DISCUSSION NOTE[1]
Groundwater contamination and rural water treatment in Gujarat
Safe drinking water for the last person?

Rajnarayan Indu* and Sunderrajan Krishnan*

ABSTRACT

Gujarat state is characterized by varied hydrogeology and vast areas with typical groundwater quality problems. Much of the coastal areas have saline groundwater and inland salinity is also present in much of the Alluvial tract. Fluoride in groundwater is present in pockets of most formations. Especially, deeper groundwater has shown high Fluoride in the Alluvial aquifer areas. Since groundwater has emerged to be the most important source of drinking water in most rural areas, these quality problems have resulted in high costs on society – in terms of health and related issues. Studies done in affected pockets of the state show that a large part of family income of affected persons is spent in medical costs and wage losses. In absence of good quality drinking water, such costs only increase with time. A variety of policies have been tried in supplying safe drinking water to rural areas. These include supplying of regional water through pipes and as well as local water treatment programs. The regional water supply schemes suffer from problems in cost recovery and therefore low funds in repair and maintenance. The supply systems therefore are not very reliable. Many different options are now in progress for treatment of water locally. Various community based programs have been tried in the past, but only few of these purely community run plants are successful. The rural rich can afford alternative options from the private sector such as domestic water treatment plants and bottled water treated by medium to large water treatment systems. Newer options that are coming up are multiple use of such treatment plants for industrial as well as domestic usage. Initiatives in involving private sector with the community are also in design now. The future lies in providing safe drinking water in rural areas with a mixture of these options so that the objectives of providing safe water at low cost for sustaining over a long time and reaching to maximum number of people is achieved.

1. Introduction and background

1.1 Physical setting: hydrogeology and water quality

The aquifers in the State comprise of Trappean Basalts, Precambrian Crystallines, Alluvial and Limestone and clay aquifers (Phadtare, 1988). Much of central Saurashtra is underlain by the Deccan Trappean Basalts. The coastal parts of Saurashtra are mostly Limestone and Clay aquifers and so are some regions in North Saurashtra close to Surendranagar. The North-South running Alluvial aquifers of varied quality stretch from the Northern most parts of Gujarat to the Central and South parts. These aquifers have a

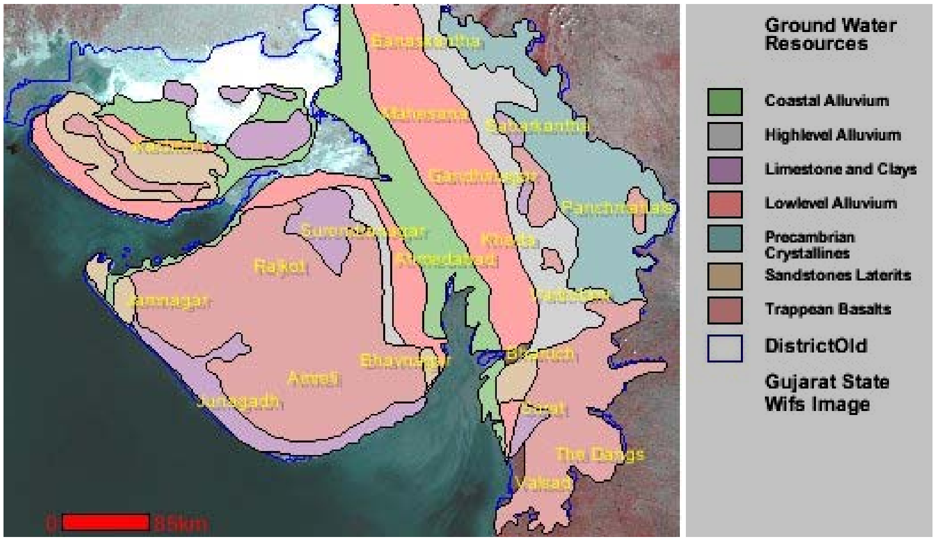
---

[1] This is a discussion note prepared as a summary of work within IWMI Tata Water Policy Program. Please do not use this paper as reference.

