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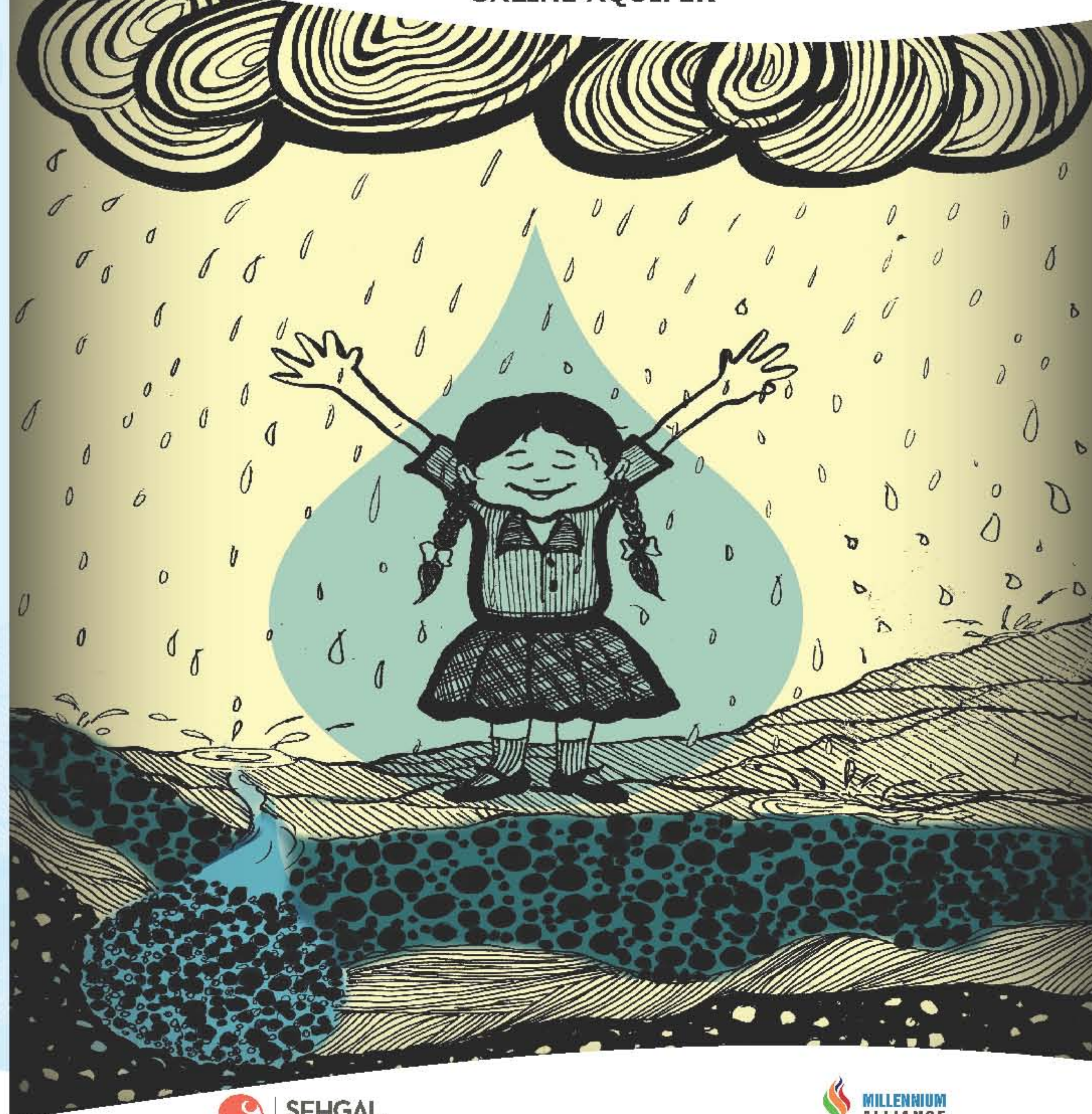
SEHGAL FOUNDATION

TOGETHER WE EMPOWER RURAL INDIA

RAINWATER HARVESTING FOR CREATION OF FRESHWATER POCKET WITHIN SALINE AQUIFER



SEHGAL FOUNDATION

MILLENNIUM ALLIANCE

RAINWATER HARVESTING FOR CREATION OF
FRESHWATER POCKET WITHIN SALINE AQUIFER

SEHGAL
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Contents

Preface

Groundwater is the primary source of water for domestic, agricultural, and industrial use in India. Eighty percent of India's net irrigated area is dependent on groundwater (Shankar et al, 2011). Eighty-five percent of India's rural domestic water requirements and fifty percent of its urban water requirements are met by groundwater (CGWB, 2011). These needs have led to an unsustainable withdrawal of groundwater, with thirty percent of India's districts having reached "unsafe" levels of groundwater exploitation (CGWB, 2006).

