Research Article

Effectiveness of Artificial Recharge Structures in Enhancing Groundwater Quantity and Quality

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Abstract

Artificial recharge is a technique used to prevent over exploitation of groundwater resources. An artificial recharge structures are practiced in the hard rock regions of Tamil Nadu for groundwater restoration and management. In the present study, an existing check dam in Udumalpet block of Amaravathi basin was selected to assess the impact of artificial recharge structures in improving the groundwater quantity and quality. In Natural recharge, depth of increase in groundwater is 1 m whereas the areas having artificial recharge structures the increase in groundwater table is 5 m (Check dam). The significant enhancement in groundwater quality was observed due to the effect of check dam. The maximum water quality improvement was near the check dam at downstream side. The standard of irrigation water is improved from C_2S_2 to C_2S_1. Hence, it is recommended to recharge the groundwater artificially by constructing/digging percolation ponds wherever feasible in the basin.

Keywords: Artificial recharge, Groundwater quality, Check dam

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Introduction

India is a country where agriculture is the primary source of income for the people and about 85 % of the population depend on groundwater for irrigation and domestic needs. Agricultural activities mostly depend on the use of groundwater especially in southern part of India. Extraction of groundwater for irrigation where it is slowly renewed is the main cause for depletion [1].Groundwater depletion and its impact is more obvious at the regional scale in agriculturally important parts of India. Artificial recharge is a technique used to prevent over exploitation of groundwater resources. Artificial recharge is the progression of replenishing groundwater by augmenting the natural infiltration of rainwater or surface water into sub surface aquifers through several methods depending on the slope, geomorphology, geology and soil conditions. An artificial recharge structures are practiced in the hard rock regions of Tamil Nadu for groundwater restoration and management.

Water quality enhancement through artificial recharge became predominant in the last decade. Quality of water is equally important as that of its quantity. Water stored behind in the check dam is primarily rainfall drained as runoff from different land use of the catchment. Hence, the recharge of this water may change the hydro-chemical characteristics of the groundwater. Several researchers have studied the impact of such structures in enhancing quality of groundwater. Artificial recharge structures improved the groundwater quality and even reduced the concentrations of toxic ions such as arsenic, fluoride and boron because of dilution [2, 3]. However, a few researchers have also highlighted the constraints implicated in using check dam for improving the water quality. It is important to maintain the quality of water stored in the check dam by taking precautions like preventing discharge from the nearby agricultural lands, dumping of domestic wastes, release of sewage etc. [4]. In the present study, an existing check dam in Udumalpet block of Amaravathi basin was selected to assess the impact of artificial recharge structures in improving the groundwater quality.

Study area

The study area located in Amaravathi basin is one among the tributary of Cauvery basin. It covers four districts namely Coimbatore, Dindigul, Karur and Tiruppur in Tamil Nadu. The basin consists of 33 blocks in which 16 blocks are identified to be under over-exploited category, 5 are critical, 2 are semi critical and 8 are under safe category. The check dam lies on 10°30’7” N latitude and 77 ° 12’07” E longitude at elevation of 364 m in Udumalpet block of

Amaravathi basin. The groundwater development in Udumalpet block is 73 per cent that falls under the semi critical category and about 64.5982 Mcum of groundwater is extracted for irrigation purpose. The major agriculture practices dependent on the groundwater, which will lead to exploiting the groundwater resources. Hence, an artificial recharge study is undertaken in Udumalpet block of Amaravathi basin. The location of check dam selected for the study was showed in **Figure 1**. The area is underlain by shallow weathered crystalline hard-rocks (Charnockites, Magmatites and banded gneisses) which have relatively low groundwater storage capacity [5].

