REVERSE OSMOSIS PLANTS FOR RURAL WATER TREATMENT IN GUJARAT

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ABSTRACT

The Reverse Osmosis (RO) technology is proving to be an important solution for drinking water treatment in rural Gujarat. Treatment plants with capacity ranging from 10 litres per hour (lph) to 6000 lph are now supplying drinking water in several hundred villages of the state. Small sized plants with capacity < 20 lph are used by individual families whereas medium to large sized plants (>100 lph) are being used for public consumption. The mode of operation of these larger plants is varied –as exclusively owned, as a pure business or owned by a community. The large RO plants (100 lph – 2000 lph) are located in few pockets of the state and are predominantly in areas where affluent non-resident Indians have donated plants for their native villages. The south Gujarat coastal stretch close to Surat comprises one such pocket where hundreds of RO plants have surfaced in the past decade. Local assemblers of treatment plants located in small towns have played a major role in this boom. Depending on the mode of ownership, the price/litre of treated water ranges from being free to Re 0.6/litre. Some of the plants are by-choice restricted to one society or community, whereas others are open-access giving rise to several offshoot water suppliers serving surrounding villages. The reach of this treated water within the areas of influence varies from 10 percent to 100 percent and is highly dependant on the mode of ownership, cost of treated water and local norms such as cross-subsidization favoring families that are unable to afford the regular prices. When compared with these areas, the northern Gujarat districts of Mehsana and Patan show a stark contrast in the mode of ownership and distribution of RO water. Private bottled-water plants are more in vogue in these areas and a repeat survey after 4 years shows a 3 fold rise from 14 to 45 in the number of private packaged water RO plants and a 7 fold increase in number of users. However, only 7 of these 45 plants are certified by ISI for selling packaged drinking water. The primary reasons motivating consumers to adopt RO water use were - poor quality of regular supplied water, the multi-purpose use of RO water and tasting RO water from previous consumers. This is different from domestic plant adopters of Anand district in central Gujarat who are mainly affluent villagers motivated by medium to poor quality of supplied water and the multi-purpose use of treated water.

In future, in the south Gujarat stretch with large density of plants, safe disposal of effluent (reject) water is expected to become an important issue, with significant environmental impacts. Approximately 0.5 million litres/day of high TDS (>1000) effluent is let out into the environment and its consequences on top soil, stream water

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quality and biota can be significant in the longer run. Planning of future treatment systems in rural areas, thus, needs to keep in mind – the need of the community, proper maintenance, awareness generation amongst potential consumers, proper regulation of price and attention to safe disposal of effluent from the plants.

1. INTRODUCTION

Purity of water and water for purification are concepts rooted in Indian culture (NIH, 1993). The perception of quality of water for different purposes is intuitively present in the language and minds of people. And similar are concepts of water used as a purifying agent in daily activities and rites. Along with these, different practices for treatment of water and protection of quality of water are also imbedded. Boiling of water for drinking, using herbs for cleansing of water, protection of drinking water wells from surface pollution are all examples of traditional knowledge and practices of water quality and protection of safe water. In certain communities it is a belief that 'natural water' such as water from wells as opposed to 'artificial water' coming from pipes is more suitable for purpose of rites. Also, some communities consider energy agents such as electricity as being artificial, therefore impure. These age-old concepts are now changing and slowly being evolved and merged with modern scientific-based ideas of water quality, pollution, protection of water and water treatment. Any new technology that gains acceptance within this society in flux needs to keep pace with these evolving perceptions and beliefs about water quality.

The drinking water situation in the country is seeing major changes today. Whereas the past fifty years witnessed increasing reliance on groundwater for domestic purposes (Planning Commission, 2002), recent trends are showing greater allocation of surface water for this use eg. Narmada, Mahi water in Gujarat, Godavari waters in Andhra Pradesh etc.. This is happening due to the exploitation of groundwater resulting in poor quantity and quality of local sources (CGWB, 2004). However, experience from many such projects supplying water regionally suggests that such water is unreliable especially in times of stress and suffers from any problem associated with large public delivery systems (DSC 2005). They, at best, can be relied upon as supplemental sources for domestic water.

Then, using local groundwater, though of poor quality becomes the only long term solution for many areas of the country. Treatment of this local groundwater is essential since various problems of biological and chemical contamination affect these sources. The important question is what kind of water treatment would best suit the local needs and adapt to local culture, be within affordability of the users and as a technology be reasonably adept to maintenance and long-term upkeep.

Fluoride, Arsenic, Nitrate, Salinity and biological contamination are broadly the main pollutants that need to be removed by any water treatment for drinking. Add to these, individual and cultural factors such as colour, odour, taste and smell. Different water treatment technologies have emerged catering to specific purposes in the past few decades. A popular technology that gained popularity in the past 2 decades has been bio-filters that can be fitted to the tap. This technology guaranteed with-flow removal of biological contaminants without requiring any storage and at no extra time for treatment. Variants of this technology are still popular in many areas that suffer only from biological contamination. But when it comes to removing chemical contaminants, the need remained. Specific filters such as defluoridation (Activated Alumina, Resin) have been developed, and they are effective in areas where Fluoride is the only problem with water contamination. But, removal of other salts was still a question. The one technology till now that has been able to address all these problems together has been that of Reverse Osmosis (RO). The major question with RO has been that of cost and handling of effluent (reject) water, both of which present constraints to adoption and wider spread of this technology.

1.1 Osmosis and Reverse Osmosis: The Process

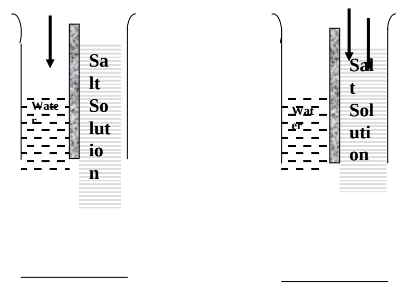
The principle of Osmosis and Reverse Osmosis is based on semi-permeable membrane science. Osmosis[3] and Reverse Osmosis are important diffusional processes through a semipermeable membrane, driven by concentration difference and pressure respectively. The natural force that drives the water through the semi-permeable membrane is called ‘osmotic pressure’, and the process is called ‘osmosis’. The concept of Reverse Osmosis came to light in the middle of 1950’s and can be considered a need-based invention.

Literally the two phrases signify just the opposite process, however thermodynamically they are similar. In osmosis, the solvent (water) flows to solution (salt-water) through semipermeable membrane, whereas in reverse osmosis, the flow of water is from solution (salt-water) to solvent (water) by applying pressure on solution (salt-water) side. In both these cases, only solvent (water) molecules migrate from one side to other.
The principle of RO is shown in Figure 1.

Figure 1: Osmosis and Reverse Osmosis principles

[3] Osmosis is a natural process involving fluid flow across a membrane known over the last 250 years (Bhattacharya, 2001; pp 47-48). The term ‘osmosis’ was coined by the French Physiologist Henri Dutrochet 80 years after Abbe Nolet made the discovery of the phenomenon in 1748. Later on Van’t Hoff established the scientific principle behind the process for dilute solutions. Osmosis is the process by which plants and animals survive because it is a regulatory process in cells of all plants and living beings. The photosynthesis mechanism for the plants operates due to the osmosis and it starts from the passing of water from the soil into the plants across the walls and membranes of the cells in the roots and root hair.