This situation is further compounded by the poor water quality, particularly in rural areas. The Department of Drinking Water Supply (DDWS) reported high levels of contamination in the 593 districts across India for which data is available (DDWS, 2006). A study on vulnerability of populations to groundwater quality and quantity issues indicates that 347 districts (or 59 of those surveyed) face such issues (S Krishnan, 2009). Salinity is a common problem in the arid regions of north-central India, notably in Haryana and Rajasthan, and affects groundwater acceptability for drinking and irrigation purposes (British Geological Survey, 2004).

S M Sehgal Foundation (Sehgal Foundation) works with communities in these regions to improve water availability for domestic and agricultural use. The innovation, Creation of freshwater pocket within a saline aquifer, is the outcome of the Foundation's continuous efforts to seek alternative sources of freshwater in saline areas. The model was first adopted in Karheda village (Mewat) in 2006. Following this, the Department of Science and Technology, Government of India, provided financial support to set up the model in six villages of Mewat (Rajaka, Jaitaka, Malab, Untaka, Raipur and Chandanki).

In November 2014, Millennium Alliance[1] awarded a grant to Sehgal Foundation to build the innovation in other locations of Mewat. The project *Pressurised Recharge Wells: Ensuring Water Availability in Saline Water Areas* was implemented under this grant in four government schools of Nagina block of Mewat district (Jargali, Sukhpuri, Danibas, and Saral). The project provides drinking water to 942 children and teachers as well as 519 people from aanganwadi. The promotion of this technology helps meet the challenge of the Sustainable Development Goal[2] No. 6: Ensure Access to Water and Sanitation for All.

1. The Millennium Alliance is a consortia of funding partners of United States Agency for International Development (USAID), Department for International Development (DFID), United Kingdom, Interchurch Organization for Development Cooperation (ICCO), Dutch Government, Federation of Indian Chambers of Commerce and Industry (FICCI), Department of Science and Technology, Government of India, WISH, and ICICI Foundation.
2. The sustainable development goals (SDGs) are a new, universal set of goals, targets and indicators that United Nations member states are expected to use to frame their agendas and political policies over the next fifteen years. The SDGs follow and expand on the millennium development goals (MDGs), which were agreed by the governments in 2001.

of the booklet

This two-part booklet summarizes the successful work of Sehgal Foundation to design a unique model that harvests rainwater and stores it within a saline aquifer. The booklet has been developed under the Information Education and Communication (IEC) activities of the *Pressurised Recharge Wells: Ensuring Water Availability in Saline Water Areas* project and is intended to be a beneficial resource for other implementing organizations and stakeholders involved in rainwater harvesting in saline groundwater areas.

Part A describes the key aspects of groundwater and rainwater harvesting.

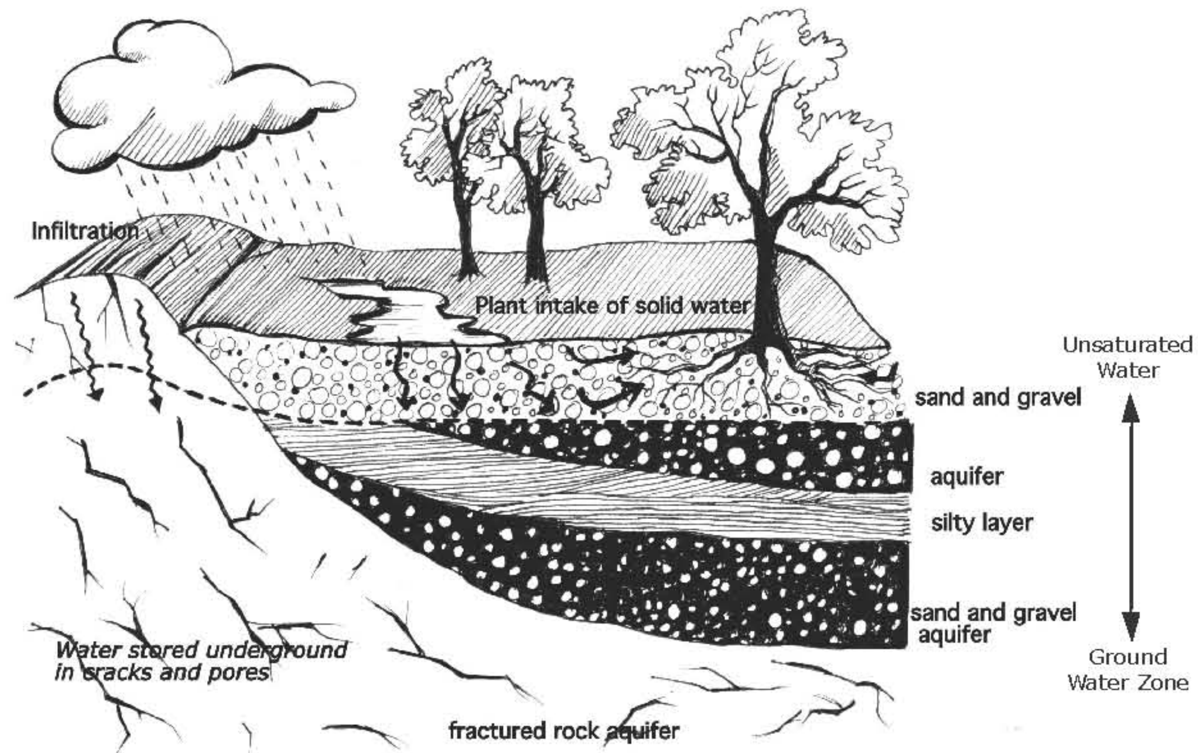
Part B provides guidance for implementation of the model and concentrates on the design, advantages and limitations, and operation and maintenance issues.

