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Groundwater Quality Assessment for Drinking Purpose in Vijayawada Region, Andhra Pradesh, India

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Abstract— The quality of groundwater is an important parameter for domestic and industrial usage. Due to rapid development in the urban infrastructure and increased anthropogenic activities as the new capital of Andhra Pradesh state is announced near Vijayawada, the quality of groundwater in the Vijayawada region is getting affected from the past few years. This article analyses the ground water quality in Vijayawada region using the groundwater data taken from the Groundwater and Water Audit department. These data were taken from 29 bore wells during pre-monsoon (May) and post - monsoon (November) seasons from 2013 to 2017. The authors have collected another set of samples from the same set of bore wells during February 2019. The collected groundwater samples were tested for various water quality parameters such as pH, total dissolved solids, total hardness, chlorides, sulphates, calcium and magnesium as per IS 3025 (1984). Water quality index is a quality rating reflecting the effect of each water quality parameter on the overall water quality. The groundwater quality in the Vijayawada region is presented in terms of water quality index against the IS 10500 (2012) specifications for drinking water and recommended the remedial measures to improve the groundwater quality.

Keywords: Groundwater quality, water quality index, water quality parameter

1. INTRODUCTION

Due to rapid proliferation of industries, increased urban infrastructure and overexploitation of groundwater for agricultural activities during the last few decades, the groundwater quality has been affected. Ground water quality depends on several factors such as aquifer buffering capacity, composition of the recharge water, and the presence of sedimentary rocks such as limestone (chalk) and dolomite (Asit et. al., 2015). It also depends on the concentrations of fuel combustion gases in the atmosphere, anthropogenic activities such as over exploitation of groundwater, over use of fertilizers, improper manure storage and the decomposition of construction waste (Asit et. al., 2015). All these factors contribute to the variations in the concentration of various ions present in the ground water. High concentrations of TDS in drinking water may cause kidney and heart diseases (Dhiviyaa et. al., 2011, Sarala et. al., 2012, Sajjad et. al., 2013, Abbulu et. al., 2013, Yasoda et. al., 2014, Leelavathi et. al., 2016). The excess concentration of calcium and magnesium in groundwater is due to the chemical reactions between the groundwater and rocks bearing salts of calcium and magnesium like calcite rock deposits, dolomite and gypsum (Akilesh et. al., 2008, Sarala et. al., 2012). Presence of excess hardness in water leads to health problems like stomach diseases and gastric troubles (Rathod, 2016, Sirajudeen et. al., 2014).

Various methods are being used for evaluating the overall quality of ground water. One of the most effective methods is the water quality index. Water quality index reflects the composite influence of different parameters on the overall water quality (Yogendra et. al., 2008, Rupal et. al., 2012, Srinivasarao et. al., 2013, Asit et. al., 2015, Shenbagarani et. al., 2015, Sundara et. al., 2015, Lalitha et. al., 2017, Shayaq Ali, 2018). Arithmetic water quality index, Canadian water quality index, Oregon water quality index, National sanitation foundation water quality index are some of the predominantly used water quality indices. Out of these water quality indices, it is observed that the weighted arithmetic water quality index offers more flexibility to use several water quality parameters in the determination of water quality index and hence is considered for this study.

2. STUDY AREA

This study was carried out in the Vijayawada region covering all parts of Vijayawada city, Andhra Pradesh, India. The Vijayawada region covers about 61.88km2 area with the latitude 16° 30' 54.3564" N and longitude 80° 37' 55.5420" E. The climate of the city is tropical, and the annual mean temperatures varies in between 23.40C to 340C with maximum temperature often crossing 400C in the month of May and the minimum in December and January. The area receives a total rainfall of 977.9 mm every year (IMD, 2016). The city lies on the bank of river Krishna, covered by hills and canals and at an altitude of 11m above the mean sea level. At present around 1.5 Million is the population of the city and expecting to meet 2 Million by 2025.

3. METHODOLOGY

A total 29 sample locations were identified such that they cover the entire Vijayawada region including the major groundwater pollution zones.

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The Groundwater and Water Audit department, Vijayawada, monitors the groundwater and their observations on groundwater quality parameters in pre monsoon (May) and post monsoon (November) seasons and the data during 2013 to 2017 were considered for further analysis. The authors have taken another set of samples from the same bore wells during the month of February 2019 and measured the ground water quality parameters as per IS 3025 (1984).

