Original Research Article

Hydrogeochemical characteristics of shallow and deep aquifers and its suitability for drinking and irrigation use in Uttar Mand sub-basin of Krishna river basin, Maharashtra, India

Gaikwad M R

Department of Geology, Khare-Dhere-Bhosale College, Guhagar, Ratnagiri – 415703, Maharashtra, INDIA.
Email: prof.mrgaikwad@gmail.com

Abstract

Groundwater is the most important water resources in modern water supply and its quality is the determining factor, especially for the groundwater supply under extreme events. Groundwater quality survey was carried out in Uttar Mand sub-basin of Krishna River Basin, Maharashtra, India, which is a famous for sugarcane cultivation. The result shows that the distribution of major ions in the groundwater as $Ca^{2+} > Mg^{2+} > Na^{+} > K^{+}$ and $HCO_3^{-} > SO_4^{2-} > Cl^{-} > B$. The influences of agricultural fertilizers and irrigation practices are the reason for increasing trends of NO_3^{-} ions in the groundwater from studied area. According to the drinking water quality standards, the groundwater is not suitable for drinking with reference to the concentrations of total hardness, Ca^{2+}, Mg^{2+} and B in many locations. Based on the parameters mentioned above (Sodium Adsorption Ratio, Residual Soluble Carbonate and Permeability Index), the groundwater quality is assessed and the overall irrigation qualities of wells are demarcated as suitable for irrigation.

Key Words: Shallow and deep aquifers, hydrogeochemistry, Uttar Mand river basin.

***Address for Correspondence:**
Mr. Gaikwad M. R., Department of Geology, Khare-Dhere-Bhosale College, Guhagar, Ratnagiri – 415703, Maharashtra, INDIA.
Email: prof.mrgaikwad@gmail.com

Received Date: 13/11/2017 Revised Date: 01/12/2017 Accepted Date: 23/01/2018
DOI: https://doi.org/10.26611/202611

Access this article online	
Quick Response Code:	Website: www.statperson.com
	Accessed Date: 10 February 2018

INTRODUCTION

Water is one the most valuable natural resource existing on our planet and 71% of the Earth's surface comprises of it. Without this valuable compound, life on the Earth would not exist. However, due to rapid growth in the global population, the difference between supply and demand of water is widening and is reaching the alarming or dangerous levels in some part of the world. However, due to increased anthropogenic activities i.e. domestic as well as economic, these valued resources are increasingly under threat, both qualitatively and quantitatively. Quality of water resources is directly affecting the quality of our food, health and environment. As population increases and development calls for increased allocations of groundwater and surface water for the domestic, agriculture and industrial sectors, the pressure on water resources intensifies. Thus, increasing stress on freshwater resources brought about by ever-rising demand and profligate use, as well as by growing pollution worldwide, is of serious concern. At the beginning of the 21st century earth faces serious problems of environmental pollution occurs due to anthropogenic activities. The municipal waste generation and its disposal is the common problem being faced today. The improper use and disposal of wastewater affects the human health and environment. Hence, the quality of the water and soil has been deteriorating day by day. The contamination and quality of water is main concern in the region with limited water resources. The industrial and municipal effluent is main source of water contamination. Generally, some of natural processes such as aquifer

How to cite this article: Gaikwad M R. Hydrogeochemical characteristics of shallow and deep aquifers and its suitability for drinking and irrigation use in Uttar Mand sub-basin of Krishna river basin, Maharashtra, India. *International Journal of Recent Trends in Science and Technology.* February to April 2018; 26(1): 01-11 http://www.statperson.com

lithology, water and geological formations interactions, water velocity and its residence time control the groundwater chemistry in the aquifer[1]. In addition, the intense anthropogenic activities cause a very important risk to the groundwater quality. For this reason, the identification of the main processes controlling the hydrochemical groundwater becomes necessary. So, the assessment and the understood of chemical processes occurring in aquifer are indispensable to define the mineralization origin and the water quality. For country like India, the problem has faced due to temporal and spatial variation of rainfall, improper management of surface runoff, uneven geographical distribution of surface water resources, persistent droughts, overuse of groundwater, contamination due improper untreated wastewater etc.[2] Water resources are not distributed equally on the earth's surface. The arid and semi-arid climatic areas, where potential evaporation and transpiration exceed precipitation, lack of water resources is a frequent problem, where there is not enough water to sustain agricultural production, for rural population[l]. Thus, increased demand of fresh water due increasing population and depletion of water resources has thus pressed upon use of different wastewater techniques, such as, desalination, water reuse, rainwater harvesting, enhanced groundwater recharge and inter-basin transfers[4]. However, many municipalities' disposes off their treated or partly treated or untreated wastewater into natural drains joining rivers or lakes or used on land for irrigation or fodder cultivation or into sea or combination of these. In most of the cases, where wastewater is let out untreated and it either percolates into the ground or in turn contaminates the groundwater into the natural drainage system causing pollution in downstream areas. For present study Uttar Mand sub-basin of Krishna River Basin has been chosen which is a famous for sugarcane cultivation. The Uttar Mand river basin bounded between latitude 17° 20' 12" N to 17 ° 25' 24" N and longitude 73 ° 55' 07" E to 74 ° 5' 7" E in Survey of India Toposheet numbers 47 G/15, 47 K/3 and having area of about 109 km^2 (Fig. 1). The Uttar Mand river is one of the tributary of the Krishna river. The present study area geologically covers a Deccan Volcanic Basalt of Upper Cretaceous to Lower Eocene age. The soil cover of the study area is fertile and this very useful for agriculture purpose. The climate of the area comes across as an amusing blend of the coastal and inland climate of Maharashtra. The temperature ranged from 10° C and 40° C. The average annual rainfall of the area is 4,800 mm. The Uttar Mand river basin shows well developed dendritic to sub dendritic type drainage pattern (Fig. 2).

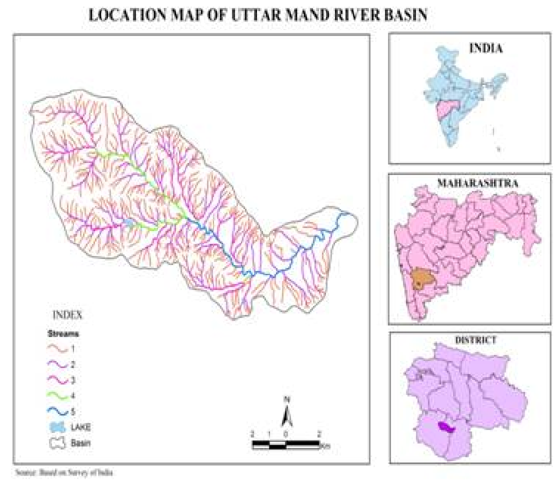


Figure 1: Location Map of the Study Area

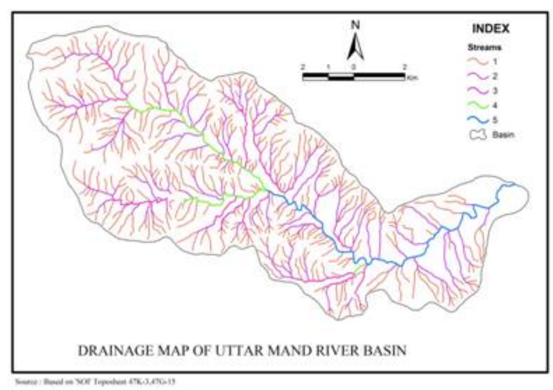


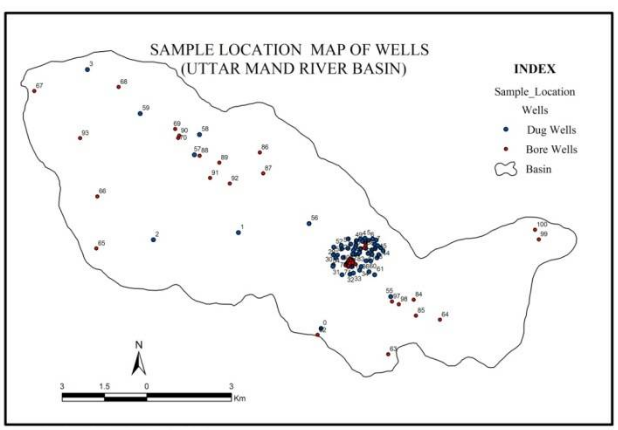
Figure 2: Drainage map of the Study area

