A Review on Artificial Groundwater Recharge in India

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Abstract

Artificial groundwater recharge is as a process of induced replenishment of theground water reservoir by human activities. It is the planned, human activity of augmenting the amount of ground water available through works designed to increase the natural replenishment or percolation of surface water into the groundwater aquifers, resulting in a corresponding increase in the amount of groundwater available for abstraction.

The primary objective of this technology is to preserve or enhance groundwater resources in various parts of India which includes conservation or disposal of floodwaters, control of saltwater intrusion, storage of water to reduce pumping and piping costs, temporary regulation of groundwater abstractions, and water quality improvement by dilution by mixing with naturally-occurring groundwater (Asano, 1985). In such areas, there is need for artificial recharge of groundwater by methods such as water spreading, recharge through pits, shafts, wells and many more. The choice of a particular method is governed by local topographical, geological and soil conditions; the quantity and quality of water available for recharge; and the technological-economical viability and social acceptability of such schemes. This paper discusses various issues involved in the artificial recharge of groundwater.

I. INTRODUCTION

The recharge of ground water occurs both naturally and artificially. The natural recharge occurs through the process of infiltration where the water percolates from the surface to the bed of the aquifer. But due to rapid development and stupendous growth of population in the recent past the areas for natural infiltration have been lessening day by day, hence the scope for natural recharge of the groundwater is also declining. In contrast to natural recharge (which results from natural causes); artificial recharge is the use of water to replenish artificially the water supply in an aquifer. Of all the factors in the evaluation of groundwater resources, the rate of recharge is one of the most difficult to derive with confidence. Estimates of recharge are normally subject to large uncertainties and spatial and temporal variability. The increasing demand for water has increased awareness towards the use of artificial recharge to augment ground water supplies. Stated simply, artificial recharge is a process by which excess surface-water is directed into the ground – either by spreading on the surface, by using recharge wells, or by altering natural conditions to increase infiltration – to replenish an aquifer. It refers to the movement of water through man-made systems from the surface of the earth to underground water-bearing strata where it may be stored for future use. Artificial recharge (sometimes called planned recharge) is a way to store water underground in times of water surplus to meet demand in times of shortage. Some applications of artificial recharge are in wastewater disposal, waste treatment, secondary oil recovery, prevention of land subsidence, storage of freshwater within saline aquifers, crop development, and streamflow augmentation (Oaksford, 1985).

II. METHODOLOGY FOR ARTIFICIAL RECHARGEPROGRAMMES/SCHEMES

An artificial recharge scheme may be aimed at recharge augmentation in aspecific area for making up the shortage in ground water recharge compared to the ground water draft either fully or partially. Important issues in planning such schemes are the selection of a suitable source of water, the location of the artificial recharge area, the geohydrological conditions, community involvement, and cost. The schemes should be planned in accordance with the available technical skills, manpower, and management capabilities, and the capacity and willingness of the user community to bear the costs.For planning and implementation of any successful artificial recharge project with proper scientific investigations the following aspects is important for evolving a realistic plan for an artificial recharge scheme. These include:

a) Suitability of the area for recharge in terms of climate, topography, soil and land use characteristics and hydrogeologic set-up
b) Appraisal of economic viability
c) Finalization of Physical Plan.
d) Preparation of a Plan document

A. These are Generally Conducted in Three Phases:

1) Attainability

Hydrogeologicalreports for regulatory oversight and permitting agencies, where applicable.

2) Design and Operation

A test programme is designed, using existing facilities if possible. This work includes chemical and physical modelling of recharge options and measurement of recharge rates in the test programme.

3) Project Implementation

Test programme results are used to recommend final, full-scale implementationof the project, including sites for new artificial recharge structures,additional wells or infiltration ponds (if necessary), potential future options for sourcing of surface-water, planning of recharge management during regular operations, and necessary monitoring. Focus is kept on keeping the system design flexible, so that changing needs of the client can be integrated with existing recharge operations and facilities.

III. METHODS OF ARTIFICIAL RECHARGE

Artificial recharge methods can be classified into two broad groups (i) Direct methods, and (ii) Indirect methods.

