A Method for Evaluation of Artificial Recharge Through Percolation Tanks Using Environmental Chloride

by B. S. Sukhija, D. V. Reddy, M. V. Nandakumar, and Rama[1]

Abstract

For meeting the growing demand on ground water in hard rock areas of India, man-made percolation tanks have become important structures for augmenting ground-water recharge. Keeping in view their increasing number and cost involved in their construction and their temporal variation in percolation due to silting or desilting operations if undertaken, it is vital to develop proper methodology to evaluate the performance of these structures. A method employing the mass balance of environmental chloride in the tank has been developed for this purpose. The results obtained using this method at one experimental site indicate that an average of 30-35% of impounded water is recharged through this structure situated in granitic gneissic terrain of a semiarid region of India. The remainder is lost through evaporation. The method developed is simple, inexpensive, and sensitive enough to observe the temporal variation in the recharge rate through such tanks.

Introduction

About two-thirds of India, comprising Southern Peninsular and Western India, is underlain by hard rocks consisting of granites, gneisses, charnockites, basalts, etc. This land mass receives most of its rainfall during June to September. The pulsed nature of the rainfall, the low infiltration rate in soil, and the poor storage underneath result in a large runoff component. The net recharge to ground water in such environs is usually only a few percent of the average total rainfall (Sukhija, 1978; Sukhija et al., 1996). A continued increase in population has resulted in greater agricultural and industrial growth in recent times. This has only been possible by greater ground-water exploitation, leading to continued decline of the water table. Dug wells usually go dry in early summer, thus there is a need for artificial recharge. Of the various possible artificial recharge methods in Peninsular India, percolation tanks are currently the most popular. A percolation tank impounds the water of a monsoon stream behind a small earthen dam (Figure 1) with the hope that water collected in this tank during the rainy season will recharge the ground water until infiltration and evaporation exhaust the entire collection of the tank. Typically, there are a number of wells on the downstream side of the percolation tank (Figure 1), which are expected to be recharged by the water that has infiltrated in the bed of the tank. The construction cost of a medium size percolation tank is about half a million rupees (about U.S. $15,000). Thousands of such tanks are constructed every year. As no reliable and practical method is available to evaluate their performance in recharging the ground water, the opinion has sometimes been expressed that the "percolation tanks" are merely "evaporation tanks." In view of the large monetary investment being made, it is vital to develop a reliable, simple, and inexpensive method for evaluating the performance of these tanks.

In this paper, we describe the development of a method based on a series of environmental chloride measurements in the tank water. The results from a pilot experimental study encompassing two consecutive years are presented here.

Previously two methods have been utilized to evaluate the performance of the percolation tanks in India: the water balance method and the environmental stable isotope and/or radiotracer method. In the former approach, the water level in the tank is monitored and the changes are ascribed to the sum total of evaporation and percolation. Evaporation is either computed from a handful of meteorological data or estimated from measurements of an evaporimeter installed at a meteorological sta-

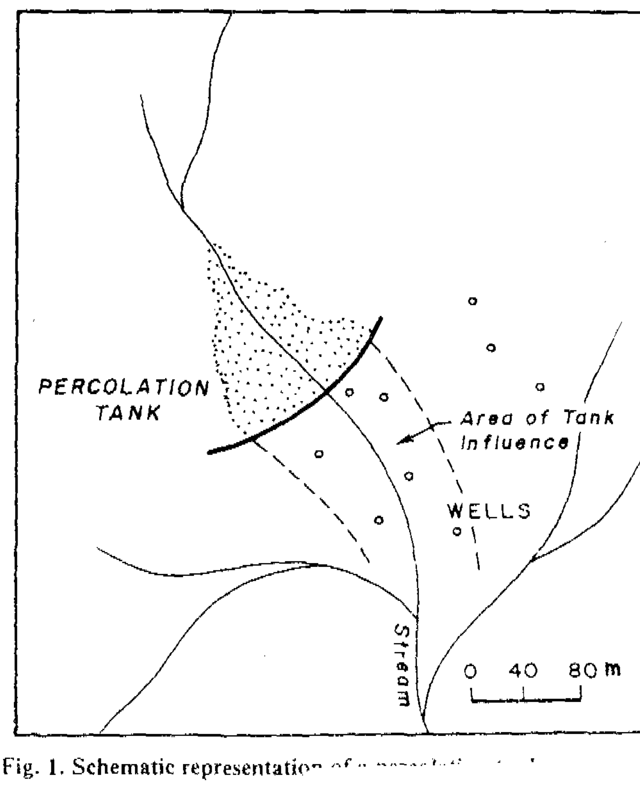

Fig. 1. Schematic representation of a percolati...

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Table 1. Progressive Four Week Percolation Fraction Estimated Using the Environmental Chloride Method and Water Balance Method for the Singaram Tank

	Chloride method			Water balance method			
Starting date	*Tank water cu. m*	*Cl conc. mg/l*	*Percolated fraction (1 − f)*	*Water column loss, cm*	*Evaporation (cm)*	*Percolation (cm)*	*Percolated fraction (1 − f)*
25-Nov-92	3219	13.3					
02-Dec-92	2879	14.2	—	—	—	—	—
09-Dec-92	2564	15.5	0.25	16.5	7.0	9.5	0.58
16-Dec-92	2328	16.5	0.26	15.0	7.1	7.9	0.52
22-Dec-92	2214	17.5	0.34	14.0	7.4	6.6	0.47
29-Dec-92	1999	18.5	0.38	14.0	7.9	6.1	0.44
05-Jan-93	1801	19.5	0.49	15.5	8.5	7.0	0.45
12-Jan-93	1621	20.6	0.49	15.0	10.3	4.7	0.32
19-Jan-93	1455	21.5	0.43	20.0	10.4	9.6	0.48
26-Jan-93	1337	22.6	0.21	20.0	10.5	9.5	0.48
08-Feb-93	1018	27.0	0.21	22.0	11.6	10.4	0.47
15-Feb-93	895	33.0	0.15	24.0	9.5	14.5	0.60
22-Feb-93	726	37.1	0.13	19.5	10.5	9.0	0.46
03-Mar-93	603	44.0	0.24	20.0	12.4	7.6	0.38
18-Mar-93	514	48.4	—	—	—	—	—
15-Mar-93	416	58.6	—	—	—	—	—