Natural Pressure **Generated Pressure**



Osmosis **Reverse Osmosis**

Reverse Osmosis is a process that uses semi-permeable spiral wound membranes to separate and remove Dissolved Solids, Organic, Pyrogens, Submicron colloidal matter and Bacteria from water. Inlet water is delivered under pressure through the membrane, where water permeates the minute pores of the membrane and is delivered as purified water. Impurities in the water are concentrated in the reject stream and flushed to the drain. Reverse Osmosis is capable of removing 90-98 per cent of the Total Dissolved Solids (TDS), 99 per cent of the Organics (Including pyrogens), and 99 per cent of all Bacteria. Currently available membranes can eliminate as much as 99 per cent of the mineral content of the water in one pass. It is advantageously used to remove water from the concentrated solution. Since the cost of RO treatment increases very little with increased TDS, it is economically attractive for the desalination of both brackish water supplies at TDS concentrations of 10,000 ppm and seawater supplies at 45,000 ppm. Along with TDS RO process removes fluoride proportionately. If TDS is at tolerable level and fluoride content is high then one can use special alum-resin filter, works under gravitational force.

A typical RO system consists of pre-treatment, high-pressure feed pump(s), an 3-2-1 array of membranes housed in pressure vessels, and a network of piping and valves to divide the feed water and collect the permeate product. The process utilises four different configurations, namely plate and frame, tubular, spiral and hollow fine fibre.

2. RESEARCH OBJECTIVES AND METHODOLOGY

Gujarat state in Western India has seen a tremendous rise in adoption of RO technology in the past decade. This has happened almost entirely through private initiatives with donors playing a major role. Hundreds of plants are supplying drinking water in villages across the state with variety of local arrangements making it possible. Plants ranging from capacity of 5-10 litres/hour (lph) to larger ones of capacity 5000 lph are currently supplying treated water. These plants are operating under numerous arrangements. The small ones are domestic plants owned by families. But medium to large sized plants ranging from size 100 lph and upwards have no fixed mode of ownership or water distribution system. This research study started from the need to look at how such a complex and costly technology has picked up in the rural areas of the state and continuing to operate successfully, in many cases for more than 5 years. We wished to first explore the expanse of these plants and see which the major pockets of high density of plants were. Then, our objective was to understand the mode of management and the life-cycle cost of these plants. We then studied what were the issues of equity in the reach of this water within the areas of influence and to connect if there is any link between the mode of management and reach of treated water. Finally, we wish to learn from all the current experiences of managing medium to large RO plants in rural areas and synthesize this knowledge for use in planning of future such programs.

2.1 Domestic RO Plants

Our study area for rural domestic RO plants was Anand district. We procured customer lists of **3** RO suppliers based in Anand town and selected from their customers. Our objective was to determine the profile of these customers and the motivation behind their route to procuring the plant. Appendix A shows some relevant questions from the interview schedule administered to these plant users. We also collected the income and education of the family through a structured schedule.

2.2. Community based RO Plants

For convenience, we define community RO plants as those being managed by a trust, elected body or local committees of these elected bodies or cooperatives. In our study of community RO plants, we assumed a unit of study for the purpose of standardization. We chose to have a village as a unit and later realized that this might not be applicable for every community RO plant. Still we maintain this for commonality. We have 4 tools for this purpose:

i) A village level schedule: In this schedule, we obtain certain basic information about the village: population, composition in terms of age, caste, sex, any other arrangements for drinking water,

ii) An RO plant schedule: capacity of plant treatment, expenses incurred, plant manufacturer, maintenance contract, storage capacity, running expenses, selling price of water, number of hours of operation, production/day, mode of water distribution, disposal of effluent, ownership of plant, mode of funding, profile of users, information about off-shoot water distributors. The water quality of raw water, treated water and effluent water were collected one-time and tested by us.

iii) RO water users schedule: family profile, volume of water bought, reasons why RO water was bought (Appendix B).

iv) RO water non-users schedule: family profile, current drinking water arrangement, awareness of RO water, reasons why not buying RO water

2.3 Commercial Packaged Drinking Water Plants

These packaged drinking water (PDW) RO plants are owned and managed for the business of selling treated water. These are spread all over urban Gujarat and in some areas cater to the rural population as well. Our previous study looked at the growth of these plants and the adoption of the treated water by rural users (Indu, 2003). Here, we revisited the same districts of Mehsana and Patan to look at the change after 4 years. Also, we employed the same interview schedules as that for community RO plants to interview users and non-users of these plants. Note that in the case of PDW plants, it is difficult to define non-users of the plant since the area of influence is wide-spread and there is no specific target community.

3. THE LANDSCAPE OF RO PLANTS IN RURAL GUJARAT

We performed our studies in primarily 3 areas of the state – south, central and north. The south Gujarat stretch comprised of some talukas in the 3 districts of Surat, Bharuch and Navsari. In central Gujarat, we looked at plants in Anand district and in north Gujarat, we studied plants in the districts of Mehsana and Patan. Many of the plants in the northern Gujarat districts have been looked at previously in another study (Indu, 2003), and most of the current study in that area was a revisit to those previously studied plants.

In all, our samples covered 41 medium to large sized RO plants that have a total of around 6000 users of treated water in 6 districts of Gujarat. A total of 12 of these plants were chosen for in-depth study of both users of the treated water and non-users within the areas of influence. One plant based in Dantali village of Anand district was chosen for a complete exhaustive study. We interviewed a total of 500 users (around 7% sampling) of this treated water and 550 non-users within the areas of influence of the supplied water. In addition to this, we have sampled 63 domestic RO plants, all located in villages of Anand district. Apart from these we procured customer lists of various plant assemblers and suppliers which have helped us to build a larger picture of the current situation.

3.1 Domestic RO Plants

Anand district represents one of the more affluent areas in Gujarat. Rural amenities in some villages of this district are better that those in many urban areas. It is underlain mainly by multi-layered alluvial aquifers within which TDS of groundwater shows gradual variation from 400-500 in the eastern parts to 2500-3000 in the western parts of the district. There are pockets of high Fluoride content (> 1 mg/l) in this district. Apart from these, biological contamination of groundwater shows a seasonal trend with flood related contamination being common (Krishnan et al, 2006).

Several RO plant assemblers operate out of Anand city and maintain small to medium size RO plants around this area. We sampled 63 users from 3 of these suppliers and located in 12 villages of Anand, Borsad, Petlad and Sojitra talukas of Anand district. On an average, there are 5-10 such users per village of this area. The average size of the plant is of capacity 11 litres/hour and the average cost of the plant is Rs. 11,900. The education levels of family members are almost in all cases, above matriculation. Most of these users reported sharing their treated water with neighbors, but do not charge for this. All except one user were unaware of the disposal of reject effluent from the plant. The average monthly reported income was Rs. 5000. From our observations and data on expenses, we suspect the incomes to be higher, especially after accounting for remittances from abroad.

Figure 2: Motivation behind buying domestic RO plant in rural Anand district

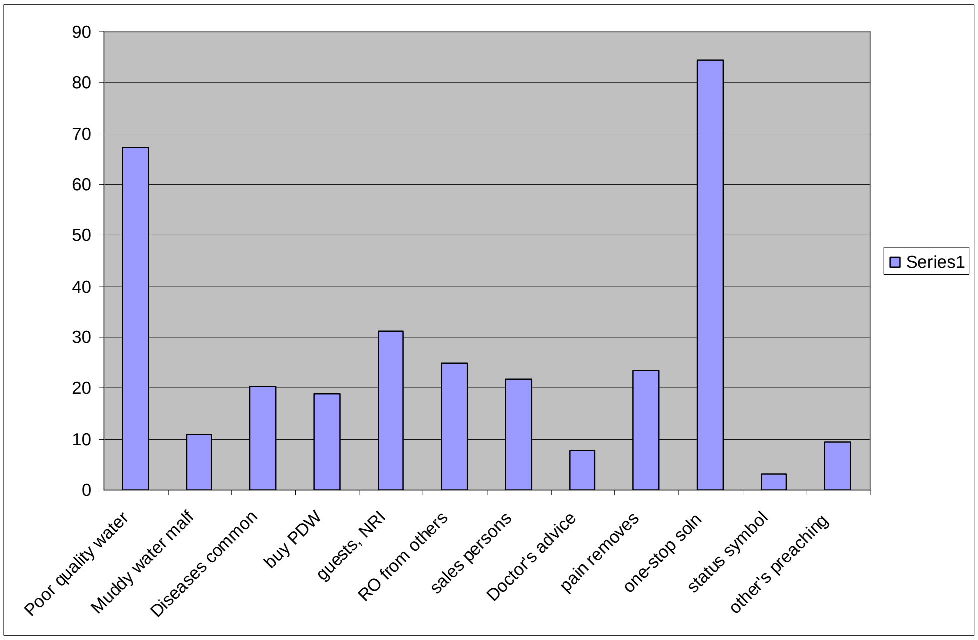


Figure 2 shows the summary of responses of these users to various questions asked about why they chose to opt for the domestic RO plant. Two main reasons are prominent: i.e. perception of poor quality of supplied water and that RO water is a one-stop solution to many uses such as drinking, cooking, washing vessels etc. Our conclusion from this study is that the rural educated rich, who also have exposure to better quality of domestic water from other places, opt for these costly domestic plants. Domestic RO plant is not a solutions en-masse to the rural drinking water treatment question.