A. Direct Methods

1) Surface Spreading Techniques

This method of artificial recharge of groundwater employ different techniques of increasing the contact area and resident time of surface-water over the soil to enhance the infiltration and to augment the ground water storage in phreatic aquifers. The area should have gently sloping land without gullies or ridges and vadose zone should be permeable and free from clay lenses.

Flooding

The technique of flooding is very useful in selected areas where a favorable hydro-geological situation exists for recharging the unconfined aquifer by spreading the surplus surface-water from canals / streams over large area for sufficiently long period so that it recharges the groundwater body. This technique can be used for gently sloping land with slope around 1 to 3 percentage points without gullies and ridges.

Ditches and Furrows

In areas with irregular topography, shallow, flat-bottomed and closely spaced ditches and furrows This concerns to the identification of the basin or impermeable layers within the aquifer that inhibit recharge to the underground aquifers. Also important are concerns about chemical mixing of surface waters and native groundwater, hydrological variability within the aquifers. Prepare necessary feasibility and provide maximum water contact area for recharging water from the source stream or canal. This technique requires less soil preparation than the recharge basin technique and is less sensitive to silting.

Recharge Basins

Artificial recharge basins are either excavated or enclosed by dykes or levees. They are commonly built parallel to ephemeral or intermittent stream-channels. The water contact area in this method is quite high which typically ranges from 75 to 90 percentage points of the total recharge area. In this method, efficient use of space is made and the shape of basins can be adjusted to suite the terrain condition and the available space.

Run-off Conservation Structures

They are suitable in areas receiving low to moderate rainfall mostly during a single monsoon season and having little or no scope for transfer of water from other areas..

Bench Terracing helps in soil conservation and holding runoff water on the terraced area for longer durations, leading to increased infiltration and ground water recharge

Gully plugs are the smallest run-off conservation structures built across small gullies and streams rushing down the hill slopes carrying drainage of tiny catchments during rainy season. Usually, the barrier is constructed by using local stones, earth and weathered rock, brushwood, and other such local materials.

Contour bunds involve a watershed management practice so as to build up soil moisture storages. This technique is generally adopted in areas receiving low rainfall.

Contour trenchesare rainwater harvesting structures, which can be constructed on hill
slopes as well as on degraded and barren waste lands in both high- and low- rainfall
areas

Percolation tanks is an artificially created surface water body submerging a highly permeable land area so that the surface runoff is made to percolate and recharge the ground water storage. Normally, a percolation tank should not retain water beyond

February in the Indian context. It should be located downstream of a run-off zone.

Stream-channel Modification

These methods arecommonly applied in alluvial areas, but can also be gainfully used in hard rock areas where thin river alluvium overlies good phreatic aquifers or the rocks are extensively weathered or fractured in and around the stream channel. Artificial recharge through stream channel modifications could be made more effective if surface storage dams exist upstream of the recharge sites as they facilitate controlled release of waters.

Surface Irrigation

Surface irrigation aims at increasing agricultural production by providing dependable watering of crops during gaps in monsoon and during non-monsoon period. Wherever adequate drainage is assured, if additional source water becomes available, surface irrigation should be given first priority as it gives a dual benefit of augmenting groundwater resources.

2) ***Sub-Surface Techniques***

These aim at recharging deeper aquifers that are overlain by impermeable layers, preventing the infiltration from surface sources to recharge them under natural conditions

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Injection Wells (Recharge Wells)

Injection wells are structures similar to a tube well but with the purpose of augmenting the groundwater storage of a confined aquifer by "pumping in" treated surface-water under pressure. The aquifer to be replenished is generally one that is already over exploited by tube well pumping and the declining trend of water levels in the aquifer has set in. Artificial recharge of aquifers by injection wells is also done in coastal regions to arrest the ingress of seawater and to combat the problems of land subsidence in areas where confined

Gravity-Head Recharge Wells

Ordinary bore wells and dug wells used for pumping may also be alternatively used as recharge wells, whenever source water becomes available in addition to injection wells. Care should be taken to ensure that the source water is adequately filtered and disinfected when existing wells are being used for recharge. The recharge water should be guided through a pipe to the bottom of well, below the water level to avoid scouring of bottom and entrapment of air bubbles in the aquifer.

