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Design, Development and Evaluation of Artificial Well Recharging System for Groundwater Enhancement

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ABSTRACT: An artificial well recharge system model was designed and constructed near open well for groundwater enhancement. The filtration efficiency of primary filter was determined and found to be in tune of 64 to 70% and for main filter 90 to 94%. During the year 2011, 630 mm of rainfall produced 203 mm of runoff which is 32.21% of the rainfall. Similarly, during the year 2012, 678 mm of rainfall generated 152 mm of runoff i.e. 22.41% of the rainfall. The total rainfall received during the year 2013 was 1131 mm and it produced 407 mm runoff. The water level in the well was recorded periodically at an interval of 15 days to observe the groundwater level fluctuation. Comparison of water levels of 2011 to 2013 indicated that there was an increase in water level varied between 0.3 m and 3.4 m due to artificial well recharging.

Key words: Rainfed agriculture, artificial recharge, groundwater, filters

A majority of world population suffers from the water problem. To tackle the problems of declining groundwater table, artificial groundwater recharge is one of the effective measures. Out of the various techniques of artificial groundwater recharge, recharge through the existing irrigation wells is better suited in Maharashtra State.

During the post south-west monsoon season, the groundwater is the major source of irrigation water for agriculture. There is 30% runoff potential from the rainfall events during south-west monsoon. In Marathwada region of Maharashtra state, the rainfed agriculture is prominent however; there is vast scope for rainwater harvesting, recycling and its utilization for increasing the productivity of rainfed crops. Rain water is pure but when it flows over the land surface or ground, the sediment mix with water. The runoff water needs to be filtered before further use.

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 with free of cost, evaporation losses are negligible and biological purity is high with minimum temperature variations (Bhalerao and Kelkar, 2013).

The various methods of artificial groundwater recharge are through percolation tanks, recharge of open wells, through ponds, ditches, furrows, and recharge through different soil conservation structures and roof water harvesting. Bhattacharya (2010) studied artificial groundwater recharge and concluded that the cost of recharge scheme depends upon the degree of treatment of the source-water, the distance over which the source-water needs to be transported and the stability of the recharge structure, and resistance to silting or clogging.

But in these methods, rate of recharge is limited and the time required for recharge is more. The research on the artificial recharge of open well by using surface runoff through filtration unit is scanty. In Marathwada region, many open wells are defunct which can be used for recharging. In this study, an attempt has been made to undertake a systematic study on design, construction and evaluation of artificial well recharge model (filtration system) for recharging open wells.

Materials and Methods

The experiment was conducted at the demonstration field of Vasantrao Naik Marathwada Krishi Vidyapeeth, Parbhani (19°16'N latitude and 76°47'E longitude and at 409 m above mean sea level).

The mean annual rainfall of Parbhani district is 889 mm with an average number of rainy days as 48 and falls under assured rainfall zone. Southwest monsoon is the major source of rainfall for the region. About 90% of total rainfall is being received during the month of June to September. The maximum rainfall intensity recorded at Parbhani station is 127 mm/hr during the year 2011 to 2013.

Soils of the region are very deep black with bulk density of 1.3 g/cc and pH 8.2. The soil moisture retention at field capacity is 36% and wilting point is 13%. The average infiltration rate of soil is 1.6 cm/hr.

The filtration efficiency was worked out using the following formula:

$$F.E. = 100 \times 1 - \left(\frac{So}{Si} \right)$$

Where, F.E. = Filtration efficiency (%),

So = Component concentration at the filter outlet (mg/lit) and

Si = Component concentration at the filter inlet (mg/lit)

The specific gravity was calculated by using formula:

$$G = \frac{Dry\ mass\ of\ soil}{Mass\ of\ water\ of\ equal\ volume} = \frac{M_2 - M_1}{(M_4 - M_1) - (M_3 - M_2)}$$

M_1 = Empty mass of bottle

M_2 = Bottle + Dry soil mass

M_3 = Bottle + Soil + Water

M_4 = Bottle + Water mass

The velocity at which muddy water (v) flowing through the filtration process was computed by using Stokes law.

