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Artificial Recharge of Ground Water-State of Art

By

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Abstract : *Artificial recharge of ground water is one of a management practice. It is the practice of increasing by artificial methods the amount of water that enters an aquifer. The article reviews objective and advantage of a artificial recharge scheme. It can supplement the amount of artificial recharge to an aquifer, store water in aquifers for use during droughts, optimise water use, control saline water intrusion, check the large scale depletion in ground water levels on account of over-exploitation and improves water quality in an aquifer. It also discuses various geologic factors that control artificial recharge work and the several techniques in which artificial recharge is accomplished. The Scenario of world recharge experiments and those conducted in India in different geologic and geographic environment have shown that such schemes have been largely conducted in areas of ground water over exploitation. It is seen that recharge basins are by far the most widely adopted means of artificially recharging ground water. In India both infiltration basin and injection well methods have been experimented. The advantages af artificial recharge schemes are generally claimed to be economic.*

1. Introduction

Artificial recharge means replenishment of groundwater storage through works primarily provided for this purpose. Natural annual replenishment of ground water occurs very slowly. Exploitation in excess of replenishment causes declining ground water levels and may lead to situation of ground water mining if not appropriately controlled. Artificial recharge of ground water is thus becoming increasingly important in ground water management in meeting regional water requirements.

1.1 Purpose of Artificial Recharge

Purpose of artificial recharge has been to :

(i) Augment natural ground resource

(ii) Preserve it as long-term economic resource

(iii) Raise ground water levels to reduce pumping costs

(iv) Reverse declining ground water levels

(v) Combat adversity of sea-water intrusion

(vi) Combat and protect local saline water where caused by overdraft

(vii) Provide sub-surface storage to surface waters

(viii) Provide dilution of waste-water prior to reuse.

1.2 Advantage of Artificial Recharge

There are several advantages of storing water in underground reservoirs as listed below :

- Cost of recharge as compared to equivalent surface reservoirs is lower.
- Ground water storage has perfect horizontal availability and eliminates distribution works.
- Sub-surface storage is relatively free from evaporation losses.
- Immunity to degradation
- Not readily subjected to pollution.

In any ground water basin or management area, one or all of the above listed purposes and obvious advantages might be served by recharge operations. However, the methods used and recharge sites will vary with purpose. In case the natural recharge is reduced or is inadequate to balance withdrawals then artificial recharge is the only remedy to balancing ground water storage. Artificial recharge can thus be an effective tool in management of a ground water basin's resource. Benefits are, however, contingent upon varying geologic, economic, physical and political factors associated with management of an area.

2. Effect of Geologic Environment

The feasibility of artificial ground water recharge in a basin or water management area requires an understanding and analysis of the geologic nature and structures of the area. In ground water basin where aquifers are of alluvial orizin the recharge capacity is controlled by layering and granular nature of the material. The storage capacity of hard rock material is low but water can be transmitted over long distances through fissures and solution cavaties Intake rates for such rocks depend on gaining access to fissure net-work. Thus for an analysis of the value of artificial recharge in ground water basin management, the definition of physical boundaries, hydraulic function accessibility of ground water reservoir are always required. The Hydrogeologist is concerned with defining its geometry and continuity and geographic location relative to discharge and transmission requirements of the recharge sequence. The geologic environment that affects artificial recharge work are :

(i) Intake area

(ii) Sub-surface transmission to the point of discharge

(iii) Sub-surface storage at the point of discharge

In order to assess the potential value of recharge in a ground water basin the following points worth need to be mentioned.

(a) Origin of water bearing sediments.

(b) Characteristics and extent of sediments.

(c) Horizontal and vertical dimensions of ground water storage reservoir.

All the above listed factors are of paramount importance in the geologic context of a ground water basin under consideration for artificial recharge.

3. Hydrology of Artificial Recharge

In artificial recharge project the major concern is that of the availability and the distribution of surface and ground water storage, its development potential as well as its accessibility. The available of surface storage, the factor of surface water conveyance, ground water storage and ground water flow are important parameters which are required to be assessed before an artificial recharge of ground water on a basin-scale is manipulated.

The surface storage system are characterised by limited storage capacity, fast reaction time where as ground water storage reservoir has the great capacity and limited reaction time. The surface conveyance system provides high transmitting velocity and capacity and can be easily controlled whereas ground water transmission is extremely slow.

An ideal recharge hydrology system therefore uses surface conveyance to transmit source water to areas of ground water storage in the basin.

In view of the above it may be said that design and operation of recharge system should keep in view the following factors of hydrology.

(i) Possible sources of water recharge, its volume and time of availability.