Connector Wells

Connector wells are special type of recharge wells where water can be made to flow from one aquifer to other without any pumping. The aquifer horizons having higher heads start recharging aquifer having lower heads.

Recharge pits

Recharge pits are structures that overcome the difficulty of artificial recharge of phreatic aquifer from surface-water sources. They are similar to recharge basins in principle, with the only difference being that they are deeper and have restricted bottom area.

Recharge Shafts

In case, poorly permeable strata overlie the water table aquifer located deep below land surface, a shaft is used for causing artificial recharge. A recharge shaft is similar to a recharge pit but much smaller in cross-section.

B. Indirect Methods

1) ***Induced Recharge***

It is an indirect method of artificial recharge involves pumping water from aquifer, which is hydraulically connected with surface-water, to induce recharge to the groundwater reservoir. The greatest advantage of this method is that under favorable hydro-geological situations, the quality of surface-water generally improves due to its path through the aquifer materials before it is discharged from the pumping well.

Pumping Wells

Induced recharge system is installed near perennial streams that are hydraulically connected to an aquifer through the permeable rock material of the stream-channel. The outer edge of a bend in the stream is favorable for location of well site. The chemical quality of surface-water source is one of the most important considerations during induced recharge.

Collector Wells

For obtaining very large water supplies from river-bed, lake-bed deposits or waterlogged areas, collector wells are constructed. In areas where the phreatic aquifer adjacent to the river is of limited thickness, horizontal wells may be more appropriate than vertical wells. Collector well with horizontal laterals and infiltration galleries can get more induced recharge from the stream.

Infiltration Gallery

Infiltration galleries are other structures used for tapping groundwater reservoir below river-bed strata. The gallery is a horizontal perforated or porous structure (pipe) with open joints, surrounded by a gravel filter envelope laid in permeable saturated strata having shallow water table and a perennial source of recharge. The galleries are usually laid at depths between 3 to 6 metres to collect water under gravity flow.. Hence, choice should be made by the required yield followed by economic aspects.

*2) **Aquifer Modification Techniques***

These techniques modify the aquifer characteristics to increase its capacity to store and transmit water. Though they are yield augmentation techniques rather than artificial recharge structures, they are also being considered as artificial recharge structures owing to the resultant increase in the storage of ground water in the aquifers.

Bore Blasting

These techniques are suited to hard crystalline and consolidated strata. Through hydro-geological investigation, suitable sites are fixed where the aquifer displays limited yield that dwindles or dries in winter or summer months. All the blast holes reach the depth of the aquifer required to be benefited, whether unconfined or confined. All the charges of row or circle are exploded at a time.

Hydro-Fracturing

In many cases, blasting has given indifferent results. Hydro-fracturing is a recent technique that is used to improve secondary porosity in hard rock strata. Hydro-fracturing is a process whereby hydraulic pressure is applied to an isolated zone of bore wells to initiate and propagate fractures and extend existing fractures. The water under high-pressure break up the fissures cleans away clogging and leads to a better contact with adjacent water bearing strata

*3) **Groundwater Conservation Structures***

The water artificially recharged into an aquifer is immediately governed by natural groundwater flow regime. It is necessary to adopt groundwater conservation measures so that the recharged water remains available when needed.

Groundwater Dams / Underground Barriers

A groundwater dam is a sub-surface barrier across stream that retards the natural groundwater flow of the system and stores water below ground surface to meet the demands during the period of greatest need. The main purpose of groundwater dam is to arrest the flow of groundwater out of the sub-basin and increase the storage within the aquifer.

Fracture-Sealing Cementation Technique

Fracture-sealing cementation is a suitable water conservation measure in dry situations. The boreholes located on such zones prove productive but due to dissipation of the limited storage along preferred flow planes, in case of adverse topographical situation, these become dry by the end of winter or summer. This measure can also be used to prevent ingress of saline or polluted water from a known source.

Various combinations of surface and sub-surface recharge methods may be used inconjunction under favorable hydrogeological conditions for optimum recharge ofgroundwater reservoirs.

