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Recovery Efficiency of An Aquifer Storage and Recovery (ASR) Experiment from Saline Aquifer under Controlled Conditions

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Abstract

Present work was carried out in an experimental model developed at the institute, sand was used as prototype artificial aquifer and was saturated with highly saline water having Electrical Conductivity (EC) equal to 8500 µS/cm. Fresh water with average EC = 467.50 µS/cm and temperature = 25°C was injected in the known amount in the saline water and this water was extracted at a fixed time interval of 1, 1.5, 2, 2.5, 3, 3.5, 4, 4, 8 24, 48, 72, 96, 120, 144, and 168 hours in a cumulative time of 735.30 hours with average recovery efficiency of 63%. Recovered water has salinity equal to or less than 1000 µS/cm. Although, this experiment was carried out at a small scale but this can be tried at a bigger scale for skillfully managing the surface or reclaimed water in problematic areas where demand exceeds the supply.

Article History

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Keywords

Aquifer Storage and Recovery;
Experimental Model;
Fresh Water;
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Recovery Efficiency;
Saline Water.

Introduction

Groundwater, a precious dynamic renewable natural resource of earth, is essential for the sustenance of the human life and plays an important role in economic and social progress of a region. During last 4-5 decades ever increasing demands and climate change impacts not only affected availability of this resource in terms of quality and quantity[1,2] but also led to variability in space and time.[2] Salinity and its intrusion in the fresh water aquifers is the most common groundwater contamination problem in coastal areas as well as in arid and semi-arid regions of the world.[3,4,5,6,7,8,9,10] Aquifer Storage and Recovery (ASR) system can prove to be important technique for seasonal, durable and future storage of this resource[3,4] mainly at the time of its inaccessibility due to contamination, water losses, natural disaster and other unexpected conditions. ASR depends

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on hydro-geological feasibility determined by soil and sub-surface characteristics which are related to percolation rates, porosity, permeability, water quality and connecting recharge zones.[11] Some of the important aquifer characteristics[12] are: type, permeability, thickness, storage, pore type, uniformity, groundwater redox and chemistry. Keeping in view above issues, an experiment was carried out at National Institute of Hydrology Roorkee in an experimental model fabricated under World Bank funded, Mewat Purpose Driven Study (PDS) under National Hydrology Project with an aim to recover fresh water from injected saline water and to assess recovery efficiency.

Material and Methods

This experiment was conducted in an experimental model having dimensions: length 125 cm, width 58 cm, height 153 cm (Fig. 1). Two Self-Prime Regenerative Pumps were used for injecting and extracting water. For conducting the experiment, saline solution of concentration 8500 µs/cm was prepared from sodium chloride (NaCl) salt. EC and temperature were measured with EC meter (Eutech). 100 litres of this salt solution with temperature 25°C was inserted in sand of size ranging between 0.075 to 1.00 mm till saturation. Sand is kept in an experiment model for prototype artificial aquifer. The sand with volume of 0.479 m^3 was filled to mid-section upto height of 66 cm. After saturating the sand with saline water, fresh water was injected and simultaneously recovered at a certain time interval of 1, 1.5, 2, 2.5, 3, 3.5, 4, 4, 8 24, 48, 72, 96, 120, 144, and 168 hours. The cumulative hours are 768.30.

The freshwater carrier pipe was connected to the freshwater tank above experiment model to maintain the gravity flow (Fig. 2). 60 litres of freshwater with average EC 467.50 µs/cm and average temperature 24.91°C was injected through the freshwater carrier pipe which was regulated through a tap. Two pipes were fixed upto the bottom of the sand bed. The recovery pipe was connected to the pump with the chuck valve in between to retain water in the pipe (fig. 2).

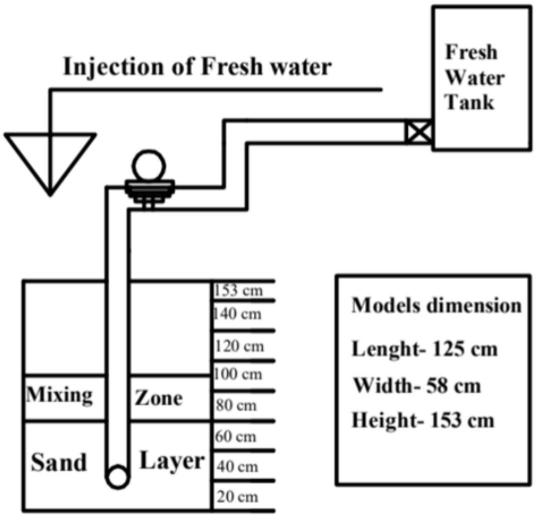

Fig. 1. Experimental model layout.