(ii) The most efficient route of surface water source into ground water storage,

(iii) Procedures that would make most efficient use of available surface storage in combination with ground water storage in the basin,

(iv) Aquifer capacity for storage and transmission.

(v) Response of water table in the neighbourhood of proposed ground water recharge basins.

4. Artificial Recharge Techniques

In the techniques used for artificial recharge, two principle factors which influence infiltration are the increase in wetted area and the length of time where water is in contact with land surface. Water spreading is important commonly used method of artificial recharge whereby water is diverted from streams and surface reservoirs and spread over porous formation thereby increasing the wetted area.

Six general methods of artificial recharge are :

(i) Basins
(ii) Ditches or Furrows
(iii) Flooding
(iv) Stream channels
(v) Pits and Shafts
(vi) Injection wells

(i) Basins

In this method of recharge, water is impounded in the series of spreading tanks. The basin are so arranged that the flow of water from upper into the lower basins can be easily regulated following the ground surface contour. The objective of basins type approach is to obtain optimum ratio of wetted area to grass land area. The design of multiple basin should provide sufficient control for flow of water between basins. Basin method has advantage over other methods because its surface storage capacity can be used to even out fluctuation of the inflow.

(ii) Ditches or Furrows

Such methods use flat–bottomed ditches to transport water and provides opportunity for percolation. Ditches and furrows may follow the ground contour, could be tree-shaped or they may be laterals where the series of small ditches extend from the main canal. The maximum width of such ditches may be 2 m. depending upon a terrain. An advantage of ditch system is that the ratio of perimeter to wetted area is large thereby causing more lateral flow.

(iii) Flooding

The flooding simulates irrigation system in which water is allowed to release from high points to flow down-slope. Good results can be obtained by this method on gentle slopes. The infiltration rates with this method is higher than with other methods,

(iv) Stream Channels

This method involves increasing the amount of water that percolate to ground water in natural stream channels. The percolation is controlled by the factor of wetted area of the stream bed and the period of time the water is available for seepage. The another method of using beds of stream is by extending a low dam or weir across the bed where the stream width is large. This method is used extensively in southern California.

(v) Pits & Shafts

The Pits & Shafts excavated in relatively permeable formation is ideal for recharging ground water. The pits used for recharge may be abandoned or excavated sands and gravel querries. Shafts are used to limited extent unless silt free water is available.

(vi) Injection Well

The application of Injection Well is practiced in areas where surface spreading method is not feasible because of the presence of extensive thick impermeable beds overlaying principle aquifers. Such methods are economical in urban and Metropolitan Centres where land values are too high to permit use of basin or spreading methods. The gravel packed wells are known to operate very efficiently and require less maintenance than non-gravel packed wells. It is pertinent to quote examples from Manhattans Beach, California and Long Island Newyork. The water to be recharged should be supplied at constant pressure and should not be allowed to fall free into the well. In yet another example the Los Angles County, California successfully operated injecting wells as a part of experiments to ascertain the feasibility of creating and maintaining a fresh water mound to check sea water intrusion.

5. Water Quality

Water under goes chemical, physical and biological changes as it passes through the hydrologic cycle. The artificial recharge changes the character of water. The following studies are important in artificial recharge project.

(i) Physical characteristics affecting water quality.

(ii) Chemical constituents affecting water quality such as dominant cations and dominant anions.

(iii) Biological factors affecting water quality such as water micro-biology, soil-micro-biology:

(iv) Salt balance.

In the maintenance of the ground water quality a Geo-Chemist engaged in artificial recharge experiments must analyse water quality criteria important to Agriculture, Industry and domestic use in the basin. It is also important to know sources of possible water borne constituents that might affect water quality. Equally important are water treatment procedure which will maximise recharge rates through existing water sources. A yet another parameter of importance is the Salt-balance and the procedure to monitor it with the objective to optimise water balance efficiency of a basin.

6. Review of Artificial Recharge Experiments

Artificial recharge of ground water reservoirs with surplus surface run off and reconditioned waste waters is widely practiced in United States and Europe. In Australia, pits, bores and recharge weirs on stream are in practice.

The State of Art of artificial recharge in India, is in general, at an embroynic stage with traditional sources of check dams on streams being used. Of late water spreading & injection well methods have also been tested as pilot schemes.

In India, pilot project studies with UNDP assistance were carried out in Mehsana and Coastal Saurashtra in Gujarat State to examine Technical feasibility of artificial recharge to deplated aquifers and for control of salinity. In Mehsana area, decline of 1 to 2.5 metres per year in ground water levels was registered. The total decline from 1960 to 1980 was 10 to 18 metres. Both surface spreading and injection well experiments were carried out. Excess surface water from river Sabarmati was used for spreading experiments. In Kamliwara in Central Mehsana, Gujarat, injection technique was used employing ground water from the upper aquifer.

