Artificial Groundwater Recharging In India

Vedavati R Pujari.[1] and V. V. Diwan[2]

[1]Walchand College of Engineering, Sangli—416415Email- vedavati.pujari@gmail.com,

[2]New Polytechnic, Uchangoan, Kolhapur - 416 005. Email- diwanvv@gmail.com,

Abstract

The various techniques used for the artificial recharge of groundwater aquifers proved to be effective in storing water for human use in all of the states of India, with the possible exception of the coastal zone, where the extreme porosity of the aquifer and its connection to the sea resulted in less water being available for harvest than was injected. In general, recharge was effective in minimizing water loss due to evaporation compared with similar surface storage systems.

Among the spreading methods, subsurface dikes are most desirable because they need little maintenance, safe, minimize evaporative losses and avoid many of the environmental problems arising from surface storage. There is also no loss of agricultural lands or forests by inundation as would occur behind a surface storage structure. In cases where channels are used for groundwater recharge, multiple benefits may be achieved by combining irrigation and infiltration channels in a number of river basins.

One of the main disadvantages of recharge structures such as ponds, trenches and percolation tanks, is that they require regular maintenance to avoid silting and subsequent clogging of the recharge basin. There is also the possibility of water logging in some areas due increased groundwater levels. Further, injection and connector wells are costly schemes requiring high order of quality control of the infiltration source water.

Introduction:

Technological developments in construction of open wells and pumping methods have resulted in the large-scale exploitation of groundwater not only in India but also elsewhere. In many parts of India, due to the variation in intensity of the monsoon and in the arid and semi-arid regions face the lack or scarcity of surface water. Dependence on groundwater has increased tremendously in recent years. There is high potential for controlling over-exploitation of groundwater resources. It is now essential that proper storage and management of available groundwater resources must be done.

Replenishment of groundwater by artificial recharge of aquifers in the arid and semi-arid regions of India is essential as the intensity of normal rainfalls 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 during the last ten to twenty years. Techniques such as N*alah* bunding, constructing percolation tanks, trenching along slopes and around hills etc. 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. For this reason, between 1980 to 1985, the Central Ground Water Board (CGWB) implemented a full-scale technical feasibility and economic viability study of various artificial recharge methods in the semi-arid and drought affected areas of Gujarat, Maharashtra, Tamil Nadu and Kerala. In Gujarat, detailed investigations were carried out (i) in the Central Mehsana area of North Gujarat where large-scale over-exploitation of groundwater has resulted in substantial declines in the water table during past three decades, and (ii) in the coastal areas of Saurashtra where overexploitation of groundwater has resulted in salt water intrusions into the aquifers. In Maharashtra, detailed studies of recharge of basaltic and alluvial aquifers using percolation tanks were carried out in the Sina and Man River basins. In Tamil Nadu and Kerala, similar studies were carried out in the Noyil Ponani and Vattamalai River basins, respectively.

Technical Description :

The CGWB survey identified a number of techniques commonly used for artificial recharge. Use of injection or connector wells are largely experimental while others such as surface spreading methods are actively used. The critical feature of the injection well technique is the selection of the aquifer to be recharged. The selection of sites for these recharge structures depends on the configuration of the deep (greater than 100 m depth) confined aquifers, the hydraulic gradient and the location of the source of excess surface water. As a thumb rule, it is always better to construct the structures close to water source to save on the cost of transportation of water to the recharge site and to minimize the potential lag time involved as a consequence of the slow rate of subsurface movement of groundwater. The actual designs of the injection wells and connector wells are not much different from those of the normal tube wells and depending upon the aquifer characteristics, slot sizes, casing sizes and gravel packing are to be selected. In contrast, groundwater recharge by spreading is best practiced in shallow (40 m to 100 m), unconfined or leaky aquifers. Several methods are commonly used. Channel spreading involves changing the pattern of the surface flow in the river channel using "L"-shaped levees (sand bunds), slowing the rate of river flow and increasing the channel length to provide more time for infiltration. However, in areas where rivers are ephemeral and prone to flash flooding, the application of this technique is limited as the levees are destroyed during the flash floods. More successful is the use of spreading channels which use artificial, unlined canals to recharge the groundwater reservoirs. The spreading channels have side slopes of 1:1 and very gentle floor gradient slowing the downstream movement of water, allowing time for infiltration and reducing erosive action of the water. These features make the structures relatively stable and limit the deposition of wind blown silt on sides of the canals. A variant of this technique is the use of contour trenching, which is better suited for use in hilly areas where surface runoff rates are very high. Planting of trees along contour bunds or trenches further helps to reduce surface runoff rates and soil loss due to erosion. A further variation of the surface spreading technique is the use of recharge ponds, percolation tanks, check dams, and subsurface dikes. These are the cheapest modes of artificial recharge.