$$\left\{v = \frac{1}{18} D^2 (G-1)\gamma_w/\eta\right\}$$

Where,

v = terminal velocity (m/s)

D = diameter of spherical particle (m)

γ_w= unit weight of water (kN/m^3)

η = viscosity of water ($kN\text{-}s/m^2$)

G = specific gravity of soil particle i.e. 2.66

Experimental setup

Artificial well recharging system

The filter unit was designed and constructed near the open well at demonstration field. The filter unit consists of three blocks, one is called primary filter (0.6 x 0.6m) which is combined with layers of stones, sand and gravels. The filter collects major sediments from runoff water. Primary filter is joined by 4" diameter pipe to silt trapping unit / energy dissipation unit (1.1 x 1 x 1.5 m) having a rectangular notch opening in main filter unit. Third block acts as main filtration tank with dimensions 2 x 2 x 2 m. having three layers of different filter material such as 30 cm sand, 30 cm gravels and 30 cm stones. The main filter unit is joined to open well by the 4" diameter PVC pipe. The filter unit is constructed with brick walls and cement concrete (2 x 2 x 2 m).

The suspended load with the surface runoff flows alternately through trench and collected in the silt trapping unit with 6" diameter pipe. To determine the filtration efficiency of filter system, the water samples at inlet were collected at various time intervals. These samples are allowed to settle for 24 hours and then placed in hot air oven for 24 hours at 105^0C. After 24 hours the weight of dry silt was weighed for determination of silt content at inlet of filter. Similarly the water sample at outlet i.e. in the well was also collected and followed the same procedure for analysis of silt content of outlet water. The efficiency of filtration unit was determined.

Results and Discussions

The results of present study with respect to specific gravity, filtration efficiency and its effect on groundwater potential are as follows.

Specific gravity of soil solids:

As the specific gravity of soil is basic property and primary requisite for determination of velocities of silt contained water, it has been determined by pychrometer test (Punmia, 1973).

Specific gravity computation:

Parameters	**Observations**
M_1 Mass of empty, dry bottle	370g
M_2 Mass of oven dried soil, cooled in a desiccator put in bottle	636g
M_3 Mass of soil and water (full up to the top)	1388g
M_4 Mass of bottle filled with clean at the top	1228g

$$G = \frac{266}{266 - (1388-1228)} = 2.51$$

The specific gravity was determined and found to be 2.51 for collected soil samples. Specific gravity data are useful to calculate the velocity of runoff water flowing through the filtration unit.

Verification of design criteria

Velocity of suspended soil solids:

The soil samples collected from field through which runoff is flowing was collected and analyzed for determination of particle size using particle size distribution curve. Accordingly, the particle size was found to be in the tune of 0.01 to 0.1mm.

Considering determined specific gravity and standard values of viscosity and specific weight.

G = 2.51, η=0.01 poise=10^{-6} $kN\text{-}s/m^2$

$V = 0.8228\ D^2$

1) Coarse Soil Particle D = 0.1mm

$V_{max} = 0.8228 \times 10^{-2}$ m/s

2) Finest Soil Particle D = 0.01mm

$V_{min} = 0.8228 \times 10^{-4}$ m/s

The minimum and maximum values of velocity were determined as 8.228×10^{-3} m/s and 8.228×10^{-5}m/s with an average velocity value 411.40×10^{-5} m/s.

Standardization of filter material criteria:

Alternatively the time required to flow water from inlet to outlet was noted which is 293 seconds and accordingly considering the average velocity value, the head through which water passes was determined as:

h = v/t

h = $\{411.40 \times 10^{-5}\}/293$

h = 1.4m = 140 cm

The head comes out to be 140 cm. Based on these calculations;

the depth of filtration material was worked out as 90 cm with 50 cm as a head of standing water which is essentially required for easy flow of water through filtration unit.

