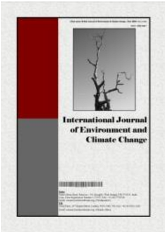

International Journal of Environment and Climate Change

11(10): 59-66, 2021; Article no.IJECC.74808
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Influence of Rain Water Recharging on the Chemical Properties of Groundwater

N. Soundarya[1*], H. G. Ashoka[2], K. Devaraja[3], K. S. Rajashekarappa[4] and M. N. Thimmegowda[3]

[1]Department of Agricultural Engineering, University of Agricultural Sciences, Bangalore, India.
[2]Directorate of Research, University of Agricultural Sciences, Bangalore, India.
[3]AICRP on Dryland Agriculture, University of Agricultural Sciences, Bangalore, India.
[4]University of Agricultural Sciences, Bangalore, India.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2021/v11i1030492
Editor(s):
(1) Dr. Fang Xiang, University of International and Business Economics, China.
Reviewers:
(1) Chemutai Roseline, Bukalasa Agricultural College, Uganda.
(2) Nachana'a Timothy, Adamawa State University, Nigeria.
Complete Peer review History: https://www.sdiarticle4.com/review-history/74808

Original Research Article

Received 07 August 2021
Accepted 14 October 2021
Published 23 October 2021

ABSTRACT

The study was conducted to analyze the impact of different seasons and sources of rainwater (rooftop runoff and runoff plots) used in recharging borewells on chemical properties of groundwater. There were nine borewells considered for the study, among them five borewells are recharged through rooftop runoff water, two borewells are recharged through water from runoff plots and the two borewells have no treatments. After each runoff event, water samples from each borewell were collected for five days and analyzed for various chemical parameters. The electrical conductivity, pH and concentration of bicarbonate ions were *analyzed*. The result revealed that the recharge that took place during the *Kharif* season had an impact through reduced salt concentration and it also had an influence during the Rabi season. The electrical conductivity and concentration of bicarbonates in water samples from borewells was low in Kharif than rabi. The values of these chemical properties indicated that recharging of borewells is having the beneficial effect on the groundwater properties.

**Corresponding author: E-mail: soundarya.n.gopal@gmail.com;*

Keywords: Rainwater harvesting; groundwater; recharge; chemical properties.

1. INTRODUCTION

Water is an important resource for the sustenance of life. Groundwater plays a prominent role in meeting the water requirement for human consumption and also governs economical, industrial and agricultural growth of the country. India exploits groundwater to greater extent in the world. It is estimated to be about 230 km³ of groundwater per year [1] that accounts to about one-fourth of the total global usage.

Artificial recharge is a technique for directing excess surface water into the ground by dispersing it on the surface, using recharging wells, or altering natural conditions to facilitate infiltration and replenish an aquifer. It's one of the most effective methods for storing water underground during periods of abundant water to fulfil demand during times of scarcity.

Subsurface reservoirs are the only technically viable option for storing monsoon runoff. These geological formations beneath the surface can be thought of as a water-storage warehouse. Aside from lithological properties, favourable geological structures and physiographic units that are dimensioned and structured in such a way that huge volumes of water can be preserved in porous and permeable strata will be assessed [2]. Water storage beneath the ground will have a beneficial impact on the current groundwater regime.

Soil and water conservation methods rely heavily on groundwater. Evaporation and runoff are responsible for a considerable percentage of water loss. Where there is the potential for expanded subsurface storage, a greater emphasis on conservation and utilization of excess runoff is necessary. Artificial recharging procedures, in contrast to natural recharge methods, are one of the most effective ways to refill groundwater.

In India, the average annual surface runoff is 185 million ha-m (Central Water Commission 2011), although the amount of water that can be used is substantially less. Out of the total annual runoff, 90% of annual runoff in the peninsular rivers and 80% of annual runoff occur during the south west monsoon (June to September). It would be better to utilize this excess runoff by adapting suitable scientific conservation measures.

