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Water Quality and Human Health in Mewat

Challenges and Innovative Solutions

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INTRODUCTION

GROUNDWATER IS A vital component of water resource system. Being the largest reserve of drinkable water for human population, groundwater has always been crucial to human civilisation. Groundwater is often utilised for drinking, irrigation and industrial purposes, and is normally preferred as it tends to be less contaminated by wastes and organisms. The deteriorating quality of groundwater due to increasing contamination by various toxic substances is a growing concern (Tariq et al. 2008).

Groundwater gets depleted when mining is more than the recharge. This further changes the flow of the groundwater which in turn causes ingress of sea water, intrusion of other saline groundwater or polluted water from the surrounding areas. The result is that the quality of groundwater is adversely affected. The situation gets further exacerbated in the absence of any regulatory policy for groundwater mining. Health related studies have shown that intake of toxic compounds through water may result in extreme risks including water-borne diseases. In India alone, water-borne diseases annually put a burden of US$ 3.1 to 8.3 million (Mukherjee 2008). One of the major aspects in the deterioration of water quality is an increase in the overall salinity. Saline water has a relatively high concentration of dissolved salts such as cations and anions.

Besides containing sodium chloride, salt also has dissolved calcium, magnesium, sulfate, bicarbonate, boron, and other ions. It is assessed in terms of 'total dissolved solids' (TDS) measured in part

per million (ppm) or mg/l, but approximated by measuring the electrical conductivity (EC) of water, expressed in decisiemens per metre (dS/m). The palatability of water with a TDS level of less than 600 mg/l is generally considered to be good (Table 10.1). Drinking water becomes significantly unpalatable at TDS levels greater than 1,000 mg/l (Department of Primary Industries and Fisheries 2008).

Table 10.1: Parametres for Saline Water (in ppm)

Freshwater	<1,000
Slightly saline water	1,000–3,000
Moderately saline water	3,000–10,000
Highly saline water	10,000–35,000

Source: U.S. Geological Survey (2008).

Presence of fluoride, nitrate, Iron, arsenic, total hardness and a few toxic metal ions determine salinity levels in groundwater. In India, saline groundwater is found in many states, particularly in the arid and semi-arid regions of Rajasthan, Haryana, Punjab and Gujarat, and to a lesser extent in Uttar Pradesh, Delhi, Madhya Pradesh, Maharashtra, Karnataka, Bihar and Tamil Nadu. In India, about 200,000 sq. km area has been estimated to be affected by saline water (CGWB 2008a).

This chapter focuses on an intervention piloted by S M Sehgal Foundation in Karheda, a village in Mewat district, which adopted an innovative model of roof water harvesting (RWH). This model addresses the issues of groundwater salinity as well as provision of safe drinking water through creation of fresh groundwater pockets within saline aquifers. The model promotes bio-sand filters to mitigate biological contamination. The chapter underscores the uniqueness of this cost-effective, replicable, sustainable and almost maintenance-free approach.

PROFILE OF MEWAT

Mewat district, with a population of 1.2 million, has been carved out of Gurgaon and Faridabad, two satellite districts of Haryana bordering Delhi, India's capital in 2005. Compared to most districts in the state, Mewat lags behind on several socio-economic indicators (Table 10.2). For instance, female literacy rate is as low as 31 per cent. Similarly, access to improved water and sanitation is very poor.

Table 10.2: Socio-economic Profile of Mewat and Haryana

	Percentage	
Indicators	*Mewat*	*Haryana*
Total literacy rate	51.8	73.4
Female literacy rate	31.3	55.7
Households with below poverty line (BPL) card	24.6	12.4
Households with access to toilets	12	56.2
Households with access to piped water	31.6	61
Households owning agricultural land	57	40.3
Households owning irrigated land	35	38
Households' standard of living	67.3	17.4
Low		
Medium	24.4	39.6
High	8.3	43

Source: IIPS (2007, 2009), MDA (2009), RGI (2001).

Consequences of Salinity in Groundwater

Certain heavy metals found in groundwater such as arsenic, cadmium, copper, mercury and lead are toxic to humans and wildlife. According to the International Agency for Research on Cancer (IARC), prolonged consumption of drinking water containing arsenic at levels close to or higher than the established guideline value of 0.025 mg/l increases the risk of skin cancer and tumors of the bladder, kidney, liver and lung (Pollution Probe 2004). Salinity in groundwater also causes limits to use of water and can also enhance some kinds of corrosion and scaling. It also reduces the choice of technologies to be used for treatment such as ion-exchange resins (Table 10.3).

Water salinity also affects agricultural productivity directly and indirectly. Salinity decreases the permeability of the soil as the surface becomes more crusted and compacted under such conditions. Therefore, low moisture availability in the root zone affects the plant growth. Certain ions in saline waters can be specifically toxic to the plants, if present in excessive concentrations or proportions. Of particular

Table 10.3: Sources and Likely Consequences of Prolonged Use of Selected Contaminants

Contaminant	*Source*	*Consequences of Use*
Nitrate	Fertilisers, septic systems and manure	Methaemoglobinaemia, or 'blue baby' syndrome, cardiac failure or pulmonary disease (hypoxia)
Fluoride	Igneous and metamorphic rocks	Dental fluorosis to crippling skeletal fluorosis
Iron	Earth crust	Promotes undesirable bacterial growth, staining of laundry
Chlorides	Widely distributed in nature	Congestive heart failure (when impaired with sodium)
Cadmium	Fertilisers produced from phosphate ores	Carcinogenic by the inhalation route, causes damage to kidney
Sulfates	Natural in numerous minerals	Diarrhoea, dehydration
Lead	Batteries, ammunition, metal products, and so on	Lead poisoning, anaemia, damage to reproductive system, brain, kidneys, nervous system, and red blood cells

Sources: CDC (2003), Dept. of National Health and Welfare (1990), Ros and Sloof (1988), WHO (1996, 2003, 2004).

concern are sodium, chloride and boron. Thus, the plant population and diversity is highly affected due to salinity (Rhoades et al. 1992).

