flocculation, sedimentation and filtration. Generally, the stirring requires a motored power and then settling for few hours. The name of the plant comes from the place where it was first implemented and popularized. Around 500 of these plants were commissioned by the central government as large community plants across the country in the 1980s and 1990s. But several problems were encountered both with the technology and with the management of these huge plants. Long settling time, sometimes more than 5-6 hours; high sulphate and aluminium concentrations due to Alum; were some of the technical problems, but apart from these all the plants ran into management issues once they were handed over to the community with the result that almost none of them survive today. As a result, investment of several hundred crore rupees went totally

into disuse. There was also an attempt at promoting domestic models of the Nalgonda type filter, but since they require much individual effort daily, they were not accepted.

In the 1980s itself, UNICEF along with IIT Kanpur tested the Activated Alumina (AA) technology for defluoridation which had been developed in the US in the 1930s (Churchill 1936). The defluoridation capacity of AA was much better than the Nalgonda type mechanism, since there was no daily processing requiring, only a regeneration of the AA material after say 3-4 months for an average household with Caustic Soda (NaOH) and sulphuric acid. Mostly, the AA filters were promoted as domestic units and they were piloted in 2 locations with severe Fluorosis – Dungarpur in Rajasthan and Anantapur in AP.

Two organizations – Sanitation, Water and Community Health (SWACH) in Dungarpur and Mytry Social Service Society in Kadiri, Anantapur anchored these pilot testing of the domestic defluoridation units (DDUs). Mostly these programs after piloting in the early 1990s, went on into peak of implementation around 2000-01. The idea was to have DDUs in households to take care of domestic water consumption and regeneration to managed by Sanitary Marts either at the village level or in nearby towns. Resource persons in the village were trained for carrying out regeneration of AA material. Community regeneration centres were also constructed in Kadiri area.

The two organizations, SWACH and Mytry took very different routes. Whereas Mytry tried to absorb all activities of the manufacturing and maintenance in-house by going towards constructing a filter manufacturing plant, SWACH was more focused on creating village institutions that would later on take charge of material regeneration. Mytry later also obtained support from a venture fund to start a business around filter manufacturing which it successfully carried out by supplying filters to nearby towns. Mytry also found a client in UNICEF and different government department for implementing their programs in other states. Therefore the route that the DDU program took in Kadiri went on to create an infrastructure for defluoridation filter manufacturing in a small town of rural India, Kadiri, whereas such defluoridation filters are still not available in the bigger cities even today.

Mytry also established village-level AA regeneration centres and trained villagers to operate them. However, after 4-5 years of the program completion, the regeneration centres are in disuse. Even though villagers can travel to nearby towns for regeneration, they rarely do so. The only remaining users of AA filters are the urban ones who are serviced by Mytry and their agents. Otherwise, the rural defluoridation program is now defunct.

In Dungarpur, there was no attempt at establishing a business, but some of the village resource persons of SWACH still continue to conduct AA regeneration for a fee. A few hundred customers still continue to use AA filters even after 5 years of termination of the program. This sustenance is totally on a private basis and based on a few resource persons who have taken up as their own small business activity and were trained by SWACH.

But what about the thousands of DDU's distributed through these 2 programs? Can the massive investment on these programs be salvaged? If only some services are offered locally for AA regeneration and filter maintenance, there would be many more patients continuing to use these filters. But, what about sustenance of such an activity? Would it be commercially viable?

Reverse Osmosis as a physical process was known since 1748, but it was only in 1960 that practical demonstration of RO using membranes was achieved (Loeb and Sourirajan, 1960). After several decades of use in US and other countries, RO for community and domestic purposes came to India in the 1980s mainly in salinity affected areas for desalination purposes. Soon, the industry developed manifold and a variety of products started developing. It was also seen as a possible technology for community plants and numerous plants were in place in southern Gujarat by 2000. By 2005-06, Gujarat has several hundred RO plants with 200 lph and higher capacity being used in a variety of management procedures privately and through village level institutions (Krishnan et al, 2007).