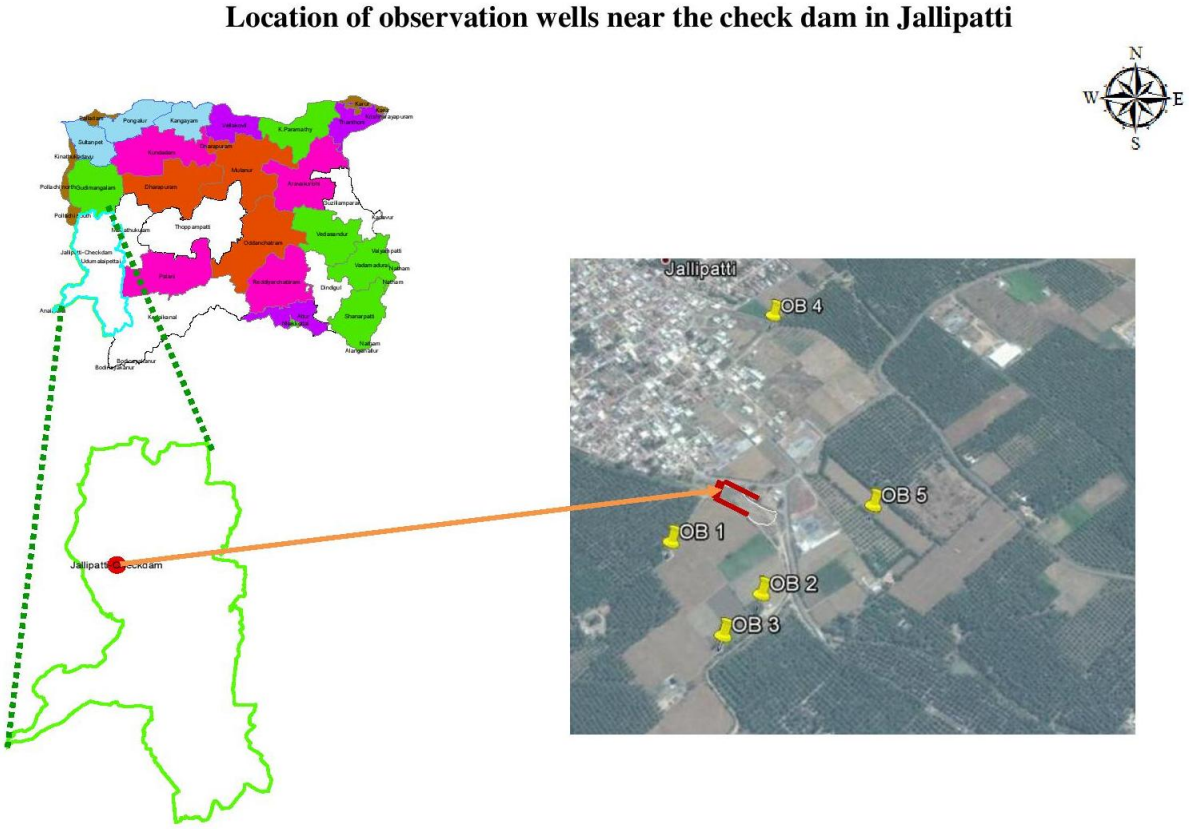

Figure 1 Location of observation wells at Jallipatti check dam in Udumalpet block

Methodology

Check dam was constructed in second order stream having gentle slope. The selected check dam is having a high coefficient weir of 14.00 m length and height of 2.0 m **(Figure 2 and 3).** Necessary cut off walls had been provided both in upstream and downstream sides of the weir as per the design. Suitable length of solid apron on the downstream side and foundation are constructed against the up lift pressure. The capacity of the selected check dam is 1050 m^3 **(Figure 4).** The salient feature of the check dam is presented in **Table 1**.

Table 1 Salient features of the check dam

1.	Name of village	Jallipatti
2.	Name of block	Udumalpet
3.	Name of district	Tiruppur
4.	Sub basin	Amaravathi
5.	Year of construction	2008
6.	Water spread area	0.50 ha
7.	Capacity of the tank	1050 m^3
8.	Number of fillings expected	2 times
9.	Total quantity of water impounded in a year	2100 m^3
10.	Weir details	
	i. Type of weir	High co-efficient weir
	ii. Length of weir	14.00 m
	iii. Height of weir	2.0 m

Figure 2 Check dam filled with water

Figure 3 Check dam without water

For monitoring the water levels during different seasons, five open well points within a distance of 500 metres downstream of the check dam were selected. The latitude and longitude values of the located observation wells are given in **Table 2**. The contour map of groundwater table is generated by using surfer software.