MATERIAL AND METHODS

The main objective of the study is to assess the impact of the quality of water on drinking and agricultural use. Thus, the methodology adopted to fulfill the objectives of the research work. It give details about of methodology adopted like field surveys, sample site selection, collection of water samples from the sampling site and then the analytical procedures adopted to get the desired result. The standard techniques and procedures are adopted for the purpose of sampling, data processing and analysis [5,6,7,8, 9]. In the coming years, there will be a twin edged problem to deal with reduced fresh water availability and increased wastewater generation. Thus, reuse of wastewater for irrigation by using domestic sewage or treated industrial effluents has been studied widely by experts. Keeping in mind these points, the standard methods were adopted during the research work. The study also incorporates geochemical status of the available surface and subsurface waters and soil resources in a particular Geo-environmental set-up under semi-arid climatic regime to check the stresses on natural resources as a consequence of pollution from municipal wastes and rapid urban developments. This information is vital for successful integrated management the natural of resources, as most of the local population depend on them for their live hood.

Field Methodology: The detailed field surveys were carried to understand the soil and water problem in the study area and the sample data were collected from the surroundings within the study area. This section describes the methodologies adopted for site selection and details of sample data.

Sampling Site Selection: The accurate selection of sampling site survey is the most important task to obtain the reliable results. The standard random sampling methods were used for the selection of water samples. The water samples sites were selected near the solid waste dumping areas and also, the starting point of the stream i.e. upper reaches, middle stretch and lower stretch of the river channels (Fig. 3). The groundwater monitoring sites were selected near to the solid waste dumping sites and also, were wastewater streams flows. The groundwater samples were also collected from the semi urban area and agricultural belt. Total 100 groundwater sampling sites were selected which includes 62 dug wells sites and 32 bore wells sites. To mark the sampling site location (latitude and longitude) and fixed the sampling site, Global Positioning System (GPS) technology were used at the time of sampling.



Source : Based on 'SOI' Toposheet 47K-3,47G-15

Figure 3: Location map of the water sampling stations

Groundwater Sampling: The groundwater samples were collected from the dug and bore wells from the selected sampling stations (Fig. 1). Total 100 groundwater sampling sites were selected which includes 62 dug wells (shallow aquifer) sites and 38 bore wells (deep aquifer) sites. The guidelines given by APHA (2005) were followed for the groundwater sampling [10]. The whole process of sample collections was conducted continuously for two seasons (2014-2015) during the post and pre monsoon in the study area from the fixed sampling stations. To avoid the contamination of water samples following precautions were taken during collection of samples.

1. Pre cleaned polyethylene containers were used for water sample collection and storage and separate containers used at every sampling site.
2. Dug well water samples were collected after the pumping for half an hour. In case of bore wells (Hand pump), before collecting the samples bore wells were pumped for few minutes.
3. To identify the collected samples, each sample was labeled indicating there location i.e. sampling site and sampling dates and was given specific code numbers.
4. The collected samples were preserved as per requirement of the parameter following their standard method.

Water quality analysis: The collected water samples were analysed for various parameters such as physico-chemical parameters and irrigation characteristics. The analysis of the water samples was carried out as per the methods prescribed in the standard methods for examination of water and wastewater[10].

Physico-chemical parameters: The chemical analysis of parameters like pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS) was carried out using pH meter, conductivity meter and TDS meter, respectively. The cations, anions were analysed by standard methods. Na, K were analyzed by using flame photometer. Volumetric method use for the analysis of total alkalinity, calcium, total hardness and chloride in water samples from the area under study. Total hardness (TH) and Ca^{2+} determined by using standard EDTA titrimetric method, and magnesium determined by difference in total hardness and calcium titration by calculation method [10]. $AgNO_3$ method was used for estimation of Cl^-. Analysis of Sulphate concentration in water samples by using UV-VIS Spectrophotometer.

Irrigation water quality parameters: In the study case, the assessment of groundwater suitability for irrigation was determined through three indexes: Sodium Adsorption Ratio (SAR), Residual Soluble Carbonate (RSC) and Permeability Index (PI).

Sodium Adsorption Ratio (SAR): The excess of sodium concentration in groundwater affects the soil properties and reduces the soil permeability. Hence, the determination of the groundwater suitability for irrigation was performed by calculating the Sodium Adsorption Ratio (SAR). This ratio measures the risk of alkalisodium for crops. Moreover, it determines the degree from which water tends to enter into cation-exchange reactions in soil. Generally, the Sodium reaches the aquifer through rain and rocks dissolution. It replaces the absorbed magnesium and calcium, and consequently causes the soil structure damage. Because of its effect on soils and plants, it has been considered among the main factors governing irrigation water [11]. This ratio was determined using the following equation (Eq. 2):

$$SAR = \frac{Na^+}{\sqrt{\frac{Ca^{2+}+Mg^{2+}}{2}}} \quad (1)$$

According to SAR ratio, waters were grouped into three classes. Water with SAR ranging from 0 to 3 is considered as good, while SAR ranging from 3 to 9 is characterized by moderate type and greater than 9 is considered unsuitable for irrigation purpose (Table 1).

Residual Sodium Carbonate (RSC): Residual sodium carbonate (RSC) is an index used to determine the HCO_3^- hazard. High bicarbonate concentration in water can arrest plant growth and lead to calcite precipitation, decreased soil permeability, lowered infiltration capacity and an increase in erosion[12].

The value of RSC is calculated as per Eaton (1950),

$$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+}) \quad (2)$$

Where all ionic concentration expressed in meq/l

The water having excess of CO_3^{2-} and HCO_3^- concentration over the Ca^{2+} and Mg^{2+} in excess of limits have unfavorable effects on agriculture [12]. According to Lloyd and Heathcote (1985) water from the study area has been classified based on RSC [13]. Classification of RSC has depicted in Table 5.

Permeability index (PI)

The soil permeability is influenced through continues and intensive use of groundwater sources for irrigation. The permeability is affected through the sodium, calcium, magnesium and bicarbonate content in the soil. The permeability index (PI) was determined by the equation 1 created by Doneen *et al*. (1964) where all elements are in milli equivalent per liter [14].

$$PI = \frac{(Na^+ + \sqrt{HCO_3^-})}{(Ca^{2+}+Mg^{2+}+Na^+)} \times 100 \quad (3)$$

To assess the groundwater suitability for irrigation, Doneen *et al*. (1964) evolved a water classification based on the PI [14]. Hence, three classes were identified: Class I which is characterized by PI <25%, and classify the water as unsuitable for irrigation, Class II are categorized as good and suitable water for irrigation with a 25 % < PI > 75% and the last class III where the PI >75%, is distinguished by excellent water for irrigation.

