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Prospects of Artificial Ground Water Recharge in India

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Ground water has become an important source of water for agricultural, domestic, and industrial needs of the country. However, due to adoption of high-water demanding cropping system, growth of industries, and increasing population, the exploitation of ground water has increased many folds in the past decades. The ground water development was intensive in the alluvial areas of Indo-Ganga-Yamuna plains of Punjab, Haryana, U.P. and Rajasthan, which accounted for more than 85% of utilizable ground water potential. The overexploitation has also been observed in parts of hard rock terrains of southern states, viz. Tamil Nadu, AndhraPradesh and Karnataka. Looking into the increasing demand of water in the years to come, it has become imperative to adopt appropriate ground water recharging techniques, which are safe and sustainable. This is possible, if every drop of water available from rainfall and surface runoff is harnessed and conserved properly. Before planning for any ground water recharge project, it is necessary to study the need, feasibility and scope of recharge, existing hydro-geologic conditions, and suitable recharging techniques in the region. In the present paper, various recharging techniques designed and evaluated under several case studies conducted in different parts of the country have been discussed. These case studies and discussion will help the planners and policy makers in taking decisions regarding appropriate recharging techniques suitable for various geological conditions prevailing in our country.

INTRODUCTION

Out of rain, surface and ground water resources, the latter one is very precious and natural reliable resource for assured and timely water supply to meet the requirement of agriculture, domestic and industrial sectors. The area irrigated by ground water resources has increased five times during the past four decades. The share of ground water in irrigation sector has also increased to more than 50% as on today. As per the National Water Policy, development of ground water resources is to be limited to utilization of the dynamic component of ground water, which is replenished annually. The dynamic resource has been assessed as 43.189 million ha m. After making a provision of 7.093 million ha m for domestic, industrial, and other uses, the available ground water resource for irrigation is assessed as 36.096 million ha m. Though, based on norms of Ground Water Estimation Committee, the level of ground water development is only around 35% and still a large volume of replenishable ground water resources are available for future use, but in number of areas, high stage of ground water development has been registered. About 7.5% of the area of the country is over exploited, i.e. the quantum of withdrawal has exceeded the annual replenishable recharge. The over pumping of ground has led to local declines of 2 to 4 m in ground water levels in many places. Therefore, the importance for the augmentation of available ground water resources by altering the natural condition of replenishment is being felt day by day. Chauhan and Upadhyaya (1998) categorized ground water recharge in three forms as (i) recharge due to rainfall, (ii) recharge due to irrigation and return flows, and (iii) artificial recharge. The first two recharging processes occur naturally, whereas in the

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third case one has to think about certain man made interventions or artificial means of recharging ground water. Artificial recharge assumes its importance in augmentation of ground water storage, conservation of surface runoff in subsurface aquifers, preventing evaporation losses from surface water reservoirs by diverting a part of ground water, improving the quality of ground water as well as prevention of saline water intrusion in coastal areas.

NEED FOR ARTIFICIAL RECHARGE

As per CGWB's National Report on "Ground Water Resources of India", 249 blocks/ mandals/ talukas/ watersheds fall under 'over-exploited' category (utilization > 100 %) and 179 blocks/ mandals/ talukas/ watersheds fall under 'dark' category (utilization > 85% but <100%) in 12 states of the country viz. Uttar Pradesh, Bihar, Andhra Pradesh, Madhya Pradesh, Tamil Nadu, Kerala, Karnataka, Maharashtra, Gujarat, Rajasthan, Haryana, and Punjab. In such areas, declining water levels necessitates deepening of existing abstraction structures thereby increasing cost of pumping and quality deterioration etc.

Ground water levels have also shown more than 4 m decline on long term basis in parts of Uttar Pradesh (24 districts), Bihar (2 districts), West Bengal (1 districts), Assam (4 districts), Orissa (2 districts), Andhra Pradesh (6 districts), Madhya Pradesh (22 districts), Tamil Nadu (10 districts), Karnataka (11 districts), Maharashtra (1 district), Gujarat (7 districts), Rajasthan (26 districts), Punjab (9 districts), and Haryana (12 districts) for premonsoon season. The main reasons for lowering of ground water table are: (i) increased area under irrigation, (ii) diversification of cropping systems towards more water requiring crops, (iii) improper management of surface water resources, which force the farmers to utilize ensured ground water, (iv) deficit available water resources, and (v) over-draft of ground water for agriculture, industrial and domestic uses. The decline in water levels has resulted in failure of wells/ tubewells, shortage in water supplies, increase in pumping costs and higher energy consumption. Unscientific development of ground water in some coastal areas in the country has led to landward movement of sea water-fresh water interface resulting in contamination of fresh water aquifers. Problem of salinity ingress has manifested in Minjur area of Tamil Nadu and Mangrol-Chorwad-Porbandar belt along Saurashtra coast. This has rendered a number of tubewells out of use. Shallow wells in Pondicherry Region east of Neyveli Lignite Mines have started yielding saline water due to salinity ingress. With decline of ground water salinization is increasing and ground water quality is deteriorating. In all such areas it is necessary to develop strategies for artificial recharge of ground water on large scale.