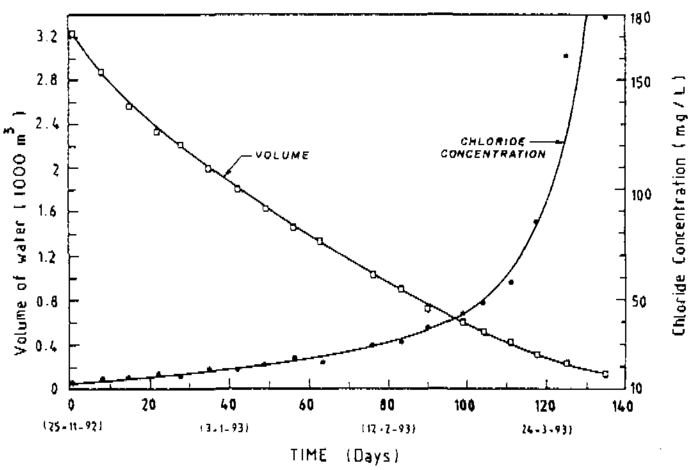

Fig. 5. Volume of water in the tank and chloride concentration as a function of time.

vs. time, and the measured weekly chloride concentration are shown in Figure 5. Similar to the water level curve, for the first three months following impounding, the increase in the chloride concentration with time is approximately linear. Later, when the quantity of water in the tank becomes meager, the concentration increases many folds. A smooth curve is drawn through the available data for the period November 1992 to February 1993. Most of the recharge from the tank has taken place during this period. High chloride concentration is evident after 90 to 110 days. This is largely due to the fact that the volume of water in the tank has reduced considerably (~750 cu. m compared to about 3500 cu. m initially, and evaporation amounts to progressively larger volume fractions.

Table 1 shows the weekly chloride concentration along with the total quantity of water in the tank on that day. These two measured quantities form the basis of equation (1). Progressive four week percolation fractions are calculated and shown in Table 1. The four week interval was chosen so that the change in chloride concentration was sizable and accurately measurable. The method, therefore, is applicable only if dry spells last for more than a month (which happens to be the case in most parts of India, where dry spells last for months). The progressive percolation fraction shows time variation (Table 1), i.e., maximum percolation fraction during December-January, when the evaporation rate is expected to be minimum. Minimum percolation fraction is discernible in the month of February when the evaporation rates are higher.

The second half of Table 1 shows the results obtained using the conventional water balance technique. Here the percolated fraction is obtained from the loss of water level in the tank minus evaporation during the same period (evaporation loss is directly obtained from the evaporimeter data collected at Hyderabad Airport station of Indian Meteorological Department).

Based on the abvove methodology, average percolation fractions and percolation rate (average of seven weeks) were also worked out for 1993-94 and compared for the corresponding weekly average (Table 2).

The analysis of percolation data (Table 2) shows that the percolation rates, as determined using chloride method for 1993-94, show a falling trend very conspicuously when compared with

Table 2. Seven Week Average Percolated Fractions and Volumes for the Singaram Percolation Tank

	Percolated fraction				Percolated vol. (cl method) m^3	
	1992-93		1993-94			
Time period	*(1)**	*(2)**	*(1)**	*(2)**	*1992-93*	*1993-94*
25 Nov. to 15 Jan.	0.34	0.53	0.24	0.44	543	439
3 Dec. to 22 Jan.	0.37	0.49	0.13	0.43	526	230
10 Dec. to 29 Jan.	0.40	0.47	0.37	0.55	490	843
17 Dec. to 5 Jan.	0.41	0.47	0.24	0.53	537	515
24 Dec. to 12 Feb.	0.32	0.47	0.19	0.50	422	362
1 Jan. to 19 Feb.	0.33	0.50	0.23	0.48	420	421
8 Jan. to 26 Feb.	0.27	0.49	0.12	0.50	323	270
Average	0.35	0.49	0.22	0.49	466	440

(1)* Using chloride method; (2)* Using water balance method.

the corresponding time period of 1992-93. Such a variation is not observed using the water balance method. The reduction in percolation rates can be expected due to siltation of the tank. Furthermore, unlike as in the case of the chloride method, the water balance method does not indicate any significant time variation (seasonal or annual). The water balance method must make use of questionable evaporation data (measured by evaporimeter at the meteorological observatory). The chloride method, on the other hand, evaluates evaporation and recharge using directly measured quantities with some valid assumptions. Thus, the latter can be considered more reliable.

As we can see from Tables 1 and 2, the average monthly percolation fraction of the tank volume is about 30-35% using the chloride method and about 50% using the water balance method.

Conclusions

Percolation tanks are being constructed extensively in India with the hope of recharging the ground water artificially. It is vital to develop appropriate methods to estimate recharge to ground water through these tanks. We demonstrated the use of environmental chloride to estimate the recharge through the tanks to ground water. The method developed is simple, inexpensive, and practical, and provides authentic measured recharge rates at various stages of silting (and desilting) of the percolation tanks.

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