* International Water Management Institute, Anand-Sojitra Road, V. V. Nagar, Anand district, 388120, r.indu@cgiar.org and s.krishnan@cgiar.org

deeper depth in the Northern parts and are more shallow towards the Southern regions. The Southern parts of the State again possess aquifers of Deccan Basalts which are

Figure 1: Aquifers of Gujarat



spatially contiguous with the rest of the massive Basalt terrain comprising Maharashtra and some parts of Madhya Pradesh. Crystalline Aravalli aquifers comprise the North-East parts of the State. Kutch shows a wide variety of aquifers ranging from Alluvial, Limestone, Clay and Laterites.

Recharge processes in the aquifers varies from spatially and temporally concentrated contribution from ephemeral streams to diffuse recharge from canal networks. The arid and semi-arid climate flat terrain of Saurashtra and Kutch are characterized by recharge occurring from the monsoon streams which spring during the showers. Recharge is primarily limited to a few humid pockets in hilly areas and the periphery of streams and rivers. The hilly regions of North Gujarat have little to any recharge from the ephemeral streams with some recharge happening in the plain Alluvial terrain from these streams. Due to a high variability of rainfall, the inter-annual recharge is also highly variable (Kumar, 2004). The rivers of Central and South Gujarat contribute in vast amounts to groundwater recharge and in some dry times also receive contribution from these aquifers. The canal networks of the Mahi, Sabarmati and Narmada contribute wide, diffuse recharge across the year in the plains of south and Central Gujarat. These are the regions of maximum recharge across the State also characterized by intensive agriculture which again contributes to recharge from irrigation return flow.

Table 1 Level of Groundwater Development (as per cent) in Gujarat for 1995 and 2004 Statistics

Name of District	GW DEV 1995	GW DEV 2004
Banaskantha	63	118
Bharuch	22	46
Bhavnagar	30	64
Gandhinagar	68	184
Jamnagar	33	60
Junagadh	51	74
Kutch	36	90
Kheda	36	62
Mehsana	124	148
Panchmahals	28	60
Rajkot	37	72
Sabarkantha	50	84
Surat	37	65
The Dangs	3	4
Vadodara	38	52
Valsad	39	60

Table 1 shows the level of groundwater development in each district of Gujarat according to the CGWB groundwater statistics (CGWB, 1995; CGWB, 2004). The methodology of estimation has been revised since 1997 and new data especially from the Hydrology project has been used for estimation now. These are the reasons why the level of groundwater development shows difference from the 1995 and 2004 estimates. In all cases, we see a distinct rise in the development figure.

Aquifers in Gujarat are beset with numerous quality problems, some of which are increasing in intensity over the years. Having a longest coastline in the country, sea water intrusion into aquifers is a common problem all across Gujarat right from Kutch and Saurashtra to Vadodara and Valsad. Excessive Fluoride is another problem in groundwater of North Gujarat, some parts of Saurashtra and some pockets of South Gujarat. Over the years, excessive amounts of Nitrate are surfacing in groundwater in various parts of the state. In addition to all this, Gujarat has various pockets of high industrial activity where large amounts of effluents are released, sometimes directly into wells. High amounts of toxic waste have been detected in aquifers of South and Central Gujarat.

Table 2: District-wise number of villages affected by groundwater quality problems

District name	Fluoride	Nitrate	Salinity
AHMADABAD	120	2	74
AMRELI	49	23	109
ANAND	96	62	70
BANAS KANTHA	521	71	68
BHARUCH	21	25	104
BHAVNAGAR	108	34	96
DOHAD	286	37	25
GANDHINAGAR	132	32	9
JAMNAGAR	52	7	243
JUNAGADH	76	174	138
KACHCHH	34	1	168
KHEDA	406	104	174
MAHESANA	176	15	87
NARMADA	49	27	8
NAVSARI	22	2	56
PANCH MAHALS	401	61	55
PATAN	246	0	70
PORBANDAR	46	26	34
RAJKOT	126	220	251
SABAR KANTHA	531	216	59
SURAT	44	69	185
SURENDRANAGAR	205	23	79
VADODARA	438	100	144
VALSAD	2	4	202
Grand Total	**4187**	**1335**	**2508**

Table 2 shows the number of villages in each district affected by either Salinity, Fluoride or Nitrate problem (Source: WASMO and GWSSB Statistics on rural water quality).