Semi-arid regions are most vulnerable to the adverse effects of groundwater salinity since surface water resources are scarce and highly unreliable here due to low rainfall (200–500 mm). Thus, groundwater tends to be the primary source of water. Increasing demands on limited water availability leads to fast-depleting aquifers. It is often observed that groundwater salinity increases with depth. Thus, fast depletion of the groundwater further increases salinity.

Distribution of Saline Water in Haryana

The south-western part of Haryana faces acute salinity in groundwater. At some places here salinity is so high that salt can be manufactured by solar evaporation. High salinity is one of the major groundwater quality problems in these areas (Figure 10.1). More than 30 per cent of the area in the districts of Gurgaon, Bhiwani, Rohtak, Kaithal, Mahindergarh, Mewat and Sonepat has saline groundwater (Table 10.4).

However, of these districts, Mewat is a case in point as far as groundwater salinity and fluoride contamination are concerned. Mewat suffers from acute water scarcity and lacks good quality water as it is underlined with saline groundwater aquifers. Out of 503 villages in Mewat, only 61 have fresh groundwater; the rest have saline groundwater (SANDRP 2004). In these villages, the high salinity content and constant rise in groundwater table has led to deterioration in agricultural productivity (Tanwar and Kruseman 1985). The average annual rainfall is just 480 mm spread over 31 days.

In this district, fresh groundwater is available only in a few small pockets, usually located at the foot of Aravalis having high ground gradient. Aravalis are a range of mountains in western India running approximately 800 km from northeast to southwest across Rajasthan, Haryana and Gujarat. Here, the soil is sandy and highly permeable. However, run-off concentration time is very limited because of high ground gradient. Consequently, recharging of fresh groundwater pockets is minimal and surface water is sparse. Moreover, surrounding villages depend on these pockets for freshwater. Karheda exemplifies

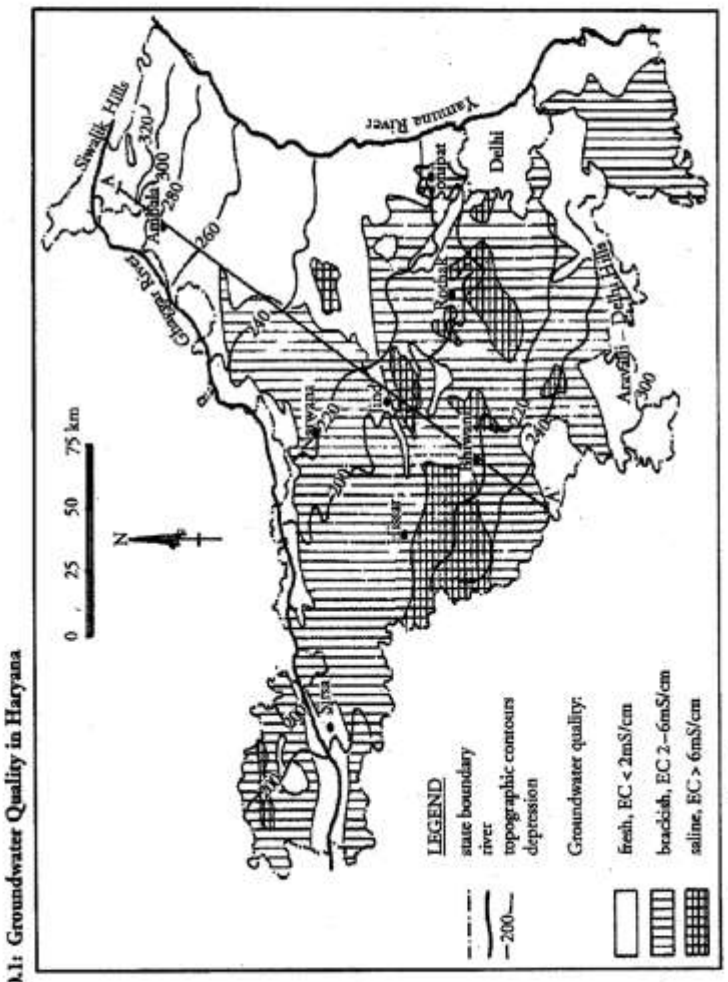


Figure 10.1: Groundwater Quality in Haryana

Source: Tanwar and Kruseman (1985).

Table 10.4: Salinity and Fluoride Affected Districts in Haryana

Contaminants	*Districts Affected in Parts*
Salinity	Sonepat, Rohtak, Hissar, Sirsa, Faridabad*, Jind, Gurgaon*, Bhiwani, Mahendragarh
Fluoride	Rohtak, Jind, Hissar, Bhiwani, Mahendragarh, Faridabad

Source: CGWB (2008b).
Note: *Mewat was recently carved out of Faridabad and Gurgaon.

this situation, where groundwater is highly saline and the erratic public water supply from an adjoining village 4 km away is the only source of water.

To address this problem in Mewat, the state government launched the Rajiv Gandhi Drinking Water Supply Augmentation Scheme in 2005. The scheme is a mix of Ranney Well and Tube Well technologies. Ranney wells are being installed in the vicinity of Yamuna river where recharging is considered to be high. Yamuna passes through Haryana and becomes a perennial drain rather than a river by the time it reaches Delhi as it carries industrial effluents and domestic sewage. Inevitably, the highly polluted Yamuna water recharging the aquifer increases the concentrations of dissolved chemical pollutants in groundwater. Moreover, in this scheme there is no mechanism for monitoring water quality.