Table 2 Latitude and longitude data of observation wells

Observation well	Latitude	Longitude
1	10°30'08"N	77°12'01"E
2	10°30'03"N	77°11'56"E
3	10°30'02"N	77°11'58"E
4	10°30'14"N	77°12'16"E
5	10°30'13"N	77°12'23"E

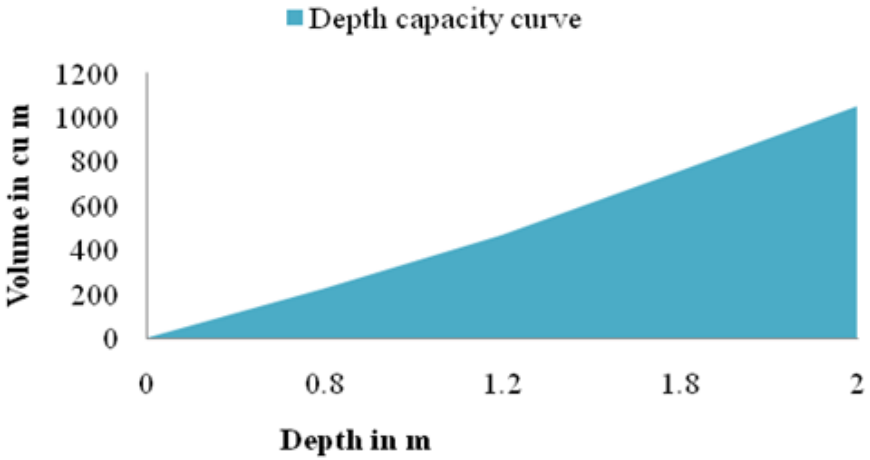

Figure 4 Depth capacity curve of Jallipatti check dam

Groundwater recharge

Groundwater recharge estimation is done by the water level fluctuation method. The observation of water levels in the observation well (OBW1to OBW 5) was done during the year 2015-16. The specific yield of the aquifer formation in the study area is found to vary between 2.5 to 3 per cent and influencing area is taken as 1.0 sq km

The recharge volume is given by,

$$\text{Recharge volume, R } (m^3) = \text{Area } (m^2) \times \text{Average water level fluctuation (m)} \times \text{Specific yield} \quad (1)$$

Water sampling

Regular sampling was done to analyze the quality of native water and the changes due to the artificial recharge structures, from observation well network. Five water samples from observation wells and one sample from native water were collected in the year 2015 and analysed for various parameters (**Figure 5**). The collected water samples were analysed for pH, EC, cations ($Ca^{2+,}$ Mg^{2+}, Na^{+} and K^{+}) and anions (CO^{3-}, HCO^{3-} and Cl^{-}).

Irrigation water suitability as per USSL classification

In the present study, the collected samples of recharged water were classified as per the criteria suggested by the US Salinity Laboratory of the Department of Agriculture (**Table 3-6**).

Figure 5 Sample collection from check dam and open wells

Parameters selected and their calculation

Parameters selected for the present study are EC, SAR and RSC. Sodium Absorption ratio (SAR) and Residual Sodium Carbonate (RSC) are calculated by the following equations.

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++}+Mg^{++}}{2}}} \quad (2)$$

$$RSC(meL^{-1}) = (CO_3^{-} + HCO_3^{-}) - (Ca^{++} + Mg^{++}) \quad (3)$$

All values of cations and anions are in me L-1

Table 3 Salinity hazard classes based on USSL classification

Salinity hazard class	EC in (dS m^{-1})	Remark on quality
C1	0.1-0.25	Excellent
C2	0.25-0.75	Good
C3	0.75-2.25	Doubtful
C4 and C5	>2.25	Unsuitable

Table 4 Sodium hazard classes based on USSL classification

Sodium Hazard class	SAR	Remark on quality
S1	10	Excellent
S2	10-18	Good
S3	18-26	Doubtful
S4 and S5	>26	Unsuitable

Table 5 Groundwater quality based on RSC (Residual sodium carbonate)

RSC (me L^{-1})	Remark on quality
<1.25	Good
1.25-2.5	Doubtful
>2.5	Unsuitable

Table 6 Groundwater table fluctuations in Jallipatti check dam

Monsoon	OB1	OB 2	OB 3	OB 4	OB 5
South west monsoon	0.07	0.75	0.8	1.05	0.2
North east monsoon	0.87	1.15	0.18	0.7	0.1

Results and Discussion

The water levels and quality of the water was monitored regularly in the selected observation wells during the study period. The water level in the check dam was also monitored. The changes in groundwater table and quality due to check dam was analyzed and presented.