IV. ARTIFICIAL GROUNDWATER RECHARGE IN INDIA

A large percentage of artificial recharge projects are designed to replenish ground water resources in depleted aquifers and to conserve water for future use. Other such projects recharge water for various objectives such as control of salt-water encroachment, filtration of water, control of land subsidence, disposal of wastes andrecovery of oil from partially depleted oil fields. Thus, given the possibility of the available groundwater resources to be over-exploited in these areas, it is essential that proper storage and management of available groundwater resources be instituted.

Replenishment of groundwater by artificial recharge of aquifers in the arid and semi-arid regions of India is essential, as the intensity of normal rainfall is grossly inadequate to produce any moisture surplus under normal infiltration conditions. Although artificial groundwater recharge methods have been extensively used in the developed nations for several decades, their use in developing nations, like India, has occurred only recently. Techniques such as canal barriers, construction of percolation tanks, and of trenches along slopes and around hills, et cetera, have been used for some time, but have typically lacked a scientific basis (e.g., knowledge of the geological, hydrological and morphological features of the areas) for selecting the sites on which the recharge structures are located.

Various techniques for artificial groundwater recharge have been employed in the states of Maharashtra, Gujarat, Tamil Nadu and Kerala. In Maharashtra, studies were carried out on seven percolation tanks in the Sina and the Main River basins.In Gujarat, studies of artificial recharge were carried out in two areas. In the Central Mehsana area of North Gujarat, artificial recharge was carried out using injection wells, connector wells, and infiltration channels and ponds. Surplus groundwater from the floodplain aquifers of the major rivers in Mehsana area and tail end releases from the Dharoi Canal System were utilised as the water sources. In addition, the injection of water from the phreatic aquifers into the deeper, overexploited aquifers was investigated in the Central Mehsana area. In the coastal areas of Saurashtra, artificial recharge was carried out using injection wells and recharge basins.

Storm-water run-off and tail-end releases from the canal system of the Hiran Irrigation Project were used as the water sources, and the studies included an evaluation of the effectiveness of the existing tidal regulators and check dams, designed to limit the extent of seawater intrusion. Of the methods studied in the Central Mehsana area, spreading methods, using techniques such as spreading channels, recharge pits and ponds, were found to be more economical than injection methods, although dual purpose connector wells were found to be more economical for recharging the deep aquifer. The dual-purpose connector wells not only supplied water by gravity to the deep aquifer, but also abstracted water by periodic pumping, which reduced the extent of clogging of the wells. In contrast, the coastal Saurashtra area where the aquifers are highly porous and drain to the coastal zone, the rapid outflow of recharged water to the sea did not make artificial recharge a viable proposal. However, the tidal regulators that created barriers of freshwater along the creeks and in coastal depressions effectively prevented seawater intrusion in these areas. Also in Gujarat, studies of sub-surface storage were carried out. In the Jamnagar District, naturally occurring basaltic dykes were known to retain groundwater. In Tamil Nadu and Kerala, studies were carried out on nine percolation tanks in the semi-arid regions of the Noyil Ponani and Vattamalai River basins. Rates of percolation were as high as 163 mm per day at the beginning of the rainy season, but diminished thereafter mainly due to the accumulation of silt in the bottoms of the tanks. Periodic de-silting, therefore, was determined to be an essential element in the maintenance of these tanks. In contrast, sub-surface dykes of 1 metre to 4 metre in height were found effective in augmenting groundwater resources, particularly in the hard rock areas underlain by fractured aquifers.

Studies of artificial recharge using injection wells were carried out in the Ghaggar River basin, using canal water as the primary surface-water source. The injection rate was initially 43.8 litres per second at an injection pressure of one atmosphere. The pressure was increased to two atmospheres after 5 hours, and was kept constant thereafter, although the recharge rate gradually diminished to 3.5 litres per second after a few days. The reproducible recharge rate obtained using the pressure injection system was found to be about 10 times greater than the rate obtained using gravity flow. The increase in pressure during injection was due to clogging of the interstitial spaces within the aquifer, which can be minimized by careful control of the quality of source water. Periodic cleansing of well was also required, whenever the pressure increased beyond six atmospheres or showed a sudden rise. Further studies were conducted on induced recharge from the Ghaggar River using a well field, with individual wells spaced at 200-metre intervals, within 100 metre of the riverbank. As with the injection wells, periodic removal of the clay film deposited in the floodplain above the natural recharge areas of the aquifer was required to improve recharge efficiency.