Table 1 : Specification of filter material

Filter material	Size	Thickness of layer
Sand	0.4”	30 cm
Gravel	1.5”	30 cm
Stones	3 to 4”	30 cm

The depth of 90 cm of the filtration unit was considered as three layers of sand, gravel and stones arranged one above another with constant thickness of 30 cm each. At the bottom stones were arranged and above gravel and sand was arranged. The filtration pipe laid at the bottom i.e. below the filter material (Table 1 and Figure 1).

Aggarwal 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. Artificial groundwater recharge by harvesting of rain water using different method is becoming increasingly popular now-a-days. However, the runoff from surface, roof top contains sediments that have to be removed before groundwater recharging.

Filtration efficiency of primary filter

The filtration efficiency of primary filter is found to be in the range of 64 to 70% proves that it is capable of arresting the major silt component of the runoff water (Table 2).

Table 2 : Filtration efficiency of primary filter

Sample No.	Inlet silt composition (g)	Outlet silt composition (g)	Efficiency (%)
1	2.6	0.9	65.40
2	2.5	0.75	70.00
3	2.9	0.95	67.20
4	2.8	1.0	64.30
5	3.0	1.1	63.30
Mean	2.76	0.94	67.00

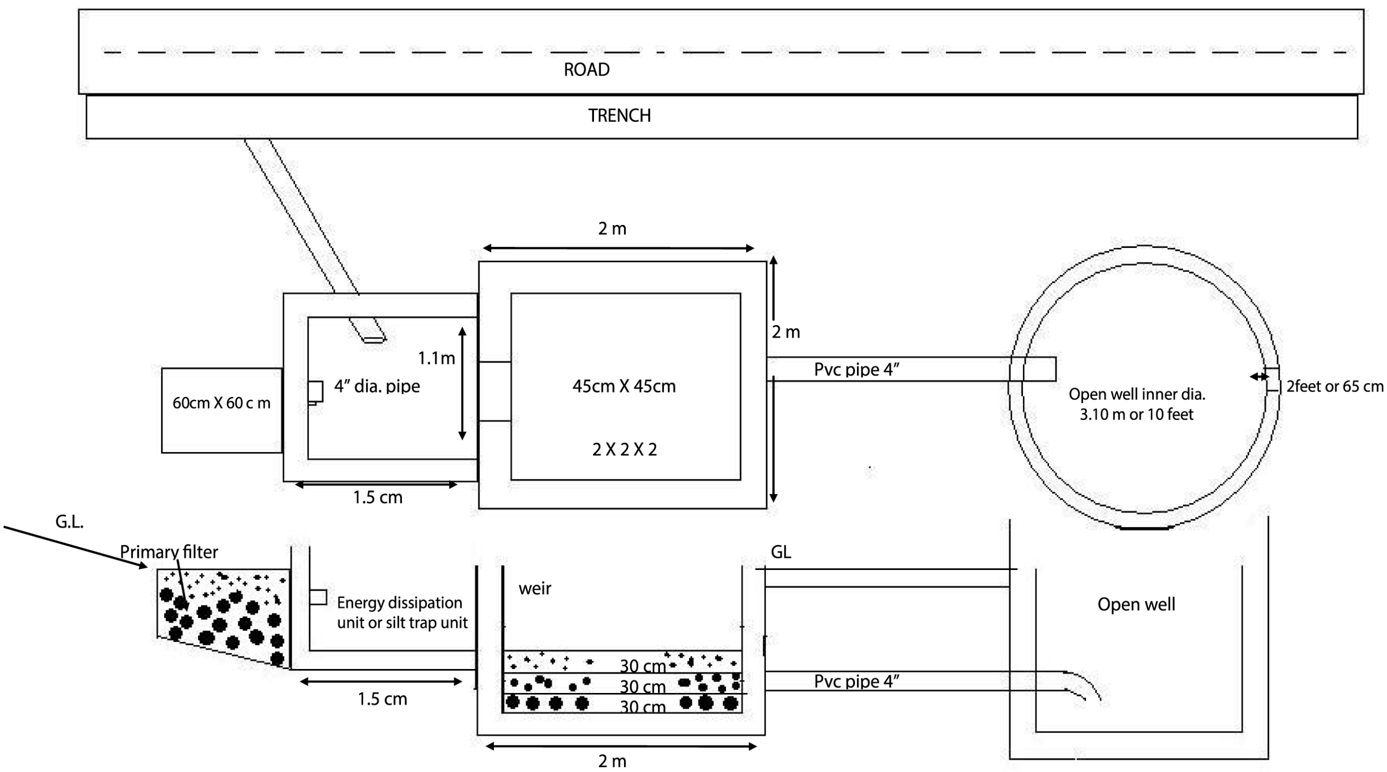

Fig. 1 : Schematic diagram of artificial well recharging system

Filtration efficiency of main filter

The filtration efficiency of main filtration unit was determined in last three years based on the sample data collected from time to time interval. The year-wise data is presented in Table 3 to Table 5.

The filtration efficiency is found to be in the range from 92 to 95%. The efficiency of main filtration unit is more than 90% indicating that the performance of filter material with respect to its depth and quality.

Patel *et al.* (2011) stated that pure water should be passed for groundwater recharge in dug wells. The filtration efficiency of recharging unit should be in the tune of 80 to 90%. The present study confirms the results reported earlier.

Table 3 : Filtration efficiency (2011-13)

Test Sample No.	Inlet silt composition (g)			Outlet silt composition (g)			Filtration Efficiency (%)		