Rainfall in Udumalpet block

Rainfall for the period of 1991-2014 taken for detailed analysis. The average annual rainfall of Udumalpet block ranges from 750 to 850 mm (**Figure 6**). The northeast monsoon contributes maximum rainfall of 395.7mm followed by southwest monsoon of 313.8mm. The maximum amount of rainfall was recorded during 2005 (1321 mm) and the minimum amount of rainfall was observed during 2012 (242 mm).

The high amount of rainfall was observed during October (160.9 mm) followed by November month (158.7 mm) (North east Monsoon). Very less amount of monthly rainfall was observed during February (8.8 mm) followed by January (10.4 mm) (**Figure 7**).

Groundwater table in Jallipatti check dam

From the observed groundwater table data, it was noted that, the groundwater table in the five observation wells ranges from 4.3 to 7.85 m BGL (**Figure 8**). Very less amount of fluctuation was noted in observation well 1 while comparing with other wells. High amount of groundwater fluctuation was observed in observation well 4 (nearly 1.5 m).

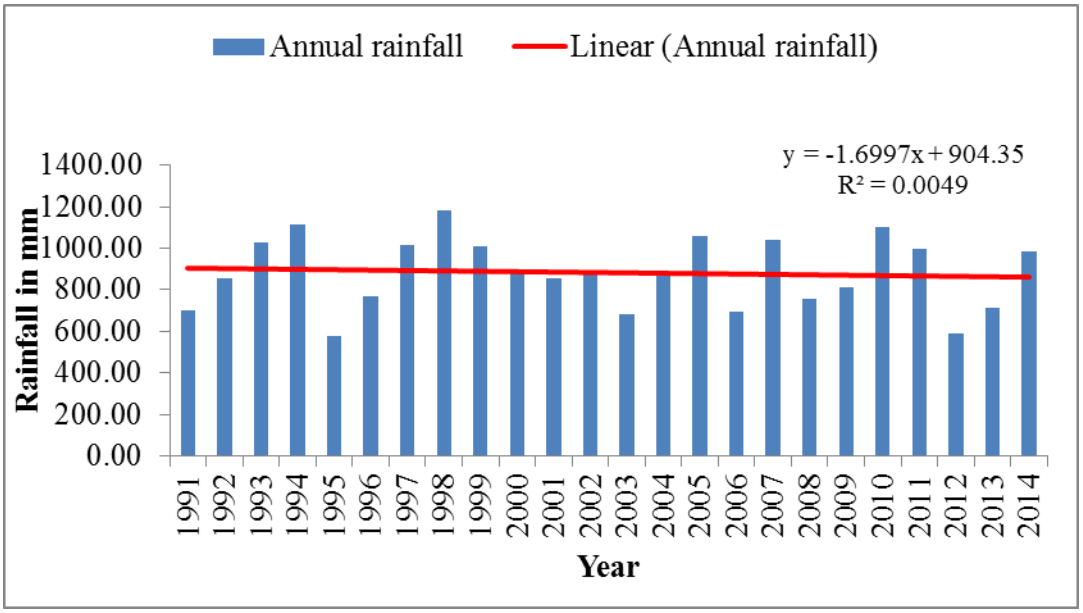

Figure 6 Annual rainfall in Udumalpet block from 1991 to 2014

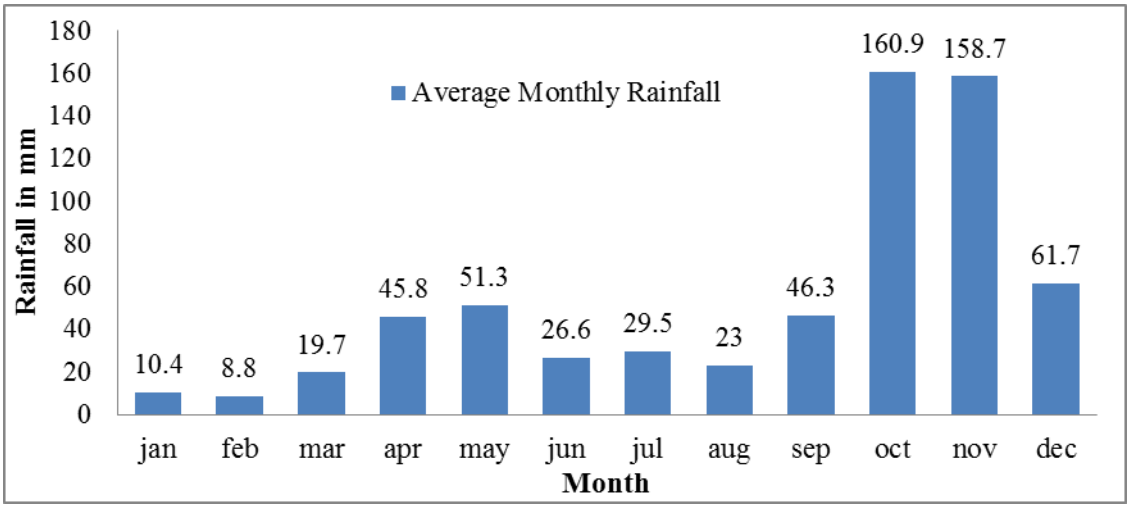

Figure 7 Average monthly rainfall of Udumalpet block

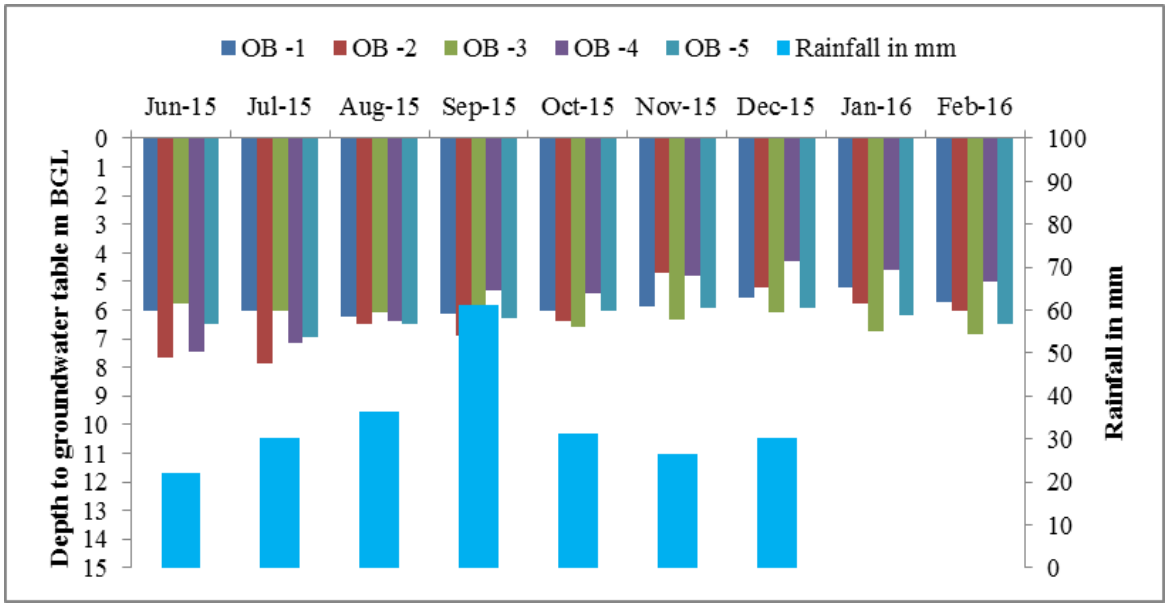

Figure 8 Water level fluctuations in observation wells at Jallipatti

The water levels increased slightly around 1 m during July 2015 due to south west monsoon and it reduced during September month. Due to rainfall in north east monsoon and stored water in Jallipatti check dam, the water level was again increased in all the observation wells during December 2015. One-month lag period was observed for recharging of the groundwater from recharge structures.

