Studies on Borewell Recharge through Filter Bed using Runoff Water in Eastern Dry Zone of Karnataka

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ABSTRACT: Recharge of defunct borewells through filter bed was studied for 4 years from 2011-12 to 2014-15 at 3 locations using five defunct borewells with base line discharge ranged between 0 and 126.6 lpm at UAS, GKVK, Bengaluru and Hosapalya village, Nelamangala Taluk, Bengaluru rural district, Karnataka. The discharge rate at 15 days interval after the treatment was recorded. The results showed that over the study period of 4 years, the average discharge rate of borewells 1 to 4 with filter bed treatment was higher in rainy season but lower in summer season and *vice-versa* (46.8 and 138.0 lpm, respectively) in case of borewell-5. The physico-chemical component values of recharge water of borewells with filter bed recharge system of pH ranged between 8.59 and 7.44, conductivity between 31.00 and 858.00 µs/cm, chloride 63.9 – 92.3 mg/l, sodium absorption ratio 5.59 – 10.70, sulphate 124.8 – 172.8 mg/l and residual sodium carbonate between 0.16 and 1.44 mg/l showing suitability for drinking purpose.

Key words: Borewell recharge, runoff, filtration beds, rain water harvesting

Water crisis as a result of climate change though altered annual rainfall and river flow regimes, affected the groundwater recharge rate. Prevention of stress on ground water can be made possible by way of recharging the ground water through scientific watershed management.

In order to augment the depleting ground water resources, it is essential to conserve and recharge the surplus monsoon runoff that flows into the sea. Ground water storage that could be feasible has been estimated as 214 Billion Cubic Meters (BCM), of which 160 BCM is considered retrievable. The Central Ground Water Board (CGWB) has prepared the master plan in 2013 for artificial recharge of ground water for all the states in the country. Out of total geographical area of 3287263 sq. km. of the country, an area of 448760 sq. km. has been identified feasible for artificial recharge. The total quantity of surplus monsoon runoff that can be recharged, works out to be 36.4 BCM. The master plan envisages around 39 lakh artificial recharge and water conservation structures in the country at an estimated cost of ₹ 24500 crores (Anon., 2013).

The depletion of ground water on one side and its quality deterioration on the other side are equally vexing. Pollution of ground water due to external contaminants produced by industrial, urban and agricultural activities is quite well documented (Bhatnagar and Sharma, 2001). Over-exploitation of ground water can lead to lowering of ground water levels besides increasing total dissolved solids (TDS).

A major problem encountered in developing ground water resources in hard rock areas is the sharply declining ground water levels leading to the formation of over-exploited pockets. Borewells drilled in hard rocks often become unproductive as the weathered / partly weathered rocks as well as the shallower water bearing fracture zones progressively become desaturated. In such areas, borewells are drilled too deeper over the years with the hope of encountering deep fracture zones leading to mining of ground water, since there is no replenishment of the deep fracture zones taking place.

In order to counter the over-exploitation of hard rock aquifers, the concept of rainwater harvesting and artificial recharge to the ground water system has lately caught the imagination of technocrats dealing with water resources as well as by the public. It is well known that artificial recharging of aquifers has in many cases resulted in a remarkable recovery of ground water levels locally in the vicinity of artificial recharging structures, at least in the first few years of their construction. Artificial recharging is becoming increasingly necessary to ensure sustainable groundwater supplies to satisfy the needs of growing population. The important advantages of artificial recharge are subsurface storage at no cost, negligible evaporation losses and higher biological purity with minimum temperature variations (Bhalerao and Kelkar, 2013).

The rain water harvesting and recharging of borewells by using runoff water is gaining importance under dryland areas because of reduced rainfall, increased intensity and depleted ground water level. In order to rejuvenate the defunct/ low yielding borewells, they are treated with runoff filtration beds to enhance the ground water level and improve the water yield. Selecting suitable site for recharge is most important for successful implementation. It needs a due consideration of intake capacity and ability to transmit water in to the groundwater zone. By using preliminary well survey and hydrological studies, borewells were selected and the filter system was evaluated for discharge. Hence, the present investigation was carried out over years by selecting defunct borewells.

Materials and Methods

During 2011-12, the experiment was carried out for two low yielding borewells of 150 mm diameter at GKVK farm, Bengaluru which were lying idle. Borewell-1 is located near horticulture farm. During *kharif* 2012-14, the experiment was set up under NICRA project at Hosapalya, Nelamangala Taluk, Bengaluru rural district to record the impact of recharging by feeding the runoff water to the failed low yielding borewell-2 with filter bed. During 2014-15, the experiment was set up at National Seed Project, GKVK for recording discharge rate of borewell-3, borewell-4 and borewell-5 from August 2014 to February 2015.