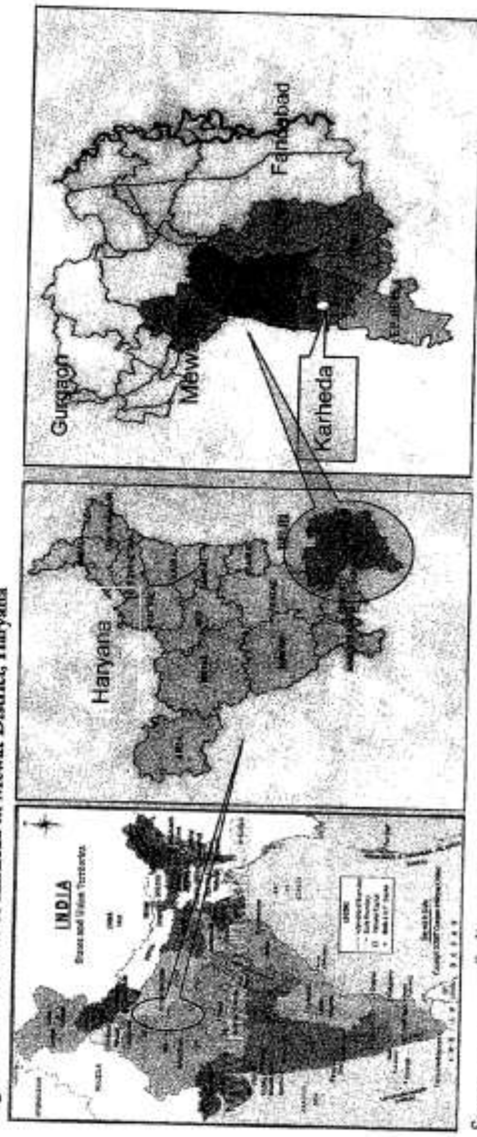
Tubewells are being installed in areas with fresh groundwater pockets. The tubewell technology, however, is not sustainable in the long term as the groundwater table is depleting fast and quality is deteriorating. This project is underway and in the absence of some efficient arrangements for recharging aquifers, the scheme does not hold much promise for providing safe drinking water.

Situation Analysis of Karheda

Karheda, with 375 households and a population of 2,400, falls in the Nagina block of Mewat (Figure 10.2). The groundwater situation in this block is very grim, where only 11 out of 63 villages have fresh groundwater and the rest have saline water.

In 2005, we conducted a preliminary survey which revealed the groundwater was just 7 feet below the ground but highly saline and

Figure 10.2: Location of Karheda in Mewat District, Haryana



Source: www.mapsofindia.com
Note: Maps not to scale and do not represent authentic international boundaries.

unfit for human and animal consumption or even irrigation. We further conducted a chemical analysis of the groundwater and public water supply in Karheda to compare the quality of water from both the sources with desirable limits according to Indian standards (Table 10.5).

Table 10.5: Chemical Contaminants in Groundwater and Public Water Supply, 2005

S. No.	*Characteristics*	*Desirable Limits as per Indian Standards*	*Local Groundwater*	*Public Supply Water*
1	pH value	6.5 to 8.5	7.4	8
2	Total hardness mg/l	300	7702	400
3	Iron mg/l	0.3	0.6	1
4	Chlorides mg/l	250	9792	269
5	Fluoride mg/l	1.0	2.5	1.5
6	Dissolved solids mg/l	500	30230	710
7	Magnesium mg/l	30	1273	29
8	Calcium mg/l	75	958	111
9	Sulphate mg/l	200	6972	61
10	Nitrate mg/l	45	1626	135
11	Cadmium mg/l	0.01	0.07	<0.01
12	Lead mg/l	0.05	0.4	<0.01
13	Alkalinity mg/l	200	353	190
14	Most probable number (MPN) Coli form/100 ml	10	7	278

Source: S M Sehgal Foundation (2005).

These results suggest that chemical contaminants in the groundwater in Karheda far exceed the desirable limits. It is interesting to note that with TDS levels of 30,230, the groundwater in Karheda is as saline as sea water. Chloride, lead, sulfates, nitrates, magnesium and calcium levels are also higher than the desired levels. Even the public water supply fails on several standards. For instance, iron, chlorides, nitrates and calcium levels in the water, and the total hardness, are higher than the permissible levels.

Shallow groundwater table, coupled with high salinity, impacted the socio-economic conditions in Karheda. In this village, more

than three-fourths of the work force is engaged in agriculture-related activities and more than 56 per cent of the households own agricultural land. However, salinity in the groundwater has adversely affected agricultural productivity by deteriorating soil quality which in turn limited the choice of crops that could be grown in the village. The domestic water demands of Karheda inhabitants were met by a public water supply system originating from Ghagas, a village 4 km away.

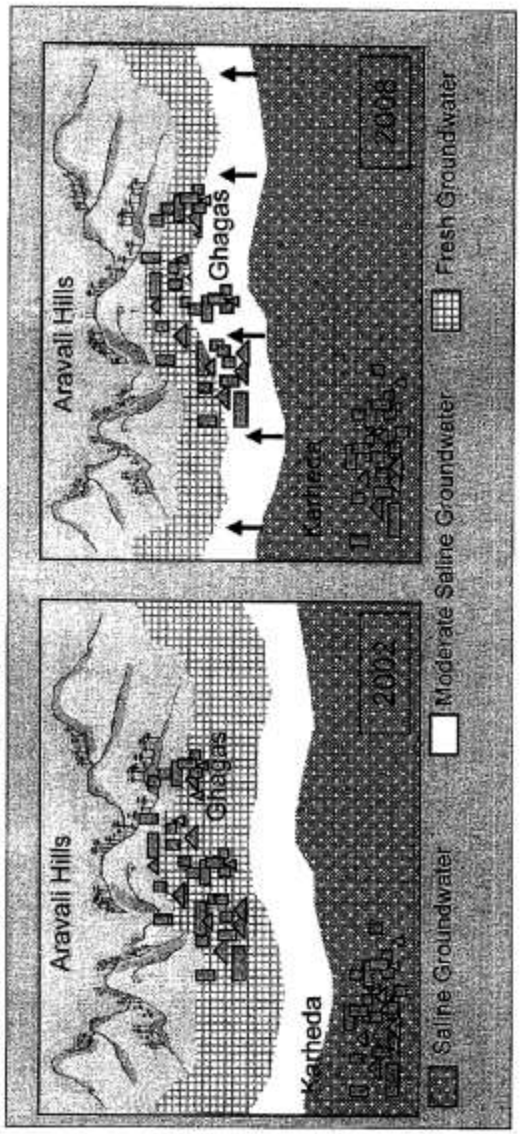
Haryana lacks clear policies on groundwater extraction rights. In such a scenario, we found that some economically well-off farmers purchased small patches of land in Ghagas and installed tubewells. Water from these tubewells is pumped into agricultural lands of villages that have saline groundwater through 4–6 km long underground pipelines, further exacerbating the situation.