The standard specifications as per IS 10500: 2012 are used for the determination of unit weight of water quality parameters in the weighted arithmetic Water Quality Index (WQI) as recommended by Yogendra and Puttaiah, 2008, Sundara et. al., 2015, Vijaya Lalitha and Sai Tejaswini, 2017, Shayaq Ali, 2018 as shown in Table 1.

The weighted arithmetic water quality index (WQI) is calculated as: $WQI = \frac{\sum_{i=1}^{n} W_i Q_i}{\sum_{i=1}^{n} W_i}$

Where, W_i is the Unit weight of each parameter as given in Table 2, n is the number of parameters and Q_i is the quality rating of each parameter, $Q_i = \frac{C_i - V_{io}}{S_i - V_{io}} X100$, where, C_i is the concentration of water quality parameter in the tested water sample, S_i is the acceptable value, which is the lower limit in Table 2 for other than P^H, and for pH, it is considered as 8.5, i.e., permissible limit for P^H as per IS 10500:2012. V_{io} is the value of each parameter of neutral water. (For pH, V_{io} = 7 and for dissolved oxygen, V_{io} =14.6 mg/l, and for other parameters V_{io} =0), W_i is the unit weight for water quality parameter $W_i = k/S_i$, and k is the proportionality constant.

Table 1: Water quality status for different values of Water Quality Index (Chatterji and Raziuddin, 2002)

WQI	0-25	26-50	51-75	76-100	>100
Water Qality Status	Excellent	Good	Poor	Very Poor	Unsuitable for Drinking
Grade	A	B	C	D	E

Table 2: Unit weights of the water quality parameters for WQI

S. No	Water Quality Parameter	BIS limits	$1/S_i$	Unit weight $W_i = K / S_i$
1	pH	6.5-8.5	0.118	0.65
2	Total dissolved solids in ppm	500-2000	0.002	0.01
3	Total hardness in ppm	200-600	0.005	0.03
5	Chloride in ppm	250-1000	0.004	0.02
6	Sulphates in ppm	200-400	0.005	0.03
9	Calcium in ppm	75-200	0.013	0.07
10	Magnesium in ppm	30-100	0.033	0.18
		$\sum 1/S_i$	0.18	1
		$K=1/(\sum 1/S_i)$	5.546	