Sehgal Foundation gratefully acknowledges the financial support of the Federation of Indian Chambers of Commerce and Industry (FICCI) for the realization of this project. Thanks also to friends and rainwater harvesting specialists, especially the innovator, Mr. Lalit Mohan Sharma, for his valuable suggestions. Special thanks to Ms. Chicu Lokgariwar for editing the booklet and Ms. Usha Dewani Das for designing the booklet and creating the illustrations.

1. Part A: The basics of groundwater

a. What is groundwater?

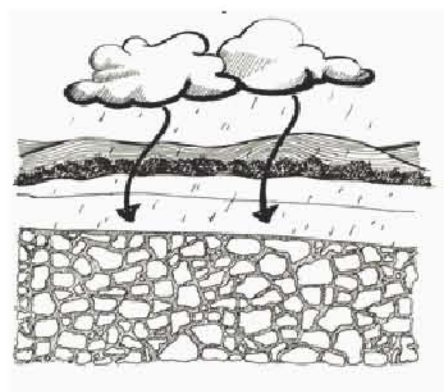
Groundwater refers to the water within geological formations, which originates from atmospheric precipitation either directly by rainfall infiltration or indirectly by seepage from rivers, lakes, and canals. Water stored in the soil beneath the earth's surface is groundwater.



Groundwater recharge

Given a continuous supply, water enters a porous geological formation, replacing the air and gradually saturating the pore spaces, forming an underground reservoir. The accumulated water moves slowly through geological formations of soil, sand, and rocks and forms aquifers.

Aquifers are typically made up of gravel, sand, sandstone, or fractured rock, like limestone. Water can move through these materials because they have large interconnected void spaces that make them permeable. The speed at which the groundwater flows depends on the size of the void spaces in the soil or rock and their interconnection.



Aquifer Recharge

b. Accessing groundwater

Groundwater sometimes comes naturally to the surface in the form of a spring or seepage. This seepage replenishes rivers in non-monsoon months in most areas of peninsular India. More often, groundwater is tapped by sinking a well into the aquifer. From these wells, water can either be pulled up manually (from a shallow aquifer in the case of an open well) or pumped up (from a deep aquifer in the case of a deep well). As of 2010, India had twenty million such wells (World Bank, 2010). The excessive withdrawal of groundwater has led to the depletion of aquifers.

The Central Groundwater Board (CGWB) of India evaluates the state of groundwater for each assessment unit based upon the extent of groundwater exploitation (as a ratio of annual withdrawal to replenishment) and the long-term water level trend. Accordingly, assessment areas (blocks or districts) are classified as safe, semi-critical, critical, or over-exploited (CGWB, 2011).