The adoption of an RO water treatment for household purpose means that it tends to replace slowly any other mode of treatment of water, be it a traditional one, or one of a previous technology. It slowly transitions to capture uses beyond drinking – washing of utensils, in some cases washing hair, use for cooking etc. In isolated cases, our observation has been that there is tendency to use this treated water for all domestic purposes, under the reasoning that it saves the cost of say, washing of tiles in sinks and bathroom. Such adoption of technology reflects also a changing mindset that appears to savor a lifestyle with high perceptions of luxury. If this is a trend to be expected in the future, the figures for per capita consumption for domestic use would need severe revision.

3.2. Community-based RO Plants

The rapid rise of community-based RO plants is a story typical to Gujarat. It could have happened first only in this state which has a strong non-Resident Indians (NRI) presence whose attachments to native villages and desire to achieve a healthy lifestyle in them spur them to invest on various developmental activities. Well-paved roads, clean sanitation and well-endowed health clinics dot the rural Gujarat landscape. RO plants are just another addition to these rural amenities. The first community RO plants in our samples were installed in 1999, but there were few plants operating even before that time. Most of these initial plants have been donated by NRIs and therefore they are located in such pockets of the state. But the coastal talukas of Surat, Bharuch and Navsari stand unique in this respect. A rough counting covering 5 major RO suppliers in this area gave us an estimate of at least 325 such plants operating in villages of this area. Out of these, 100 have been installed solely by a non-ISO local assembler operating out of Olpad town.

Appendix D gives some description of the surveyed plants in south Gujarat. These plants operate under a variety of funding, ownership, management and distribution arrangements. The plant in Obha village was funded by WASMO (90%) and local (Birla factory , 10%) combination. It is run by the Pani Samiti and is open to anybody buying water at Re. 0.25/litre. An offshoot water supplier buys water from this plant and supplies 1000 lpd to neighboring villages. The Pani Samiti identified 62 families who are below poverty line and were unable to afford the treated water. The Samiti decided that there is enough surplus generated from the plant to justify cross-subsidization, thus making treated water free for these residents of the village. Compare with this Nani Chaubeesi, located in Navsari where the plant was installed specifically for one community of 30 residents. The treated water is restricted to one community here and is sold at a low Re. 0.11/litre. Another example is that of Kacholi village in Navsari where an NRI donated plant is operated by a local trust. The treated water is sold at Re 0.3/litre to anybody and an offshoot water supplier distributes 2500 lpd to 8 neighboring villages. The case of village Manikpura of Navsari is unique in the sense that two farmer members (one being NRI) of a local seed cooperative donated the plant which is managed by the cooperative for its members. All villagers receive highly subsidized treated water at a low cost of Re. 0.11/litre. A few villages in this area have plants operated by the Rotary club who collect small donations locally from villagers to install a plant. In village Varad of Bardoli taluka of Surat district, an NRI donated plant sells water at a very low rate of Re. 0.03/litre to general category residents and Re. 0.06/litre otherwise. Still, there is very low reach among other residents of the village.

Table 1: Summary of RO plants surveyed in south Gujarat

	Minimum	Average	Maximum-
Capacity	250 lph	560 lph	1000 lph
Storage	200 litres	2000 litres	6000 litres
Plant cost	1.25 lakhs	2.32 lakhs	5 lakhs
Cost/litre	0	Re 0.28	Re 0.6
Prod/day	300 litres	1200 litres	2500 litres

Buyers in village	30	86	325
Reach	10%	42%	100%

A summary of 19 plants from south Gujarat shows wide variation in different parameters (Table 1). The reach within the area of influence varies from 10% to a maximum of 100%. The mode of management of these plants are varied, from community based to operating on a business mode. The plants that operate on a business mode show greater number of hours of operation, eg., Kacholi plant, 6hrs/day, as compared with Nani Chaubeesi, 2.5 hrs/day. The Kacholi plant has a large production therefore being able to cater to a large number of customers with a single plant through offshoot water suppliers. This plant also maintains a higher output TDS of treated water (TDS > 100) in order to cut down on cost. However, the reach within the area of influence (taken as village) is less than 10%. On the other hand, community-owned plants have an imperative towards achieving greater reach within the community. Whereas the seed cooperative in Manikpur offers a highly subsidized rate to all members and therefore achieves 100% coverage, the Obha plant has chosen to cover all members through cross-subsidization with extra earnings from a business mode. In all, from our observation of these 19 plants, we feel that a judicious mixture of business orientation and community feeling is needed to achieve sustainability of the plant and maximizing reach within target communities. The role played by the plant manufacturers is also important. Our observation has been that manufacturers operating and based locally offer better and regular service and cater to problems such as leakage that arise frequently. In the long run, such regular service and contact is necessary to keep such complex technology alive in a rural setting.

3.2.1 Adoption and non-adoption of RO water from community plants

Dantali village in Anand district was shown for a complete census to obtain a full picture about users and non-users of RO water. This plant has a capacity of 1000 LPH and produces 2500 LPD. It was funded by an NRI lady of the village and started in 2006. The treated water is delivered at home and there is a charge of Re. 0.3/litre. The input TDS of water in the village is 650. A total of 97 users and 156 non-users were surveyed for our study.

Figure 3: Comparison of monthly income of users and non-users in Dantali, Anand district

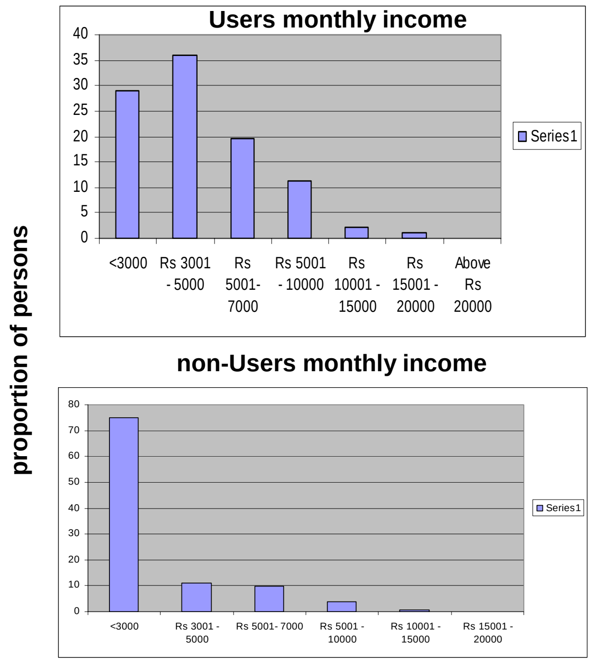


Figure 3 shows the monthly income distribution of users and non-users. It is clear that non-users belong to the economically poorer sections of the village. 83% of the users belong to the Patel community and 20% of non-users belong to this community. 46% of non-users belong to Rajput community and 24% to SC community.