Apart from Karheda, seven other surrounding villages which have saline groundwater also depend on Ghagas for freshwater. This led to steady depletion of fresh groundwater in Ghagas. Moreover, the survey also found that the rising saline groundwater table was steadily advancing towards the fresh groundwater aquifer in Ghagas, thereby shrinking the already diminishing fresh groundwater pocket in Ghagas (Figure 10.3). Consequently, many wells that fall between Karheda and Ghagas, which had freshwater, now have saline water.

Following the preliminary survey, we carried out an in-depth situation analysis of Karheda in order to get a clear understanding of the water situation in the village, including the problems with existing local groundwater, current source and its reliability. The situation analysis was also intended to work out an innovative method to create some source of potable water within Karheda. As part of this analysis, a comprehensive survey was conducted to assess the community's behaviour regarding water usage, conservation and disposal, as well as their level of awareness on sanitation and hygiene.

A sample of 166 households out of 375 was randomly selected for the study. The respondents for the survey were women as they are usually responsible for water collection and would be able to give an accurate picture. Moreover, an in-depth focus group discussion (FGD) was also conducted with the villagers (both men and women) to get their perceptions on public water supply.

Figure 10.3: Advancing Saline and Shrinking Fresh Groundwater Pockets



Results of the Survey

Table 10.6 presents the characteristics of the respondents in the village. In Karheda, a majority of the household heads are Muslims and belong to other backward classes. Literacy levels—reading and writing in Hindi or Urdu—are moderate, and 40 per cent of the household heads are illiterate.

Table 10.6: Characteristics of the Sample Households (Sample Size = 166)

Characteristics	*Share (percentage)*
Religion	
Hindu	28
Muslim	71
Others	1
Caste	
Scheduled caste	16
Other backward classes	84
Education	
Literate	60
Illiterate	40

Table 10.7 presents the availability of water and sanitation facilities for households. Eighty-seven per cent of the households depend on public water supply. Of these, nearly three-fourths of the households collect water from shared stand posts located outside household premises. A majority of these households spend about 1–2 hours to fetch water every day, and about 20 per cent spend more than three hours. Sanitation facilities in Karheda are abysmal with 80 per cent of households lacking any toilet facilities (Table 10.7). On an average, a household fetches about 200 litres of water per day.

The respondents were asked who was responsible for providing water in the village. Eighty-six per cent of the respondents felt that the government or panchayat was responsible for provision of water in the village. We also collected information on the prevalence of diarrhoea two weeks prior to the survey in all the households with children below 5 years. The prevalence of diarrhoea was recorded as reported and defined by the respondent. In our survey, incidence of diarrhoea was reported in 56 per cent of the households. In order to capture awareness levels, respondents were asked a series of questions regarding

Table 10.7: Water and Sanitation Facilities

Characteristics	*Share (Percentage)*
Water source (N = 166)	
Public water supply	87
Others	13
Location of public water supply (N = 144)	
Within houses (individual)	29
Outside house premises (shared)	71
Time for fetching water from public source outside the house (N = 102)	
Less than 1 hr	2
1–2 hrs	46
2–3 hrs	31
More than 3 hrs	21
Toilet facility (N = 166)	
Yes	20
No	80

causes and ways to prevent diarrhoea. Ten per cent respondents did not know any cause while 77 per cent mentioned 'dirty water' as the main reason for diarrhoea. Four per cent respondents mentioned teething as the cause, while 96 per cent mentioned unclean food, poor hygiene, open defecation and dirty hands as causes of diarrhoea.

Further, 64 per cent of the respondents felt that diarrhoea could be prevented. Of the respondents, 65 per cent mentioned the practice of rinsing their hands with water as a preventive measure. Only 12 per cent mentioned washing hands with soap as the sure way of preventing the disease. Safe sanitation and clean water were mentioned by 3 and 12 per cent of the respondents respectively to prevent diarrhoea. It is interesting to note that less than one per cent of the respondents mentioned burying faeces, preparing food hygienically and treating drinking water as ways of preventing diarrhoea. Information on select hygiene practices was also collected in the survey (Table 10.8). Nearly half of the households did not purify water. Although 50 per cent households reported to some form of purifying water such as straining with cloth, using alum or just boiling, these practices individually are insufficient to completely remove the pathogens from water.

The above findings suggested that although awareness existed, it was limited to a few practices and there is need for increasing in-depth awareness of all possible causes and preventive measures.