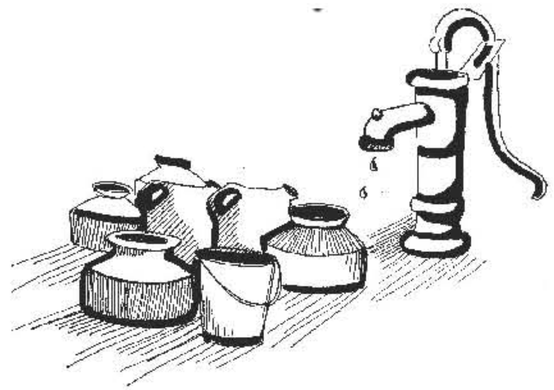
The CGWB has estimated that, as of 2009, India withdraws 61 percent of its total annual replenishable groundwater. The assessment provides a system for permitting withdrawals but does not take into account water quality.

c. Groundwater quality

Water is considered to be of poor quality if it has undesirable contaminants such as physical, chemical, or biological impurities. In the case of groundwater, these contaminants can enter the aquifer by seepage from the surface or by leaching from the rocks that form the aquifer (CGWB, 2010). The most common of these contaminants are geogenic (produced by the rocks), including fluoride and arsenic, or are caused by anthropogenic activities such as overexploitation of groundwater in coastal regions, which results in salinity due to seawater ingress, excessive use of fertilizers and pesticides in agriculture, and improper disposal of urban/industrial waste.

Inorganic contaminants, such as salinity, chloride, fluoride, nitrate, iron, and arsenic, and organic contaminants, such as coliform bacteria, are important in determining the suitability of groundwater for drinking purposes.

With respect to finding solutions to depleting groundwater and poor water quality, options are to find alternate or additional water resources or to use the limited water resources more efficiently. Rainwater harvesting has emerged as the most effective way to augment freshwater resources.



Did you know?

- Groundwater salinity is found in many Indian states, particularly in arid and semi-arid regions of Rajasthan, Haryana, Punjab, Gujarat, Uttar Pradesh, Delhi, Madhya Pradesh, Maharashtra, Karnataka, Bihar, and Tamil Nadu. Semi-arid regions are vulnerable to the adverse effects of salinity because water sources are scarce coupled with low rainfall (Sharma et al, 2012).
- More than 77220.43 square miles of India contain salty groundwater (Sharma et al, 2012).

d. Rainwater harvesting

Rainwater harvesting, in the broadest sense, is the process of collectng and storing rainwater from rooftops, land surfaces, or rock catchments. Harvested rainwater can be stored for direct use or for groundwater recharge. This recharging improves the quality of groundwater by dilution of the salts and causes the water levels in wells and bore wells to rise.

Storage of harvested rainwater provides an alternative source of good quality water, particularly in areas with water scarcity or where there is groundwater contamination.

Sehgal Foundation actively promotes rainwaterharvesting technologies in the rural pockets of Mewat district of Hary-ana and Alwar district of Rajasthan in order to augment the groundwater resources through recharging or storage.

What is salinity?

Salinity is a term used to describe the amount of salt in a given water sample. It is referred to in terms of total dissolved solids (TDS) and is measured in milligrams of solids per litre (mg/L) (Alley, 2003). In India, water with a TDS concentration great-er than 500 mg/L is considered saline. This is the acceptable limit and is suitable for human consumption. Water with TDS 2,000 mg/L is used for domestic supply in areas where water of lower TDS content is not available.

e. Water situation in Mewat, Haryana

Mewat district of Haryana is located in the alluvial plains of northern India. In addition to the underlying alluvium, the district is traversed by elongated ridges of Delhi quartzites (CGWB, 2012). Average annual rainfall in the area is 594 mm spread over 31 days (CGWB, 2012).

The lack of a canal system, the semi-arid to hot climate, and low rainfall mean that there is very little surface water most of the year. Therefore, groundwater forms the principal source of water for domestic use, drinking, and irrigation (Sitender et al, 2011).

The depth of the water level in Mewat is between 5 to 29 meters below ground level (m bgl). Net groundwater available in the district is 22,902 ham (CGWB, 2007). Of 431 villages in the district, only 61 villages in the foothills of the Aravallis have fresh groundwater. The remaining villages have saline groundwater that is unusable for drinking (SANDRP, 2004). Villages therefore harvest and use rainwater.

Dynamics of saline groundwater

The geographic distribution of fresh, brackish, and saline groundwater is subject to change. Some changes take place very slowly and are only significant at a geological time scale. Others proceed more quickly. The formation of saline groundwater, its migration, and its mixing with freshwater are driven by factors such as geological processes, meteorological processes, climate change, tsunamis, earthquakes, consolidation of compressible sediments and anthropogenic factors, such as drainage, irrigation, groundwater pumping, waste or wastewater disposal, etc. (Weert et al, 2009)

f. Initial experience

Earlier Sehgal Foundation stored harvested water in concrete tanks for use in a village throughout the year. The villagers appreciated the storage structure, but the high cost of construction proved to be a stumbling block.