Elsewhere in India, watershed management practices adopted in some states to minimize soil loss in erosion gullies also contribute to groundwater recharge.

V. EFFECTIVENESS OF THE TECHNOLOGY

Many artificial recharge experiments have been carried out in India by different organizations, and have established the technical feasibility of the artificial recharge of unconfined, semi-confined and confined aquifer systems. However, the most important, and somewhat elusive, issue in determining the utility of this technology is the economic and institutional aspects of artificial groundwater recharge. Experiences with full-scale artificial recharge operations in India and elsewhere in Asia are limited. As a consequence, cost information from such operations is incomplete. The available data, from certain hydrological environs in which recharge experiments have been initiated and/or are in progress, suggest that the cost of groundwater recharge can vary substantially. These costs are a function of availability of source water, conveyance facilities, civil constructions, land, and groundwater pumping and monitoring facilities (CGWB, 1994).

VI. ADVANTAGES AND DISADVANTAGES

The important advantages of artificial recharge are:

- Ithas no adverse social impacts such as displacement of population, loss of scarce agricultural land etc.
- The technology is appropriate and generally well understood by both the technologistsand the general population.
- It is environment friendly, controls soil erosion and flood and provides sufficientsoil moisture even during summer months.
- Groundwater recharge stores water during the wet season for use in the dry seasonwhen demand is the highest.
- The quality of the aquifer water can be improved by recharging with high-qualityinjected water.
- Recharge can significantly increase the sustainable yield of an aquifer.
- Recharge methods are environmentally attractive, particularly in arid regions.
- Most aquifer recharge systems are easy to operate.

- In many river basins, control of surface-water run-off to provide aquifer rechargereduces sedimentation problems.
- Results in energy saving due to reduction in suction and delivery head as a resultof rise in water levels.

- Disadvantages of artificial recharge are:
- There are a number of problems associated with the use of artificial recharge techniques. These include disadvantages related to aspects such as recovery efficiency (e.g., not all of the added water may be recoverable), cost effectiveness, contamination risks due to injection of recharge water of poor quality, clogging of aquifers, and a lack of knowledge about the long term implications of the recharge process. Hence, careful consideration should be given to the selection of an appropriate site for artificial recharge in a specific area.

VII. OPERATION AND MAINTENANCE

To ensure the effective and efficient operation of an artificial recharge system, a thorough and detailed hydrogeological study must be conducted before selecting the site and method of recharge. Periodic maintenance of artificial recharge structures is essential because infiltration capacity is rapidly reduced because of silting, chemical precipitation, and accumulation of organic matter. By converting the injection or connector wells into dual-purpose wells, the time interval between one cleansing and another can be extended, but, in the case of spreading structures, except for sub-surface dykes constructed with an overflow or outlet, annual de-silting is necessary. Unfortunately, because the structures are installed as a drought-relief measure, periodic maintenance is often neglected until a drought occurs, at which time the structures must be restored (the 5 to 7 year frequency of droughts, however, means that some maintenance does takeplace). Several agencies and individuals normally carry out structural maintenance.

VIII. CONCLUSION

- Artificial recharge of ground water should be licensed and controlled by competent authorities according to specific requirements laid down in an appropriate permit system that should be flexible to adapt to site-specific conditions. The question of ground-water exploitation should be clarified on a case-by-case basis, taking into account all relevant aspects, including ecological ones. The relevant regulations should establish the extent to which exemptions are allowed.
- Authorization for artificially recharging the aquifer should be granted only if the hydro-geological situation, environmental condition and the recharge-water quality permit injection, percolation or infiltration of water by artificial means into aquifers for storage and retrieval.
- Thus, there is a need for further research and development of artificial recharge techniques for a variety of conditions. In addition, the economic, managerial and institutional aspects of artificial recharge projects need to be studied further.
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