However, the design of the recharge structure requires careful consideration to ensure the correct sizing of the pond both to provide sufficient recharge to meet abstraction demands and to adequately contain storm water runoff. For an average village with population of up to 500 persons, a 0.5 hector pond, with little water loss due to overflow, is sufficient to provide enough recharge to service the potable water requirements of a tube well-based water supply system. Where there is insufficient storm water runoff to fill the pond, water from the surrounding area should be diverted to the pond with minor trenches. In India, the subsurface dike is the most suitable structure for promoting groundwater recharge as it is safe from floods, needs no elaborate overflow devices and is least susceptible to silting. In addition, subsurface structures do not require extensive areas of land for their implementation and hence have minimal ecological repercussions following their construction. Since the entire structure is underground, evaporative losses are also insignificant. Two subsurface dikes of 100 m length each, within 300 m upstream and downstream of the water supply well, can capture and infiltrate enough water to service the potable water requirements of a village of up to 500 persons (if only one structure is constructed, it should be downstream of the well point, as the groundwater mound created by the barrier will also act as a subsurface barrier and capture groundwater flows from upstream of the well). Some arrangement for subsurface outflow from the dike is often desirable to avoid water logging. Check dams are the least desirable form of this technology and should generally be used only where the recharge requirement is very high or there is a need to control soil erosion. Check dams require a 300 mm to 600 mm wide concrete or brick masonry dike extending down to an impermeable base stratum or compacted foundation. In general, the sites selected for construction of ponds, tanks, dams and dikes are normally those where manual excavation is possible. Such sites are typically those that (1) have undergone intense weathering, and, as a result, have a high fracture porosity, or (2) are in alluvial areas which are best suited for infiltration.

Terracing and afforestation of hillsides which help to retain runoff and increase infiltration may also form part of an integrated basin-scale water resources development plan.

In India, an important factor in the design of artificial recharge structures is the consideration of their stability during probable, high flow storms during years of above average rainfall and occasional flash floods. Such structures should also be designed in such a manner as to minimize the accumulation of silt and organic matter within the structure. For example, the infiltration capacity of ponds is reduced by up to 25% each year as a result of silting and by the end of fifth year of operation is reduced to about 10% of the total storage. Thus, 90% of stored water is lost to evaporation. The Table bellow summarizes the relative suitability of the various types of artificial recharge structures for a number of typical applications.

Lithology	Topography	Type of Structure
Alluvial or hard rock	Plain area or gently undulating area	Spreading pond, subsurface to 40 m depth undulating area dike, minor irrigation tank, check dam, percolation tank, or unlined canal system
Hard rock down to 40 m depth	Valley slopes	Contour bunding or trenching
Hard rock	Plateau Regions	Recharge ponds
Alluvial or Hard rock with confined aquifer to 40 m depth	Plain area or gently	Injection well or connection well
Alluvial or Hard rock with confined aquifer to 40 m depth	Floodplain deposits	Injection well or connection well
Hard rock	Foot hill zones	Farm ponds or recharge trenches
Hard rock or alluvium	Forested areas	Subsurface dikes

Table-1:- Suitability of Artificial Recharge Structure for Common Water Resource Development Purposes

Extent of Use :