Figure 4: User's motivation for RO water in Dantali, Anand district

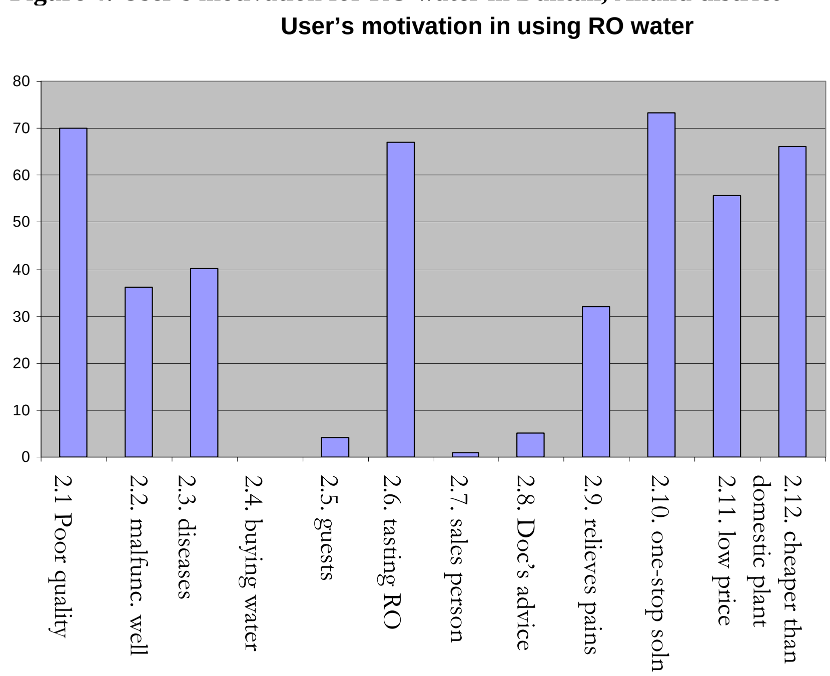


Figure 4 shows the summary of user's responses to motivation behind adopting RO water. First look at questions 2.1 till 2.10 that are comparable with Figure 2 for domestic RO plants. The same two reasons that scored on top for domestic plants again show high responses here, i.e., poor quality of supplied water and RO as one-stop solution to many problems. But another response here scores high, i.e., of being motivated by occasionally tasting water from other users. This is something unique to community plants in that one of the factors of adoption is of peer behaviour which is not so important for the domestic plants. Apart from these, the last two factors specific to community plants i.e. much lesser investment for buying water rather than investing on a domestic plant is an important factor.

Figure 5: Non-users responses in Dantali, Anand district

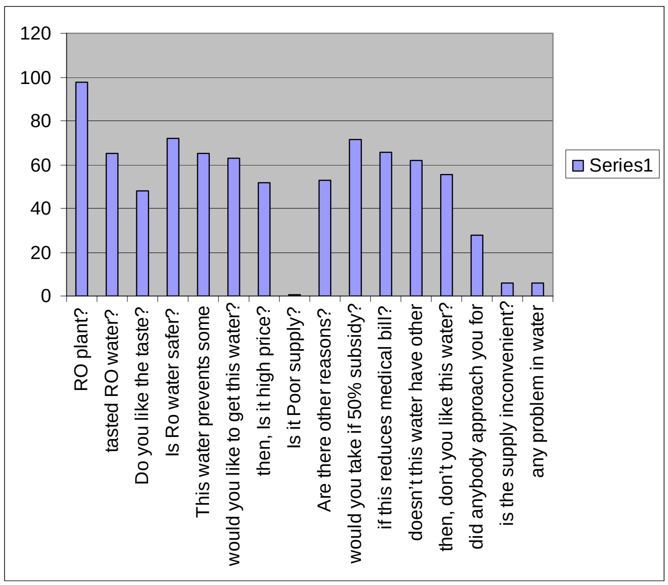
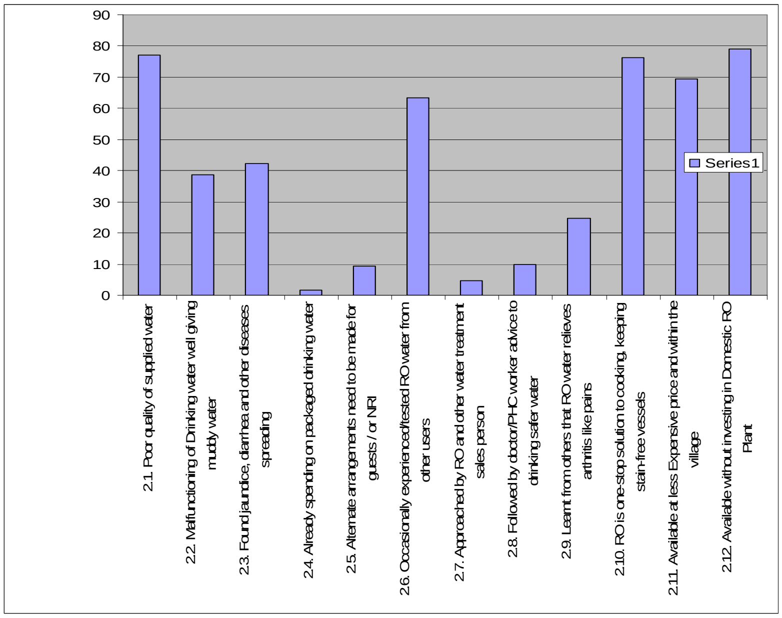


Figure 5 shows the summary of responses from 167 non-users in Dantali. Most were aware of the RO plant, that it is much safer water and can prevent some water-borne diseases and can reduce medical expenses to some extent. There was no indication of any discrepancy in the water supply distribution within the village. Around 50% of respondents responded that the price is quite high and they would like the water to either be free or subsidized to 50% of the current cost. The other 50% cite various reasons: strange taste of RO water, regular water is safe enough and that they already possess a bio-filtration unit at home.

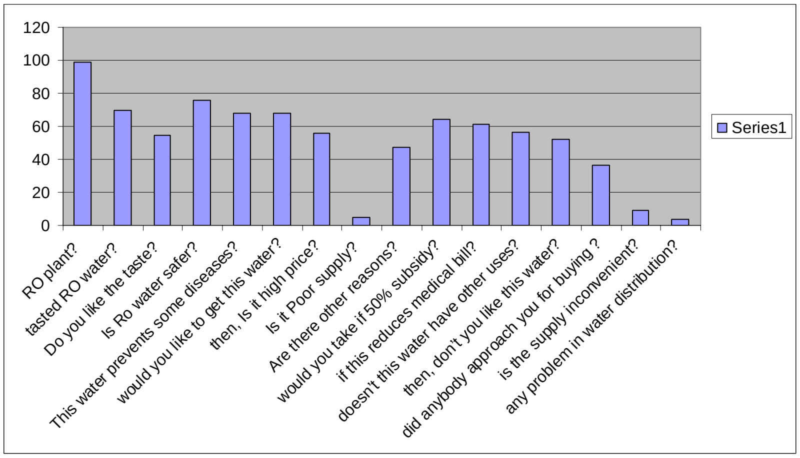
Very importantly, only 25% of the non-users reported that they have ever been approached by anyone with regard to promoting the RO water. Clearly, there is not much effort put at increasing the reach within the village till now. Our conversations with the plant operator and other functionaries seem to indicate that there are fixed conceptions within the dominant community about the non-users, eg. non-users have poor idea of sanitation and health, they would rather spend on alcohol etc. But when asked whether they would encourage an external subsidy for a limited period to promote treated water to non-user, the plant managers were supportive. Clearly, not much effort is applied in promotion of safe water among non-users whereas just a small push is enough to convince atleast 50% of the non-users of this importance. We conclude that the plant functions efficiently, will continue for longer period, but inherently there are very less inclination on part of the RO plant managers in having more users adopting this treated water within the village. There is absence of both a business profit-making urge and also a sense of goodwill for the village community. In effect, such plants would continue operating with a similar proportion of reach of treated water.