2. MATERIALS AND METHODS

The present study was carried out during the *Kharif* (June to October) and Rabi season (November to March) of the year 2020-21. At GKVK campus, UAS, Bengaluru, nine separate borewell locations have been identified for the study, and the experimental site is located at the GKVK campus, Karnataka's Eastern Dry Zone (Zone 5).

The nine different borewells were numbered as BW 1, BW 2, BW 3, BW 4, BW 5, BW 6, BW 7, BW 8 and BW 9. Among them seven borewells (BW 1 to BW 7) were subjected to various recharging techniques and the two borewells (BW 8 and BW 9) were with no recharge technique. The borewell, BW 1 was subjected to rooftop water harvesting with a screen filter and the borewells BW 2, BW 3, BW 4 and BW 5 were having the individual filtration units to recharge the borewell. The BW 6 and BW 7 were recharged through runoff plots. The two borewells numbered as BW 8 and BW 9 were not recharged and they serve as control.

Water samples were taken at regular intervals of 15 days from all the borewells and tested for the impact of recharging on chemical characteristics. An EC meter was used to determine the electrical conductivity. A pH meter was used to measure the pH of the water samples. Titrimetric analysis was used to determine the concentration of bicarbonate ions.

The runoff estimation from the open field is made by employing curve number method. The rooftop runoff water was estimated by depth and area method.

3. RESULTS AND DISCUSSION

The experiment was carried out according to the experimental strategy outlined in the material and methods section. The experiment's findings are described in further detail under the following headings.

3.1 Estimation of Volume of Water Available for Recharging the Borewells

The rainfall recorded at the GKVK campus during the study period was 1182.2 mm which resulted in 38 and 7 runoff events for rooftop water harvesting for *Kharif* and Rabi seasons respectively (Tables 1 & 2). For the open fields, it is estimated that about 201.81 mm which accounts for 18 percent of the total annual rainfall [3] available for recharge and the corresponding runoff events occurred for 15 and 3 days in the months *Kharif* and Rabi season respectively. Rooftop rainwater harvesting allows 90 percent (Rooftop rainwater harvesting manual, 2004) of total rain for recharging. Since the runoff contributing from open fields to the BW 6 and BW 7 is large, the contribution of volume of runoff discharged is higher compared to the rooftop discharge.

The highest one day rainfall recorded during the study period was 93.6 mm which had generated a runoff of 37.44 mm for open fields. During this event, the borewell BW 6 and BW 7 received the highest volume of water through the runoff plot and it accounted for 272.68 m^3 (Table 1).

The highest rainfall recorded during the Rabi season was 42mm that generated a runoff of 16.8mm. The borewells BW and BW7 received maximum runoff volume of 100.93m^3 (Table 2).

The result of the analysis of the chemical properties of groundwater revealed that borewell BW 7 had the lowest electrical conductivity, pH, and bicarbonate ions, whereas borewell BW 8 had the greatest (Table 3), due to dilution, the ion concentration in the recharged borewells decreased. Natural recharging may have occurred in the control borewells, but the dilution effect is negligible.

The electrical conductivity and the concentration of bicarbonate ions was lower in BW 7 and higher in BW 8. The pH was lower in BW 2 and higher in BW 9 (Table 4).

The borewells that were recharged through rainwater had a considerable impact on chemical properties. The borewells recharged through runoff plots showed a greater dilution effect. Among the five borewells recharged through the roof top runoff borewell BW 1 had a greater dilution effect. However, the area and the amount of water received in individual borewell has a great influence on dilution.

In comparison, of the average electrical conductivity of both the seasons, the value of electrical conductivity was low in the *Kharif* season compared to Rabi season (Tables 3 & 4). The recharge took place during the *Kharif* season might have diluted the salt content in the borewell water resulting in a lower value of electrical conductivity, whereas during Rabi season the recharge was very low and the salt concentration was increased showing an increase in the electrical conductivity. The findings were in conformity to P.G. Vadher's [4] study on artificial recharging of wells, the pattern of salt distribution under the effect of the water table was explored by Bandopadhya [5], who found that electrical conductivity was higher near the watertable.