1.2 Health and Social impacts of water quality problems

Pollution of environmental resources such as water imposes a cost on society. The costs of water pollution would depend for what purpose that specific water is being used. For example, in the case of saline water used for industrial purpose, one needs to consider the cost incurred on desalinating the water. In case of diseases occurring due to contamination, one needs to consider the health costs directly due to the affliction such as Fluorosis. These include both the treatment cost and also the opportunity cost in terms of lost wages. The canvas therefore is quite wide and one needs to define the boundaries clearly when defining the costs of pollution. One attempt at nationwide assessment of the cost of water pollution has been made by Maria(2003). The emphasis however, has been mainly at surface water pollution and the challenges in assessing the impacts of groundwater pollution have been mentioned in this paper.

A study of the socioeconomic impact of Fluorosis was conducted by IWMI-Tata Programme in 25 villages of North Gujarat by surveying a total number of 28,425 respondents (Shah and Indu, 2004, IWMI-Tata unpublished). 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. Amongst 4590 people who were severely affected persons, 14% or 643 cannot walk properly and more than 64% per cent cannot sit-up and bend forward properly. Only 4% of the total population and about 23% of the afflicted persons took medical treatment; rest 77% either could not afford or did not believe in medication to cure their pain. The severity of Fluorosis disease was observed to be the highest in the people above 60 years. 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 and 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.

Consumption of water with high Salinity causes kidney stones, blood pressure and several skin diseases. A joint study has been taken by IWMI and AKRSP on Social Impact of High Incidence of Kidney Stone in Coastal Villages in Junagadh district. It is observed at the first cut analysis that 6 to 7 per cent people is suffering from kidney stone in the selected five villages in the coastal area of Mangrol taluka in Junagadh district. We have also found that average expenses for one time operation is Rs 15-20 thousand depending upon the size and location of the stone; and there is a 80% chance of recurrence of this problem as opined a local Urologist. Results from this study are in process and would be published by March 2007.

2. Addressing water quality problems

The government policies for rural drinking water through Swajaldhara and other programs have been mainly focused on ensuring supply of drinking water and the institutional mechanisms needed to sustain the system. However, not much emphasis has been paid towards water quality problems due to biological and chemical contamination. What seems to be clear from current experience on water treatment is that to explore a single solution or technology would not be suitable for any place. A variety of factors add challenges to the problem:

- the nature of quality problems – Salinity, Fluoride, Biological, Arsenic, Iron – and their combinations require different technologies for treatment. Also, we keep coming across newer problems such as increasing agrochemicals presence in drinking water of some areas.

- 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,
- 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,
- 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

These compel us to take a more detailed view of the picture – one that takes into account the heterogeneity of problems and asks for multiple alternatives and locally anchored solutions. An intervention such as single community owned plant for a village could ignore such complexities leading to potential failure of the system in the long run. This has been observed with several RO plants installed in villages of Gujarat by governments in past few decades.