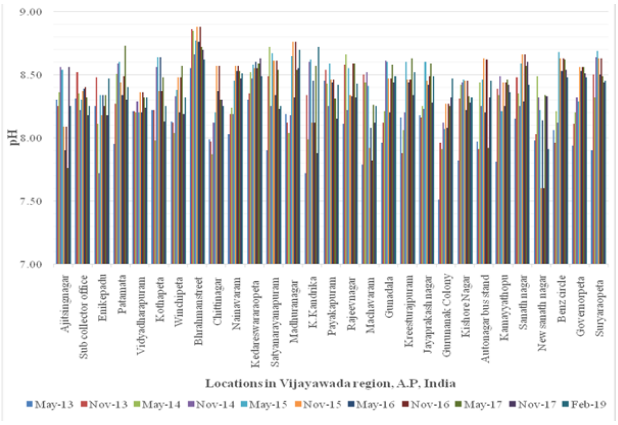

Fig. 1: pH Values at Various Locations in Vijayawada Region

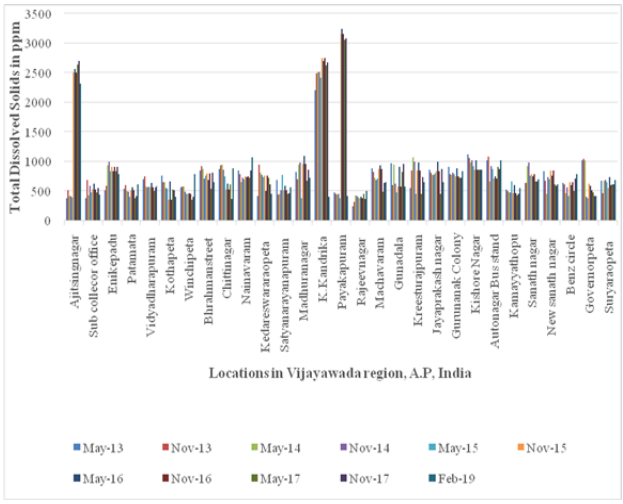

Fig. 2: Total Dissolved Solids at Various Locations in Vijayawada Region

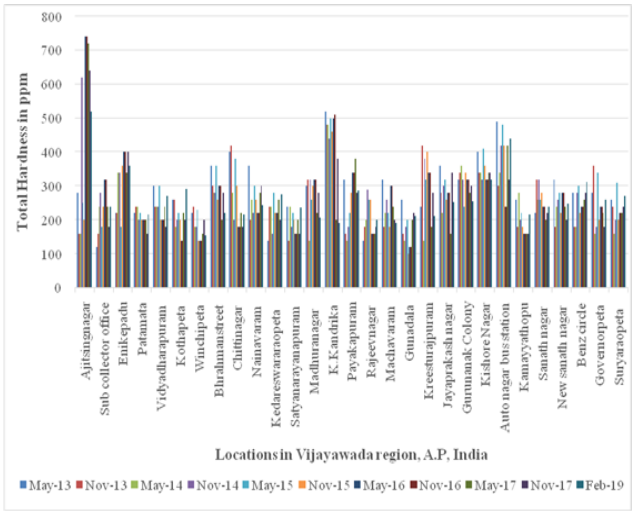

Fig. 3: Total Hardness at Various Locations in Vijayawada Region

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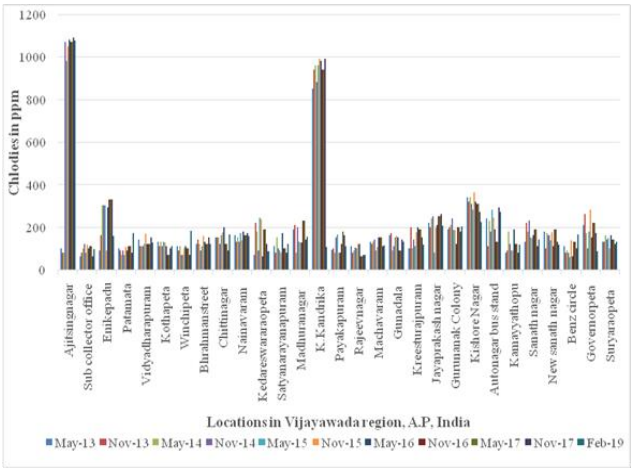