The techniques described above 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. The average recharge volume of these tanks was 50% of the capacity of the tank, provided the tank bottom was maintained by removing accumulated sediment and debris prior to the annual monsoon. Best results were obtained from systems located in areas of vesicular or fractured basalt. *Nalah* (stream) bunding where the recharge structure was situated within the course of the *nalah* was found to be most effective and economical as the surface area exposed to evaporation was on average 10% of that of an average-sized percolation tank. Within nalah bunds, the rate of infiltration varied from 50% to 70% of the capacity of the reservoir. Infiltration was aided by a connector well linking the phreatic, alluvial aquifer at 6 m depth with the deeper, confined basaltic aquifer at 63 m depth allowing the free flow of water by gravity from phreatic aquifer to the confined aquifer at the rate of 0.19 million m3/year. The water level in the phreatic aquifer which was saturated due to infiltration from the surface reservoir was 3 m below ground level and the piezometric level in confined aquifer was 30 m below ground level.

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/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, subsurface dikes of 1 m to 4 m in height were found effective in augmenting groundwater resources particularly in the hard rock areas underlain by fractured aquifers.

In Punjab, 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 43.80 Liters/sec at an injection pressure of one atmosphere (atm). The pressure increased to 2 atm after 5 hours, and remained constant thereafter, although the recharge rate gradually diminished to 3.5 Liters/sec after few days. The natural, gravity-controlled recharge rate was 5.1 Liters/sec. 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 source water quality. Periodic cleaning of well was also required whenever the pressure increased beyond 6 atm 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 m intervals within 100 m of the river bank. As with the injection wells, periodic removal of the clay film deposited in the flood plain above the natural recharge areas of the aquifer was required to improve recharge efficiency.

In the Central Mehsan area of North Gujarat, artificial recharge was carried out using injection wells, connector wells and infiltration channels and ponds. Surplus groundwater from the flood plain aquifers of the major rivers in Mehsana area and tail-end releases from the Dharoi Canal System were utilized as the water sources. In addition, the injection of water from the phreatic aquifers into the deeper, overexploited aquifers were 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 runoff 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. Out 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 which created barriers of freshwater along the creeks and in coastal depressions effectively prevented seawater intrusion in these areas.

In the Jamnagar District, naturally-occurring baslatic dikes were known to retain groundwater. However, it was also known that the surface soils in the District were not waterlogged. The studies indicated that while the lower portion of the dike acted as a barrier to the passage of groundwater, the top few meters of the dike, composed of fractured basalt, allowed the passage of groundwater through the soil profile, preventing water logging in the aquifer area. This design feature was subsequently incorporated into the specifications of subsurface dikes.

Elsewhere in India, watershed management practices adopted in some states to minimize soil loss in erosion gullies also contribute to groundwater recharge. Check dams not only store surface water during portions of the year, but also encourage infiltration into the shallow aquifers providing a threefold benefit to communities (i.e. prevention of soil loss, provision of water for livestock watering and human use and groundwater recharge). Such works have been implemented on an extensive scale in Gujarat, Maharashtra, Madhya Pradesh, and Rajasthan since 1960.

Operation and Maintenance :

Periodic maintenance of artificial recharge structures is essential because infiltration capacity is rapidly reduced as a result of silting, chemical precipitation, and accumulation of organic matter. In the case of spreading structures annual maintenance consists of scraping the infiltration surfaces to remove accumulated silt and organic matter. In the case of injection wells and connector wells, periodic maintenance of the system consists of pumping and/or flushing with a mildly acidic solution to remove encrusting chemical precipitates and bacterial growths on the well tube slots. By converting the injection or connector wells into dual purpose wells, the interval between periodic cleanings can be extended, but in the case of spreading structures except for subsurface dikes constructed with an overflow or outlet annual de-silting is a must. Unfortunately, because the structures are installed as a drought relief measure, the periodic maintenance is often neglected until a subsequent drought at which time the structures must be restored (the 5 to 7 year frequency of droughts however means that some maintenance does take place). Structural maintenance is normally carried out by several agencies and individuals. Maintenance of minor irrigation tanks is normally carried out by the state irrigation department, maintenance of contour bunds and trenches (along with related afforestation activities) by the state forestry department and maintenance of farm ponds and related structures by the cultivators.