The detailed specifications and locations of all the borewells were indicated in Table 1. The catchment area, discharge rate and the approximate runoff considering the catchment, rainfall and runoff events were calculated before the diversion of runoff water to the filter bed.

Design aspects of recharging of borewell in filter bed system

A pit of 3 m x 3 m x 2.9 m dimension was excavated in the region centering the casing of the borewell. At the bottom of the pit, filter holes were made to a casing pipe and mosquito mesh was fixed tightly such that the casing pipe will function as a filter (Ramachandrappa *et al.,* 2013). Then different layers of filter bed system were laid as per the the following specification and diagrammatically indicated in Figure 1.

- The first layer of pit was filled with big sized boulders from the base up to a height of 1.2 m depth, accounting 10.8 m^3 volume.

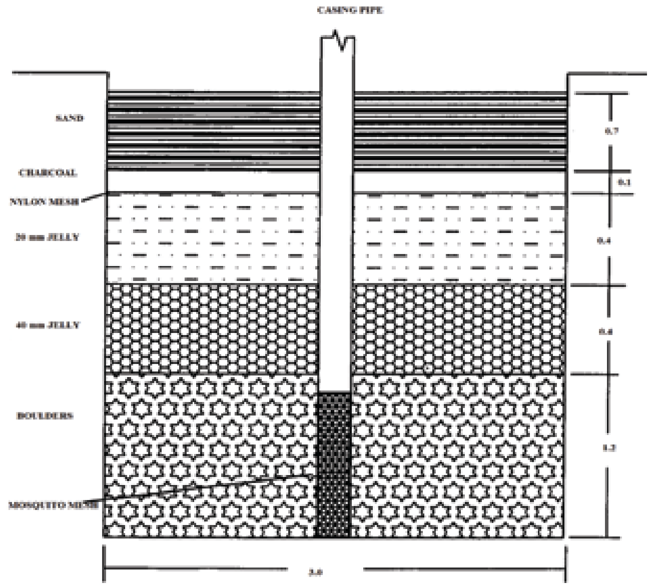

Fig. 1 : Schematic diagram of borewell recharging with different layers (all the units are in meters)

- The second layer of 0.4 m height was filled with jelly stones of 40 mm size, accounting for a volume of 3.6 m^3.
- The third layer comprises 3.6 m^3 volume of 0.4 m height jelly stones of 20 mm size.
- The fourth layer was layed with nylon mesh and filled with charcoal of 0.1 m depth and 0.9 m^3.
- The fifth layer was filled with sand of 0.7 m depth and volume 6.3 m^3.
- The remaining space of 0.1 m was left as a gap for ponding water.

Table 1 : Specifications of recharging of borewells by using runoff water

Particulars	Borewell No.1	Borewell No.2	Borewell No.3	Borewell No.4	Borewell No.5
Location of the borewells	Near Horticultural farm	Hosapalya Nelamangala	National Seed Project, GKVK, Bengaluru		
Depth of borewell (m)	45.2	76.2	259.0	228.6	182.8
Discharge at the time of installation (lpm)	126.6	0	0	96.0	24.0
Capacity of pumps	5 HP	5 HP	5 HP	5 HP	5 HP
Type of pumps	Multi stage submersible				
Filter dimensions	Length – 3 m Width – 3 m Depth - 2.9 m	Length: 3.00 m Width : 3.00 m Depth : 2.9 m	Length: 3.00 m Width : 3.00 m Depth : 2.9 m		
Catchment area (ha)	15	1	1.2	1.6	2.4
Diversion of runoff (cu.m)	~20,000	~ 5,000	~ 10,000	~ 12,000	~ 15,000

The runoff water from the catchment was diverted to the pit for artificial recharging. The rainfall and runoff events were recorded in the respective locations adopting standard procedure (Table 2). After completing the filling of filter bed recharge pit, observation on borewell yield was recorded at 15 days interval by collecting water in a measuring tub per unit time and the discharge was calculated by adopting standard procedure outlined by Michael and Ojha (2014). The correlation between the rainfall during different months of study and that of borewell discharge was computed as per the procedure indicated by Gomez and Gomez (1984).

In order to study the ground water quality, samples of ground water were collected and analyzed for physico-chemical parameters *viz.,* pH (measured with the help of pH meter which is standardized with pH buffer nos. 4, 7 and 9.2), electrical conductivity, residual sodium carbonate, SAR, sulphur and chloride by adopting standard procedure (Jackson, 1973). Samples collected for physico-chemical analysis in poly propylene plastic bottles were collected and analyzed in chemical laboratory within 6 hours of their collection.