Table 10.8: Hygiene Practices (Sample Size = 166)

Characteristics	*Share (Percentage)*
Water purifying methods	
Not purified	49
Strain by cloth/alum/boiling	50
Water filter	1
Storage of water	
In uncovered container	14
In covered container	86
Keeping food covered	
No	4
Yes	96
Washing of hands after defecation	
No	1
Yes	99
Washing of hands before cooking and eating food	
No	2
Yes	98
Wastewater stagnation outside the household	
No	54
Yes	46
Wearing footwear	
No	27
Yes	73
Burning or burying of waste from households	
No	95
Yes	5
Following all hygienic practices	
No	98
Yes	2

Focus Group Discussion (FGD)

The results of the survey were also substantiated by in-depth FGDs with women and men in the village. The FGDs were conducted in order to fathom critical issues and problems related to water faced by them. Discussions revealed that salinity was indeed extremely high in the groundwater of Karheda. For instance, a woman said that the non-availability of freshwater and dependence on saline groundwater had several ramifications and impacted her household's social, economic, political and health aspects. She said:

> Saline groundwater is the main cause of our poverty. The water cannot be used for irrigating the fields and our crops are only rain fed. In case rains are scanty or untimely, we are not able to grow even one crop a year. Productivity is very low because the soil is also saline.

The water could not be used for bathing or washing purposes. Women reported of allergic reactions like skin rashes and lesions due to the use of saline groundwater. Further, the water could not be used for construction because the salt posed problems of efflorescence—precipitation of salts on the surface leading to decay—in the structure, reducing the life of the structure drastically. Even mud plastering, which is common across villages in India, cannot be done with this water because after drying, the salt precipitates on the surface and white powder like deposits peel off the plaster. The water is unfit for cooking or animal consumption because of salty taste and chemical pollution. One respondent stated:

> The water is so saline that we cannot make even a cup of tea with it, let alone drinking ...we cannot cook 'dal' (lentils) because it does not soften even after boiling it for long. The utensils are left with white spots when washed with this water.

Further, women and young girls travelled for an hour (3–4 km) per trip to nearby villages to fetch water during periods of non-supply, estimated to be about 120 days a year. On an average, a household makes at least five trips to collect water to meet daily requirements. As a result, most young girls are unable to attend school regularly. Another alarming and thought-provoking finding was that fast depletion and shrinking of fresh groundwater pockets have been creating unrest among the communities in Ghagas. They have started resisting water supply being channelled to other villages. On the other hand, since the villages in saline groundwater pockets have no alternative, their situation worsened every day. This led to inter-village community conflicts. For instance, Karheda is heavily dependent on water supply from Ghagas. However, in Ghagas, due to fast depletion of groundwater and steady deterioration of its quality, a union has been formed to resist water supply to Karheda and other villages.

It was found that most of the community members have limited knowledge about the concept of safe drinking water, water-borne

diseases and preventive practices. Most of them are unaware about the effects of presence of dissolved salts in the water. The community members also pointed out the presence of leaking supply lines, a potential source of contamination. It was also pointed out that most of the inhabitants had yellow and brown stains on their teeth. Some elderly people also informed that they had knee and joint pains and suspected water that has fluoride to be the cause. The detrimental consequences on health mentioned during FGDs were further reinforced by Chowdhury's study (2005) on health status of school children from government primary schools in seven villages of Mewat (Table 10.9).

Table 10.9: Morbidity among School Children of Mewat

Disease	*Boys (N = 995)*	*Girls (N = 481)*	*Total (N = 1476)*
Dental problems	787 (79.1%)	425 (88.4%)	1,400 (94.9%)
ENT problems	107 (10.8%)	56 (11.6%)	163 (11.04%)
Anaemia	102 (10.3%)	60 (12.5%)	162 (10.9%)
Poor nutritional status	151 (15.2%)	107 (22.2%)	158 (10.7%)
Eye and vision problems	100 (10.1%)	35 (7.2%)	135 (9.2%)
Skin problems	56 (5.6%)	24 (4.9%)	81 (5.5%)
Respiratory problems	18 (1.8%)	8 (1.7%)	26 (1.8%)
Abdominal pain	21 (1.4%)	5 (1%)	26 (1.8%)
Orthopedic problems	6 (0.6%)	2 (0.4%)	8 (0.5%)

Source: Chowdhury (2005).

There was an urgent need to develop an innovative approach to ensure sustainable potable water source within the village, taking into account the social, economic, environmental and technical aspects suitable to the local conditions. A crucial component of this approach was to create awareness on various aspects of water such as conservation, collection, judicious use and safe disposal of wastewater.

Innovative Approach

In order to address water-related issues in Karheda, an innovative model was conceived based on the thorough understanding of the local conditions and constraints. These constraints included:

- Non-availability of reliable grid electric supply.
- Financial constraints of the community to afford costlier solutions.
- Short Rainy season restricted to once a year (just 31 wet days per year).
- High levels of groundwater salinity.
- Low levels of skills among local communities.

Given the above constraints and weighing various technologies, resources and prevailing local conditions, three technologies were shortlisted to work out the most suitable solution for Karheda. These included:

- Reverse osmosis using local saline groundwater.
- Solar desalination using local saline groundwater.
- Roof Water Harvesting (RWH).

On the question of treating either saline groundwater or harvested rain water, the latter was considered a better option. Table 10.10 highlights the salient features of probable solutions.

Roof Water Harvesting (RWH)

Keeping in view the opportunities and constraints in Karheda, RWH seemed the most suitable option. In many rural parts of India, particularly in Rajasthan and Gujarat, which have similar geographical conditions, RWH has been a traditional practice to solve water scarcity.