Surfer images clearly indicates that groundwater table around the check dam was found to be more (7.1 m) during the pre monsoon season. Meanwhile, a uniform decline in the groundwater table was observed from 7.01 to 5.4 m BGL during post monsoon season (5.4m). Lower groundwater level around the check dam indicated that, the water, which got stored in the check dam during the monsoon season influenced the groundwater recharge (**Figure 9a, b**). During the southwest monsoon, the total rainfall received as 149.8 mm for the years 2015-16. The water level rise in the observation wells in the study area found to occur in all the 5 observation wells dates from August onwards. Nevertheless, the drastic increase in groundwater table observed from October onwards (5.1 m BGL).

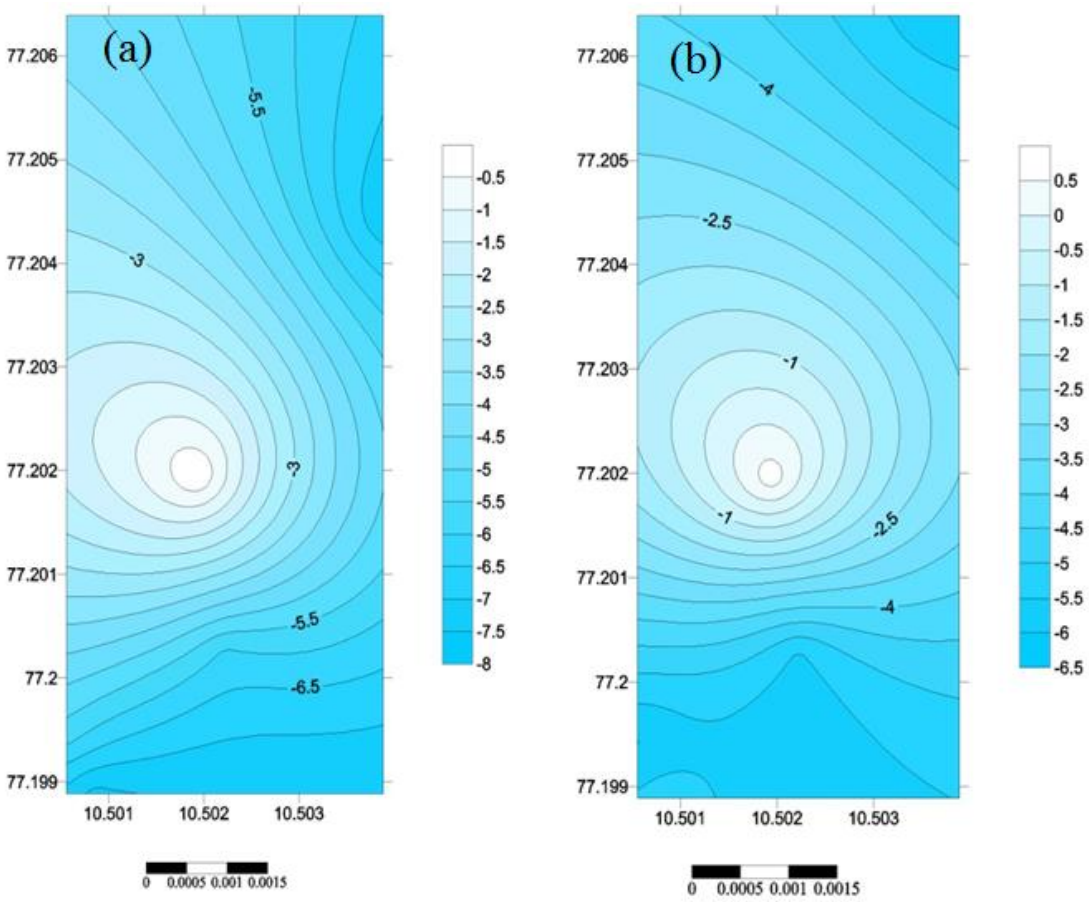

Figure 9 Water table contours during (a) pre monsoon, (b) post monsoon at Jallipatti

The recharge during the northeast monsoon for a period upto December is about 14.3 per cent with average water level fluctuation of about 0.6 m in the study area. The recharge during the southwest monsoon for a period upto September is about 16.2 per cent with average water level fluctuation of about 0.54 m in the study area (Table 6).