With regard to defluoridation, RO can treat it to the level of demineralization achieved. Potentially, RO can remove up to 98% of Fluoride ions, but in practice it depends on the level of pressure applied and membrane capacity. And also depends on quantity of fluoride available in water, if it is more than 15 mg/l as it is found in cases of North Gujarat, even 90% removal may not fluoride to a permissible level. RO systems have also been used in many Fluoride affected areas now, initially as a private initiative, and in a business manner for bottled water plants, but now as part of government programs. The current trend for RO plants, starting from Gujarat and AP, but catching on in other states also, is to establish a public-private partnership by involving the RO supplier in a contract with the village institution, but monitored by a government agency. Different management arrangements exist, for example, complete investment by the private party, but payment per litre of supplied water by the villagers. In some places, a rough cost of Rs. 0.15/litre is set, but it varies based on the size of plant, level of treatment required and demand for RO water.

RO water as compared with Rs. 12/litre for current bottled water, is very cheap, but payment of Rs. 2/day for 10 litres, is still a difficult proposition for many rural families. In the existing plants, in rural Gujarat, we find that the RO water has 40% reach within the village on average. Some RO plants sustain with a very high cost per litre Rs 0.6/litre, or Rs 1/litre, but very few affluent families are able to afford this water and also run the plant. Therefore, in such cases, RO water would serve the more affluent families, and would perhaps leave out the poorer majority.

3. Integrated Plans for Water Quality Management

a) Comprehensive geological and geochemical surveys

Identification of water quality problems areas need to be part of a larger groundwater assessment program. Within the concept of local and regional aquifers, water quality issues need to be identified properly. The combination of local water quality problems across different aquifers, the mechanisms of pollution have to be ascertained by geochemical analysis. Unless one understands the extent of contamination locally, it is difficult to construct a water quality mitigation program. So this needs to be a starting point for all further action.

b) Continuous monitoring of water quality

Since concentrations of different contaminants change with time, it is essential to have continuous monitoring. A variety of possibilities can be explored here. Firstly one needs to have a proper strategy at each scale. Here, the recent experience from Assam for Arsenic monitoring is worth looking at. This exercise carried out by PHED Assam with help from IIT Guwahati took a multi-scale approach with appropriate level of monitoring at each scale. Traditional laboratory analysis can be supplemented by wider scale monitoring using water quality kits, sensor and electrode based instrumentation etc. These field based kits can compromise on accuracy, but offer cost advantage. Using a combination of these equipments, a wide monitoring of water quality can be carried out.

Water quality monitoring is an opportunity also to create awareness and demand among people for mitigating action. Therefore, appropriate involvement of people's institutions could be tried. Where possible the PRIs could be involved in such monitoring of water quality and results discussed in Gram Sabhas.

c) Identification of Health impacts of poor water quality

Water quality problems are important because of the health impacts they cause. Many of these established health problems are however hard to detect and establish locally by epidemiological studies. However, several established and easily detectable impacts also exist, for eg. impacts of high Fluoride and Arsenic. On the contrary, direct visible impacts of high Salinity, Iron, Nitrate and agrochemicals are hard to detect. Therefore, whereas it is possible in theory to have a proper census of affected Fluorosis patients, as with today's science, it is hard to arrive at a census patients affected by say, high Nitrate concentrations in groundwater.

But in today's situation, we do not have even a proper estimate of patients of the former type i.e. those affected by say, high Fluoride and Arsenic. There have been sporadic surveys by research institutions, aid agencies, and civil society groups. These are mainly localized and when regional, mostly suffer from quality of diagnosis or sampling. Therefore, the first step is to establish diagnostic centres where such patients can be identified locally. The problem is that doctors are not trained to detect these emerging health problems. Therefore one would need to start from a training of doctors or establish a parallel system for these purposes; however that option seems more difficult.

d) Creation of demand for mitigating impacts of poor water quality

Apart from aesthetic aspects such as taste, odour or colour and directly visible impacts of poor water quality such as Diarrhoea, there is less chance for affected people to even feel that there is a problem with the water quality. Many water quality mitigation programs in even high affected areas have failed just because the patients themselves do not attribute their state to a water quality problem. The first step therefore should be to create demand among affected people for mitigation. Who would create that demand?