RESULT AND DISCUSSION

The post monsoon season groundwater quality results of shallow aquifer and deep aquifers were presented in Table 1 and 2, respectively. The pre monsoon season groundwater quality results of shallow aquifer and deep aquifers were presented in Table 3 and 4, respectively.

Table 1: Physico-chemical and irrigation water quality characteristics of shallow aquifer (dug water samples) from the study area (post monsoon 2014)

Sampling Code	pH	EC	TDS	Hardness	Ca++	Mg++	Na+	K+	Cl-	SO4	CO3	HCO3	B	SAR	RSC	PI
DW 1	7.08	906.0	543.6	375.1	120.0	99.6	5.1	44.5	56.7	162.7	0.0	585.6	4.74	0.07	-4.60	23.04
DW 2	7.39	721.0	432.6	298.5	121.0	57.7	3.6	44.1	70.9	190.1	0.0	414.8	4.58	0.05	-4.00	25.23
DW 3	7.40	425.0	255.0	176.0	61.0	48.0	2.8	45.0	85.1	201.6	0.0	341.6	4.46	0.05	-1.40	34.92
DW 4	6.61	192.0	115.2	79.5	42.0	20.7	1.9	43.4	70.9	199.2	0.0	219.6	4.47	0.05	-0.20	50.99
DW 5	7.10	726.0	435.6	300.6	115.0	78.4	4.9	42.8	56.7	201.1	0.0	268.4	4.49	0.07	-7.80	18.63
DW 6	7.34	820.0	492.0	339.5	125.0	103.9	6.6	42.5	70.9	197.8	0.0	463.6	4.42	0.09	-7.20	20.18
DW 7	7.18	888.0	532.8	367.6	130.0	96.0	5.5	43.2	85.1	194.9	0.0	414.8	4.34	0.07	-7.60	19.46
DW 8	7.51	866.0	519.6	358.5	102.0	115.4	5.9	45.0	85.1	203.0	0.0	463.6	4.42	0.08	-7.00	20.30
DW 9	7.57	661.0	396.6	273.7	105.0	55.3	3.2	41.5	70.9	201.1	0.0	390.4	4.37	0.05	-3.40	26.85
DW 10	7.22	859.0	515.4	355.6	106.0	110.6	5.8	45.6	113.4	187.7	0.0	414.8	4.44	0.08	-7.60	19.53
DW 11	7.19	685.0	411.0	283.6	110.0	79.0	5.2	41.7	70.9	216.0	0.0	414.8	4.44	0.08	-5.20	23.17
DW 12	7.45	785.0	471.0	325.0	107.0	83.2	4.4	43.4	99.3	215.0	0.0	512.4	4.59	0.06	-3.80	24.93
DW 13	7.07	772.0	463.2	319.6	112.0	85.1	4.9	42.4	85.1	207.4	0.0	414.8	4.87	0.07	-5.80	22.01
DW 14	7.21	875.0	525.0	362.3	97.0	113.6	5.5	40.3	99.3	183.4	0.0	439.2	4.81	0.08	-7.00	20.23
DW 15	7.07	811.0	486.6	335.8	110.0	108.1	6.3	40.5	56.7	200.2	0.0	390.4	4.75	0.09	-8.00	19.11
DW 16	7.22	838.0	502.8	346.9	105.0	111.2	6.0	43.9	70.9	203.0	0.0	366.0	4.73	0.08	-8.40	18.50
DW 17	7.12	775.0	465.0	320.9	98.0	100.8	5.5	40.5	85.1	197.8	0.0	366.0	4.85	0.08	-7.20	20.00
DW 18	7.08	904.0	542.4	374.3	95.0	131.8	6.6	41.0	99.3	212.6	0.0	439.2	4.81	0.09	-8.40	18.69
DW 19	7.14	839.0	503.4	347.3	118.0	98.4	5.6	41.5	113.4	212.2	0.0	463.6	4.81	0.08	-6.40	21.07
DW 20	6.79	954.0	572.4	395.0	151.0	80.8	4.7	39.9	127.6	206.4	0.0	463.6	4.85	0.06	-6.60	20.55
DW 21	6.86	769.0	461.4	318.4	145.0	50.4	3.7	40.5	70.9	208.8	0.0	561.2	4.82	0.05	-2.20	27.63
DW 22	6.79	1055.0	633.0	436.8	162.0	76.6	3.9	40.3	127.6	200.6	0.0	536.8	4.77	0.05	-5.60	21.52
DW 23	6.92	958.0	574.8	396.6	154.0	79.0	4.6	40.2	127.6	205.4	0.0	512.4	4.90	0.06	-5.80	21.53
DW 24	7.11	858.0	514.8	355.2	149.0	82.0	5.6	39.2	127.6	200.2	0.0	512.4	4.77	0.08	-5.80	21.76
DW 25	7.14	865.0	519.0	358.1	143.0	85.7	5.6	39.5	127.6	210.7	0.0	512.4	4.85	0.07	-5.80	21.75
DW 26	7.21	883.0	529.8	365.6	155.0	78.4	5.4	41.8	127.6	202.1	0.0	488.0	4.66	0.07	-6.20	21.22
DW 27	7.39	874.0	524.4	361.8	144.0	85.1	5.5	41.1	113.4	205.9	0.0	512.4	4.51	0.07	-5.80	21.72
DW 28	7.55	864.0	518.4	357.7	154.0	88.7	6.4	40.5	113.4	205.4	0.0	512.4	4.63	0.08	-6.60	20.80
DW 29	7.27	861.0	516.6	356.5	165.0	77.2	6.0	42.6	113.4	198.2	0.0	488.0	4.77	0.08	-6.60	20.79
DW 30	7.10	980.0	588.0	405.7	186.0	76.6	5.8	48.4	113.4	201.6	0.0	512.4	4.46	0.07	-7.20	19.88
DW 31	7.04	936.0	561.6	387.5	153.0	77.2	4.6	39.6	113.4	174.7	0.0	488.0	4.76	0.06	-6.00	21.34
DW 32	6.80	1205.0	723.0	498.9	168.0	70.5	2.2	45.0	127.6	197.3	0.0	512.4	4.70	0.03	-5.80	20.93
DW 33	7.08	1005.0	603.0	416.1	179.0	90.5	6.4	41.8	127.6	210.2	0.0	512.4	4.62	0.08	-8.00	19.04
DW 34	7.49	836.0	501.6	346.1	141.0	82.0	5.4	41.0	156.0	215.5	0.0	488.0	4.72	0.07	-5.80	21.84
DW 35	7.30	884.0	530.4	366.0	128.0	65.6	3.0	43.7	141.8	197.8	0.0	488.0	4.81	0.04	-3.80	24.79
DW 36	7.28	871.0	522.6	360.6	144.0	87.5	5.7	41.9	141.8	204.0	0.0	488.0	4.53	0.08	-6.40	21.00
DW 37	7.37	790.0	474.0	327.1	141.0	65.0	4.5	40.3	141.8	185.8	0.0	463.6	4.87	0.06	-4.80	23.45
DW 38	7.32	840.0	504.0	347.8	159.0	56.6	4.2	43.3	156.0	190.1	0.0	414.8	4.61	0.06	-5.80	21.83
DW 39	7.50	818.0	490.8	338.7	186.0	30.4	3.6	36.9	99.3	186.7	0.0	512.4	4.63	0.05	-3.40	25.56
DW 40	7.23	882.0	529.2	365.1	166.0	42.5	3.0	40.0	99.3	179.0	0.0	536.8	4.44	0.04	-3.00	25.96
DW 41	7.25	871.0	522.6	360.6	173.0	62.6	5.1	42.4	99.3	201.1	0.0	536.8	4.50	0.07	-5.00	22.74
DW 42	7.16	856.0	513.6	354.4	173.0	52.9	4.4	42.6	99.3	196.3	0.0	463.6	4.33	0.06	-5.40	22.36
DW 43	7.15	841.0	504.6	348.2	187.0	44.4	4.6	39.8	99.3	197.8	0.0	463.6	4.43	0.06	-5.40	22.40
DW 44	7.23	855.0	513.0	354.0	191.0	39.5	4.3	42.5	113.4	200.2	0.0	390.4	4.47	0.06	-6.40	20.91
DW 45	6.70	812.0	487.2	336.2	187.0	39.5	4.5	42.5	113.4	150.2	0.0	390.4	4.42	0.06	-6.20	21.30
DW 46	7.34	806.0	483.6	333.7	182.0	47.4	4.9	42.2	127.6	210.2	0.0	366.0	4.18	0.07	-7.00	20.16
DW 47	7.20	766.0	459.6	317.1	197.0	35.8	5.1	37.6	70.9	213.1	0.0	341.6	4.80	0.07	-7.20	19.89
DW 48	7.23	853.0	511.8	353.1	167.0	34.6	2.7	39.7	127.6	213.6	0.0	390.4	4.81	0.04	-4.80	23.39
DW 49	7.18	766.0	459.6	317.1	211.0	24.9	4.9	40.3	85.1	209.3	0.0	390.4	4.73	0.06	-6.20	21.42
DW 50	7.20	741.0	444.6	306.8	189.0	43.1	5.6	40.4	56.7	212.6	0.0	488.0	4.56	0.07	-5.00	23.20
DW 51	7.16	956.0	573.6	395.8	205.0	55.3	5.2	41.8	99.3	214.1	0.0	463.6	4.61	0.07	-7.20	19.87
DW 52	7.19	871.0	522.6	360.6	202.0	45.0	5.1	43.2	114.5	196.3	0.0	463.6	4.76	0.06	-6.20	21.25
DW 53	7.11	833.0	499.8	344.9	189.0	35.8	4.1	41.9	99.3	214.6	0.0	390.4	4.76	0.05	-6.00	21.53
DW 54	7.09	849.0	509.4	351.5	185.0	38.3	3.9	44.0	85.1	205.0	0.0	414.8	4.56	0.05	-5.60	22.10
DW 55	7.22	818.0	490.8	338.7	177.0	38.3	3.5	39.2	70.9	210.2	0.0	414.8	4.72	0.05	-5.20	22.72