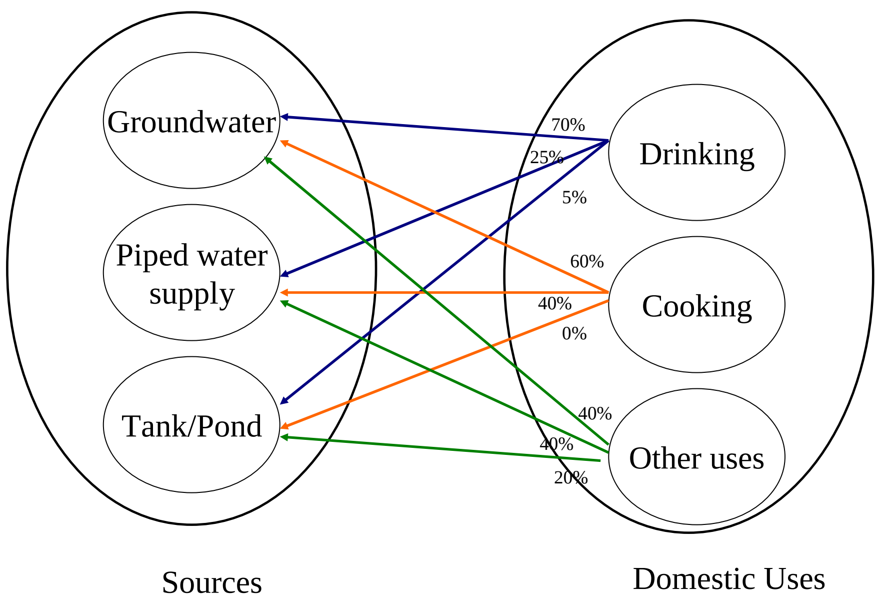
The success of rural drinking water programs in Gujarat has led to coverage of most villages under supply by either local or regional sources. However, the quality of this water is far from being safe. The next step in supply of drinking water should be therefore to look at treatment of this supplied water in rural areas.

In the current situation, various solutions are emerging to this question. One can look at different ways to categorize these solutions- based on the type of problems i.e. bacterial, viral, fluoride, salinity, pesticide related quality issues; based on technology i.e. simple filtration, boiling, Chlorination, domestic bacterial filters, Activated Alumina (AA) or Selective Resin (SR), Reverse Osmosis (RO), distillation; mode of supply i.e. common treatment, domestic treatment, private seller of treated water through packaged water either as bottled water or as door-step supplied can-water. To make this discussion easier, we would focus on the technology and mode of supply factors. Within the type of problems, the quality issues due to biological contaminants are mostly removed by boiling and Chlorination. So we focus mainly on Salinity and Fluoride as the key quality problems.

We are left with several technology options and modes of supply to implement these technologies in treatment of water with high Salinity (TDS) and high Fluoride. Looking at the extent of these problems, we use village level data (supplied by WASMO), and observe that 35% of the 7675 villages from which data was used are affected by salinity and 55% of the villages are affected by Fluoride and only 2% of the villages affected by both Salinity and Fluoride i.e. 88% of villages that have either Salinity or a Fluoride problem. The degree of severity varies a lot between these areas. It is common to find many villages were only a single well might show high Fluoride. In those cases, drinking water can be obtained from other wells that provide water of safer quality. For salinity, the main affected areas are the coastal areas and some inland areas in northern Gujarat. For Fluoride the severely affected zones are in northern Gujarat and in southern Saurashtra.

Out of these, many villages are being currently supplied drinking water under the numerous regional water supply schemes for which the source of water are either surface water from reservoir or groundwater pumped from safer aquifers and supplied to these affected villages. Examples are Dharoi scheme in northern Gujarat, the Ghogha and Kaluwar schemes in Saurashtra which supply Mahi and Narmada water and smaller schemes such as Karnewal tank in Khambat and Tarapur coastal blocks of Anand district. For these covered villages, during times when this supplied water is reliable, the quality issues are limited to biological contaminants and for most cases free from high levels of fluoride or TDS. However, the reliability of this supplied water is an issue within many