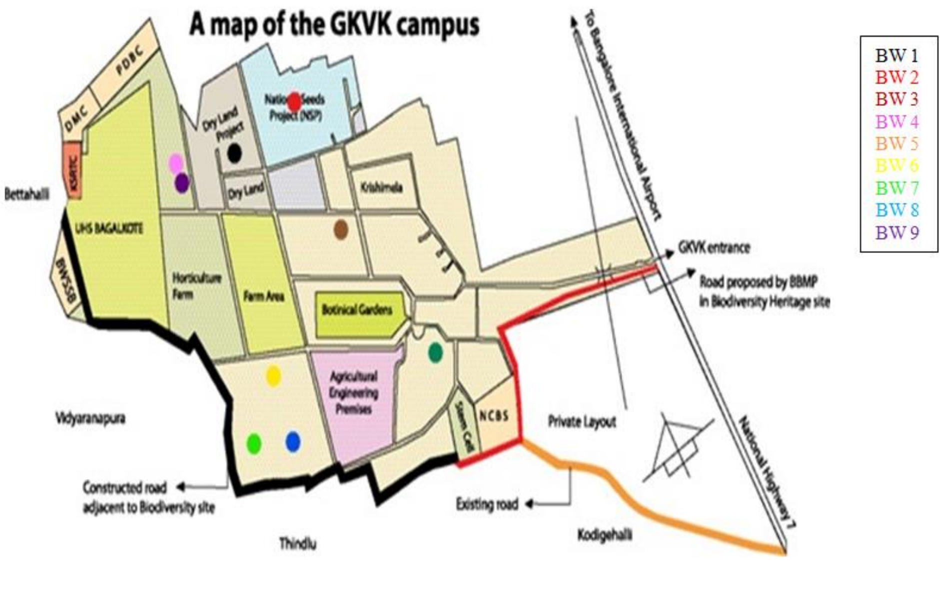

Fig. 1. Location of various borewells in GKVK campus

Table 1. Estimated rainwater availability for the recharge of borewell during *Kharif* season

RO event	Date	RO. causing rain (mm)	Cum. RF (mm)	RO (mm)	BW 1 RO vol (m³)	BW 2 RO vol (m³)	BW 3 RO vol (m³)	BW 4 RO vol (m³)	BW 5 RO vol (m³)	BW 6 RO vol (m³)	BW 7 RO vol (m³)
Catchment Area (m²)					203	1133	600	574	400	8094	8094
1	25-5-20	27.6	27.6	4.15	5.04	28.12	14.90	14.25	9.93	33.59	33.59
2	27-5-20	12.4	40.0	-	2.26	12.63	6.60	6.40	4.46	-	-
3	28-5-20	18.6	58.6	0.83	3.39	18.95	10.04	9.60	6.69	6.71	6.71
4	30-5-20	44.2	102.8	13.9	8.07	45.03	23.86	22.83	15.91	112.5	112.5
5	12-6-20	27.6	130.4	4.15	5.04	28.12	14.90	14.25	9.93	33.59	33.59
6	25-6-20	10.0	140.4	-	1.87	10.19	5.4	5.16	3.6	-	-
7	26-6-20	29.4	169.8	5.03	5.37	29.95	15.87	15.18	10.58	40.71	40.71
8	4-7-20	9.8	179.6	-	1.79	9.98	5.09	5.06	3.52	-	-
9	9-7-20	23.8	203.4	2.51	4.34	24.25	12.85	12.29	8.56	20.31	20.31
10	10-7-20	14.4	217.8	-	2.63	14.67	7.77	7.43	5.18	-	-
11	11-7-20	5.6	223.4	-	1.02	5.70	3.02	2.89	2.01	-	-
12	14-7-20	5.2	228.6	-	0.95	5.29	2.80	2.68	1.87	-	-
13	17-7-20	15.2	243.8	0.19	2.77	15.48	8.20	7.85	5.47	1.53	1.53
14	20-7-20	15	258.8	0.16	2.74	15.38	8.1	7.74	5.4	1.29	1.29
15	21-7-20	52.8	311.6	20.1	9.64	53.80	28.51	27.27	19.00	162.68	162.68
16	24-7-20	65.8	377.4	30.2	12.02	67.05	35.53	33.99	23.68	244.43	244.43
17	30-7-20	12	389.4	-	2.19	12.22	6.48	6.19	4.32	-	-
18	3-8-20	10	399.4	-	1.82	10.19	5.40	5.16	3.60	-	-
19	9-8-20	6.8	406.2	-	1.24	6.92	3.67	3.51	2.44	-	-
20	10-8-20	5.2	411.4	-	0.95	5.09	2.80	2.68	1.87	--	-
21	12-8-20	12.8	424.2	-	2.33	13.04	6.91	6.61	4.60	-	-