Table 10.10: Comparison of Suitable Technologies for Karheda's Water Situation

	Technologies for Saline Groundwater		*Technologies for Harvested Roof Water*	
	Reverse Osmosis	*Solar Distillation*	*Storage*	*Recharging*
Advantages	- Effectively removes all types of contaminants to some extent (particles, microorganisms, colloids and dissolved inorganic matter). - Requires minimal maintenance.	- Removes a broad range of contaminants - Reusable	Can create high quality water locally	- Low cost - No space required
Limitations	- High TDS of input - Cost (capital, operation and maintenance) - Energy - Low Recovery - Waste Disposal	- Low productivity - Sun dependent - Inconsistent output - Need Space - Contaminants with low boiling point cannot be removed	- High cost - Need Space - Contamination - Rain dependent - Rains are once a year	- Highly saline groundwater - Low potential in shallow groundwater areas - Contamination - No control over underground spread

Traditionally, harvested water is stored in underground tanks called *Tankas.* Design and storage capacity of these tanks were determined by water demand and availability of rain water. With time, owing to changes in lifestyles, the demand for water increased considerably. Consequently, bigger tanks were required with greater storage capacity but the costs are prohibitive and beyond the community's reach. As a result, these traditional practices have reduced drastically.

Another popular traditional option for storing water underground is ***kund*** or ***kundi,*** practised in Churu district of Rajasthan. These ***kunds*** are roughly 6 metres deep and 2 metres wide tanks resting over semi-permeable or non-permeable soil strata. They are used to store the harvested rain water. The stored water remains intact as it is not exposed to light and air. The water does not percolate down because of low permeability of the strata, which is further plugged by fine silt coming with water (Agarwal and Narain 1997). In the context of Karheda, the traditional practice of *tanka* cannot be afforded by the poor community. Moreover, the geological conditions of Mewat do not permit the adoption of *kund* in the region, as the soil is sandy and groundwater is just seven feet below the ground.

Another option was recharging the groundwater with harvested rain water. Usually, recharging is done deep under the ground, leaving enough distance above the groundwater table, so that the recharged water is allowed to infiltrate into the ground in order to avoid chances of its contamination. But this recharged freshwater does not remain in a consolidated mass but spreads out over a period of time ultimately to produce a thin layer of fresh groundwater over the existing saline groundwater (Figure 10.4).

Exploiting this thin layer of fresh groundwater separately is practically very difficult because in the process of extraction it could mix with the saline groundwater. In order to exploit this harvested rain water it should form a pocket of sizeable depth rather than a thin layer. To achieve this, an innovative change to the traditional recharging method was adopted in Karheda. In the new innovative model, recharge wells were sunk to a depth lower than groundwater table (Figure 10.5). With this small change the desired freshwater pocket could be formed easily. This pocket was formed by pushing away and replacing the existing saline groundwater by harvested freshwater within the aquifer.

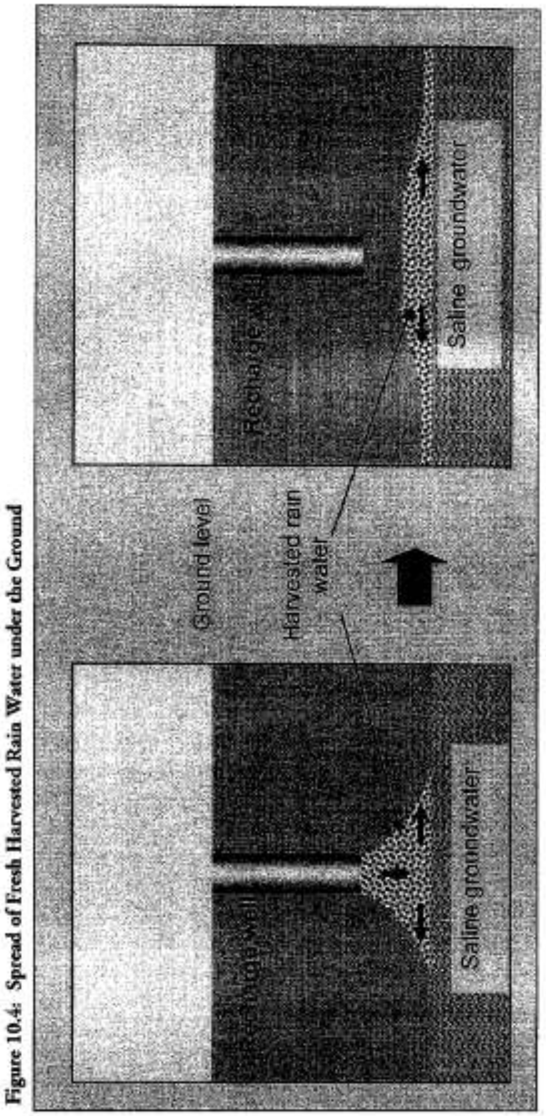
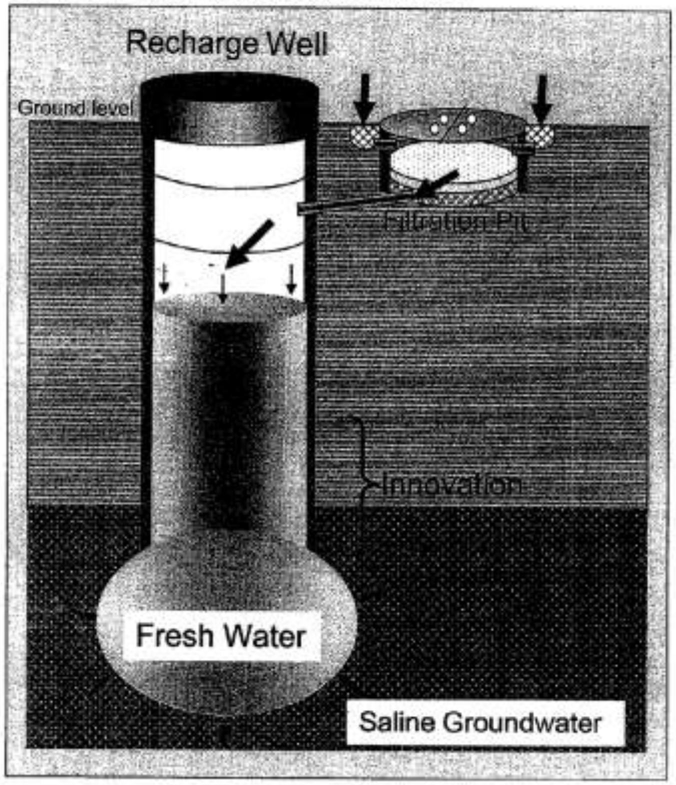


Figure 10.4: Spread of Fresh Harvested Rain Water under the Ground

Figure 10.5: Innovative Model of RWH in Karheda



When groundwater is extracted from the recharge well, the harvested freshwater from this pocket could be reached first as it is pushed up by the surrounding saline groundwater.