Again, following from the previous step, once patients are identified, it is imperative on doctors to create demand among patients for a water quality mitigation program. This requires lot of coordination among officers conducting such a water quality program eg. engineers, and the doctors or health workers in the area. Any inconsistency in information between them can confuse patients, and often the patients follows the doctors for health concerns rather than the engineer. Also, one would need to approach this creation of demand through alternative practitioners who have a greater hold over the minds of many patients.

e) Services offered for mitigation of health problems

The existing health care system in rural areas might not cater to many of the water quality related health problems. It does cater to some such as Diarrhea, but for special problems such as Fluorosis, there are no specific arrangements for diagnosis and mitigation. Such specific health centres need to come up in affected rural areas and nodal local hospitals be designated as *Referral Hospitals* for these health concerns. For more complex cases, these Referral hospitals would need to refer to other specialized centres for eg. for complex Neuro cases in Skeletal Fluorosis.

These referral centres could also act as a nodal point for demand generation for action on water quality mitigation. This should be prior to any planning of water related programs in an area.

f) Preventing further problems due to poor water quality

What are the solutions available today for preventing problems due to poor quality. One could classify these solutions into three categories:

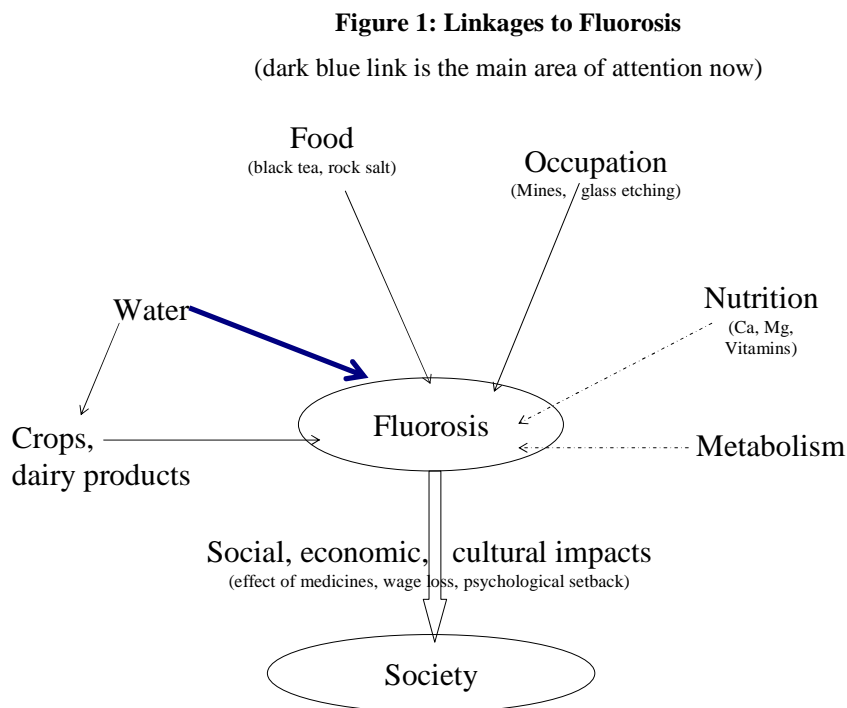
- a) In situ solutions
- b) Treatment prior to use
- c) Indirect solutions

Within the range on in-situ possibilities one can count, water harvesting and recharging, bio-remediation, injection-withdrawal systems etc. These possibilities are not established solutions for the water quality problems of our concern. For example, one needs a good understanding of the contamination process to apply any of these. Such good understanding is currently lacking. Also, the cost associated with say, bioremediation is

prohibitive currently for the regional scale problems across the country. There are currently attempts at watershed treatment to enhance water harvesting and groundwater recharge for improving water quality. In case of coastal salinity ingress, these approaches provide some local relief because of the “fresh water bubble” formed locally. Otherwise, in case of Fluoride and Arsenic, experiments are currently on and it is possible that this approach might be useful in some places.