Figure 2: Different sources of drinking water for a single household



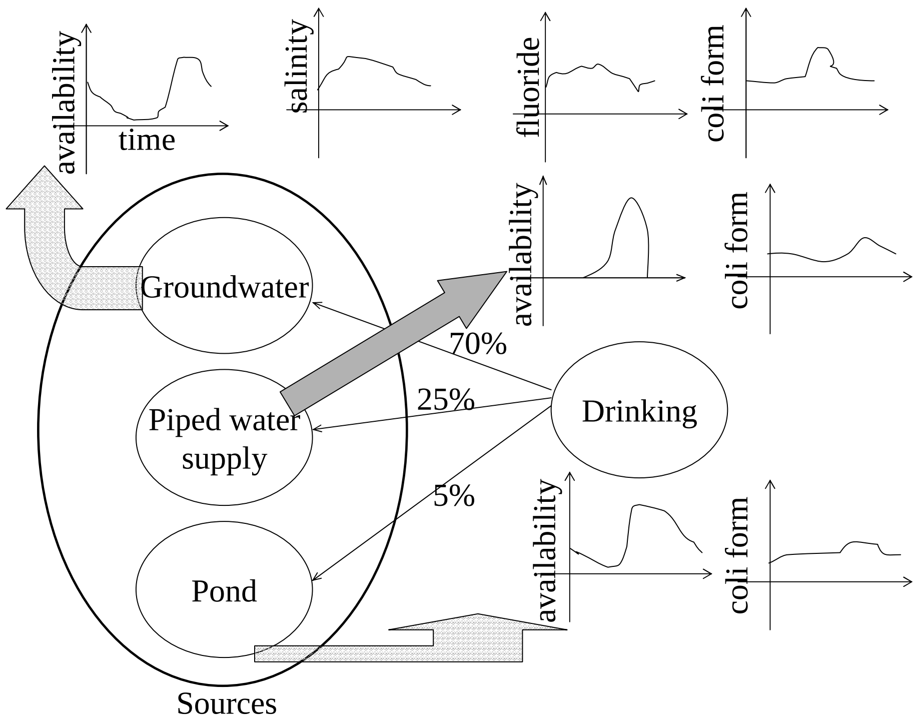
villages under these schemes and the question of depending on unsafe local water sources remain (DSC, 2005).

That leaves a certain percentage of villages which have to mostly depend on local water sources for drinking and access to such local sources which are free from high levels of Fluoride or Salinity is minimal. This lack of access can be due to different reasons: few wells with safe drinking water, social reasons for lack of access and economic reasons for lack of affordability.

The reality in local water quality situation is more complex than just assuming a certain village or household to be faced with a similar water quality problem throughout the year. Often the same household depends on several sources for drinking water at different times of the year. Figure 1 shows these dependencies for multiple uses of water from different sources.

The quality of water from a single source can show significant variations at different times of the year. For example, salinity in groundwater can be higher before monsoon and reduce after the monsoon. This is observed strongly in most of the coastal areas. This differing water quality from the same source and across sources makes it improper to say that one household is situated with a typical water quality problem constantly. In a scenario in which regional water supply schemes are being developed, local water supply programs are also promoted and private market also supplying water, one needs to be looking at multiple water quality for different sources as shown in Figure 2.

Figure 3: Multiple quality of drinking water for a single household in a year



Under this scenario, we try to capture the current matrix of possibilities in rural drinking water treatment through this table (note that we are not considering here water supply options such as Roof-top Rainwater Harvesting Systems which could be a viable option for many areas in Gujarat),

Out of these we question the viability of options A1, C1 and C3 on the following reasons:

- A1 since it might not be economical to have large treatment plants with AA or SR
- C1 for the same reason since large AA or SR plants are economical
- C3 since high discharge distillation plant can be uneconomical and very large in size

Then that leaves the 6 options A2, A3, B1, B2, B3 and C2 as technology and mode of supply combinations for rural water treatment in areas affected by Salinity and Fluoride. The next step we undertake is to rank these 6 options in terms of different parameters based upon our observations and some considerations of economics and social situations. This ranking is purely based on our subjective judgment and is not validated as yet.