DW 56	7.31	743.0	445.8	307.6	185.0	43.1	5.4	44.0	85.1	165.6	0.0	463.6	4.72	0.07	-5.20	22.95
DW 57	7.39	845.0	507.0	349.8	196.0	65.6	6.8	41.9	113.4	216.0	0.0	390.4	2.99	0.08	-8.80	18.23
DW 58	7.19	883.0	529.8	365.6	162.0	74.1	5.4	42.9	99.3	212.6	0.0	414.8	4.46	0.07	-7.40	19.69
DW 59	7.32	726.0	435.6	300.6	176.0	19.4	3.1	42.7	85.1	203.5	0.0	414.8	4.36	0.04	-3.60	26.05
DW 60	7.15	792.0	475.2	327.9	167.0	71.1	6.3	41.8	70.9	195.4	0.0	439.2	4.70	0.08	-7.00	20.43
DW 61	7.22	625.0	375.0	258.8	176.0	46.2	6.4	43.3	85.1	205.0	0.0	292.8	4.69	0.09	-7.80	19.17
DW 62	6.92	368.0	220.8	152.4	127.0	27.3	4.9	42.6	56.7	201.1	0.0	292.8	4.73	0.08	-3.80	27.29
Minimum	6.61	192.0	115.2	79.5	42.0	19.4	1.9	36.9	56.7	150.2	0.0	219.6	2.99	0.03	-8.80	18.23
Maximum	7.57	1205.0	723.0	498.9	211.0	131.8	6.8	48.4	156.0	216.0	0.0	585.6	4.90	0.09	-0.20	50.99
Average	7.18	819.5	491.7	339.3	149.3	67.9	4.9	41.9	100.0	200.3	0.0	441.6	4.60	0.07	-5.81	22.43

All parameters are expressed in mg/L except EC (µS cm), pH, SAR, RSC and PI (%)

Table 2: Physico-chemical and irrigation water quality characteristics of deep aquifer (borewell water samples) from the study area (post monsoon 2014)