The degradation in water quality in coastal plain of Saurashtra is on account of contamination from Gaj formation. Chorwad and Maliya, in Coastal Saurashtra was studied using spreading and injection methods.

Artificial recharge experiments in Ghaggar river basin, India during 1976–78, examined feasibility of induced recharge to Kandi formation comprising boulders, gravel and sand. Dabkheri site in Kurukshetra, Haryana was found feasible from hydrogeological stand point for injection well recharge using Narwana Canal water.

Resource augmentation through suitably constructed sub-surface dykes in a narrow valley in hard rock region of Kerala proved an efficient method of augmenting ground water which resulted in raising double crop in the area.

Artificial recharge in Israel commenced in 1964 using surplus flood waters and pre-treated waste waters. Artificial recharge works are being implemented in USSR in arid regions with periodical surface flow, over highly urbanised centres and in mountainous regions.

Approximately 60 artificial recharge schemes are being implemented at water intakes in Rega, Kannas, Tbilisri, Novokuzhetsk, Kursk, Taskent, The Urals and Kazakhstan etc. During past ten years, in USSR, the problem of artificial recharge have been intensely studied. Strong emphasis is being given to large scale ground water development for irrigation and other uses in developing countries of India, Pakistan, Iran, Turkey, Egypt, Taiwan & Chile etc. As development procedures intensifies, increasing attention will need to be given to artificial recharge for replenishment of depleted ground water storage and control of water quality.

In United States of America, the use of fresh ground water supplies has fastly increased over the year. In California, for instance, it accounts for 48 percent of total water supply in use for various purposes. The increasing reliance on ground water has resulted in embarking upon artificial recharge of ground water particularly in Western United States.

Surface methods of artificial recharge using recharge pits are in practice at Peora, Illionois since 1951 to supplement industrial water needs. The pits are made in permeable sand and gravel aquifers and recharged by chlorinated water. Settling basins are used to filter suspended sediments from surface waters before effecting recharge.

As part of evolving humid zone water-management technology, artificial recharge practices are in vogue since 1933 using injection wells. The purpose of injection well experiments at Bay park, New York was to protect highly used ground water resource and to learn about the hydraulic and geo-chemical problems involved and the feasibility of injecting treated sewage into aquifer through deep injecting well structure. The experiments proved the feasibility of injecting treated sewage into the aquifer.

The artificial recharge project at Meadowbrook in Long Island was experimented to solve problems produced by increased urbanisation and excessive over-draft situation. The studies predicted a maximum rise of 3.35 to 5.18 m. of groundwater levels beneath the spreading basins.

Arizona Recharge project owe its experiments because of rapid urbanisation. In the Phonenix project, Arizona secondary effluents were used. This project is an example of how water of inferior quality could be used for irrigation so that the fresh water conserved thereby can be used for drinking water supply.

The Orange County area, California consists of local aquifer comprising sand and gravel and Talbert aquifer in the island portion of the plain under confined conditions. The water spreading from Santa Ana River over Orange County district commenced in 1933 and began use of imported water for the purpose in 1949. The ground water levels improved significantly by 1969. Recharge of ground water included both surface recharge to recharge low flows of local stream and well recharge to maintain sea-water intrusion barriers. Surface water recharge was unable to control sea water intrusion in coastal area. Composite recharge wells with injected imported water were able to protect multiple aquifers. The studies concluded that additional recharge basins will be required, and also recommended maintenance of sea water intrusion barriers along the coast. According to Richter and Chun, there were 276 active artificial recharge projects in California in 1958. Of these, the basin method constituted 149 projects or 54 percent of all projects. Stream bed percolation procedure was used in 15 percent, ditches and furrows in 8 percent, pits in 7 per cent, flooding in 4 percent and injection wells in 12 percent. Basin method handled 58.4 percent of all water reported to be recharged, stream bed 29.5 percent, ditch and furrow 9.4 percent, pit 1.3 percent, injection well 1 per cent and flooding 0.4 percent.

In Netherlands, since 1940, coastal sand dune aquifers are being recharged by Rhine river water. Operational recharge works are located at the Hauge, Amsterdam and in northern part of the Netherlands. The primary objective of recharge works is to improve water quality. Similar operations are in practice in Wiesbaden, West Germany along Rhine valley with the purpose of purifying Rhine river water to maintain ground water level at reasonable level for abstraction.