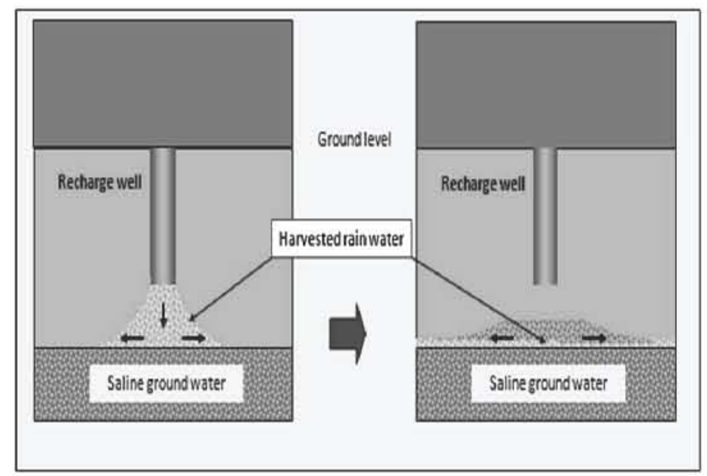
Where cost was a concern, groundwater recharge by directing harvested rainwater into a recharge well was an effective solution. However, in areas like Mewat where the groundwater is totally saline, this method had some shortcomings.

Where is saline groundwater

Little is known about the hydrogeology of aquifers that contain saline water, because the use of saline groundwater has been limited. Evaluations of saline water-bearing units have been mostly devoted to determining the effects on freshwater movement (Alley, 2003).

In a conventional recharge well, rainwater (freshwater) floats over the saline groundwater. Hydraulic equilibrium causes this freshwater layer to gradually spread over a large area. This layer is too thin to extract because any attempt to pump it out causes an influx of saline groundwater.

Harvested rain water does not remain consolidated at one place and eventually spreads out



Spread of fresh harvested rainwater under the ground
(Source: Sharma et al, 2012)

In order to extract the harvested rainwater, formation of a pocket of sizeable depth is essential.

Effects of saline groundwater on freshwater resources

Since parts of aquifers containing saline water are commonly connected hydraulically to parts of the same aquifer that contain freshwater, the development of one resource affects the other. This in turn affects the flow and quality of surface water bodies connected to the groundwater system. These effects may extend over many years or decades (Alley, 2003).

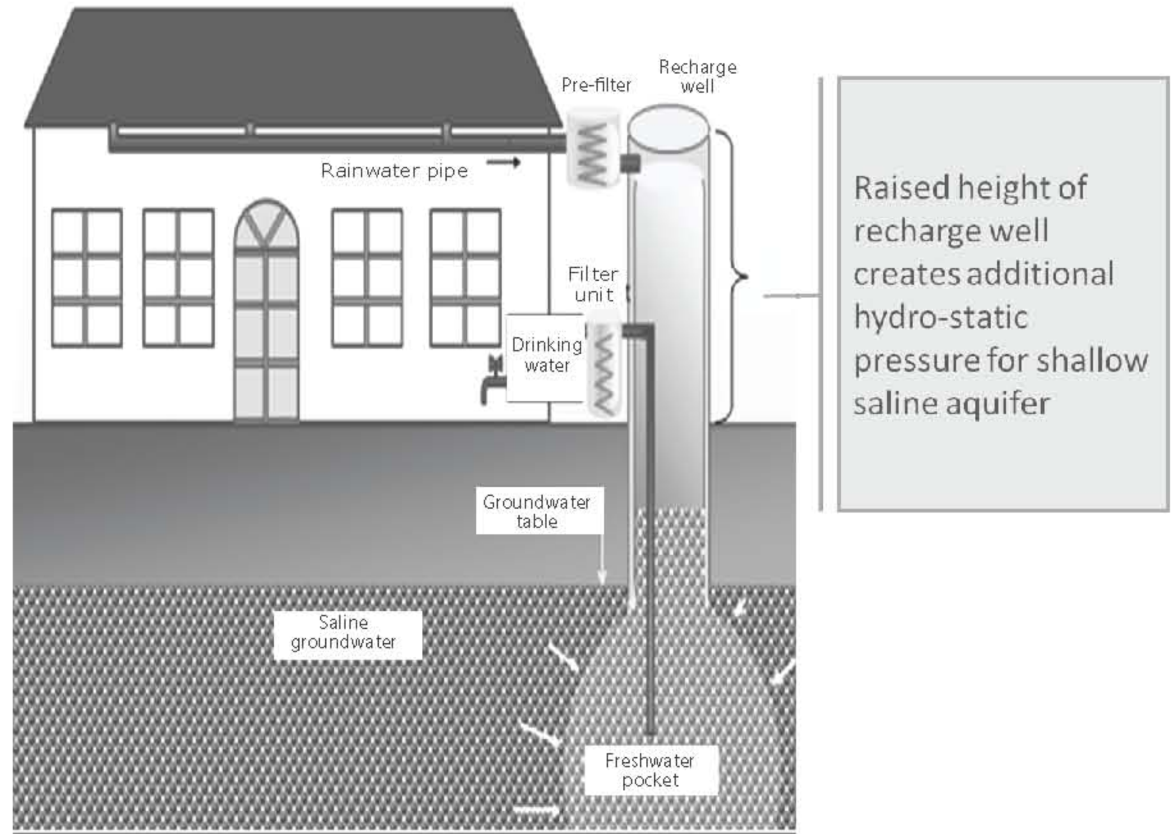
5.Part B: Innovative approach to manage saline groundwater