Sampling Code	pH	EC	TDS	Hardness	Ca++	Mg++	Na+	K+	Cl-	SO4	CO3	HCO3	B	SAR	RSC	PI
BW 1	6.57	915.0	549.0	378.8	179.0	85.7	6.9	26.4	99.3	110.4	0.0	512.4	0.76	0.09	-7.60	19.62
BW 2	6.95	694.0	416.4	287.3	181.0	16.4	3.5	16.6	85.1	124.8	0.0	463.6	0.32	0.05	-2.80	27.56
BW 3	7.20	508.0	304.8	210.3	157.0	22.5	0.9	30.0	85.1	139.2	0.0	366.0	0.76	0.01	-3.70	25.56
BW 4	6.86	276.0	165.6	114.3	145.0	15.2	3.2	40.0	70.9	153.6	0.0	244.0	0.54	0.05	-4.50	24.78
BW 5	5.99	191.0	114.6	79.1	58.0	40.1	4.3	45.9	70.9	168.0	0.0	146.4	0.32	0.09	-3.80	27.19
BW 6	5.99	202.0	121.2	83.6	95.0	3.0	3.0	45.9	70.9	182.4	0.0	146.4	0.54	0.06	-2.60	32.73
BW 7	6.54	359.0	215.4	148.6	85.0	9.1	1.4	44.5	85.1	196.8	0.0	268.4	1.62	0.03	-0.60	42.66
BW 8	6.82	745.0	447.0	308.4	167.0	66.2	6.4	45.5	99.3	211.2	0.0	439.2	0.32	0.08	-6.60	21.03
BW 9	6.93	773.0	463.8	320.0	154.0	69.3	5.7	45.3	99.3	225.1	0.0	414.8	0.76	0.08	-6.60	20.92
BW 10	7.26	818.0	490.8	338.7	166.0	59.5	5.0	45.5	113.4	240.0	0.0	463.6	0.00	0.07	-5.60	22.18
BW 11	6.69	810.0	486.0	335.3	146.0	83.8	6.1	45.0	85.1	124.8	0.0	488.0	0.00	0.08	-6.20	21.39
BW 12	6.79	785.0	471.0	325.0	102.0	91.1	4.8	44.8	99.3	224.2	0.0	512.4	0.00	0.07	-4.20	24.25
BW 13	7.42	763.0	457.8	315.9	128.0	65.6	4.2	45.2	99.3	217.4	0.0	439.2	2.05	0.06	-4.60	23.91
BW 14	7.02	722.0	433.2	298.9	136.0	58.3	4.4	46.4	85.1	215.5	0.0	390.4	0.00	0.06	-5.20	23.08
BW 15	7.19	716.0	429.6	296.4	137.0	67.4	5.2	45.7	113.4	215.5	0.0	463.6	0.76	0.07	-4.80	23.64
BW 16	7.35	792.0	475.2	327.9	147.0	71.1	5.3	45.7	85.1	214.1	0.0	366.0	3.35	0.07	-7.20	19.95
BW 17	7.25	812.0	487.2	336.2	131.0	100.2	6.7	45.8	99.3	218.9	0.0	439.2	1.73	0.09	-7.60	19.71
BW 18	6.91	959.0	575.4	397.0	123.0	107.5	5.4	45.9	113.4	219.8	0.0	488.0	0.00	0.07	-7.00	20.11
BW 19	6.80	878.0	526.8	363.5	149.0	91.7	6.2	45.7	99.3	217.9	0.0	463.6	0.65	0.08	-7.40	19.83
BW 20	6.58	787.0	472.2	325.8	150.0	69.3	5.3	45.8	85.1	212.6	0.0	390.4	0.22	0.07	-6.80	20.57
BW 21	7.53	783.0	469.8	324.2	112.0	85.1	4.8	45.8	99.3	218.4	0.0	390.4	0.43	0.07	-6.20	21.38
BW 22	7.19	806.0	483.6	333.7	170.0	59.5	5.3	45.2	184.3	223.2	0.0	463.6	0.54	0.07	-5.80	21.93
BW 23	7.28	669.0	401.4	277.0	157.0	40.7	4.5	45.5	85.1	226.1	0.0	390.4	0.86	0.06	-4.80	23.93
BW 24	7.28	721.0	432.6	298.5	156.0	51.0	4.8	45.6	70.9	219.8	0.0	341.6	2.70	0.07	-6.40	21.10
BW 25	7.46	635.0	381.0	262.9	106.0	32.8	1.7	45.7	85.1	220.3	0.0	341.6	2.70	0.03	-2.40	30.21
BW 26	7.82	713.0	427.8	295.2	144.0	63.2	5.3	45.0	85.1	217.4	0.0	341.6	0.65	0.07	-6.80	20.56
BW 27	7.44	580.0	348.0	240.1	86.0	42.5	2.0	43.6	56.7	223.7	0.0	268.4	0.00	0.04	-3.40	27.70
BW 28	7.26	496.0	297.6	205.3	101.0	48.0	4.0	44.9	85.1	225.1	0.0	268.4	0.00	0.07	-4.60	24.78
BW 29	7.33	780.0	468.0	322.9	161.0	79.6	6.8	45.2	56.7	220.3	0.0	341.6	0.00	0.09	-9.00	17.88
BW 30	7.10	785.0	471.0	325.0	136.0	80.2	5.6	46.8	85.1	221.3	0.0	390.4	0.00	0.08	-7.00	20.32
BW 31	6.91	614.0	368.4	254.2	101.0	84.4	5.9	45.3	70.9	222.7	0.0	292.8	0.00	0.09	-7.20	19.96
BW 32	7.35	855.0	513.0	354.0	166.0	54.7	4.3	44.5	99.3	229.0	0.0	439.2	0.76	0.06	-5.60	22.09
BW 33	7.58	860.0	516.0	356.0	201.0	60.1	6.4	42.2	99.3	223.7	0.0	439.2	0.00	0.08	-7.80	19.39
BW 34	7.59	1017.0	610.2	421.0	199.0	80.8	6.4	44.8	113.4	223.7	0.0	536.8	0.00	0.08	-7.80	19.24
BW 35	7.47	907.0	544.2	375.5	184.0	82.6	6.9	44.7	56.7	224.2	0.0	366.0	0.00	0.09	-10.00	16.88
BW 36	7.59	854.0	512.4	353.6	163.0	63.8	4.9	41.6	99.3	220.3	0.0	414.8	0.00	0.07	-6.60	20.72
BW 37	7.67	960.0	576.0	397.4	193.0	67.4	5.6	46.2	113.4	222.7	0.0	463.6	0.00	0.07	-7.60	19.43
BW 38	7.71	1020.0	612.0	422.3	197.0	60.1	4.6	44.4	113.4	222.7	0.0	341.6	0.00	0.06	-9.20	17.11
Minimum	6.58	496.0	297.6	205.3	86.0	32.8	1.7	41.6	56.7	124.8	0.0	268.4	0.00	0.03	-10.00	16.88
Maximum	7.82	1020.0	612.0	422.3	201.0	107.5	6.9	46.8	184.3	240.0	0.0	536.8	3.35	0.09	-0.60	42.66
Average	7.07	700.6	420.3	290.0	139.2	60.5	4.7	43.3	91.7	204.3	0.0	386.8	0.69	0.07	-5.59	23.27

All parameters are expressed in mg/L except EC (µS cm), pH, SAR, RSC and PI (%)

Table 3: Physico-chemical and irrigation water quality characteristics of shallow aquifer (dug ell water samples) from the study area (pre monsoon 2015)