	2011	2012	2013	2011	2012	2013	2011	2012	2013
1	2.8	2.9	2.5	0.2	0.2	0.13	92.85	93.1	94.8
2	3.2	3.1	2.9	0.2	0.2	0.2	93.92	93.54	93.1
3	1.5	3.4	3.3	0.1	0.12	0.3	93.3	96.47	90.9
4	3.5	3.3	1.5	0.3	0.15	0.1	91.42	95.45	93.33
5	2.5	2.2	2.8	0.15	0.15	0.2	94.1	93.18	92.85
6	1	2.3	1.6	0.12	0.12	0.14	90.1	94.78	91.25
Mean	2.42	2.87	2.43	0.18	0.16	0.18	92.62	94.42	92.71

Runoff availability for well recharging

The daily runoff events during the year 2011 to 2013 were recorded and the data is presented in Table 4 to Table 6. During the year 2011, 630 mm of rainfall occurred which is 24% less than the average annual rainfall of the region. During 2011 year, 203 mm of runoff produced in the monsoon season (32.21% of rainfall) contributed 3654 m^3 of runoff water from 1.8 ha of area. This runoff volume was utilized for artificial well recharging for enhancing the groundwater levels in the well.

Table 4 : Runoff events at the experimental site at Parbhani during 2011

Date	Runoff (mm)	Runoff from 1.8 ha field (m^3)
June 7	8.0	144
July 14	37.0	666
July 15	10.0	180
July 26	12.0	216
July 27	37.0	666
August 2	37.0	666
August 26	5.0	90
August 27	13.0	234
September 16	18.0	324
September 17	26.0	468
Total	203	3654

During the year 2012, 678 mm of rainfall occurred which is 23% less than the average annual rainfall of the region. During 2012 year, 152 mm of runoff produced (22.41% of rainfall) contributed 2736 m^3 of runoff volume from the same area for well recharging.

Table 5 : Runoff events at the experimental site at Parbhani during 2012

Date	Runoff (mm)	Runoff from 1.8 ha field (m^3)
June 17	26.0	468
July 18	56.0	1008
September 03	56.0	1008
September 05	14.0	252
Total	152.0	2736

During the year 2013, all the runoff events were estimated and accordingly 1131 mm of rainfall occurred which produced 407 mm of runoff. The total quantity of runoff water available from 1.8 ha field area was estimated as 7326 m^3 (73 lakh litre) which was diverted to the well for well recharging. This indicates that in the assured rainfall region, sufficient quantity of runoff water is available for well recharging.