Contd……

Table 1. Contd

RO event	Date	RO. causing rain (mm)	Cum. RF (mm)	RO (mm)	BW 1 RO vol (m³)	BW 2 RO vol (m³)	BW 3 RO vol (m³)	BW 4 RO vol (m³)	BW 5 RO vol (m³)	BW 6 RO vol (m³)	BW 7 RO vol (m³)
22	18-8-20	10.2	434.4	-	1.86	10.39	5.50	5.26	3.67	-	-
23	31-8-20	10	444.4	-	1.82	10.19	5.40	5.16	3.60	-	-
24	1-9-20	7.2	451.6	-	1.31	7.33	3.88	3.71	2.59	-	-
25	2-9-20	9.6	461.2	-	1.75	9.78	5.18	4.95	3.45	-	-
26	3-9-20	34.6	495.8	7.8	6.32	35.25	18.64	17.87	12.45	63.12	63.12
27	4-9-20	19.4	515.2	1.04	3.54	19.76	10.47	10.02	6.98	8.41	8.41
28	9-9-20	93.6	608.8	54.04	17.10	95.37	50.54	48.35	33.69	272.68	272.68
29	10-9-20	6.2	615	-	1.13	6. 31	3.34	3.20	22.32	-	-
30	21-9-20	10	625	-	1.82	10.19	5.40	5.16	3.60	-	-
31	30-9-20	41	666	11.8	7.49	41.77	22.14	21.18	14.76	95.50	95.50
32	4-10-20	6.8	672.8	-	1.24	6.92	3.67	3.51	2.44	-	-
33	10-10-20	12.2	685	-	2.22	12.4	6.58	6.30	4.39	-	-
34	11-10-20	6	691	-	1.09	6.11	3.24	3.09	2.16	-	-
35	13-10-20	8	699	-	1.4	8.15	4.32	4.13	2.88	-	-
36	21-10-20	61.2	760.2	26.59	11.18	62.36	53.04	31.61	22.03	215.21	215.21
37	23-10-20	10.6	770.8	-	1.93	10.80	5.72	5.47	3.81	-	-
38	24-10-20	6.2	777	-	1.13	6.31	3.34	3.20	2.23	-	-
Total					**135.55**	**744.38**	**439.1**	**346.04**	**299.67**	**1312.2**	**1312.26**

Table 2. Estimation of runoff water for the recharge of borewell during Rabi season