Figure 6: Summary of responses from 235 users of 6 RO plants



The same survey was performed for 6 other plants in south and central Gujarat: Thamna, Dharmaj and Dantali villages of Anand district and Obha (Bharuch), Kacholi (Navsari) and Varad (Surat). Figure 6 shows the summary of user’s responses from 235 users of RO water in these villages. The overall responses show a similar trend i.e. poor quality of supplied water, tasting of RO water from other users, RO as one-stop solution and lower price of this treated water as compared to domestic plant are the major reasons of adoption. These responses are over villages with variation in the size of plant, price of treated water, and quality of raw water and composition of the village.

Figure 7: Summary of responses from 280 non-users of 6 RO plants



Non-users in different villagers cite various reasons for non-adoption, but on an average 55% cite high price of treated water as the main reason. The rest of non-users cite different reasons that range from perceptive ones such as taste, cultural reasons such as feeling that RO water would not stay safe in earthern pot, being content with current supply of drinking water. These reasons can be overcome through awareness generation and only 1 village (Obha) showed a step in that direction because of the involvement of the village Pani Samiti in management of the RO plant. Whereas the plant in Thamna is slowly transitioning towards a more business-oriented mode, the profits from which would be funding other activities such as an education trust in the village. We see here two examples of cross-subsidization, one aimed at reaching drinking water to more persons in the village and the other aimed at providing other facilities within the village. In both cases, RO water is creating a surplus for the managers of the plant, and current users are also satisfied with the price.

The study of these 20-odd plants in south and central Gujarat shows different motivation of plant owners in running the plant. The motivation varies from personal ones to community-oriented goals. Whereas some plants run with the aim to reaching to more persons in the target community, others are not bound to any particular community or village, but are interested in reaching to more persons from neighboring villages too. The reach of treated water is highly dependant on these basic decisions and has much learning to provide for plants to be installed in future programs.

3.2.2 A community RO plant in North Gujarat

Our observation in North Gujarat has been very different from that seen in the south and central parts. After a long search we found one village community plant, which was similar to a few of south Gujarat. It is thoroughly organised by the people, for people and of the people of Bhavsor village in Vijapur taluka of Mehsana district.

The plant was established in November 2006. The plant has a capacity of 1000 LPH. It was installed with an investment of Rs 2.25 lac, It runs for 2 hrs daily at present as there were not many users households they sale at 30paise/L or Rs 3/10L in a plastic jerry can. They have coupon system of 30 coupons in booklet at Rs 100/- this includes vending charges at the door. It is Re 0.33 per litre all-inclusive. One can use coupon for the next month if all are not used in current month. In the village 250 families are the users of this facility. The amount of investment came from the village fund, which was made with the contributions by the villagers. Most of the villagers gave Rs 11000, some of them given much higher donation. The fund was of about Rs 30 lac – from this amount they paid the cost of RO Plant, rest of the amount was spent for a very big village community hall with facilities of sound system and kitchen etc.

There are 290 households in the village of which 150 are Patels. Among the users of RO water the Patels are more but there are good number of users from the Harijan and ST, SC class too. We interviewed 18 users of RO water who responded that RO water was less expensive and available in the village; 83% said they got RO water without investing in domestic plants which require one time money and long time maintenance and the same percent of people said that the water quality of the village was poor so they opted for RO water; they felt their health better. The average TDS of the raw water in the village was found 859 ppm. 78 percent people said that it was one stop solution for cooking and keeping stain free vessels.

We interviewed 12 non-users and received some interesting arguments from them:
1.) 100% non-users said that they are aware of village RO plant, 91% said they like to get safe water,75% said that price is high, 83% of the non-users said that they would use RO water if they would get 50% subsidy (however the organizer does not wish to have differential prices) – the non users are largely comprised of peoples of other communities than the Patels, more than 66% people said that RO water is safer than other supplied water. We have come across certain educated non-users who said that there was no such assurance of keeping good health if they would have used RO water.

This village has some interesting facts to notice, which might be considered for establishing this community RO plant in the village.

1. There is an over all 'unity' found in the village and a group of elderly people take decisions for village development, which generally accepted without much opposition.
2. Almost all the houses we visited are of the same built in areas of 85x15 sq. ft.
3. The village has underground sewerage since 1957 and no maintenance till date.
4. They have separate connection of electricity for agriculture and domestic use since 1982, which is design for "Jyotigram" now.
5. The farmers are mainly the Patels, who used to take decision on profitable cropping pattern since long, and never hesitated to change frequently – presently they mainly grow good quality Bt cottonseeds. This fetches them a very good return of Rs 250 to Rs 750 per kg when they sell to Mahyco Industries.

3.3 Commercial Packaged Drinking Water Plants

The large number of community plants as seen in the southern and central Gujarat is almost absent in northern Gujarat. In North Gujarat PDW (Packaged Drinking Water) plants serve the purpose of community plants though there is difference in management. What may be 'hidden' – the 'commerce' in the community plants is explicit in the PDW plants. These plants are first business in PDW plants and then welfare. Nearly 4 years ago IWMI did a study of PDW plants in North Gujarat (Indu, 2003). There was rise and fall of this business in 2002. Rise was due to huge demand in the market for 'good quality' water and fall due the intervention of Bureau of Indian Standards (BIS) for making the PDW products standardised. However, after 4 years, travelling in the same area for a resurvey of these plants, the present researchers found a booming rise in the number of plants and its users as well.

This rise explains the poor quality of drinking water followed by health complaints, which were not improved much since 2002. The situation of groundwater quality was too poor in North Gujarat particularly in Mehsana, Patan region; it was with TDS varying from 1200 to nearly 3000 ppm and with fluoride more than the permissible limit of 1.0 to 1.5 ppm in many villages. The groundwater was the most important source of drinking water, as Dharoi dam water did not reach then. People were suffering from different kinds of joint pains including fluorosis. People gradually came to know that the pains in the joints and other problems like indigestion etc were due to quality of water; and with doctors' advice, many families tried with expensive bottled water in the towns of these districts. But it was restricted only to the higher income families and those migrated families in ONGC colonies in Mehsana town. These people used to buy from the products under brand name like 'Bisleri' and "Yes" etc. Later they shifted to the product of local PDW plants.

There were some Alum-based plants in Islamailpur, Methan and other villages established by government initiative. However those plants were closed down after few years of working because of poor management and maintenance. In the 1980s the manufacturers of RO plants started producing plants for small industries. The local entrepreneurs purchased small RO plants of low capacity, which were manufactured by Ionexchange in Bombay, Thermax in Pune, and Doshi Ionexchange in Ahmedabad[4]. Some success story of using RO water from some villages like Bramhanwada and towns of Mehsana encouraged people to use packaged drinking water made by local vendors. Thus, a market for the production of de-fluoridated water with less TDS by 'cottage' RO plants came into existence. This market is getting wider and so are the PDW plants in northern Gujarat. The market will grow continuously as long as the water quality remains poor and the government supply is not found reliable.

3.3.1 Growth of Market in Gujarat

The growth of RO plants in the cottage sector in Gujarat reached its peak between 1997 and 2001. Smaller capacity RO plants were designed on the one hand and packaging system were developed on the other. Liquid package system, started in milk sector, helped the water sector too. Those occupied in producing mineral water in bottles of one

[4] There were only 3 or 4 Reverse Osmosis and membrane plant manufacturers in India till 1995: Ionexchange in Bombay, Thermax in Pune, and Doshi Ionexchange in Ahmedabad. Currently, there are as many as 16 plants in India (CSMCRI Report, 1997, pp 117-8).

litre found their market in Jerry cans of 10 and 20 litres. Later, with the introduction of packing machine for water pouches, people started producing pouches of 250ml. Pouches have their own market segments. Travelers, students and roadside workers largely use them in summer. It has also good demand in the villages in summer. Pouches fetch more profit to producers. The pouch market is very big in places like Mahesana city, Unjha, Sidhpur, Surat, Rajkot etc.