Mehta *et al.* (2002) worked on the project artificial recharge of groundwater through surface runoff harvesting in Chandigarh. It was noticed that water table rises in the surrounding three piezometers of recharge well. The available runoff volume from the field is utilized for recharging of open well in the present study.

Table 6 : Runoff events at the experimental site at Parbhani during 2013

Date	Runoff (mm)	Runoff from 1.8 ha field (m^3)
June 7	43.0	774
July 9	27.0	486
July 12	22.0	396
July 17	32.0	576
July 18	29.0	522
July 19	12.0	216
July 24	26.0	468
August 1	23.0	414
August 7	12.0	216
September 16	43.0	774
September 17	27.0	486
September 18	38.0	684
September 19	14.0	252
September 20	31.0	558
October 12	28.0	504
Total	407	7326

Effect of well recharging on groundwater level fluctuation

The groundwater levels (MSL) in well were recorded since 2011 and the data are presented in Table 7. In the year 2011, the water table starts rising since June after onset of monsoon. The increase in water table was observed up to the month of November and later a gradual reduction in water table was observed. The total runoff water from 1.8 ha field was diverted to well through well recharging model. During the year 2012, same tend was observed. Ravichandran *et al.* (2011) stated that in order to improve the groundwater situation, it is necessary to artificially recharge the depleted groundwater aquifer.

During the year 2013, due to early onset of monsoon, the water table improved during May itself. Due to sufficient rainfall in the month of June, sudden rise in water table was observed. A well distributed rainfall was observed in monsoon season of 2013, a continuous higher water table was observed and up to November 2013, no reduction in water level was observed (Figure 2).

Reddy and Khybri (2008) conducted similar type of study and observed that the groundwater level in the open wells and bore wells started rising from June till the end of September and later declined in the first week of October. Gore *et al.* (1998) reported that storage of runoff water in water harvesting structures reflect rise in water table in open wells by 2 m. This is because of the seepage of stored water to well profile. However, an artificial recharging i.e. diverting of filtered runoff water to open well reflects to increase the water level upto 3.1 m particularly in monsoon season wherein there is no lifting of water from well for irrigating crops due to monsoon season. Similar trend of water table rise was observed in the present investigation.

Water levels in dug well as influenced by monthly rainfall is presented in Figure 3. During the year 2011 and 2012, due to less rainfall the significant increase in water levels in wells were not observed. However, during the year 2013 more than normal rainfall occurred which produced sufficient surface runoff (407 mm). This has reflected in increase in water level in well.