Sampling Code	PH	EC	TDS	Hardness	Ca++	Mg++	Na+	K+	Cl-	SO4	CO3	HCO3	B	SAR	RSC	PI
DW 1	6.98	897.0	538.2	355.2	151.0	129.9	9.2	34.8	525.4	165.1	0.0	488.0	0.60	0.07	-10.20	16.63
DW 2	6.58	714.0	428.4	282.7	136.0	148.8	11.9	27.2	397.6	102.2	0.0	439.2	0.90	0.08	-11.80	15.48
DW 3	6.51	580.0	348.0	229.7	98.0	113.5	8.4	20.9	284.0	100.3	0.0	268.4	2.10	0.07	-9.80	16.05
DW 4	6.70	233.0	139.8	92.3	55.0	61.6	5.6	27.7	269.8	100.8	0.0	244.0	2.01	0.06	-3.80	26.98
DW 5	6.53	752.0	451.2	297.8	136.0	117.1	8.9	28.7	426.0	138.2	0.0	366.0	2.40	0.07	-10.40	16.10
DW 6	6.59	802.0	481.2	317.6	132.0	195.2	14.6	27.6	397.6	133.4	0.0	439.2	1.10	0.10	-15.40	13.31
DW 7	6.55	901.0	540.6	356.8	133.0	299.5	25.2	28.5	383.4	136.8	0.0	683.2	3.20	0.15	-20.00	12.54
DW 8	6.54	885.0	531.0	350.5	135.0	173.9	5.4	28.9	284.0	137.3	0.0	463.6	2.10	0.04	-13.40	13.70
DW 9	6.66	923.0	553.8	365.5	126.0	194.0	13.0	29.1	411.8	138.7	0.0	439.2	2.00	0.09	-15.00	13.38
DW 10	6.54	901.0	540.6	356.8	144.0	178.1	12.8	27.8	426.0	137.8	0.0	463.6	2.40	0.09	-14.20	13.94
DW 11	6.72	907.0	544.2	359.2	121.0	194.6	12.9	28.6	497.0	136.8	0.0	463.6	2.00	0.09	-14.40	13.83
DW 12	6.55	819.0	491.4	324.3	125.0	143.4	9.8	29.4	426.0	142.1	0.0	439.2	2.80	0.07	-10.80	16.08
DW 13	6.55	889.0	533.4	352.0	113.0	162.9	10.1	28.3	426.0	135.8	0.0	488.0	1.10	0.07	-11.00	16.03
DW 14	6.57	876.0	525.6	346.9	130.0	154.9	10.4	28.8	511.2	139.7	0.0	585.6	2.00	0.07	-9.60	17.29
DW 15	6.57	956.0	573.6	378.6	144.0	153.7	10.2	29.4	468.6	141.1	0.0	463.6	2.80	0.07	-12.20	15.05
DW 16	6.56	870.0	522.0	344.5	146.0	169.6	12.5	29.1	596.4	138.2	0.0	610.0	2.30	0.08	-11.20	16.18
DW 17	6.57	864.0	518.4	342.1	151.0	195.8	15.0	29.3	539.6	139.2	0.0	732.0	2.30	0.10	-11.60	16.04
DW 18	6.52	1035.0	621.0	409.9	129.0	192.2	11.9	29.2	539.6	137.3	0.0	488.0	0.60	0.08	-14.20	13.92
DW 19	7.04	1016.0	609.6	402.3	123.0	154.3	8.6	30.0	482.8	145.0	0.0	390.4	2.10	0.06	-12.40	14.46
DW 20	6.84	899.0	539.4	356.0	130.0	145.2	9.4	30.1	752.6	144.0	0.0	610.0	2.50	0.07	-8.40	18.26
DW 21	6.81	845.0	507.0	334.6	112.0	146.4	9.2	29.6	710.0	141.6	0.0	561.2	3.10	0.07	-8.40	18.32
DW 22	6.81	930.0	558.0	368.3	111.0	249.5	16.7	27.9	497.0	135.8	0.0	561.2	0.90	0.11	-16.80	13.10
DW 23	6.84	901.0	540.6	356.8	140.0	219.6	16.0	29.8	397.6	141.6	0.0	829.6	1.50	0.10	-11.40	16.13
DW 24	6.58	846.0	507.6	335.0	153.0	175.1	13.5	29.8	440.2	142.6	0.0	463.6	1.50	0.09	-14.40	13.89
DW 25	6.54	918.0	550.8	363.5	147.0	125.1	8.4	30.4	497.0	146.9	0.0	366.0	2.80	0.06	-11.60	14.96
DW 26	7.04	749.0	449.4	296.6	96.0	163.5	10.7	30.2	440.2	146.9	0.0	439.2	1.00	0.08	-11.00	16.01
DW 27	7.18	983.0	589.8	389.3	97.0	170.2	9.0	29.4	71.0	139.2	0.0	341.6	1.10	0.07	-13.20	13.64
DW 28	6.56	990.0	594.0	392.0	165.0	133.2	9.3	28.9	142.0	138.7	0.0	390.4	0.60	0.06	-12.77	14.26
DW 29	6.88	956.0	573.6	378.6	162.0	130.5	9.2	28.7	71.0	138.2	0.0	414.8	2.50	0.06	-12.00	14.94
DW 30	6.73	899.0	539.4	356.0	116.0	185.4	12.0	28.4	71.0	139.7	0.0	707.6	2.00	0.08	-9.40	17.43
DW 31	6.59	903.0	541.8	357.6	136.0	151.3	10.2	29.1	85.2	139.2	0.0	585.6	2.80	0.07	-9.60	17.26
DW 32	6.72	744.0	446.4	294.6	141.0	101.9	8.0	29.3	56.8	140.6	0.0	463.6	0.00	0.06	-7.80	18.98
DW 33	7.00	694.0	416.4	274.8	96.0	129.3	8.5	29.7	28.4	138.7	0.0	414.8	2.00	0.07	-8.60	18.09
DW 34	6.57	861.0	516.6	341.0	158.0	113.5	8.6	29.1	14.2	135.8	0.0	390.4	2.10	0.06	-10.80	15.79
DW 35	7.17	664.0	398.4	262.9	89.0	104.3	6.4	29.1	71.0	137.3	0.0	463.6	2.00	0.06	-5.40	22.18
DW 36	6.86	760.0	456.0	301.0	124.0	85.4	5.6	24.9	99.4	121.0	0.0	488.0	2.91	0.05	-5.20	22.27
DW 37	6.50	850.0	510.0	336.6	104.0	148.8	8.9	30.6	213.0	146.4	0.0	610.0	1.20	0.07	-7.40	19.23
DW 38	6.83	901.0	540.6	356.8	160.0	100.0	7.2	29.2	99.4	138.7	0.0	658.8	1.70	0.05	-5.40	21.18
DW 39	6.96	658.0	394.8	260.6	100.0	114.7	7.8	29.5	127.8	142.6	0.0	439.2	1.90	0.06	-7.20	19.75
DW 40	6.57	806.0	483.6	319.2	135.0	125.1	8.9	30.4	99.4	145.9	0.0	170.8	1.90	0.07	-14.20	11.04
DW 41	6.84	801.0	480.6	317.2	133.0	114.1	8.0	29.9	71.0	140.6	0.0	561.2	1.40	0.06	-6.80	19.98
DW 42	6.66	735.0	441.0	291.1	139.0	105.5	8.3	30.6	85.2	145.0	0.0	658.8	2.00	0.06	-4.80	22.12
DW 43	7.18	557.0	334.2	220.6	83.0	110.4	7.6	30.9	85.2	150.2	0.0	561.2	0.60	0.07	-4.00	24.10
DW 44	7.02	950.0	570.0	376.2	121.0	145.8	8.5	30.4	99.4	144.5	0.0	658.8	0.90	0.06	-7.20	19.24
DW 45	6.64	361.0	216.6	143.0	135.0	110.4	12.2	30.9	127.8	147.8	0.0	756.4	2.80	0.09	-3.40	23.80
DW 46	6.61	817.0	490.2	323.5	134.0	115.9	8.0	29.1	99.4	158.4	0.0	805.2	2.70	0.06	-3.00	23.40
DW 47	6.71	838.0	502.8	331.9	127.0	83.6	4.8	30.7	42.6	145.4	0.0	658.8	2.10	0.04	-2.40	25.59
DW 48	7.03	861.0	516.6	341.0	134.0	120.8	8.0	30.5	85.2	147.4	0.0	902.8	0.90	0.06	-1.80	24.11
DW 49	7.05	892.0	535.2	353.2	131.0	117.7	7.3	29.8	71.0	145.4	0.0	707.6	1.50	0.06	-4.60	21.92
DW 50	6.59	831.0	498.6	329.1	115.0	129.9	8.1	28.9	85.2	137.3	0.0	512.4	2.20	0.06	-8.00	18.70
DW 51	6.90	728.0	436.8	288.3	117.0	155.6	11.3	29.8	85.2	146.9	0.0	658.8	0.00	0.08	-7.80	18.93
DW 52	6.51	740.0	444.0	293.0	105.0	201.9	14.4	30.0	99.4	145.4	0.0	683.2	0.90	0.10	-10.60	16.76
DW 53	6.58	361.0	216.6	143.0	70.0	128.1	10.4	29.5	113.6	140.6	0.0	536.8	0.90	0.09	-5.20	22.66
DW 54	6.77	368.2	220.9	145.8	137.7	112.6	12.4	31.5	130.4	150.8	0.0	771.5	2.86	0.09	-3.47	23.58

DW 55	6.74	833.3	500.0	330.0	136.7	118.2	8.2	29.7	101.4	161.6	0.0	821.3	2.75	0.06	-3.06	23.18
DW 56	6.84	854.8	512.9	338.5	129.5	85.2	4.9	31.3	43.5	148.4	0.0	672.0	2.14	0.04	-2.45	25.35
DW 57	7.17	878.2	526.9	347.8	136.7	123.2	8.1	31.1	86.9	150.3	0.0	920.9	0.92	0.06	-1.84	23.89
DW 58	7.19	909.8	545.9	360.3	133.6	120.1	7.4	30.3	72.4	148.4	0.0	721.8	1.53	0.06	-4.69	21.72
DW 59	6.72	847.6	508.6	335.7	117.3	132.5	8.3	29.4	86.9	140.0	0.0	522.7	2.24	0.06	-8.16	18.53
DW 60	7.04	742.6	445.5	294.1	119.3	158.7	11.5	30.4	86.9	149.8	0.0	672.0	0.00	0.08	-7.96	18.76
DW 61	6.64	754.8	452.9	298.9	107.1	206.0	14.7	30.6	101.4	148.4	0.0	696.9	0.92	0.10	-10.81	16.61
DW 62	6.71	368.2	220.9	145.8	71.4	130.7	10.6	30.1	115.9	143.5	0.0	547.5	0.92	0.09	-5.30	22.46
Minimum	6.50	233.0	139.8	92.3	55.0	61.6	4.8	20.9	14.2	100.3	0.0	170.8	0.00	0.04	-20.00	11.04
Maximum	7.19	1035.0	621.0	409.9	165.0	299.5	25.2	34.8	752.6	165.1	0.0	920.9	3.20	0.15	-1.80	26.98
Average	6.75	800.1	480.1	316.8	124.7	144.8	10.0	29.4	246.0	140.7	0.0	553.8	1.74	0.07	-9.03	18.21