The recharge scheme of coastal aquifer in Israel aimed at building sea water pressure barrier, restore ground water elevations to safe levels and provide long term flow to Jordan river. In the Hefar valley, artificial recharge is practiced to prevent sea water intrusion and in southern coastal plain, it is conducted to store storm water and flash flood waters. In all the recharge schemes In Israel, water artificially recharged is fresh as it is obtained from river flows as well as from limestone aquifers. Most common problems noticed is that of logging of injection wells in coastal aquifers.

A survey of artificial recharge experiments carried out in the World over reveal that leading aim of such schemes was replenishment of overdrafted ground water reservoir. Among other objectives are establishing the drought period pumping at higher rate, improvement of water quality by natural infiltration, fresh water barrier against sea water intrusion, flood control and injection of industrial effluents. Regarding Recharge methods as related to prevailing geologic situation, it is seen that injection devices used for artificial recharge in decreasing order of practice in case of alluvial formation include wells, basins, basins & wells, canals, basins and canals, inverted drainage sprinkling and basins, canals & wells. Such an order for consolidated formations such as limestone is wells followed by basins; for sandstone formations it is wells, basins, basins & wells and for volcanic rocks, it is wells, basins & wells.

A scenario of World artificial recharge experiments in different geo-climatic and geographic environment is given in table 1. Most experiments so far carried out pertain to fluvial and fluvo-glacial environments.

Table 1 : Scenario of World Artificial Recharge Experiments

Region		Geography	Climate	Reservoir Type	Problem	Methods of Artificial Recharge
1		2	3	4	5	6
1.	Baltezers Water works, Latvin Soviet Socialist Republic (Baltic Sea)	Glacial plains	Temperate, humid	Alluvium and moraine deposits	Over-draft	Recharge basins
2.	Barcelona area, Spain, Mediterranean	Coastal Plain	Mediterrarean	Deltaic sediments	(i) Lowering of water levels in deeper aquifers. (ii) Water quality degradation	Storage of excess flood waters
3.	Birsfelden, Basel, Switzerland	Fluvo-glacial plain	Temperate, humid	Glacial, Gravels & sands	Over-draft : drought situation	Infiltration basins
4.	Algeria, Sahara	Alluvial valley	Semi-arid	Alluvial-fill	Over - exploitation in excess of recharge	Infiltration by flooding
5.	Eastern Coast, Queonsland, Australia	Delta with many river channels	Temperate	Alluvial deposits	(i) Extractions in excess of long-term safe-yield (ii) Sea water intrusion.	Construction of wear on tidal-inlets; diversion of runoff from catchment.
6.	Eastern Shore of Mediterrarean Sea, Israel	Coastal plain	Semi-arid Mediterrarean type	Sedimentary	(i) Over-exploitation (ii) Elimination of sea water intrusion.	Storage of excess flood water from rivers; extraction wells for recharging
7.	Eastern Balkans, Danube river valley, Romaia Balgaria	Alluvial valley	Temperate	Alluvial fill in older rocks/	Water losses through evaporation and under-flow.	River water flooding.
8.	Rhone River Valley, France	Broad Alluvial Plain	Mediterrarean	Gravel and Sand	To increase water supply.	Find water of Rhini injection boreholes (vertical wells) pre-packed.

1	2	4	3	5	6
9. Kaunas, Lithunian S.S.R.	Flow plain in the valley of Neris River	Temperate, humid	Alluvium	To supplement water supply	Infiltration basins.
10. Rhur, Germany	Valley of Lippe	Temperate, humid	Alluvium, overlying thick sand layers	(i) Maintaining direction of flow towards Lippe. (ii) Over-exploitation (iii) Purification of water for artificial recharge	Infiltration basins,
11. Tokyo Metropolitan area, Kwanto, Japan	Kwanto Coastal Plain	Humid, temperate	Alluvium	Over-draft	Injection well.
12. Kalano, Island of Oahu, Hawai	Mid-ocean volcanic cone	Sub-tropical	Basalt	Controlling movement of salt water inland and upward in humid zone area.	Retention of storm surface run-off.
13. Stockhome, Sweden	Fluvio-glacial alluvium	Humid, Cold	Sand & Gravels	Thermal regulation and improvement of physico chemical characteristics.	Storage and natural infiltration of surface water.
14. Atlantic coast, U.S.A.	Long Island	Temperate	Gravel, silt, sand	(i) Declining ground water levels. (ii) Sea water intrusion (iji) Contamination of Groundwater	Injection well Method, Wing Treated water.
15. Gujarat, India	Mehsana	Semi-arid	Sand & Silt	Declining water levels	(i) Spreading method. (ii) Injection well method.