a. The model

To create an adequately sized pocket of freshwater within a saline aquifer, it is necessary to increase the hydrostatic pressure. By designing the recharge well with walls of greater height above ground and greater depth into the aquifer, hydrostatic pressure is sufficient to enable the rainwater to push aside the existing saline groundwater and form a
sizeable pocket of harvested rainwater within the saline aquifer. The pressure exerted by the surrounding saline groundwater keeps the rainwater pocket intact. A hand pump is used to extract the harvested rainwater.

The salient points of this process are as follows (Sharma et al, 2012):

- The harvested rainwater is directed into the saline aquifer through recharge well walls that extend below the groundwater table. Since the density of rainwater is less than that of saline groundwater, the former floats over the latter.
- Because of hydrostatic pressure, harvested rainwater pushes away the existing saline groundwater to form a pocket of freshwater within the saline aquifer.
- The flow of rainwater under the ground through tiny void spaces among the soil particles is a streamlined flow. There is minimal turbulence such that the harvested freshwater and existing saline water do not mix.
- The buoyant force exerted by the surrounding saline groundwater on the newly formed pocket of harvested water keeps the harvested water pocket intact.



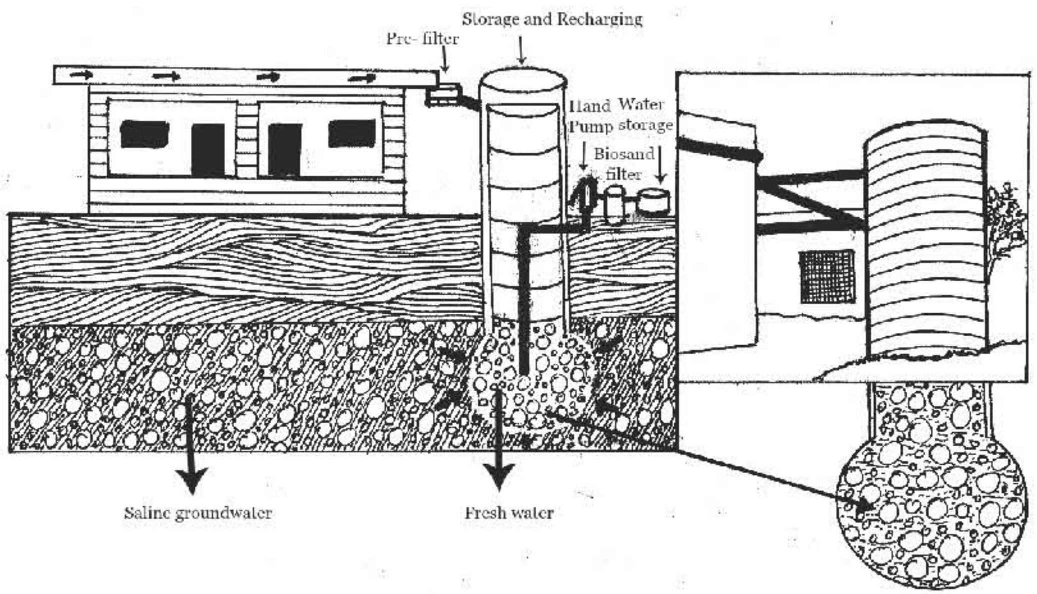
Rooftop rainwater harvesting scheme in shallow aquifer

The specific design of the construction of the recharge well depends on the soil quality, rainfall intensity, catchment area, and rate of inflow. The height and depth also depend on site conditions.

b. Water withdrawal mechanism

Extraction of water from the freshwater pocket requires care to avoid disturbances in the configuration of the pocket that would mix the fresh and saline water. For this, a pipe is inserted either inside or outside the freshwater pocket. A hand pump is connected to this pipe from which harvested water is pumped out manually as per daily requirements. An electric pump with a lower discharge rate may also be installed depending upon the quantity of harvested rainwater, daily withdrawal needs, and soil characteristics. A high-capacity pump is unsuitable because the force used to extract the water will disturb the pocket and may lead to mixing with surrounding saline water.