The BIS intervened in the market to standardize the packaged drinking water quality and for its guarantee they made in-house laboratory compulsory for each manufacturer from 29 March 2001. The smaller plant holders, who were making pouches and also selling through 20-litre jerry cans, closed down their shutters as they could not afford to have laboratory that require separate investment of Rs 3 lakh approximately. Thus, the number of active plant producing packaged water including pouches came down considerably.

In January 2007, we visited 10 PDW plants in Mehsana, Patan in North Gujarat; 5 of them were visited during our study in 2002. The clients of these 5 plants were 720 in 2002, and their clients' base is 4200 in 2007. These plants have developed their market nearly by 6 folds. The new 5 plants started with client base of 610 and today they have 4030 clients, more than 6 time increase. Interestingly two of them are only 6 months old and their number of clients has increased by 7 times during this period. These plants sell at Re 0.41 per litre in general, except two plants, which are selling at Re. 0.55 and Re 0.49. There is no such change in selling price of RO water in this market of Northern Gujarat since 2002. The present quality of raw water is far beyond permissible limit of TDS; the average TDS of raw water is 1608 ppm, average TDS of RO water 142 ppm, and the TDS of reject-effluent of RO is 2905 ppm as found from the water sample collected during our field visit in January 2007.

Largely these plants are situated in urban areas; however many of them are catering rural area people within the radius of 3 to 5 kilometres range. A few of these plants are near to the highway that has made them more accessible to both areas, rural and urban. For example Uma Beverages selling in urban Mehsana and also covering Panchot village 4 kms away and Hit Mineral water at Muktapur catering Unjha, Bramhanwada and Tundao villages – all are in a radius of 4 to 5 kms.

All these plants in North Gujarat have one thing in one common that all plants are owned by Patels except a few, and they all are related socially to each other. They follow a similar pattern of business acumen. Even they follow the pricing system same as they learnt from each other.

As told above, in 2002, many plants were closed down when ISI made compulsory of keeping a factory-attached laboratory. However, a few of them have come back in business again without any laboratory. Very interestingly the same argument is still going strong among these owners that since they are not selling water in sealed pack (except pouch) they need not have to take permission from ISI. In fact they started a forum of non-ISI plant owners in north Gujarat. In North Gujarat there are 45 non-ISI plant owners. The users of PDW water do not want that there should be any ISI standardisation for PDW. They feel that giving ISI mark may not give guarantee for standard quality. Gujarat has 138 registered ISI licensed RO factories (www.bis.org).

The clients spend on PDW RO water Rs 1500 for a 10-litre can daily, when paid total amount of one year at a time; otherwise it is Rs 150 per month for purchasing 10 litres per day. In our last study we found that about 60 percent of the PDW users were from the monthly income group of Rupees 10 to 20 thousand. Now there is a change found that largest number of users, nearly 83% of total users are from the income group of Rs 5 to 15 thousand, which were earlier between Rs 10 to 20 thousand. This shifting down to a step of lower group of income bracket means (a) people of lower income have become conscious of health and spending for better water, (b) may be they are now buying because of 'demonstration' effect from neighbouring users, and (c) the price may be more affordable due to increase in people's income, or (d) it may just for the need of good quality water.

Appendix E shows the growth of two of the surveyed plants from 2002 to 2007. There is no common base for plant prices as there is no common breakup for units of plants. The same capacity plant has different prices declared and we do not have the makers name therefore plant prices are brand specific, which we did not collect methodically. We can only say that the plant prices vary from Rs 2 lakh to 6 lakh for a capacity of 500 to 2000 LPH depending on the make of the plant. The output varies from 1600 litres to 17000 litres per day by these 10 plants visited. They supply to 8230 clients daily in their area of influence.

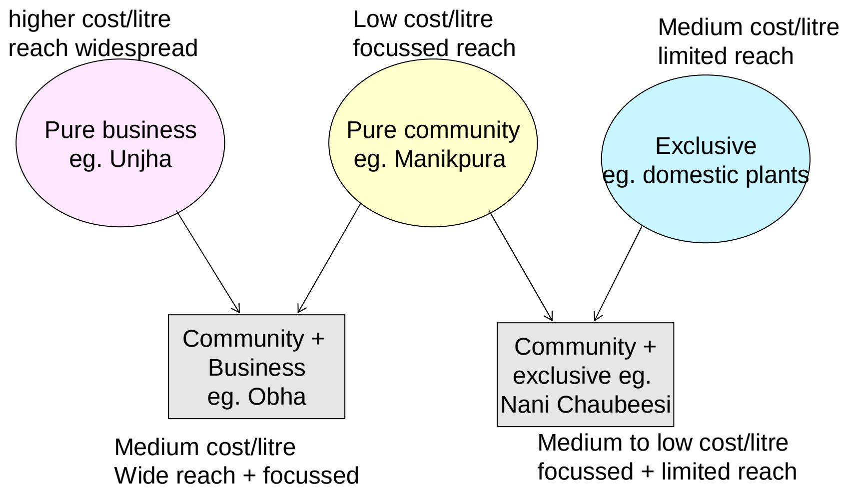
We inquired with the president of the Forum of non-ISI-PDW plants owners that why there is no such community plant exists in North Gujarat as we generally find in Central and South Gujarat. We came to know the following from him:

1. The community plants in South and Central are generally donated, here in North Gujarat donors do not feel and understand that they can donate for water plants. They donate for schools, and hospitals, this tradition is continuing and practice of donating for water has not yet started.
2. De-fluoridation plants were unsuccessful – so they could not think as a fruitful donation for water plants.
3. The price of PDW RO water is so low or affordable that people do not like to take the liability of running a plant in the community.

3.4 Cross-comparisons of Different Plants

What we see today in Gujarat's rural water treatment picture is a cumulative response by people to a problem that has till now not been addressed sufficiently by the government. A combination of charity-based goodwill, private enterprise and community mobilization have created a panorama of different arrangements under which RO water is currently being treated and supplied to a vast proportion of the state's population. It is sure now that with new government programs arriving to promote water treatment, the future would look different. How these new policies shape the scene of drinking water can only be speculated, but it will certainly have to adjust and cope with what currently exists. And for that a good understanding of the current arrangement in rural water treatment is essential.

Figure 8: Different modes of operation of RO plants in rural Gujarat



We see mainly three basic types of arrangements:

a) Pure business: The PDW plants of north Gujarat (as surveyed, but also in other parts of Gujarat) are an example of such pure business oriented establishments that supply RO water to urban and rural areas. Till now, these plants have survived mainly by supplying water to urban areas, but rural users are also picking up.
b) Pure community: Around 4-5 of the 41 plants we have studied can be said to be community owned, operated and managed plants. Examples are the plant at Manikpur village of Navsari district where a seed cooperative manages the plant, the plant at Bhavsor village of Mehsana district which sprung entirely from small donations of villagers.
c) Exclusive: The domestic RO plants in our study can be said to be exclusively owned and managed for a single household and they are also much smaller (< 20 lph) than the other plants.

But what we see for the rest of the plants are combinations of these basic arrangements. Two such combinations are evident: the community-business model and the community-exclusive model. Before going into each, it is important to understand the efficiency of each of the basic models itself.