The most common approach today is water treatment. In urban areas of India, with higher affordability, the usage of expensive water filters is rising steeply. Use of such water filters is also common among the rural rich. But for vast rural areas, there is very low practice of water treatment. Domestic and Community level technologies exist for most water quality problems. Various examples exist throughout the country of experiments for such technologies.

Solutions with Special reference to Fluorosis



Many of our health problems in the past have seen recovery and pathway towards solutions. But these have seen massive communication programmes for awareness and training of health workers. Nothing like this has happened for Fluorosis, yet on a mass scale. Mass media has a role to play in this for sure.

Doctors are at the centre of this problem. Even for sale of Fluoride removal filters, there is a need for doctors to be involved. Perhaps an incentive model for doctors in promotion of such filters needs to be pursued just like for some medicines as followed by some pharma companies. If water is seen as a major cause of Fluorosis and prevention is possible, then can health insurance schemes be utilized to address this problem? The National rural health insurance programme is now been implemented across the country. The annual expenses on Fluorosis due to medicines and loss of wage by patients comes to Rs. 5000-6000 per year (Indu et al, 2008). If this is already being incurred by patients, then shouldn't the annual treatment cost of removal of Fluoride from water of Rs. 500-600 per year, be covered by such an insurance scheme? In that case, hospitals which are now part of this scheme would be more actively involved in Fluorosis mitigation. However, accepting this logic of applying health insurance to Fluorosis is a major step forward in thinking, in that one should look at safe water as preventive for Fluorosis and that preventive care needs to be covered by the health insurance scheme.

In all, an entire package of options needs to be available locally to Fluorosis patients, to be termed as Fluorosis Mitigation Support Services (FMSS). Today, even for patients who can afford, there is no place they can visit for advice on the ailments and curative options. If one needs to buy a domestic filter for defluoridation, there is no such service available anywhere. What if all these are present together i.e. medical advice as well as on curative options. Even for Fluoride removal filters, such a service needs to offer maintenance on filters eg., repair of parts, regeneration of Activated Alumina (for eg), replacement of AA material etc. Apart from this, FMSS should be responsible in training of doctors and educating them towards proper diagnosis of Fluorosis.

All these require investment. At the initial piloting stages, it could run as an entirely funded program, but over time, it would need to generate revenue. Probably an idea such as FMSS can generate revenue from the services it offers i.e. training, sale and maintenance of filters, advice on Fluorosis mitigation etc. But the question is that whether the patients would pay for these services. This is probably where the health insurance programme needs to come in. If the services offered by FMSS can be paid for by the health insurance programme, then such a programme has a chance at long term sustenance. However, these ideas need testing on pilot scales before they can be transported over to a national level. We need integration of different plans across levels (see Figure 1).

Water quality assessment and monitoring

Firstly, we need much better databases of monitoring of drinking water (especially of wells), for water quality standards. When, there is such a huge social burden (as seen above) up to Rs. 4000-5000 every year per family, the cost of monitoring is justified. Each drinking water well needs to be monitored and there needs to be funds allocated for it. If we follow that approach and such databases are available at the Panchayat level, the Gram Panchayats can be held responsible for such monitoring. Such databases need to be maintained and integrated at regional levels.

Health agencies role in detection and mitigation

Apart from geological input into monitoring water quality, the health agencies (along with PHEDs) need to be involved also in such health monitoring programs. The health department surely acts according to priorities. Life-saving priority and epidemics always come first. On top of these emergencies keep arising, say with natural calamities such as floods. There have been doctors we have visited, who are catering to 30,000 patients single-handed! They have to cater to immediate emergencies such as accidents, pregnancies etc, and therefore longer term problems such as Fluorosis go without detection. Moreover, previously Fluorosis was not in the standard curriculum for medicine students. Now it is present in the syllabus of preventive and social medicine. Therefore, most doctors are not trained in diagnosis of Fluorosis, nor do they have facilities such as specific kits for urine and blood testing, or water quality testing for confirmation of Fluorosis. In most cases therefore, these cases get passed off as those of Musculo-skeletal disorder or disease / deformity (MSD).