Parameters of performance of technology-mode of supply combinations:

i) Reach: A2, C2, B1, B2, A3, B3 (this is under the assumption that no subsidies are present for development of a certain option mentioned here)

Table 3 Combination of technology and management options for rural water treatment

Technologies ⇒ **Modes of supply ⇓**	AA or SR (for Fluoride) **(1)**	RO (for Salinity, Fluoride) **(2)**	Solar Distillation (for Salinity, Fluoride) **(3)**
Common plants **(A)**	not possible	**A2**	**A3**
Domestic plants **(B)**	**B1**	**B2**	**B3**
Packaged water supply **(C)**	not possible	**C2**	not possible
		Low (for high capacity)	High
COST (per unit of water)	Low	High	High
		Low	
		Large*	Few
REACH (number of people)	Large	Few	Few
		Large	

* multiple plants or cluster community plants

ii) Cost: of treatment per unit volume of water: B1, A2, C2 , B2 , B3 , A3

iii) Sustenance: C2, B1, B2, A2, B3, A3 (in terms of expected life of that technology and mode of supply; in this case lifespan ends when either technology or mode of supply fails)

This analysis, however, hides several complexities. Local situations often hold the key in deciding how these combinations fare. For example, consider the tribal areas of Surat district where recently high Fluoride in groundwater is reported. In this case, private market options such as packaged drinking water would not be suitable and the best options might be to arrange for either domestic AA/SR plants or have common RO treatment plants.

Such local factors naturally come into play in the current scenario in creating the rural water treatment picture which is showing high dynamism. On one hand, private manufacturers and marketers of domestic RO plants are targeting the rural rich eg. Anand-Kheda, Mehsana-Patan and Surat districts, whereas on the other hand we have new and upcoming strategies of government organizations in devising new institutional arrangements for common RO treatment plants eg. WASMO's ideas on piloting private-community partnerships and Byrraju foundation's efforts in Andhra Pradesh(Byrraju Foundation report, 2006). Supply of packaged drinking water is especially dominant in villages close to towns and cities eg. close to Anand, Mehsana-Patan towns (Indu, 2003). A variety of privately or locally arranged common treatment plants arranged by

Panchayats or by benevolent villagers are also in place eg. in villages of Surat and Anand-Kheda.

In this scenario of multiple technologies and modes of supply, perhaps, our outlooks needs to be broad and towards looking at what is the local need? What kinds of combinations can maximize our desired parameters – say in this case of reach, cost and sustenance or any other parameters. None of these combinations A2 till B3 would pay attention to all these factors equally. For example, packaged water sellers would not be conscious of a high reach necessarily if they receive good profits from few customers whereas a common treatment plant would pay attention to sustenance and certainly to reach since it serves the community benefiting from it.

On the whole, however, these factors together matter and policy makers need to keep in mind that thirsty throats and the poor health of the last person is also satisfied maybe at some cost to others.

3. Summary

The solution to rural water treatment in Gujarat needs to be looked at from multiple fronts. Local treatment of unsafe water is currently being achieved through a variety of community and private initiatives. When looked at as a whole, it seems that a combination of these current options would develop in the future as a range of solutions to the rural water treatment question. Development of policies aimed at creating sustainable treatment systems in rural areas, therefore, have to keep in mind this heterogeneity in situation before promoting one or few of the current options.

REFERENCES

Byrraju Foundation report, 2006, Safe drinking water: An initiative in rural transformation by Byrraju Foundation

CGWB, 1995, Groundwater Statistics of India

CGWB, 2004, The Dynamic groundwater resources of India

DSC, 2005, Ensuring safe drinking water in Lathi-Liliya region

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.

Kumar D., 2004, Rural Water Supply and Sanitation in Gujarat, Sector Assessment Study

Maria, A., 2003, The costs of Water pollution in India, In Conference on Market Development of Water and Waste technologies through Environmental Economics, New Delhi.

Phadtare P. N, 1988, Geohydrology of Gujarat State, CGWB, Ahmedabad

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