Biological contaminants may make the water unfit for direct human consumption. By contrast, physical and chemical impurities in the harvested water are generally negligible. Biological impurities are likely to be present in shallow groundwater tables and in water withdrawn soon after the rainy season. The water can either be purified by a disinfectant or filtered through a biosand filter to reduce biological contamination.



Schematic diagram of the innovative model with actual model

Biosand filter is one of the most effective and sustainable water purification methods. An improvised version of slow sand filtration developed by Dr. David Manz of the University of Calgary, Alberta, works with a simple combination of biological and mechanical processes and removes biological contaminants, iron, and suspended solid particles from water.

c. Advantages

- This system provides a good supplement to existing water sources, thus relieving pressure on other water sources.
- The model can be adapted for both inland and seawater intrusion salinity in rural and urban areas.
- The technology is environmentally friendly and operates under gravity.
- Its construction, operation, and maintenance are not skill intensive.

This model of rainwater harvesting is an attractive option where there is:

- Shortage of potable water
- High groundwater salinity
- Seawater intrusion
- Financial constraints of the community regarding costlier solutions
- Short rainy season

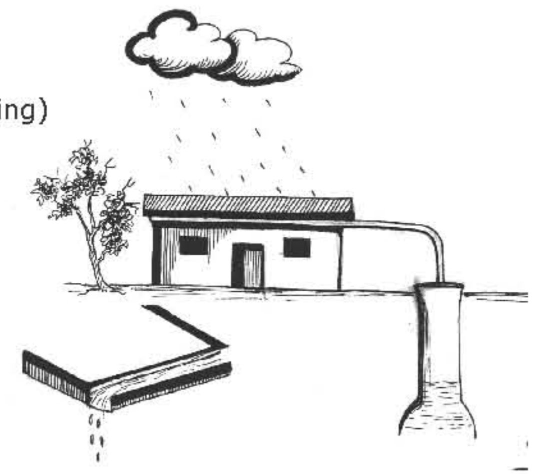
d. Limitations

- In a drought year, the freshwater pocket may shrink, making the system ineffective.

- The soil profile of the strata should be pervious so as to allow for water to percolate through the soil.

- On slopes/hills aquifers tend to be dynamic. Groundwater will flow from higher to lower gradient, thereby minimising the chances of formation of freshwater pocket.

e. Basic elements of the system



- Rainwater collection area (usually roof of building)
- Conveyance system (gutters and downpipes)
- Filtration / treatment
  (gravel, sand, metal or plastic
  mesh installed in gutters or
  entry to tank)
- Recharge well

f. Conditions for adoption

i. Catchment area

The surface of the catchment area should be hard and free from any chemical or physical impurities so that no such impurities leach into the harvested rainwater. Concrete and metallic sheet roof surfaces are the best for harvesting water for human consumption. Water quality is not important in situations where water will be used for irrigation, so other roof surfaces can also be considered.

The quantity of rainwater available from the catchment area can be obtained from the following relation (CGWB, 2007):
Water available (in liters)= Annual rainfall (in mm) x
Roof area (in sq.m)x
Runoff coefficient

Runoff coefficients of common types of roofs are as follows:

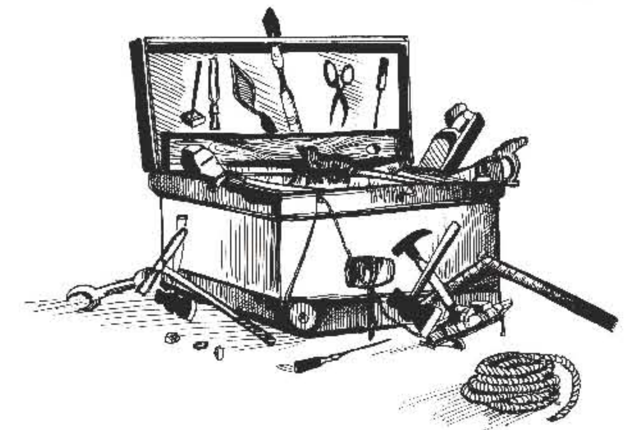
Galvanized iron (GI) sheets	0.9
Asbestos	0.8
Tiled	0.75
Concrete	0.7
Unpaved area	0.2-0.3

ii. Roof catchment

The type of catchment surface affects the quality of the water harvested. Common roof types in rural areas, such as concrete, tile, asbestos sheet, and galvanized iron sheets, are suitable for catchments. Thatch roof is unsuitable because of dirt and other contamination. The roof should be in the open rather than near big trees to avoid accumulation of leaves and bird droppings.