All parameters are expressed in mg/L except EC (µS cm), pH, SAR, RSC and PI (%)

Table 4: Physico-chemical and irrigation water quality characteristics of deep aquifer (borewell water samples) from the study area (pre monsoon 2015)

Sampling Code	PH	EC	TDS	Hardness	Ca++	Mg++	Na+	K+	Cl-	SO4	CO3	HCO3	B	SAR	RSC	PI
BW 1	7.01	1251	750.6	495.4	111.0	188.5	8.5	30.2	99.4	145.9	0.0	585.6	10.5	0.1	-11.4	16.2
BW 2	7.09	780	468.0	308.9	115.0	93.3	5.6	30.6	85.2	145.9	0.0	488.0	7.9	0.1	-5.4	22.5
BW 3	7.56	609	365.4	241.2	78.0	84.2	4.7	30.3	85.2	145.0	0.0	146.4	10.3	0.1	-8.4	15.9
BW 4	6.57	384	230.4	152.1	53.0	116.5	8.4	28.3	71.0	139.2	0.0	244.0	4.5	0.1	-8.2	18.8
BW 5	6.55	251	150.6	99.4	48.0	48.8	3.9	30.5	71.0	145.4	0.0	195.2	3.0	0.1	-3.2	29.8
BW 6	6.7	285	171.0	112.9	48.0	53.7	4.0	30.4	56.8	146.9	0.0	170.8	4.5	0.1	-4.0	26.5
BW 7	6.55	541	324.6	214.2	65.0	70.2	4.4	31.5	56.8	151.7	0.0	244.0	10.5	0.1	-5.0	23.8
BW 8	6.82	935	561.0	370.3	125.0	104.3	5.5	31.3	71.0	152.6	0.0	414.8	10.5	0.1	-8.0	18.9
BW 9	6.99	936	561.6	370.7	113.0	116.5	5.8	28.7	56.8	135.4	0.0	463.6	5.5	0.1	-7.6	19.5
BW 10	7.07	948	568.8	375.4	122.0	101.3	4.9	30.6	85.2	148.8	0.0	463.6	10.5	0.1	-6.8	20.3
BW 11	7.58	902	541.2	357.2	114.0	98.8	4.8	31.8	56.8	153.1	0.0	317.2	0.0	0.1	-8.6	17.8
BW 12	7.15	900	540.0	356.4	101.0	101.9	4.4	29.3	71.0	147.8	0.0	463.6	10.5	0.1	-5.8	21.7
BW 13	7.31	976	585.6	386.5	112.0	92.7	3.4	32.5	56.8	151.2	0.0	439.2	1.1	0.0	-6.0	21.2
BW 14	7	871	522.6	344.9	103.0	86.0	3.5	32.1	56.8	152.2	0.0	390.4	1.7	0.1	-5.8	21.7
BW 15	7.19	803	481.8	318.0	104.0	109.8	6.2	30.0	71.0	147.4	0.0	341.6	0.9	0.1	-8.6	18.2
BW 17	7.36	993	595.8	393.2	123.0	125.1	6.5	29.9	85.2	143.0	0.0	561.2	5.8	0.1	-7.2	19.9
BW 18	6.95	1100	660.0	435.6	164.0	114.7	6.6	31.1	284.0	147.4	0.0	805.2	2.9	0.1	-4.4	21.9
BW 19	6.89	992	595.2	392.8	173.0	209.2	15.9	31.3	241.4	153.1	0.0	610.0	2.1	0.2	-15.8	14.6
BW 20	6.69	808	484.8	320.0	120.0	231.8	16.9	31.6	227.2	145.4	0.0	390.4	0.0	0.2	-18.6	12.7
BW 21	7.41	956	573.6	378.6	144.0	102.5	6.0	30.9	312.4	144.5	0.0	390.4	0.0	0.1	-9.2	17.6
BW 22	6.85	915	549.0	362.3	176.0	195.2	15.7	31.4	298.2	148.8	0.0	488.0	9.4	0.2	-16.8	13.8
BW 23	7.29	745	447.0	295.0	116.0	78.1	4.8	31.3	383.4	151.2	0.0	488.0	2.0	0.1	-4.2	24.5
BW 24	6.88	786	471.6	311.3	136.0	100.0	7.1	30.5	482.8	149.8	0.0	463.6	3.8	0.1	-7.4	20.0
BW 25	7.17	733	439.8	290.3	113.0	187.3	13.7	31.9	610.6	155.0	0.0	439.2	9.1	0.2	-13.8	15.2
BW 27	6.76	654	392.4	259.0	86.0	135.4	8.9	31.2	497.0	149.3	0.0	390.4	2.7	0.1	-9.0	18.5
BW 28	6.91	599	359.4	237.2	95.0	193.4	14.6	31.6	553.8	154.6	0.0	536.8	4.7	0.2	-11.8	17.0
BW 29	7.41	871	522.6	344.9	158.0	140.3	10.6	31.0	426.0	151.7	0.0	390.4	3.1	0.1	-13.0	15.1
BW 30	7.78	867	520.2	343.3	147.0	156.8	11.5	32.9	355.0	156.0	0.0	610.0	0.6	0.1	-10.2	17.7
BW 31	6.54	800	480.0	316.8	133.0	128.7	9.2	31.1	497.0	154.1	0.0	561.2	0.9	0.1	-8.0	19.5
BW 32	7.11	972	583.2	384.9	172.0	168.4	12.7	32.2	511.2	153.6	0.0	536.8	2.8	0.1	-13.6	15.3
BW 33	7.4	985	591.0	390.1	178.0	181.8	14.0	31.9	426.0	156.0	0.0	463.6	0.0	0.2	-16.2	13.8
BW 34	7.59	1058	634.8	419.0	163.0	159.2	10.6	31.0	426.0	155.0	0.0	439.2	6.9	0.1	-14.0	14.5
BW 35	6.87	1088.19	652.9	450.5	213.4	85.9	5.9	47.4	60.7	219.7	0.0	380.6	0.0	3.8	-11.5	15.3
BW 36	6.98	970.49	582.3	401.8	189.1	66.3	4.1	44.1	106.2	215.9	0.0	431.4	0.0	3.5	-7.8	18.8
BW 37	7.06	913.78	548.3	378.3	223.9	70.1	4.8	49.0	121.4	218.3	0.0	482.1	0.0	3.8	-9.0	17.6
BW 38	7.09	1027.2	616.3	425.3	228.5	62.6	3.9	47.1	121.4	218.3	0.0	355.3	0.0	3.7	-10.7	15.5
Minimum	6.54	251	150.6	99.4	48.0	48.8	3.4	28.3	56.8	135.4	0.0	146.4	0.0	0.0	-18.6	12.7
Maximum	7.78	1251	750.6	495.4	228.5	231.8	16.9	49.0	610.6	219.7	0.0	805.2	10.5	3.8	-3.2	29.8
Average	7.06	839.05	503.4	334.3	129.6	121.1	7.8	32.7	224.4	156.9	0.0	432.8	4.1	0.5	-9.3	18.7