Fig. 4: Chlorides at Various Locations in Vijayawada Region

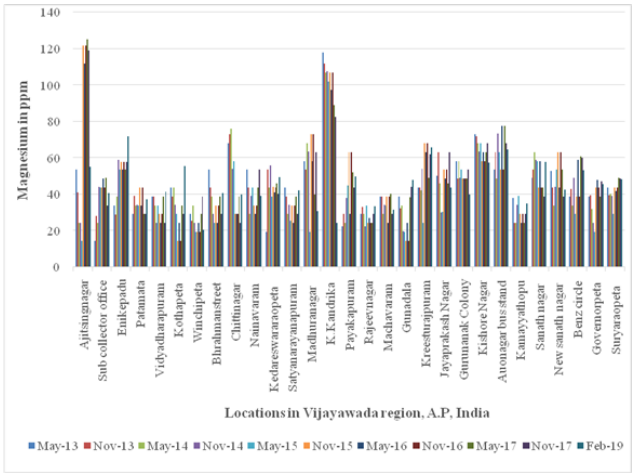

Fig. 6: Magnesium at Various Locations in Vijayawada Region

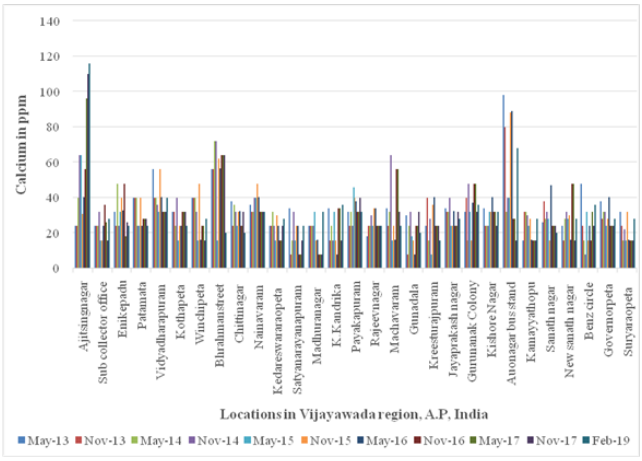

Fig. 5: Calcium at Various Locations in Vijayawada Region

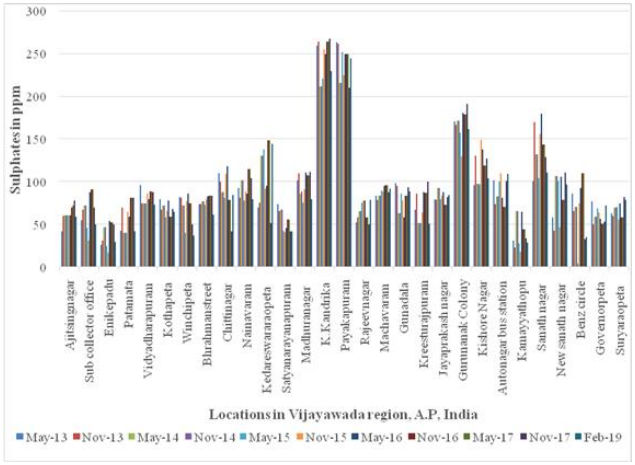

Fig. 7: Sulphates at Various Locations in Vijayawada

Table 3: Water Quality Index (WQI) at the observed locations in Vijayawada region

S.No	Location	Latitude	Longitude	Water Quality (Excellent - A, Good - B, Poor - C, Very Poor - D, Unfit for drinking - E)											Remarks
				May-13	Nov-13	May-14	Nov-14	May-15	Nov-15	May-16	Nov-16	May-17	Nov-17	Feb-19	
1	Ajithsingh nagar	16.541262^0 N	80.640160^0 E	D	D	D	D	D	E	E	E	E	E	E	**Unsuitable**
2	Sub collector office	16.507236^0 N	80.628017^0 E	D	D	D	D	D	D	D	D	D	D	D	Very poor
3	Enikepadu	16.518071^0 N	80.696814^0 E	D	D	D	D	E	E	E	E	E	E	E	**Unsuitable**
4	Patamata	16.494022^0 N	80.665438^0 E	C	D	D	D	D	D	D	D	D	D	D	Very poor
5	Brahmana street	16.52057^{0}N	80.610577^0 E	D	D	D	D	D	D	D	D	D	D	D	Very poor
6	Vidhyadara puram	16.525956^0 N	80.640158^0 E	D	D	D	D	D	D	D	D	D	D	D	Very poor
7	Kothapeta	16.713525^0 N	81.895385^0 E	D	D	D	D	D	D	D	D	D	D	D	Very poor
8	Winchipeta	16.525501^0 N	80.620015^0 E	E	E	E	E	E	E	E	E	E	E	E	**Unsuitable**
9	Chitinagar	16.532890^0 N	80.599122^0 E	D	D	D	D	D	D	D	D	D	D	D	Very poor
10	Nainavaram	16.565987^0 N	80.627481^0 E	D	D	D	D	D	D	D	D	E	E	E	Very poor
11	Kedeswararao peta	16.526145^0 N	80.627481^0 E	D	E	E	E	E	E	E	E	E	E	E	**Unsuitable**