Underlying Concept of the Model

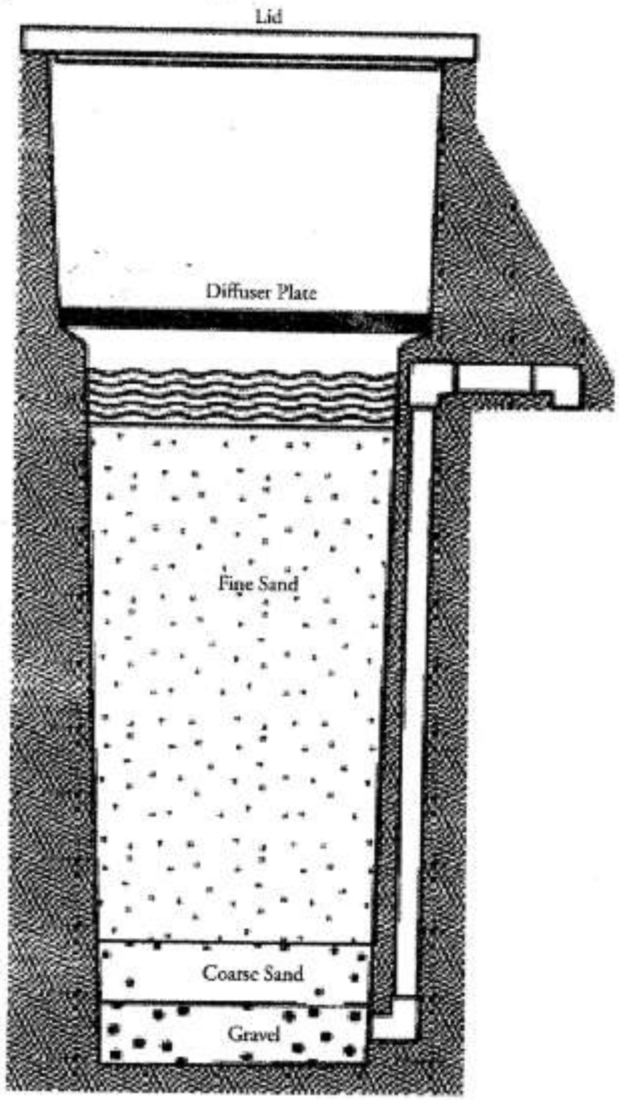
The rain water harvested from the roof is directed deep into the ground through recharge wells. This innovation is cost effective and replicable based on basic scientific principles. The scientific explanation of formation of fresh groundwater pocket within saline one is as follows:

- Density of harvested rain water is lower than that of saline groundwater. Thus when low density water comes over the higher density one, the former floats over the latter.
- Because of the pressure of overburden, harvested freshwater pushes the existing saline groundwater down taking its place to form a new pocket of itself within the saline aquifer.
- Further, the flow of freshwater under the ground, through the tiny void spaces among the soil particles, is a streamlined flow. This results in minimal turbulence negating any stirring effect, thus preventing mixing of the harvested freshwater and existing saline water.
- The first rush of water into the void spaces flushes out chemical residues of saline groundwater, minimising chemical contamination.
- The buoyant force exerted by the surrounding saline groundwater on the harvested water keeps the harvested water pocket intact from scattering.
- The process of diffusion through Brownian Motion (BM) is curtailed because of limited free space available within soil voids.
- Water thus stored under the ground remains totally cut off from sunlight and air. This prevents any growth of pathogens minimising chances of further contamination.

This model, therefore, is very cost effective as it does not require any additional cost to create a storage structure. In some cases, recharging aquifers may improve the source water quality, because the subsurface has the ability to naturally decrease many chemical and biological constituents through physical, chemical, and biological processes. However, in Karheda, since the water table is shallow, there could be a potential risk of biological contamination. In order to address this issue, bio-sand filters were promoted along with RWH structures. A bio-sand filter is a concrete container, with layers of sand and gravel inside it. The sand and gravel remove dirt, bacteria, viruses and parasites and other physical and biological impurities from the water (Figure 10.6).

In a bio-sand filter, water is poured from the top. There is a diffuser plate placed just above the sand bed that absorbs the shock of the falling water. So it does not disturb the sand. Travelling slowly

Figure 10.6: Bio-sand Filter



through the sand bed, the water then passes through several layers of sand and gravel and then is pushed up through piping encased in the concrete, and out of the filter, for the user to collect. When water is poured from the top, the organic impurities get trapped at the surface of the sand, forming a bio layer or 'schmutzdecke'. Four processes remove pathogens and other contaminants in this filter:

1. Predation: The bio layer micro-organisms eat bacteria and other pathogens found in the water.
2. Natural death: Pathogens die because there is not enough food and oxygen to sustain them all.
3. Adsorption: Viruses are adsorbed (become attached) to the sand grains. Once attached, they are metabolised by the cells or are inactivated by antiviral chemicals produced by the organisms in the filter. Certain organic compounds are also adsorbed to the sand and therefore removed from the water.
4. Mechanical trapping: Sediments, cysts and worms are removed from the water as they get trapped in the spaces between the sand grains. The filter can also remove some inorganic compounds and metals from the water when they are precipitated into solid form.