Table 2 : Rainfall, runoff, rainy days, rainfall events

Year	Borewells	Rainfall (mm)	Runoff	No. of rainy days	No. of runoff events
2011-12	Borewell-1	804.5	39.73	61	28
2012-13	Borewell-2	442.0	-	26	-
2013-14	Borewell-2	651.0	14.47	36	36
2014-15	Borewell-3,4 and 5	992.3	91.05	54	38

Rainfall and its distribution

During 2011-12, the rainfall received at Dryland Agriculture Project, GKVK, Bengaluru was 804.5 mm in 61 rainy days. During 2012-13 and 2013-14, the rainfall received in NICRA Project, Hosapalya, Nelamangala was 442.0 mm and 651.0 mm in 26 and 36 rainy days, respectively. During 2014-15, the rainfall received at National Seed Project, GKVK, Bengaluru was 992.3 mm in 54 rainy days (Table 2). The cost of different components of filter bed was accounted to workout the cost of implementation prevailed during the study period. The unit cost estimates of different components are set out in Table 3.

Table 3 : Unit cost estimates of borewell recharging (₹)

Materials	Price (₹)
Bolder (10.8 m^3)	6,000=00
40 mm Jelly (3.6 m^3)	2,000=00
20 mm Jelly (3.6 m^3)	2,500=00
Sand (6.3 m^3)	4,500=00
Charcoal (0.9 m^3)	2,000=00
Mosquito mesh	300=00
Excavation charges	1,500=00
Labour charges	500=00
Total ₹	19,300=00

Table 4 : Yield of borewell (with filter bed) after recharging at Dryland Agriculture Project, UAS, Bengaluru

Months	2011-12		
	Borewell No.1		
	Rainfall(mm)	Discharge (lpm)	
June-2011	30.0	69.0	Rainy season 56.7 lpm
July-2011	95.8	60.9	
August-2011	253.2	58.9	
September-2011	59.7	66.3	
October-2011	122.6	57.0	
November-2011	38.0	44.1	
December-2011	5.2	41.1	
January-2012	0	37.3	Summer season 32.9 lpm
February-2012	0	32.4	
March-2012	0.4	28.8	
Mean		49.6	

Results and Discussion

During 2011-12, the discharge rate of a borewell-1 recorded at every 15 days interval after implementing recharge treatment was 56.7 lpm in rainy season while it was 32.9 lpm in summer (Table 4). The correlation between the rainfall during different months and the discharge was found non-significant. It is clearly established that the rain water infiltrated in to soil needs time to percolate into the ground water aquifer. Timely good rains is mostly utilizable for replenishing the moisture in the surface layer which might be severely exposed for evaporation losses during summer. The runoff generated during these initial rainfall period helps for saturation of the rhizosphere and later rains largely recharge the aquifer.

The discharge rate of a borewell-2 with filter bed during 2012-13, was on an average of 9.7 lpm over the year and in the rainy season, the average discharge rate was 11.9 lpm while 7.1 lpm in summer season (Table 5). The discharge rate was increased with the advancement of monsoon and declined towards its cessession. During 2013-14, the average discharge rate of borewell-2 with filter bed was 9.5 lpm over the year, 10.7 lpm in the rainy season and 7.9 lpm in summer season (Table 5). Rainfall and discharge showed significant and positive correlation (r= 0.637). Similar results of improved borewell yield with artificial recharge pit were reported by Shivakumar (2006). Reddy and Khybri (2008) conducted similar type of study and observed that the groundwater level in the open wells and borewells started rising from June till the end of September and later declined during first week of October. The increased discharge rate with artificial recharge was ascribed to improved ground water resources as the diverted water is least subjected for evaporation losses. The water stored with infiltration of rain water and percolation into groundwater helped in pumping the reserved water. Agarawal and Soni (2005) worked on different types of filter using sand, pebbles, charcoal aggregates, cotton cloth, nylon mesh, etc. as porous media. This study focused on performance of developed filtering units available, which can be used as integral part of rainwater harvesting for groundwater recharge.