As Figure 8 shows, the cost/litre of treated water is higher on average for pure business plants (Re 0.4/litre), lowest for community plants (Re 0.28/litre) and medium for domestic RO plants (estimated cost approx. Re 0.3/litre). The reach in terms of maximum number of customers is for business oriented plants (500-200), focused within the target community community plants (30-350) and least for exclusive plants (1). As can be expected, the combination arrangements show a mixture of these attributes, i.e. the community-business model has a medium cost/litre and balances between wider reach outside and focused reach within the community (eg Obha village), whereas the community-exclusive model also has a low to medium cost/litre, but has a focused and also a limited reach to the exclusive community (eg Nani Chaubeesi). From our observations, data and analysis, the community-business model therefore seems most appealing and offers the best potential for future rural water treatment programs.

4. ISSUE OF RO REJECT-WATER AS EFFLUENT

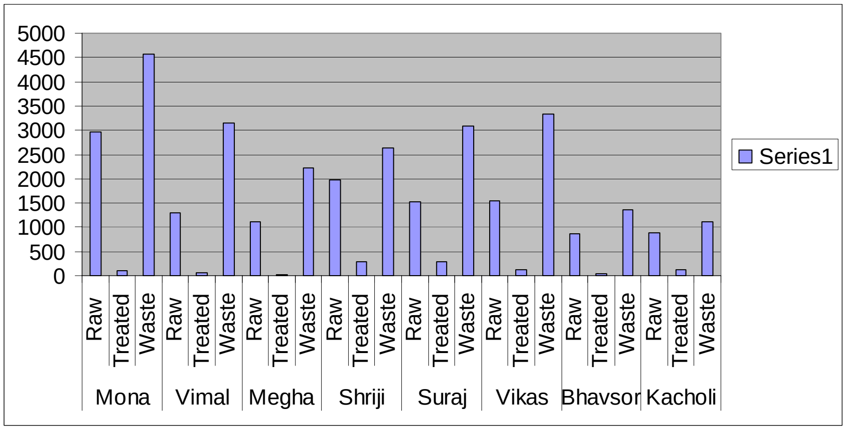
The quantity of reject water from RO plants disposed as effluent depends on variety of factors: a) TDS (or solute concentration) of input raw water, b) TDS of output treated water, c) Size of plant. Greater the difference between the TDS of raw water and treated water, greater is the volume of reject water from RO plants. Also, larger sized plants have proportionately lesser volume of reject water than smaller plants (Table 2).

Table 2: Volume of effluent from RO treatment

	A	**B**	**Volume of effluent**
Capacity	10 lph	10 lph	B > A
TDS (Input water)	1500	1500	
TDS (treated water)	100	50	
Capacity	10 lph	100 lph	A > B
TDS (Input water)	1500	1500	
TDS (treated water)	100	100	

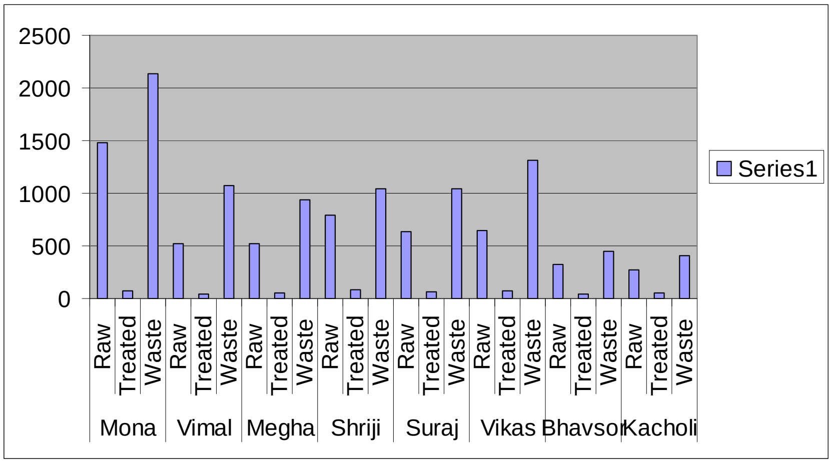
For eg. given two plants A: capacity 10 lph, raw water TDS = 1500, treated water TDS = 100, and B: capacity 10 lph, raw water TDS = 1500, treated water TDS = 50. The plants B will have greater amount of effluent than A since there is more salts to remove. But given A: capacity 10 lph, raw water TDS = 1500, treated water TDS = 100, and B: capacity 100 lph, raw water TDS = 1500, treated water TDS = 100; the plant A will have greater amount of effluent since it is of larger capacity. In general, any proportion from 30% to 90% can be rejected. The TDS of the effluent water would depend on this volume. If for eg., there is 50% reject of treatment from TDS = 1500 to TDS = 500, the reject effluent water will have a TDS of 1500 + (1500-500) = 2500.

Figure 9: TDS (ppm) of raw, treated and effluent water



Plant operators use these concepts as a knob to control the quality of treated water they need to supply and the amount of reject water they can tolerate. For eg., a commercially oriented operator who would like to maximize the volume of water sold at a reasonable quality, would maintain output TDS at 120 whereas a private society operating the RO for local purpose solely would maintain the output TDS at a lower 30-40. These decisions can affect the cost of treated water and consequently the number of users it reaches. Figure 9 shows the TDS and Figure 10 shows the Chloride concentrations of raw, treated and effluent water from different RO plants in our study. As can be seen here, high TDS water of 500 ppm -4500 ppm is let out as effluent from these plants. Also high Chloride concentrations of 500 mg/l – 2100 mg/l is released. The impact of such effluent of top soil or water bodies needs to be studied on a localized basis. For example, if one considers just the plants in the south Gujarat areas with high density of RO plants:
325 plants * 1200 litres/day * 1.5 (reject factor) = 5,85,000 litres/day of effluent which can be estimated to have a TDS of 1000-1500 in that area. Not all these plants release effluent into the same media. Some plants release this effluent into local ponds, others into rivers such as Khim river. One can argue that groundwater is anyway used for irrigation and volumes much larger than these are pumped out everyday. The difference here is that the effluent is about 1.5-2 times more concentrated than the pumped water. Releasing this effluent into ponds could impact fish production. In one case of developing problem from Junagadh district, the release of effluent into a stream is causing a minor conflict between two villages. Such local conflicts could be avoided by better planning in disposal of the effluent by constructing effluent disposal pits or by further treatment of the effluent through softening and other chemical treatment.

Figure 10: Chloride (mg/l) of raw, treated and effluent water



5. CURRENT POLICIES AND FUTURE TRENDS

The Water and Sanitation Management Organization (WASMO) of Gujarat is embarking on a rural water treatment program throughout the state. It is planned to install RO plants in villages through a variety of management options. The main participants in this arrangement would be the Pani Samiti of the village, a private RO vendor and WASMO itself. The options to be tried out are similar to current arrangements that have been explored in our study. One option is to have the private vendor invest on the RO plant (90%) and operate and charge for the RO water. Another option is for WASMO to invest on the plant (90%) and the vendor is responsible for operation and maintenance of the plant in return for which they charge for the supplied RO water. The third option is for the village itself to invest on the plant and take charge of distribution themselves. WASMO is building an insurance aspect into this model by assuring the vendor of specified market and some protection in case of non-achievement of that many users. Currently, these models are being piloted in a few villages.

The Byrraju foundation working in coastal areas of Andhra Pradesh have installed RO water treatment systems in 40 villages of coastal Andhra Pradesh (Byrraju foundation report, 2006). These plants have capacity greater than 1000 lph and are funded equally by the foundation and either villagers or non-resident villagers. The plant is operated by local youth who are trained to run the plant. There is an annual maintenance contract with the plant supplier and one maintenance team per 5 villages. The cost of treated water is Re 0.125/litre which is quite nominal as compared with the different plants that we have studied in Gujarat. These plants are now supplying treated water to 6 lakh people in 120 villages.