Prior to implementing the model in the entire village, this innovative approach was first successfully demonstrated in a primary school in Karheda in 2006. The water problems in the school epitomised those that the village faced.

RWH Model in Karheda Primary School

The school catering to 200 students had an underground tank to store water from public supply, but due to poor upkeep, the unhygienic water was not used. The water supply was extremely erratic due to various reasons such as low pressure, leakages and poor maintenance of the distribution network. The daily requirement of water in the primary school was 500 litres including 200 litres for drinking, 120 litres for cooking mid-day meals and 180 litres for sanitation and other purposes. Total annual water demand works out to be about 100,000 litres (for 200 working days). In 2006, S M Sehgal Foundation established an innovative RWH system to recharge the aquifer by passing it through a simple sand filter with the following objectives:

- To provide alternative source of water.
- To generate awareness among the school children about RWH so that they could spread the information among the community.
- To demonstrate the feasibility of the model and acquire a buy-in from the community.

The RWH unit was set up for a roof area of 300 square metres to capture rain water. The average annual rainfall of 500 mm would harvest 127,500 litres of water. Since July 2006, the school has been using the recharged water. The present water harvesting capacity surpasses the required amount resulting in sustainable and reliable water supply for the school.

Results

The Karheda primary school now has a ready and reliable source of potable water which was further made safe through bio-sand filter. Mayawati, an Anganwadi worker who is in-charge of preparation of the mid-day meal at the school, reported, '…now the problem of water in the school is solved with the installation of RWH and bio-sand filter. Now all round the year we have water sufficient for cooking, drinking and sanitation.'

Results of water analysis in Table 10.11 indicate that the properties of recharged water are better than desirable levels but show a substantial concentration of coli form. However, it should be noted that such high levels of coli form are imminent and expected in shallow groundwater given that open defecation, stagnation of wastewater and composting are highly prevalent in Karheda. This issue was addressed through the promotion of bio-sand filters. Further testing of harvested water filtered through bio-sand filters revealed absence of coli forms.

A respondent who had adopted this model in her household reported, 'There has been no diarrhoea in our household in the last

Table 10.11: Chemical Contaminants in Groundwater, Public Water Supply and Recharge Well

Characteristics	*Desirable Limits as per Indian Standards*	*Groundwater*	*Public Supply Water*	*Water from School RWH Recharge Well*
pH value	6.5 to 8.5	7.4	8	7.0
Total hardness mg/l	300	7702	400	95
Iron mg/l	0.3	0.6	1	0.02
Chlorides mg/l	250	9792	269	39
Fluoride mg/l	1.0	2.5	1.5	0.3
Dissolved solids mg/l	500	30230	710	201
Magnesium mg/l	30	1273	29	6
Calcium mg/l	75	958	111	28
Sulphate mg/l	200	6972	61	51
Nitrate mg/l	45	1626	135	4
Cadmium mg/l	0.01	0.07	<0.01	<0.01
Lead mg/l	0.05	0.4	<0.01	<0.01
Alkalinity mg/l	200	353	190	51
MPN coli form /100 ml	10	7	278	900

few months ever since we adopted the RWH and bio-sand filter. Earlier, there were white spots in the containers used for storing water, but now there are no white spots.'

Discussion and the Way Forward

Groundwater has been an important source, particularly in the rain-fed semi-arid regions of India. The quality and availability of groundwater is not uniform across the country. In most of the semi-arid and arid areas of Punjab, Haryana, Rajasthan and Gujarat the available groundwater is saline. In the absence of other sources of water, poor quality of groundwater has not only health implications but also social, economic and political ones as well. In this context, Mewat is a case in point where fresh groundwater is limited to 61 out of 503 villages.

In Mewat, salinity and fast depletion of fresh groundwater has been a serious problem as this affects the quality of life of the inhabitants in more ways than one. Given that there is no policy to regulate groundwater extraction in addition to availability of free or heavily subsidised electric supply for agricultural operations, the potential for advancement of saline groundwater pockets is extremely high in the region. The severity of the water crisis in Karheda is similar to those of the overall water problems in Mewat where salinity of groundwater is as high as that found in sea water.

In this scenario, an innovative RWH model along with bio-sand filter was a cost-effective, sustainable and replicable solution. This innovation was targeted to address issues such as groundwater salinity, groundwater depletion, drudgery of fetching water from long distances and loss of study hours due to absence of water in the school premises. Such a model was successfully demonstrated at a government primary school in Karheda. The schoolchildren, who have had firsthand experience of reaping the benefits of this model, have been spreading awareness on the effectiveness of this model. This resulted in an increase in the adoption of this model in the households not only in Karheda but also in nearby villages.

A pivotal aspect in the adoption of this model was community involvement. During the initial phases of the project demonstration at the school, concerted and consistent efforts were required to make

the community appreciate not only the gravity of the water situation but also its detrimental consequences. Once the community realised that there could be a cost-effective and reliable solution to the saline groundwater problem, they willingly came forward to adopt this model in their households. So far 24 households have adopted this model. There is also an increasing demand for adoption of this model in the surrounding villages.

The model has high potential in regions with saline groundwater and in coastal areas where sea water ingress poses a major challenge. Experiences from Karheda and its nearby villages underscore that the model is highly affordable and can be easily replicated. Replication is contingent on a strong buy-in for the model in the community and lack of awareness on water related issues as was the case in Karheda prior to the introduction of the model could pose potential challenges. It is in such a scenario that Gram Panchayats and district administration could play the role of a facilitator in promoting this model through systematic awareness generation.

Once a community is triggered to adopt this model, then the district administration as well as other stakeholders such as local non-governmental organisations (NGOs), government officials, schools, self-help groups (SHGs) could provide intermediation and financial support and capacity building particularly on the technical details to grassroots implementers. In this way, the model can be institutionalised and can be brought to scale in those areas with saline groundwater pockets.

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