ARTIFICIAL GROUNDWATER RECHARGE TECHNIQUES

Artificial recharge is the process by which the groundwater reservoir is augmented at the faster rate than natural replenishment by putting excess runoff water into the aquifer itself. Aquifers best suited for artificial recharge are those, which absorb large quantity of water and do not release too quickly i.e. the vertical hydraulic conductivity is high while the horizontal hydraulic conductivity is low or moderate. The factors, which must be considered in selecting the proper location of sites for artificial recharge are: (i) geological structure of ground water reservoir, (ii) pattern of pumping draft, (iii) movement of water within the water table, (iv) surface soils and substrata including antecedent moisture conditions, thickness and the nature of the unsaturated zone, (v) water supply source, turbidity and quality, and (vi) social and economic considerations.

The artificial recharge techniques can be broadly categorized in four groups as : (a) Direct surface techniques, (b) Direct subsurface techniques, (c) Combination of surface and subsurface techniques, and (d) Indirect techniques. Direct surface techniques include (i) Flooding, (ii) Basins or percolation tanks, (iii) Stream augmentation, (iv) Ditch and furrow system, and (v) Over irrigation. Direct subsurface techniques include (i) Injection wells or recharge wells, (ii) Recharge pits and shafts, (iii) Dug well recharge, (iv) Bore hole flooding, and (v) Natural openings, cavity fillings. Basin or percolation tanks with pit shaft or wells is an example of combination of surface and subsurface techniques, whereas induced recharge from surface water source and aquifer modification are the indirect techniques of artificial recharge. Besides above, the ground water conservation structures like ground water dams, roof top rainwater harvesting and rainwater runoff harvesting, subsurface dykes or locally termed as Bandharas, are quite prevalent to arrest surface or subsurface flows. Similarly in hard rock areas rock-fracturing techniques including sectional blasting of boreholes with suitable technique has been applied to interconnect the fractures and increase recharge.

SCOPE OF ARTIFICIAL RECHARGE IN INDIA

India has varying hydrogeological situations. The potential areas having favourable hydrological and hydrogeological conditions for creation of subsurface storage in different parts of the country are: (i) Himalayan Intermontane valleys such as Doon valley, (ii) Mountain fronts, (iii) Foothill alluvial tract of North Gujarat and Satpura mountain front, (iv) Cavernous limestones, and (v) Consolidated formations of Peninsular India. A brief description of such situations is given below.

Doon Valley

In Doon valley, highly permeable boulders and gravels provide a good scope for artificial recharge of ground water reservoir. Surface water spreading techniques like flooding, ditch and furrow, recharge basins and stream modifications are feasible.

Mountain Fronts

Sub-montane region of the Himalayas fringing the Siwalik hills, termed as Bhabar or Kandi is a steeply sloping belt of less than 10 to 30 km width, extending discontinuously from Jammu and Kashmir to Assam. The Bhabar Tarai belt in Uttaranchal and Kandi-Sirowal tract in Jammu outer plain and Bist Doab in Punjab offer an excellent set up for mega recharge projects.

Foothill Alluvial tract of North Gujarat and Satpura Mountain Front

The Satpura and Aravalli mountain front has a large potential for artificial recharge from surplus monsoon runoff, which would benefit alluvial aquifers in the southern part of the Purna and Tapi basins and deeper aquifers of North Gujarat area.

Cavernous Limestones

The cavernous limestone tracts in drought prone areas like Kurnool, Cuddaph and Anantpur district of Andhra Pradesh, Raipur, Durg, Rajnandgaon, Bastar districts of M.P., Yavatmal district of Maharashtra and Bilara, Jodhpur district of Rasjasthan are favourable for ground water recharge. An appropriate combination of check dams and percolation ponds are suitable recharge structures in these areas.

Consolidated formations of Peninsular India

In Peninsular India, most of the basins have more than 80 % of the area under these formations. In the Deccan Trap basalts, presence of thick weathered residium, vesicular horizons, fractured or faulted zones and inter trappean beds offer possible storehouse for recharge. Integrated watershed management is very effective for conserving and augmenting ground water resources in these environments.