The standard recommendation from doctors is therefore pain-killers to relieve pain. Brufen based medicines are commonly recommended and in fact, some of our studies have taken the route of pain-killer sales to get to Fluorosis victims (Gadag field study of Indu et al, 2008). Many of the victims of Fluorosis start from a dosage of low amount of pain killers which then increase to more than one a day, many a times requiring a dose to get up from bed in the morning. These expenses on medicine alone can go as high as up to Rs.2000/year for a family on average in Fluorosis affected areas (Indu et al, 2008).

But, why still this apathy from the health departments? We asked this question to one of the DMOs (District Medical Officer) our studies. The straight response was that Fluorosis is preventable and supply of safe drinking water is primarily the responsibility of the Public Health and Engineering Department (PHED). This is probably the reason why some of the Fluorosis mitigation programmes are hosted within the PHED department. Probably once the health department accepts Fluorosis officially, it somewhat absolves the PHED of its duty. But unless the health department officially accepts its responsibility, and trains doctors in detection, there would be no demand created among patients for a solution. Currently, the patients hardly understand the root cause of their problems. It is the responsibility of doctors to make them realize that. They will play a critical role in creating demand for solutions.

Technologies

Lastly technologies are critical in this challenge and they need cater to the requirement of the people they are serving. It is a trend now to install RO systems for solving water quality problems. But let us think of the time beyond 2 years when the RO membrane will fail and think about who pays for the maintenance then. We need much more grounded technologies which can be maintained in villages or nearby towns at low costs. From our experience, such solutions are available for every water quality problem – for eg. Activated Alumina for Fluoride removal. If the question of local maintenance is taken care of, such technologies will have some possibility of sustenance.

Finally, it is important to mention that we need integrated plans over different such domains – technology, health, water quality assessment etc. Some such programs are now in planning and maybe in the future we will see some examples of such pilot programmes which can serve as model for water quality and health management across India.

References

- Agrawal, G. D., Lunkad, S. K. and T. Malkhed, 1999, Diffuse agricultural Nitrate pollution of groundwaters in India, *Water Science Technology*, Vol. 39, No. 3, pp. 67-75.
- Brikowski, T. H., Lotan Y. and M. S. Pearle, Climate-related increase in the prevalence of urolithiasis in the United States, 2007, PNAS
- Chakraborti, D., S. C. Mukherjee, S. Pati, M. K. Sengupta, M. M. Rahman, U. K. Chowdhury, D. Lodh, C. R. Chanda, A. K. Chakraborty, and G. K. Basul, 2003. Arsenic Groundwater Contamination in Middle Ganga Plain, Bihar, India: A Future Danger? *Environmental Health Perspectives* 111:1194–1201.
- Chakraborti, D., B. K. Biswas, T. R. Chowdhury, G. K. Basu, B. K. Mandal, U. K. Chowdhury, S. C. Mukherjee, J. P. Gupta, S. R. Chowdhury, and K. C. Rathore, 1999, Arsenic Groundwater Contamination and Sufferings of People in Rajnandgaon District, Madhya Pradesh, India, *Current Science* 77:502–504.
- Chowdhury T. R., G. K. Basu, B. K. Mandal, B. K. Biswas, U.K. Chowdhury, C. R. Chanda, D. Lodh, S. L. Roy, K. C. Saha, S. Roy, S. Kabir, Q. Quamruzzaman and D. Chakraborti., 1999, Arsenic poisoning in the Ganges delta *Nature*, 401, 545-546.
- Churchill H. V., New Kensington, Pa.: "Removal of fluorine from water", US Patent 2,059,553; filed Oct. 2, 1933; granted Nov. 3, 1936 (using activated alumina)
- Indu, R., 2003, Fluoride-free drinking water supply in North Gujarat: The rise of Reverse Osmosis plants as a cottage industry, Unpublished report of IWMI-Tata Water policy programme, Vallabh Vidyanagar, India.
- Indu, Rajnarayan and Alka Rawal, 2007, Incidences of kidney stone in Mangrol Taluka, Junagadh district, in IWMI-Tata Annual Partner's Meet, Anand
- JECFA, Joint FAO/WHO Expert Committee on Food Additives, 1983, Toxicological evaluation of certain food additives and food contaminants. Cambridge, Cambridge University Press, (WHO Food Additives Series, No. 18)
- Krishnan S., Indu R., Bhatt S., Pathak F., Thakkar A. and U. Vadgama, 2007, Reverse Osmosis for rural water treatment in Gujarat, IWMI Tata Meet, Hyderabad, 2007
- Kumar, D. and T. Shah, 2003, Groundwater pollution and contamination in India, In Hindu Survey of the Environment.
- Loeb S. and S Sourirajan, 1962, Sea water demineralization by means of an osmotic membrane, Dept. of Engineering, University of California
- NAP, 1992, Nutrition Issues in Developing Countries: Part I: Diarrheal Diseases, Part II: Diet and Activity During Pregnancy and Lactation Subcommittee on Nutrition and Diarrheal Diseases Control, Subcommittee on Diet, Physical Activity, and Pregnancy Outcome, Committee on International Nutrition Programs, Food and Nutrition Board