Assessment of groundwater quality

The monitoring of water quality is essential to study the effectiveness of artificial recharge structure in improving the quality by water. In the study, following findings were observed in groundwater quality.

The range of pH is from 7.8 to 8.2 in the observation wells where as 7.6 was recorded in the check dam that is belongs to normal range (6.5 to 8.5). Calcium in the observation wells ranges from 300-700 during before monsoon and 233-760 mg L^{-1} during after monsoon period. The stored water in the check dam contains higher concentration of calcium (1400 mg L^{-1}). The chloride ranges from 65 -143 mg L^{-1} during pre monsoon and 65-125 mg L^{-1} during post monsoon. Magnesium in the observation wells ranges from 52.01 mg L^{-1} to 463 mg L^{-1} during pre monsoon and 42.2 - 315.65 mg L^{-1} was found post monsoon. Sodium concentration in study areas shows variations from 55 mg L^{-1} to 112 mg L^{-1} (Pre monsoon) and 60.6 to 101.4 mg L^{-1} (post monsoon).

There was considerable improvement in the groundwater quality especially in the case of EC and anions after monsoon (Post monsoon). It was found that the concentration levels did not rise after the monsoon as the recharge structures helped in diluting the native water by the huge volume of surface water stored in them, which wouldn't have been possible by natural recharge alone [6]. It was also observed that the groundwater quality improvement was maximum near the check dam area. The results showed that, OB 1 responds high in terms of groundwater quality. Moreover, the remaining wells show less response.

As per irrigation classification by USSL, the recharged water is classified (**Table 7**) for irrigation suitability. All the samples are classified as suitable for irrigation. The improvement in SAR is observed in OB 1 where the sodium absorption ratio is improved from 11.53 to 9.49. The distance from check dam to OB 1 is around 140 m and the other wells are located more than 200 m. Hence, the influence of check dam is high in OB 1 while comparing with other OB wells [7] [8].

Table 7 Irrigation suitability at Jallipatti observation wells

Well no	EC		SAR		Classification	
	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon	Pre monsoon	Post monsoon
OB 1	0.355	0.341	11.53	9.49	C2 S2	C2S1
OB 2	0.22	0.192	5.193	7.15	C1 S1	C1S1
OB 3	0.292	0.288	6.204	6.46	C2 S1	C2S1
OB 4	0.365	0.361	16.40	15.55	C2 S2	C2S2
OB 5	0.29	0.28	7.85	10.44	C2 S1	C2S1

Conclusion

The average annual rainfall of Udumalpet block is around 750 to 850 mm. The northeast monsoon (395.7mm) is contributes the major rainfall followed by southwest monsoon (313.8mm). The water levels increased slightly around 1 m during July 2015 due to south west monsoon and it reduced during September month. Due to rainfall in north east monsoon and stored water in Jallipatti check dam, the water level was again increased in all the observation wells during December 2015 (5.4 m BGL). The recharge during the northeast monsoon for a period upto December is about 14.3 per cent with average water level fluctuation of about 0.6 m in the study area. The recharge during the southwest monsoon for a period upto September is about 16.2 per cent with average water level fluctuation of about 0.54 m in the study area.

Natural recharge, depth of increase in groundwater is 1 m whereas the areas having artificial recharge structures the increase in groundwater table is 5 m (Check dam)[9],[10]. The significant enhancement in groundwater quality was observed due to the effect of Jallipatti check dam. The maximum water quality improvement was near the check dam at downstream side. The sodium absorption ratio in OBW 1 of check dam was reduced from 11.53 to 9.49. Hence, the standard of irrigation water is improved from C_2S_2 to C_2S_1. Hence, it is recommended to recharge the groundwater artificially by constructing/digging percolation ponds wherever feasible in the basin.

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Publication History
Received 11th Aug 2017
Revised 09th Sep 2017
Accepted 11th Sep 2017
Online 30th Sep 2017