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12	Sathyanarayana puram	16.522763^0 N	80.627780^0 E	D	D	D	D	D	D	D	D	D	D	D	Very poor
13	Madhura nagar	16.527880^o N	80.652082^0 E	D	D	D	D	D	E	E	E	E	E	E	**Unsuitable**
14	K.Kandrika	16.554132^0 N	80.646924^0 E	E	E	E	E	E	E	E	E	E	E	E	**Unsuitable**
15	Payakapuram	16.550787^0 N	80.657986^0 E	D	D	D	D	E	E	E	E	E	E	E	**Unsuitable**
16	Rajiv nagar	16.549117^0 N	80.647951^0 E	C	D	D	D	D	D	D	D	D	D	D	Very poor
17	Machavaram	16.518360^0 N	80.649116^0 E	C	D	D	D	D	D	D	D	D	D	D	Very poor
18	Gunadala	16.521353^0 N	80.663787^0 E	D	D	D	D	D	D	D	D	D	D	E	Very poor
19	Kreesthuraja puram	16.508658^0 N	80.649683^0 E	D	D	D	D	D	E	E	E	E	E	E	**Unsuitable**
20	Jayaprakash nagar	16.505322^0 N	80.628033^0 E	D	D	D	D	E	E	E	E	E	E	E	**Unsuitable**
21	Gurunanak colony	16.500839^0 N	80.672280^0 E	C	D	D	D	D	E	E	E	E	E	E	**Unsuitable**
22	Kishore Nagar	16.490122^0 N	80.670998^0 E	D	E	E	E	E	E	E	E	E	E	E	**Unsuitable**
23	Autonagar bus stand	16.491151^0 N	80.671394^0 E	D	D	E	E	E	E	E	E	E	E	E	**Unsuitable**
24	Kamayyathopu	16.484963^0 N	80.686787^0 E	C	D	D	D	D	D	D	D	D	D	D	Very poor
25	Sanath nagar	16.494440^0 N	80.676162 ^{0}E	D	E	E	E	E	E	E	E	E	E	E	**Unsuitable**
26	New sanath nagar	16.492119 ^{0}N	80.676210^0 E	D	D	D	D	D	D	D	D	D	D	D	Very poor
27	Benz circle	16.495626 ^{0}N	80.654156^0 E	D	D	D	D	D	E	E	E	E	E	E	**Unsuitable**
28	Governer pet	16.511533 ^{0}N	80.628033^0 E	D	D	D	D	D	E	E	E	E	E	E	**Unsuitable**
29	Suryarao peta	16.509708^0 N	80.637178^0 E	D	D	D	E	E	E	E	E	E	E	E	**Unsuitable**

Table 4: Water Quality parameters in Vijayawada region

S. No	Water Quality Parameter	Locations having water quality parameter more than the acceptable limit	Locations having water quality parameters more than the permissable limit
1	pH	Ajitsingh Nagar, Sub Collector office, Enikepadu, Patamata, Vidyadarapuram, Kothapeta, Winchipeta, Chittinagar, Nainavaram, Madhura Nagar, K.Kandrika, Payakapuram, Rajeev Nagar, Machavaram, Gunadala, Kreesthuraj puram, Jaya Prakash Nagar, Gurunanak colony, Kishore Nagar, Autonagar Bus stand, Kamayyathopu, Sanath nagar, New sananth Nagar, Benz circle, Governerpet, Suryarao pet	Bhrahmanstreet, Kedareswarao peta, Satyannarayanapuram
2	Total Dissolved Solids	Sub Collector office, Enikepadu, Patamata, Vidyadarapuram, Kothapeta, Winchipeta, Chittinagar, Nainavaram, Madhura Nagar, Payakapuram, Rajeev Nagar, Machavaram, Gunadala, Kreesthuraja puram, Jayaprakash Nagar, Gurunanak colony, Kishore Nagar, Autonagar Bus stand, Kamayyathopu, Sanath Nagar, New sananth Nagar, Benz circle, Governerpet, Suryarao pet, Bhrahmana street, Kedareswarao peta, Satyannarayana Puram	Ajith singh nagar , K.Kandrika
3	Total Hardness	Sub Collector office, Enikepadu, Patamata, Vidyadarapuram, Chittinagar, Nainavaram, Madhura Nagar, Payakapuram, Rajeev Nagar, Machavaram, Kreesthuraja puram, Jaya Prakash Nagar, Gurunanak colony, Kishore Nagar, Autonagar Bus stand, Sanath Nagar, New sananth Nagar, Benz circle, Governerpet, Surya rao pet, Bhrahmana street, Kedareswarao peta, Satyannarayanapuram, K.Kandrika	Ajithsingh nagar
4	Chlorides	Ajith Singh Nagar, Enikepadu, Kishore Nagar	K.Kandrika
5	Calcium	.....	.....
6	Magnesium	Sub Collector office, Enikepadu, Patamata, Vidyadarapuram, Kothapeta, Chittinagar, Nainavaram, Madhura Nagar, Payakapuram, Machavaram, Gunadala, Kreesthuraja Puram, Jaya Prakash Nagar, Gurunanak colony, Kishore Nagar, Autonagar Bus stand, Sanath nagar, New sananth Nagar, Benz circle, Governerpet, Surya rao pet, Bhrahmanstreet, Kedareswarao peta, Satyannarayanapuram	K.Kandrika
7	Sulphates	K.Kandrika , Payakapuram	.....