Table 5 : Yield of borewell (with filter bed) after recharging in NICRA Project, Nelamangala

Months	2013			2014			Mean (2 years)	
	Borewell No.2			Borewell No.2			Borewell No.2	
	Rainfall (mm)	Discharge (lpm)		Rainfall (mm)	Discharge (lpm)		Rainfall (mm)	Discharge (lpm)
January	0	7.6		0	7.5		0	7.6
February	0	7.9		0	7.8		0	7.9
March	8.0	5.8	Summer season 7.1 lpm	10.0	8.3	Summer season 7.9 lpm	9	7.1
April	29.0	7.6		25.5	7.8		27.25	7.7
May	81.0	6.6		81.4	8.1		81.2	7.4
June	110.0	15.1		92.0	8.1		101	11.6
July	97.0	9.7		80.8	9.5		88.9	9.6
August	73.0	12.4		116.4	10.4		94.7	11.4
September	162.0	14.9	Rainy season 11.9 lpm	128.4	11.2	Rainy season 10.7 lpm	95.2	13.1
October	56.0	*		428.2	12.4		242.1	12.4
November	35.0	11.2		28.6	12.3		31.8	11.8
December	0	8.0		1.0	11.2		0.5	9.6
Mean		9.7		Mean	9.5		Mean	9.7

*Pump under repair

During 2014-15, the discharge rate of borewell-3, 4 and 5 recorded from August 2014 to February 2015 was on an average of 234.0 lpm, 180.0 lpm and 62.0 lpm over the year, respectively (Table 6). During rainy season the average discharge was 250.8 lpm, 181.2 lpm and 46.8 lpm while during summer, it was 192.0 lpm, 177.0 lpm and 138.0 lpm, respectively. Yield of borewell-3 had significantly positively correlated with rainfall (r = 0.7677*) but, non significant positive correlation was observed between rainfall and yield in borewell-4 (r = 0.5528). Several studies also indicated that watershed development activities have significant impact on groundwater recharge and hence, policy focus must be for the development of water harvesting structures (Palinisami and Suresh Kumar, 2005; Chandrakanth and Nagaraj, 2006). Maximum yield of such wells particularly in the Beltola and Odalbakra areas reveal that water can be drawn at the rate of 80 cu.m/hr for six to eight hours daily (Devi, 1998 ; Konwar, 2004).

The physico-chemical properties of borewell water are presented in Table 7. The pH of borewell water samples

Table 6 : Yield of borewells (with filter bed) after recharging in National Seed Project, UAS, Bengaluru

Months	Rainfall (mm)	Discharge (lpm)			
		2014-15			
		Borewell-3	Borewell-4	Borewell-5	Discharge (lpm)
August-2014	110.6	216	144	48	Rainy season Borewell-3 = 250.8 Borewell-4 = 181.2 Borewell-5 = 46.8
September-2014	128.2	252	168	42	
October-2014	428.2	294	222	42	
November-2014	28.6	246	180	36	
December-2014	1	246	192	66	
January-2015	10	192	168	138*	Summer season Borewell-3 = 192.0 Borewell-4 = 177.0 Borewell-5 = 138.0

* Earlier the yield of the Borewell-5 at the time of installation was very less and later on it picked up well and the increased yield was noticed in the month of January

** Pump under repair

Table 7 : Chemical composition of recharge water of borewells through runoff water

Borewells	pH	Electrical Conductivity (µs/cm)	Sodium Absorption Ratio	Residual Sodium Carbonate (mg/l)	Sulphates (mg/l)	Chloride (mg/l)
Bore well No.2	7.44	58.00	10.70	0.16	124.8	92.3
Bore well No.3	6.79	51.00	8.59	0.34	163.2	85.2
Bore well No.4	6.59	31.00	8.66	1.44	172.8	85.2
Control	7.64	58.00	9.23	0.80	177.6	63.9
WHO (1992)	9.2	-	-	-	400	250

ranged between 6.59 and 7.44 which could be used safely while in control it was 7.64 which required treatment for further use. pH is an important parameter which determines the suitability of water for various purposes. If the water has pH less than 7, it may cause tuberculation and corrosion while higher the values may produce incrustation, sediment deposits and difficulties in chlorination for disinfection of water. In their study, the pH in all the sampling locations was found to be neutral (Jai Paul *et al.,* 2015). The conductivity of water in the entire borewell ranged between 31.00 and 58.00 µs/cm and could be used safely. The chloride content of the borewell water was low while in control it was very low. The sodium absorption ratio of borewell water samples was found in the range of 8.59 – 10.70. The sulphate content of the water ranged between 124.8 and 172.8 mg/l except borewell-4 while, the residual sodium carbonate content ranged between 0.16 and 1.44. The residual carbonate content in the borewell-4 was 1.44 which requires some management attention for usage. As per the WHO standards, the water from recharged borewell can be used for drinking purposes as it contained lesser chlorides and sulphates and neutral in pH (Jayasree, 2002).

Conclusions

The runoff water diverted from the catchment area to recharge pits of the defunct / low yielding bore wells resulted in increased discharge rate. The incremental discharge rate was greater during the advancement of monsoon and was lower towards the cessation of monsoon season.

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