The current success in running of these rural water treatment programs indicate that there is much more scope of expanding to many other villages of the country. However, we need to be cautious on:

a) What kind of technologies need to be promoted for such treatment. For example, the Byrraju foundation is currently using two types of treatment methods – for those villages with water less than 500 ppm and for those greater than this. The RO technology is required only for those areas where the dependable source of drinking water has dissolved salts and chemical pollutants, eg. Fluoride, Arsenic, high TDS etc. If biological contamination is the only problem, then such expensive technology are not required.

b) Making sure that local institution is strengthened for proper maintenance of the plant eg. Pani Samitis in Gujarat and the Panchayat's involvement in A.P. There have been several failures of such plants in the past eg. with the Nalgonda filters in the 80s-90s and RO plants in the 90s in coastal Gujarat, mainly because of poor local institutional involvement in operation of the plant. With the advent of Swajaldhara programs and community involvement in local drinking water management, this aspect can be more easily addressed.

c) Keeping a balance over cost recovery and community orientation so that both sustainability of plant and reach to maximum users is achieved. It is essential to have awareness programs and promotion schemes for introducing the treated water to non-users, many of whom just need a small push.

d) Proper disposal of the effluent from the plant is made so that any conflict is avoided with other users of water bodies.

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Appendix A: Questions administered to users of domestic RO plant

A1 Poor quality of supplied water
A2 Malfunctioning of drinking water well giving muddy water
A3 Found jaundice, diarrheoa and other diseases spreading
B4 Already spending on packaged drinking water
B5 Alternate arrangements need to be made for guests/NRI
B6 Occasionally experienced/tested RO water from other users
C7 Approached by RO and other water treatment sales persons
C8 Pushed by preaching of other users
C9 Follwed by doctor/PHC worker advice to drinking water
C10 RO is one-stop solution to cooking, keeping stain-free vessels
C11 Learnt from others that RO water relieves arthritis like pains
C12 Bought RO "just like that" as some others have bought

Appendix B: Questions administered to users of community RO water plants

2.1. Poor quality of supplied water
2.2. Malfunctioning of Drinking water well giving muddy water
2.3. Found jaundice, diarrhea and other diseases spreading
2.4. Already spending on packaged drinking water
2.5. Alternate arrangements need to be made for guests / or NRI
2.6. Occasionally experienced/tested RO water from other users
2.7. Approached by RO and other water treatment sales person
2.8. Followed by doctor/PHC worker advice to drinking safer water
2.9. Learnt from others that RO water relieves arthritis like pains
2.10. RO is one-stop solution to cooking, keeping stain-free vessels
2.11. Available at less Expensive price and within the village
2.12. Available without investing in Domestic RO Plant

Appendix C: Questions administered to non-users of community RO water

2.1 Do you know that there is a RO plant in your village?
2.2 Have you ever had a taste of the village RO water?
2.3 If yes, did you like the taste?
2.4 Do you know that RO Water is safer than other supplied water?
2.5 Do you know that jaundice and other diseases are caused by poor water quality?
2.6 If yes, do you like to get safe water?
2.7 If yes, why are you not using village RO water? Is it due to …HP
2.7 If yes, why are you not using village RO water? Is it due to … PS
2.7 If yes, why are you not using village RO water? Is it due to … OS
2.8 If it is high price to you, but some one pays 50% of the price, would you buy it?
2.9 If using RO water your medical bill reduces, would you buy RO water?
2.10 Do you know that RO water makes good cooking, keeps stain-free vessels?
2.11 If yes, don't you like to use RO water?
2.12 If yes, how much you would you like to spend for it? (Rs)
2.13 Did anyone approach and suggest you to use RO water from the village?
2.14 Is it so that you wanted to use RO water from the village plant but found difficulty to get it?
2.15 Is there any difference in distribution of RO water within the village?

Appendix D: Summary of surveyed RO plants in south Gujarat

District	Village	Year	Funded	Capacity (LPH)	8. Storage Capacity in litres	9. Price of the Plant (Rs) lakhs	15. No. of hours the plant runs – per day	16. Sale price of RO water? Paise per Litre	Daily production (LPD)	Buyers in village	General class buyers	Other buyers
Bharuch	Panjroli	2003	WASMO(90%)+ Community{Birla} (10%)	250	4400	1.75	4	20	400	50-60	35	20
Bharuch	Obha	2004	WASMO(90%)+ Community{Birla} (10%)	500	3000	2.82	6	25	1000	75	50	25
Bharuch	Asarama	2004	WASMO(90%)+ Community{Birla} (10%)	500	3000	2.5	2	25	300-400	40	32	8 to 10
Bharuch	Umrachi	2006	100% Community{Birla}	500	2000	2.4	4-5	35	2000	30	25-30	2 to 3
Surat	Isroli	2000	NRI	500	4000	2	3	Free	400	30	30	0
Surat	Afva	2000	NRI	300	2000	2	4	50	600	50	43	7
Surat	Varad	2001	NRI	900	3000	NA	5	3	1500-1600	215	210	5

Surat	Rayam	2002	NRI	300	2000	1.5	2	60	500	70	50	20
Surat	Sankadi	2000	NRI	500	2000	1.5	2	41	300	45	42	3
Surat	Palsod	2001	NRI	500	2000	1.25	3	30	1000	80-90	70-80	12
Surat	Akoti	2000	NRI	1000	4000	2	2.5	30	1800	180	120	60-65
Navsari	Manekpur	2000	NRI's	1000	2000	2.5	4	40	2000	40-50	50	10
Navsari	Kacholi	2001	NRI	1000	6000	5	6	30	2500	100	67	23
Navsari	Gadat	2002	Community	500	4000	2.5	3	30	2000	300-350	300	10 to 20
Navsari	Kaya Talav	2001	Community	500	3000	2-2.5	3	30	800-1000	30-40	30-40	0
Navsari	Dhanori	2004	NRI	500	4000	2-2.5	3-4	30	1500	70-80	65-70	5 to10
Navsari	Nani Chovisi	2005	NRI	300	2000	1.28	2.5	0.125	550	30	27	3
Navsari	Salej	2002	NRI	500	2000	3.5	5-6	0.30	1500-2000	70	70	0
Navsari	Pinjara	2005	NRI	500	1500	1.8	3-4	0.13	1500-2000	60-70	65-70	3 to 4

Source: field data

Appendix E: Summary of surveyed PDW plants in north Gujarat

Sl. No.	***Description***	***Plant***	***Plant***	***Plant***	***Plant***
	Identification				
1	Place	**Maktupur/ Unjha 2002**	**Maktupur/ Unjha 2007**	**Unjha 2002**	**Unjha 2007**
2	Name of the Company	HIT Mineral Water	HIT Mineral Water	Megha Mineral Water	Megha Mineral Water
3	Brand Name	HIT	HIT	MEGHA	MEGHA
4	Nature of the Company	Proprietary	Proprietary	Proprietary	Proprietary
5	Year of Establishment	July, 1998	July, 1998	1996	1996
6	Owns License	Yes	Yes	Yes	Yes
	Client Base, Fee, Collection				
7	Client Base	175	500	800	1700
8	Fees/Rates Annual Rs for 10-Litre	1500	1500	1500	1500
9	Fees/Rates Annual Rs for 20-Litre	2500	2500	2500	2500
10	Type of Record Keeping for Members	None		None	
11	Mode of Fee Collection	Annual Advance	Annual	Annual / Advance	Annual
12	Pouch Packing	20,000 per Day	Not given	10,000	Not given
	Plant Capacity				

13	Plant Capacity Litres Per Hour (LPH)	750	750	2000	5000
14	Cost of Plant/Machinery in Lac Rs	4.25	4.25	8.25	2.5
15	Plant Area Sq Ft	900	900	900	1350
	Annual Sales, Expd, Profit				
16	Total Annual Sale in Lac Rs	17.64	7.6	22.92	26.5
17	Total Annual Expenditure in Lac Rs	3.37	3.36	11.35	3.80
18	Total Annual Profit in Lac Rs	14.27	4.24	11.57	22.7

Source: Field Data