Level of Involvement :

The recharge schemes and related land development activities primarily depend on the cooperation of the community and hence, should be managed at the local level. Hence from the basin management perspective, the division of a basin into many micro-catchments is an essential recognition of this community role. The achievements attained depend on public participation and active contribution to the projects, with any shortage of funds being overcome by the willingness of individuals to come forward, take over the management of the system and offer *Shramadan.* As the extent of a typical village averages 1000 to 1500 hectors, a micro-catchment of a similar area extent is ideal. In addition to the community level participation, many basin development projects, being multi-disciplinary schemes, involve the state irrigation and forestry departments, and the local cultivators.

Costs :

The costs of recharge schemes in general depend upon the degree of treatment of the source water, the distance over which source water must be transported, and stability of recharge structure and resistance to silting and/or clogging. In these studies, simple methodologies were developed to minimize costs by more steeply sloping the sides of the spreading structures to reduce the rate of silt accumulation, by packing gravel into recharge pits to avoid the collapse of the sides due to wave action of the stored water, by de-silting the source water using gravel beds within the infiltration channels or in sedimentation basins and by ensuring the placement of a proper gravel pack around a phreatic zone injection well to allow silt free water to enter deeper aquifers. The initial investment and operating costs are many times less than those required for supplying potable water using tankers. When the recharge systems are constructed by state governments as relief works, thereby eliminating the labour costs, the capital cost to the beneficiary community is further reduced. Combining technologies can also result in cost savings. For example, in Maharashtra, the capital cost of an hybrid, connector well-tank scheme was about Rs.45,000/-(the cost of the borehole) compared to the cost of a comparable percolation tank system needed to achieve a similar degree recharge (estimated to be about Rs.60,00,000/- & above.)

Conclusions :

The various techniques used for the artificial recharge of groundwater aquifers proved to be effective in storing water for human use in all of the states of India, with the possible exception of the coastal zone, where the extreme porosity of the aquifer and its connection to the sea resulted in less water being available for harvest than was injected. In general, recharge was effective in minimizing water loss due to evaporation compared with similar surface storage systems.

Advantages:-Among the spreading methods, subsurface dikes are most desirable because they need little maintenance, safe, minimize evaporative losses and avoid many of the environmental problems arising from surface storage. There is also no loss of agricultural lands or forests by inundation as would occur behind a surface storage structure. In cases where channels are used for groundwater recharge, multiple benefits may be achieved by combining irrigation and infiltration channels in a number of river basins.

Disadvantages: - One of the main disadvantages of recharge structures such as ponds, trenches and percolation tanks, is that they require regular maintenance to avoid silting and subsequent clogging of the recharge basin. There is also the possibility of water logging in some areas due increased groundwater levels. Further, injection and connector wells are costly schemes requiring high order of quality control of the infiltration source water.

Future Scope for Development of the Technology :

The use of this technology requires knowledge of the geological conditions, rock formations with moderate permeability are most desirable as low permeability limit storage volumes and high permeability do not allow adequate retention of the recharged water. The relative cost of recharged water also limits its application to augmenting domestic water supplies as it is not economically viable for irrigation purposes in India. There is vast scope for research on cost effective & low maintenance groundwater recharging methods all over the world. Participation of government agencies, cultivators and communities is essential for the success of scheme.

References :

Central Ground Water Board (CGWB)

Central ground water board ministry of water resources, guide on artificial recharge to Ground water (2000)

National Drinking Water Mission and Department of Rural Development 1989.

Rain Water Harvesting, Government of India, New Dehli.

Ravichandran S., Sathish Kumar S and Singh Leena.,(2011) ,Selective Techniques in Artificial Ground Water Recharge through Dug well and Injection well methods International Journal of ChemTech Research

Singh Leena and Ravichandran S., (2011), Studies on Estimative Methods and their Role in Artificial Ground Water Recharge, International Journal of ChemTech Research