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4. RESULTS AND DISCUSSION

The ground water quality parameters measured by the Groundwater and Water Audit department, Vijayawada during pre - monsoon and post-monsoon from May 2013 to November 2017 are taken from Groundwater and Water Audit department, Vijayawada and measured the same parameters during February 2019 at the same bore wells and recorded the variation of each parameter during the above mentioned period is shown in Fig. 1 - 7 for PH, Total Dissolved Solids, Total Hardness, Chlorides, Calcium, Magnesium and Sulphates respectively. By using these ground water quality parameters, the Water Quality Index, WQI is estimated at all the 29 locations and reported in Table 3. Also the locations where the individual ground water quality parameters are more than the acceptable and permissible values as per IS 10500:2012 are reported in Table 4.

Table 3 clearly shows that the groundwater quality at 15 locations such as Ajithsingh nagar, Enikepadu, Winchpeta, Kedareswararao Peta, Madhura Nagar, K. Kandrika, Payakapuram, Kreesthurajapuram, Jaya Prakash Nagar, Gurunanak Colony, Kishore Nagar, Sanath Nagar, Benz Circle, Governer Peta, and Suryarao Peta are found to be unsuitable for drinking purpose and all other 14 locations the ground water quality is observed as very poor. Most of the locations the pH, concentration of total dissolved solids and the total hardness and magnesium are more than the standard values given by IS 10500: 2012 as per Table 4.

5. CONCLUSIONS AND REMEDIAL MEASURES

Based on the estimated Water Quality index at the observed 29 locations along with the physio chemical properties measured, the groundwater quality is observed as unsuitable for drinking at 15 locations and at another 14 locations, it is observed as very poor quality of water. Ajith singh nagar is very near to the Vambay colony dumpsite and the municipal solid waste coming from the Vijayawada city is being dumped in this dumpsite for many years, which caused high concentrations of all physiochemical properties. Depletion of ground water table due to over exploitation of ground water, unauthorized sewer lines, Industrial waste water lines connected to the unlined irrigation canals such as Bandar canal and eluru canal, panta kaluva, and budameru drain, where also lot of municipal and construction waste was dumped in these canals are also major sources of ground water pollution. In most of the locations the concentration of total dissolved solids and the total hardness and magnesium are more than the standard values given by IS 10500: 2012.

It is recommended that groundwater should be treated prior to use as drinking water by using reverse osmosis for large scale and filters for small scale needs. Also ground water recharge with rainwater improves the quality of ground water by balancing various physiochemical properties. However, it shall be ensured that the rain water reaches to the ground water aquifer, which is located at 5 to 12 m deep at several locations overlaying by black cotton soil with very low coefficient of permeability. Hence, in such regions, instead of 2m deep rain water harvesting pit used in the sandy soils, the modified pit similar to Fig. 8 which is designed for 5 acre land is recommended to ensure the recharge of ground water. The size of pit can be reduced if the percolation area is less than 5 acre, however, must reach to the aquifer zone.

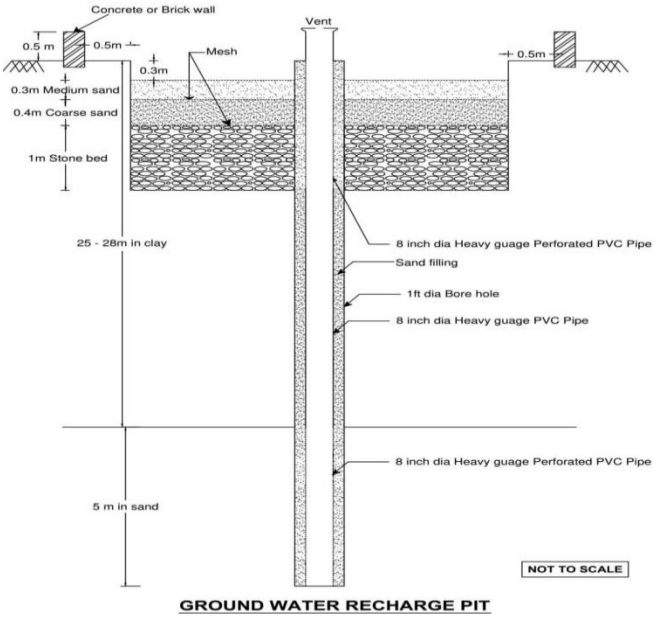

Fig. 8: Design Drawing of Rain Water Harvesting Pit

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