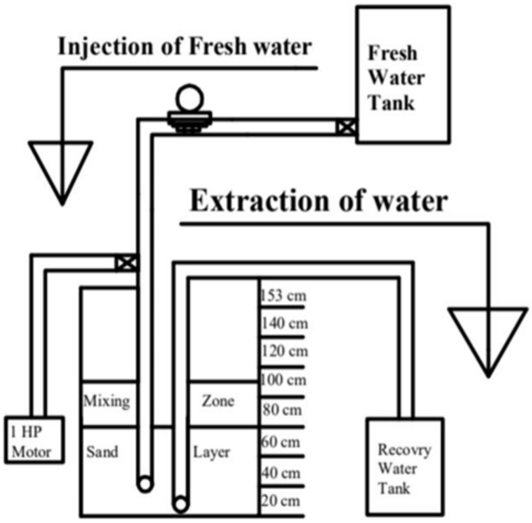

Fig. 2: Experimental model layout.

The water was pumped out through the recovery pipe and stored in the cylindrical tank having dimensions (length, bredth, width: 43cm*48cm*24 cm). The recovered water sample was taken in the 50 ml beaker for recording temperature and EC. Water is pumped from the recovery pipe and there are chances of mixing between the freshwater pocket and saline water in the sand due to the suction pressure. Performance of this ASR experiment was quantified by calculating Recovery Efficiency (RE) as volume recovered/volume injected * 100.

Results and Discussion

The electrical conductivity (EC) and temperature of saline water was maintained 8500 µS/cm and 25°C, respectively for the experiment period. Statistical summary of measured parameters, recovered volume and efficiency is given in Table 1. EC of injected freshwater was found in the range of 320–580 µS/cm with an average value of 467.50 µS/cm and temperature ranged from 21.1°C – 31.7°C with an average value of 24.91°C. EC of recovered was found in the range of 830– 7200 µS/cm with an average value of 1664.05 µS/cm and temperature ranged from 21.1°C – 31.7°C with average value of 24.91°C. An average of 60 litres freshwater was injected and a volume of recovered water ranged between 22 to 55 litres with an average value of 36.88 litres. Recovery efficiency (RE) ranged from 40 to 90.42 % with an average of 62.75%. Generally, RE is always less than 100 and mechanisms involved are mixing in the subsurface - density-gradient driven convection, dispersion and diffusion, rate-limited mass transfers etc.[13,14] Kimbler *et al.,* (1975)[13] also stressed on that the RE can be increased but with more contaminations.

Table 1: Statistical summary of measured parameters, volume of water injected/recovered and recovery efficiency

	Temperature (°C)		EC (µS/cm)		Volume (litres)		Cumulative Time (Hrs.)	Recovery efficiency (%)
	Fresh water	Recovered water	Fresh water	Recovered water	Injected	Recovered		
Min	21.10	21.90	320.00	830.00	40.00	22.00	1.00	40.00
Max	31.70	29.80	580.00	7200.00	70.00	55.00	735.30	90.42
Mean	24.91	24.96	467.50	1664.05	60.00	36.88	90.92	62.75
S. D.	2.56	1.72	35.97	1449.54	6.31	7.79	161.09	12.47

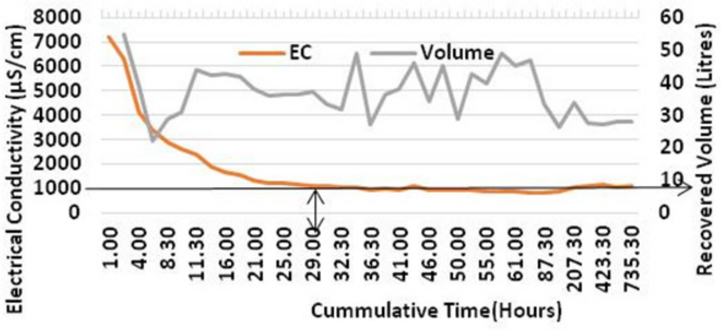

Fig. 3: Variation of EC and temperature during 735.30 hours of experiment

Variation of EC and temperature with the time is shown in figure 2. It is evident from figure 3 that EC of the recovered water was recorded below 1000 µS/cm after 29 hours. This might be due to mixing reaction of saline and fresh water and EC found almost constant after 30 hour to 735.30 hours. The resultant EC suggests that the concentration of recovered water is less than 12% of saline water concentrations which are in agreement with Kimbler *et al.,*[13] where the EC of recovered water should be equal to or less than 10%.

Conclusions

Experiment was conducted under controlled conditions to assess recovery rates from saline aquifer. Recovery efficiency of 63% was found with EC of recovered water equal to or less than 1000 µS/cm after 29 hours of experiment. Aquifer storage and recovery is found to be a significant, suitable tool for water resource management and might act as a hydraulic barrier in saline environments. There is a need to test the experiment under field conditions on a bigger scale to test its fresh water yielding potential.

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Conflict of Interest
The authors do not have any conflict of interest.

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