The roof and roof gutters must be adequately sloped to facilitate flow of runoff water from the roof to downpipes to the rainwater collection tank.

g. Operations and maintenance



In order to have potable drinking water, the following precautions must be taken:

- A smooth roof surface without excess debris (leaves, etc.) is desirable for easy flow of water.
- The roof should not be under trees or close to overhanging branches of trees to prevent leaves and bird droppings from falling on it.
- Gutters must be kept free of debris to promote the free flow of run-off water.
- Before the onset of the monsoon or rainy period or after two rains, the roof and gutters should be properly cleaned.
- All joints and bends in pipes should be regularly checked for leakage and repaired as necessary.

h. Maintenance and repair of the system

Parts	Ongoing maintenance and repairs	Frequency	Materials required
Roof	Wash off roof with water when dust/dirt accumulates diverting runoff away from tank inlet.	Check monthly. Make sure to check after long period of dry weather, cyclone, and other heavy wind.	Roofing iron Paint Water
	Trim and cut trees around tank.	As required.	
	Replace rusted roofing.	As required.	
	Fix holes for maximum runoff.	As required.	
Gutters	Remove bird droppings, leaves, and other debris	Check monthly. Make sure to check after long period of dry weather, cyclones or other heavy wind.	• Water • Gutter hanger • Gutter fittings
	Check and repair leakages	As required.	
	Ensure guttering has the proper gradient to ensure steady flow of water.	As required.	
Tap	Fix leaking taps.	As required.	• Tap • Washer • Plumbing tape • Glue • Rubber • Stones/gravel
Downpipe	Repair holes and replace if screen is damaged.	As required.	• Stainless steel wire mesh • Twine • PVC pipe • Glue
	Repair leaks at elbow joints and t-joints.		
Overflow	Ensure there are no gaps where mosquitoes can enter or exit.	As required.	• Wire mesh • Twine
	Repair screen if damaged.		
Biosand filter	Swirl the water above top layer of sand when the flow of rate is reduced.	When water flow rate is reduced.	

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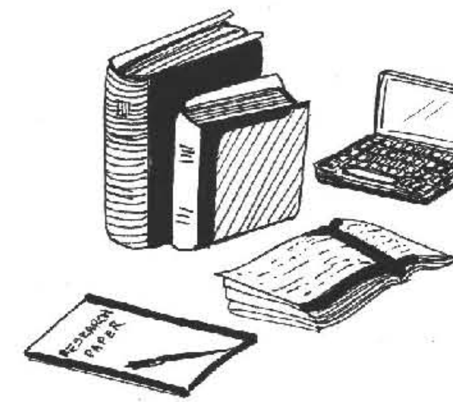

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About Millennium Alliance

The Millennium Alliance (MA) is an inclusive platform to leverage Indian creativity, expertise, and resources to identify and scale innovative solutions being developed and tested in India to address development challenges that will benefit base of the pyramid populations across India and the world. The MA is a network to bring together various actors within India's social innovation ecosystem including, but not limited to, social innovators, philanthropy organizations, social venture capitalists, angel investors, donors, service providers, and corporate foundations, to stimulate and facilitate financial contributions from the private and public sectors and offer a range of support to innovators.

Under Federation of Indian Chambers of Commerce and Industry (FICCI) leadership and in partnership with United States Agency for International Development (USAID) and the Technology Development Board (TDB), and other MA partners, the Alliance provides innovators with services such as seed funding, grants, incubation and accelerator services, networking opportunities, business support services, knowledge exchange, and technical assistance, and facilitates access to equity, debt, and other capital. The founding partners of MA are FICCI, USAID, TDB and program partners are UKAID, ICCO Co-operation, ICICI foundation and WISH. Through the Millennium Alliance, USAID, FICCI, TDB, and other partners, help realize India's role as a global innovation laboratory.

About S M Sehgal Foundation

S M Sehgal Foundation (Sehgal Foundation) is a public charitable trust registered in India since 1999.

Every person across rural India deserves to lead a more secure, prosperous, and dignified life. With that vision in mind, our mission is to strengthen community-led development initiatives to achieve positive social, economic, and environmental change across rural India.

With support from donors and partners, Sehgal Foundation designs and promotes rural development interventions that create opportunities, build resilience, and provide solutions to some of the most pressing challenges in India's poorest communities.

The foundation team works together with rural communities to create sustainable programs for managing water resources, increasing agricultural productivity, and strengthening rural governance. The team's emphasis on gender equality and women's empowerment is driven by the realization that human rights are central to developing every person's potential.