ARTIFICIAL RECHARGE PRACTICES IN INDIA

Construction of Percolation tanks, Check dams, Subsurface dykes, Underground Bandharas, Infiltration Galleries and different types of Weirs besides Watershed management and rainwater harvesting through other traditional methods etc. have been prevalent in various parts of the country especially in the state of Maharastra, Andhra Pradesh, Karnataka, Madhya Pradesh and Rajasthan. Experiments for recharge through injection wells/recharge wells, hydro fracturing of borewells has also been attempted. A brief review of case studies and experience gained in various part of the country is presented below.

Chandra Sekharan and Shivanappan (1980) selected some 15 percolation ponds in red and black soil areas of Coimbatore for ground water recharge. It was found that water level on the down streamside was rising more by 1 to 1.5 m. About 15 and 20 wells got benefited by single percolation pond. The zone of influence was 10 to 20 ha.

Mohan (1980) suggested use of surplus monsoon water in river Ganga at Hardwar for developing and augmenting rice irrigation. In the process the recharge to ground water increases, which can be used for Rabi crop.

Mathur (1983) carried out artificial recharge studies in Ghaggar river basin. In the induced recharge studies in Kurukshetra it was established that if exploitation by creation of well fields is carried out, a substantial quantity of surface flow from river can be recharged to ground water. It was also found at Dabkheri site that recharge through injection wells at the rate of 57.7 lps or even more is feasible and the process can be continued even for 15 days.

While studying ground water recharge options in Gujarat, Sharma (1987) reported that ground water can be successfully recharged at 4500 m^3/day, 900 lpm and 733m^3/day by adopting injection well techniques, injection recharge using siphon method, and spreading method, respectively.

Sikka *et al.* (1998) mentioned significant lowering of ground water levels in most parts of the Delhi during past two decades and suggested de-watering and refilling of unconfined aquifer system underlying the Yamuna flood plain, roof top rain water harvesting, construction of small check dams at favourable locations, recharging through on-channel storage of water, recharge structures such as dugwells and village ponds.

Taneja and Sondhi (1998) also emphasized the need of recharge in Punjab where water table is declining at the rate of 23 cm/year in sweet water zones of the state. According to them excess water available in rivers, drains and as surface runoff from land should be recharged into the aquifer. Recharge measures suggested to be undertaken are: (i) recharge from east and west beins (drains flowing in Doab region and ending in river, (ii) recharge from existing drains, (iii) construction of water harvesting tanks in villages, (iv) recharge through fields by raising bunds around rice fields, (v) recharge through wells, (vi) construction of check dams on streams in kandi areas of state, (vii) use of treated sewage water, and (viii) recharging through canal network during monsoon.

Khepar *et al.* (1998) reported that there is a great potential for artificial recharge through the drainage system in Punjab. A case study conducted at Rohti drain revealed that by constructing series of check structures across the drain at suitable intervals and provision of recharge shaft under specific hydrological conditions enhanced the recharge capacity of drains.

Raju (1998) pointed out that in the state of Gujarat there are thousands of tanks including minor irrigation projects, which are either defunct or their capacity has reduced due to silting. He suggested that top priority should be given to revive these structures. In the areas having deep water table, percolation ponds with recharge tubewells are suggested, whereas in the rivers of North Gujarat subsurface dykes for artificial recharge may be appropriate. Das (1993) reported that injection well method appears to be more practical in recharging deeper confined aquifers in Central Mehsana area of Gujarat.

Bagade (1998) studied the possibility of artificial recharge in Maharashtra state and suggested that for the high rainfall area along Western Ghats, roof top harvesting of rainwater and construction of recharge pit and spring development is the most feasible recharging technique. In alluvial areas of Tapi river basin artificial recharge through construction of spreading basin, recharge shafts, injection wells, and dug wells has been proposed. In the areas with over development of ground water in unconfined or semi-confined aquifer, contour bunding, nala bunding or gully control, and percolation tanks etc. are recommended. In over-exploited deeper confined aquifers, bore hole injection technique to provide direct access to the deeper aquifers is recommended.

Jain and Jain (1998) studied the possibility of artificial recharge in Nagpur city, Maharashtra and found that artificial recharge through recharge wells using surface runoff has immense scope for implementation keeping in view the land use and hydrogeological setup. It is one of the most effective alternatives for mitigating the pollution observed in ground water of the city.

Sharma and Mehta (1998) concluded that in hard rock basaltic terrain of Maharashtra construction of cement plugs or check dams on first and second order streams is the best method to augment the ground water reservoir. The percolation tanks are feasible in high reaches of watershed where natural depressions to store surplus water are available and the submergence area is underlain by highly weathered and fractured rocks.