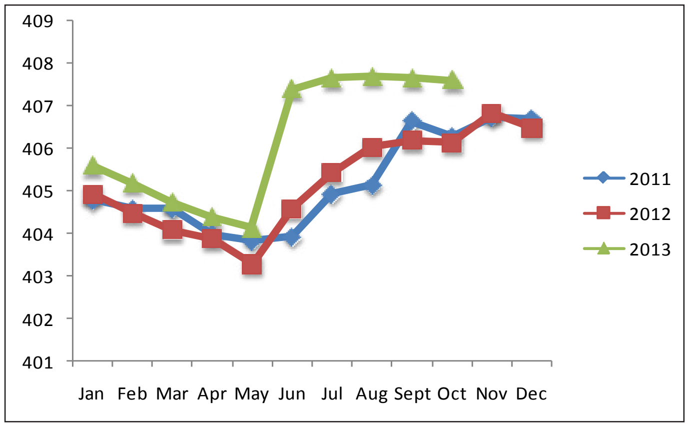

Fig. 2 : Water table (mm) as influenced by well recharging

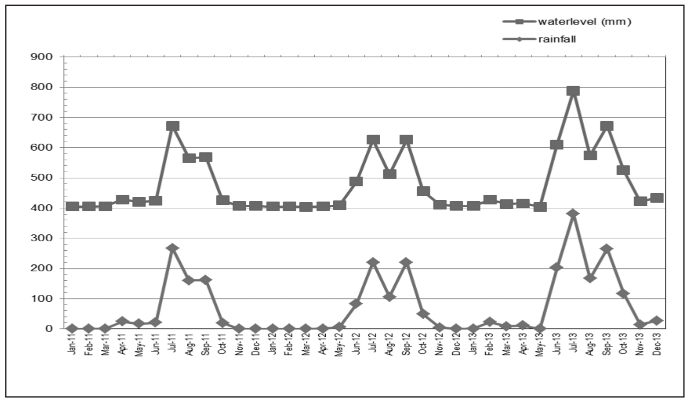

Fig. 3 : Monthly rainfall (mm) v/s water table (mm) rise during 2011-2013

Comparisons of water levels of 2011 to 2013 indicated that there is an increase in water level in the tune of 0.3 m to 3.4 m. Thus artificial well recharging on large scale can result in increasing the groundwater potential so that supplemental irrigation to *kharif* and *rabi* rainfed crops can be provided.

Table 7 : Water level in well (MSL)

Month	2011	2012	2013	Increase in water level in 2013 compared to 2011
January	404.8	405.0	405.6	0.8
February	404.6	404.5	405.2	0.6
March	404.6	404.1	404.8	0.2
April	404.0	403.9	404.4	0.4
May	403.9	403.3	404.2	0.3
June	404.0	404.6	407.4	3.4
July	405.0	405.5	407.7	2.7
August	405.2	406.1	407.7	2.5
September	406.7	406.2	407.7	1.0
October	406.3	406.2	407.6	1.3
November	406.8	406.9	407.7	0.9
December	406.7	406.5	407.5	0.8

Conclusions

The specific gravity of soil sediment was found to be 2.51. Average velocity of water passing through filter was computed as 411.40 x 10^{-5} m/s. The depth of filtration unit was worked out to be 1.4 m, with depth of filter material as 0.90 m. The filtration efficiency of primary filter was found to be 67%. The filtration efficiency of main filter was found to be 92 to 95%. The availability of 25 to 35% surface runoff for well recharging was found to be useful to build up groundwater table from 0.3 to 3.4 m

References

Aggrawal and Soni. 2005. Study of various types of filter used in roof tops rainwater harvesting, *Proceeding of the 38th Annual Convention of Indian Society of Agricultural Engineers*, pp 75-82.

Bhalerao SA and Kelkar TS. 2013. Artificial recharge of groundwater: A novel technique for replenishment of an aquifer with water from the land surface. *International journal of Geology, Earth and Environmental Science*, 3(1): 165-183.

Bhattacharya AK. 2010. Artificial groundwater recharge with a special reference to India, International Journal of Recent Research and Applied studies (IJRRAS) Vol. 4 (2) pp 214-221.

Gore KP, Pendke MS, Gurunadha Rao VVS and Gupta CP. 1998. Groundwater modelling to quantify the effect of water harvesting structures in Wagarwadi Watershed, Hydrological Processes, John Wiley & Sons ltd London, 12, pp 1043-1052.

Mehta MS, Murwaha DC, Sharma and Singh D. 2002. Artificial recharge to groundwater through roof top rain water harvesting. A case study of union territory of Chandigarh. *All India Seminar on Artificial Recharge of Groundwater*, pp 45-49.

Patel P, Desai M and Desai J. 2011. Geotechnical parameters impact on artificial groundwater recharging techniques for urban centres. *Journal of Water Resources and Protection,* 13: 275-282.

Ravichandran S, Sathishkumar S and Leena Singh. 2011. Selective techniques in artificial groundwater recharge through dug well and injection well methods. *International Journal of Chemtech Research,* 3(3): 1050-1053.

Reddy and Khybri ML. 2008. Estimation of groundwater recharge in semi arid watershed. *Indian Journal of Dryland Agricultural Research and Development,* 6(1, 2): 37-45.

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