NAP, 2000, Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium and Zinc. Panel on Micronutrients, Subcommittees on Upper Reference Levels of Nutrients and of Interpretation and Use of Dietary Reference Intakes, and the Standing Committee on the Scientific Evaluation of Dietary Reference Intakes, Food and Nutrition Board, Institute of Medicine, National Academies Press, US

Nawlakhe, W.G., Kulkarni, D.N., Pathak, B.N., Bulusu, K.R. Defluoridation of Water by Nalgonda Technique, *Indian Journal of Environmental Health*, vol. 17.1, p. 26-65, 1975

Poddar S., 2006, Hereditary Hemochromatosis – special reference to Indian scenario, *Ind. Jou. Hum. Genetics*, 6(1), pp. 73-79

Rao, N. S., Rao G. K. and D. J. Devadas, 1998, Variations of Fluoride in groundwaters of crystalline terrain, *Journal of Environmental Hydrology*, Vol. 6, Paper 3

Shah T., and R. Indu, 2004, Fluorosis in Gujarat: A disaster ahead, Unpublished report of IWMI-Tata Water policy programme, Vallabh Vidyanagar, India.

Shrestha, R. R., M. P. Shrestha, N. P. Upadhyay, R. Pradhan, R. Khadka, A. Maskey, S. Tuladhar, B. M. Dahal, S. Shrestha, and K. B. Shrestha, 2004, Groundwater Arsenic Contamination in Nepal: A New Challenge for Water Supply Sector. *Environment and Public Health Organization*.

Siener. R and A Hesse, 2003, Fluid intake and epidemiology of urolithiasis – in original communication, *European Journal of Clinical Nutrition*, 57, suppl 2, S47-S51.

Singh P. P., Barajataya, M. K., Dhing S., Bhatnagar R., Kothari S. and V. Dhar, 2001, Evidence suggesting high intake of Fluoride provokes nephrolithiasis in tribal populations, *Urol. Res.*, 29, 238:244

WHO, 2003, Iron in Drinking Water: Background document for development of WHO guidelines for Drinking-water quality, Geneva

World Bank, 2005a, Towards a more effective operation response: Arsenic contamination of groundwater in south and east asian countries, Volume I Policy report, Technical report no. 31303

World Bank, 2005b, Towards a more effective operation response: Arsenic contamination of groundwater in south and east asian countries, Volume II Technical report, Technical report no. 31303