Rao *et al.* (1998) reported that both in red soil and black soil areas of Andhra Pradesh, the rainwater harvesting structures (check dams) with storage capacity in range of 0.02 to 0.134 mcft contributed to additional ground water recharge, rise in water levels and improvement in well yields.

Thambi *et al.* (1998) reported that subsurface dykes are ideal ground water storage structures for Kerala, particularly along the higher elevations where wells go dry during the summer. Since individual land holding is very small, subsurface dykes can be beneficial when it is accepted for community irrigation projects.

The above case studies indicate that while planning for artificial recharge in the area, one should not only consider the hydrogeological conditions of the area but the economics of recharge option also. If the benefits exceed cost incurred in recharging and transmission layer upto aquifer exists, only then one should select the particular recharge option and that area for recharging.

CONCLUSIONS

Artificial ground water recharge is necessary to control: (i) the declining ground water levels, (ii) over-exploitation of ground water resources, (iii) sea water intrusion, and (iv) degradation of ground water quality. There are various regions in India, where ground water levels are depleting very fast and need attention of planners for developing some control measures. In order to maintain equilibrium between availability and withdrawal of ground water suitable and economical recharge techniques need to be adopted. There is a large scope of ground water augmentation through artificial recharge in different hydrogeological terrains of the country. Case studies and experiences on recharging under various hydrogeological conditions in different parts of the country and abroad are available. These experiences should be used as guidelines for developing appropriate strategies for artificial recharge.

References

Bagade, S.P. (1998), Artificial Recharge Techniques in Different Hydrogeological Environments in the State of Maharashtra. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. IV-45-57.

Chandra Sekharan, D. and Shivanappan, R.K. (1980), Case study Recharging Ground Water in Coimbatore District, Proc. 3rd Afro Asian Regional Conference ICID, New Delhi, pp. 228-237.

Chauhan, H.S. and Upadhyaya, A. (1998), Water Conservation through Watershed Management: Ground Water Recharge and its Efficient use. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. II-57-65.

Das, S. (1993), Hydrogeological Considerations for Recharging Coastal Aquifers. Proceedings of Workshop on Artificial Recharge of Ground Water in Coastal Aquifers, Bhubaneswar, March 27-28, 1993, pp. 1-34.

Jain, S.K. and Jain, P.K. (1998), Rainwater Management for Ground Water Recharge in Urban Inhabitation-A Case Study for Nagpur City, Maharashtra. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. V-55-65.

Khepar, S.D., Sondhi, S.K., Siag, M. and Chawla, J.K. (1998), Need and Scope for Artificial Recharge of Ground Water through Surface Drainage Systems in Punjab. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. IV-117-128.

Mathur, O.P. (1983), Artificial Recharge Studies in the Ghagger River Basin Haryana, Proceedings of Seminar on Assessment Development and Management of Ground Water Resources, New Delhi, April 29-30, 1983, pp. 317-324.

Mohan, J. (1980), Water Management in Eastern Ganga canal. Proceedings 3rd Afro Asian Regional Conference, ICID, New Delhi, pp. 195-208.

Raju, K.C.B. (1998), Case study of Ground Water Recharge in Gujarat State, India. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. IV-25-43.

Rao, P.B., Prasad, P.S. and Ahmed, S.I. (1998), Techno-economic Feasibility of Artificial Recharge Studies in Different Geomorphic unit of Anantapur District of Andhra Pradesh, India. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. VI-7-15.

Sharma, S.C. (1987), Artificial Recharge of Ground Water in Gujarat. Proceedings of First National Water Convention, New Delhi, pp. III45-50.

Sharma, S.K. (1998), Management Techniques in Artificial Recharge. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. II-1-10.

Sharma, S.K. and Mehta, M. (1998), Artificial Recharge for Ground Water Sustainability in Basaltic terrain-A Case History. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. VI-29-48.

Sikka, V.M., Singh, S.B., Chakraborty, D., Mohiddin, S.K. and Singh, D. (1998), NCT of Delhi – A Test Field Area for Artificial Recharge Studies. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. I-31-46.

Taneja, D.S. and Sondhi, S.K. (1998), Need, Scope and Measures for Artificial Ground Water Recharge in Punjab. Proceedings of Seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. I-63-71.

Thambi, D.S., Subbaraj, A., Bhowmick, A.N. (1998), Techno-economic Feasibility and Performance Evaluation of Ground Water Storage (Artificial Recharge) Structures in Kerla. Proceedings of seminar on Artificial Recharge of Ground Water, New Delhi, Dec. 15-16, 1998, pp. VI-17-28.