RO event	*Date*	*RO causing rain (mm)*	*Cum. RF (mm)*	*RO (mm)*	*BW 1 RO vol (m³)*	*BW 2 RO vol (m³)*	*BW 3 RO vol (m³)*	*BW 4 RO vol (m³)*	*BW 5 RO vol (m³)*	*BW 6 RO vol (m³)*	*BW 7 RO vol (m³)*
Catchment Area (m²)					*203*	*1133*	*600*	*574*	*400*	*8094*	*8094*
1	*6-11-20*	*42*	*777*	*12.47*	*7.67*	*42.79*	*22.68*	*21.69*	*15.12*	*100.93*	*100.93*
2	*13-11-20*	*5*	*782*	*-*	*0.91*	*5.09*	*2.70*	*2.58*	*1.80*	*-*	*-*
3	*17-11-20*	*5.2*	*787.2*	*-*	*0.95*	*5.29*	*2.80*	*2.68*	*1.87*	*-*	*-*
4	*27-11-20*	*15.2*	*802.4*	*0.19*	*2.77*	*15.48*	*8.20*	*7.85*	*5.47*	*1.53*	*1.53*
5	*1-7-21*	*11.4*	*813.8*	*-*	*2.08*	*11.61*	*6.15*	*5.88*	*4.10*	*-*	*-*
6	*20-2-21*	*23.4*	*837.2*	*2.36*	*42.75*	*23.84*	*12.63*	*12.08*	*8.42*	*19.10*	*19.10*
7	*21-2-21*	*14.6*	*851.8*	*-*	*2.66*	*14.87*	*7.88*	*7.54*	*5.25*	*-*	*-*
Total					***59.79***	***118.97***	***63.04***	***60.30***	***42.03***	***121.56***	***121.56***

Table 3. Chemical properties of groundwater samples collected during the *Kharif* season of 2020

Borewell	*EC*	*pH*	*HCO_3^-*
BW 1	*666.82*	*6.69*	*7.37*
BW 2	*743.81*	*6.72*	*9.23*
BW 3	*780.60*	*6.75*	*7.43*
BW 4	*872.37*	*6.66*	*7.01*
BW 5	*782.54*	*6.67*	*7.99*
BW 6	*539.16*	*6.48*	*5.11*
BW 7	*501.38*	*6.30*	*5.26*
BW 8	*1172.70*	*6.63*	*11.84*
BW 9	*927.80*	*6.81*	*10.33*

Table 4. Average values of chemical properties of water samples collected from borewells during Rabi season of 2020

Borewell	*EC*	*pH*	*HCO_3^-*
BW 1	*690.11*	*6.93*	*5.69*
BW 2	*935.16*	*6.74*	*5.30*
BW 3	*844.46*	*6.27*	*5.67*
BW 4	*893.90*	*6.25*	*5.60*
BW 5	*1070.70*	*6.78*	*5.05*
BW 6	*580.94*	*7.07*	*5.50*
BW 7	*516.68*	*7.08*	*4.87*
BW 8	*1286.70*	*6.86*	*7.01*
BW 9	*1130.15*	*8.01*	*6.98*

When the average pH values in both seasons were compared, the pH value was lower in *Kharif* than Rabi (Tables 3 & 4). The findings were in conformity to the research conducted by J.D. Gundalia [6] to determine the effect of recharge on water quality. He found that pH values exhibited an inverse relationship with electrical conductivity. The recharge of water during the *Kharif* season has resulted in dilution, which resulted in a change in water neutrality. Water replenishment has transported various salts with it, which had an impact throughout the rabi season by converting the neutrality to basic nature.

Bicarbonates present in water indirectly indicate the presence of salts. The concentration of these bicarbonate ions was lower in *Kharif* than Rabi season (Tables 3 & 4). A similar result was reported in the Chemical Quality Series [7]. The recharging technique dilutes water which results in decrease of the concentration of salts in *Kharif* season whereas in Rabi season due to reduced recharge and regular pumping the value had been increased.

4. CONCLUSION

The technique of recharging the borewell through runoff water harvesting had a significant effect on the quality of groundwater. Electrical conductivity, which increases from Kharif to Rabi season, indicates the presence of salts. In Kharif, the pH was slightly acidic, but in Rabi, it was slightly alkaline, indicating a change towards neutrality. From Kharif to Rabi, the bicarbonate ion concentration decreased due to the dilution effect. There's also a possibility that some of the salts and minerals exhibit unpredictable trends due to groundwater migration.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle4.com/review-history/74808