All parameters are expressed in mg/L except EC (µS cm), pH, SAR, RSC and PI (%)

Physico-chemical parameters: The pH values of the ground water samples are higher in post monsoon season than the pre monsoon season. The higher valued indicates the water and rock interaction. In post monsoon season some water samples pH value observed in alkaline nature. But pH is acidic in post monsoon season observed at the sample of fertilizer factory. The concentrations of pH for post monsoon in shallow aquifer range from 6.61 to 7.57 and in deep aquifer 5.99 to 7.82. The concentrations of pre monsoon is in shallow aquifer 6.50 to 7.19 and deep aquifer 6.54 7.78. Desirable limit of pH is 6.5 to 8.5 as per BIS. According to pH limit of BIS, most of water samples were suitable for drinking and irrigation purpose. The electrical conductivity for post monsoon and pre monsoon does not show much variation. The concentrations of EC for post monsoon in shallow aquifer ranged from 192 to 1205 µS/cm and in deep aquifer 191 to 1020 µS/cm. The EC concentrations of pre monsoon is in shallow aquifer ranged between 233 to 1035 µS/cm and in deep aquifer 251 to 1251 µS/cm. Desirable limit of EC is 1400 µS/cm as per BIS. According to EC limit of BIS, all the water samples from the study area are suitable for drinking and irrigation use. The TDS in water increases due to the agricultural runoff, urban runoff, sewage and natural sources like plant leaves, silt, planktons and rocks. These salts affect on plant growth and soil quality. Most of the samples are below the permissible limit. Concentration of total hardness in study area is observed exceeds the permissible limit of BIS [15]. The concentrations of total dissolved solid for post monsoon in shallow aquifer range from 115.2 to 723 mg/L and in deep aquifer 114.6 to 612 mg/L. The concentrations of pre monsoon is in shallow aquifer 139.8 to 621 mg/L and deep aquifer 150.6 to 750.6 mg/L. Desirable limit of TDS is 500 mg/L and maximum permissible limit is 1400 mg/L as per BIS, if TDS above 2100 mg/L it is not suitable for any purpose. Total hardness is major parameter in drinking water. The concentrations of hardness for post monsoon in shallow aquifer range from 79.5 to 498.9 mg/L and in deep aquifer 79.1 to 422.3 mg/L. The total hardness concentrations pre monsoon is in shallow aquifer 92.3 to 409.9 mg/L and in deep aquifer 99.4 to 495.4 mg/L. Calcium is a naturally present in the water. The concentrations of Ca for post monsoon in shallow aquifer range from 42 to 211 mg/L and in deep aquifer 85 to 201 mg/L. The concentrations of pre monsoon is in shallow aquifer 55 to 165 mg/L and in deep aquifer is ranged from 48 to 228.5 mg/L. Desirable limit of TDS is 75 mg/L as per BIS. The concentrations of Na for post monsoon in shallow aquifer range from 1.9 to 6.8 mg/L and in deep aquifer 0.9 to 6.9 mg/L. The concentrations of pre monsoon is in shallow aquifer 4.8 to 25.2 mg/L and in deep aquifer is ranged from 3.4 to 16.9 mg/L. Desirable limit of Na is 250 mg/L as per BIS. This indicates that the all water samples from the study and Na concentration is within the permissible limit. The K concentration in all water samples from the study area were observed beyond the permissible limit (10 mg/L). These highest concentrations are occurring in the agricultural sector and residential area. In agricultural area it could be occur due to fertilizers. The potassium contributes in groundwater through atmosphere, mineral mater and biological activity. Concentration of K in study area is observed exceeds than permissible limit of BIS [15]. The concentrations of K for post monsoon in shallow aquifer range from 36.9 to 48.4 mg/L and in deep aquifer 16.6 to 46.8 mg/L. The concentrations of pre monsoon are in shallow aquifer 20.9 to 34.8 mg/L and deep aquifer 28.3 to 49.0 mg/L. Desirable limit of K is 10 mg/L as per BIS. According to K limit of BIS, all water samples for post monsoon and pre monsoon season exhibits beyond the desirable limits. Chloride ion is the most predominant natural form of elements and its presence can be attributed to dissolution of salts. The chloride content normally increases as the mineral content increase. The concentrations of Cl for post monsoon in shallow aquifer range from 56.7 to 156.0 mg/L and in deep aquifer 56.7 to 184.3 mg/L. The concentrations of pre monsoon are in shallow aquifer 14.2 to 75.26 mg/L and deep aquifer 56.8 to 610.6 mg/L. Desirable limit of Cl is 250 mg/L as per BIS. According to Cl limit of BIS, all water samples for post monsoon within the permissible limit but pre monsoon samples exhibit the high content of chloride it may be due to over exploration of groundwater in summer. In humid region the sulphate may be removed by runoff, whereas in arid and semiarid regions sulphates may accumulate in soil and groundwater due to low precipitation and inadequate drainage[16]. The concentrations of sulphate for post monsoon in shallow aquifer range from 150.2 to 216 mg/L and in deep aquifer 110.4 to 240 mg/L. The concentrations of pre monsoon are in shallow aquifer 100.3 to 165.1 mg/L and deep aquifer 135.4 to 219.7 mg/L. Sulphate concentrations below 4 meq/l is very excellent, 4 to 7 meq/l is good, 7 to 12 meq/l is permissible 12 to 20 in doubtful and above 20 is unsuitable (James *et al*. 1982). In the present study area all the groundwater samples are under excellent. The highest sulphate concentration is observed in BW 10, it may occur due to natural and animal waste, use of fertilizers. SO_4 implies their origin from common sources like human measures, fertilizers and animal waste[17]. Boron in drinking water more than 1 ppm it is not considered to human consumption. The excessive amount of boron can affect the central nervous system [10]. The concentrations of boron for post monsoon in shallow aquifer range from 3.0 to 4.9 and in deep aquifer 0.0 to 3.3 mg/L. The concentrations of pre monsoon are in shallow aquifer 0.0 to 3.20 mg/L and deep aquifer 0.0 to 10.50 mg/L (limit of 1.0 ppm, BIS, 2003). Some shows boron concentration more than 1 mg/L in shallow aquifer (post monsoon). The average abundance of Boron in earth crust is about 12 mg/L but high in basalts rocks about 15 mg/L they may be one cause of boron in groundwater of area under study.

Groundwater suitability for irrigation

Sodium Adsorption Ratio (SAR): Table 2, 3, 4 and 5 shows classification of water with reference to the SAR[18]. If SAR concentration is less than 10 water is excellent for irrigation suggest that the all samples of post monsoon and pre monsoon fall under the excellent category.

Residual sodium carbonate (RSC): The groundwater having excess of CO_3^- and HCO_3^- concentration over the Ca^{++} and Mg^{++} in excess of limits and there are unfavorably effects on agriculture[18,12]. The RSC concentrations for shallow aquifer (post monsoon) ranges from -8.80 to -0.20, concentrations for pre monsoon ranges from -20.00 to -1.80 and deep aquifer (Post monsoon) ranges from – 10.00 to -0.60 and pre monsoon it ranges from -18.60 to -3.20. Lloyd and Heathcote (1985) have classified irrigation water based on RSC as suitable (< 1.25), marginal (1.25 to 2.5) and not suitable (> 2.5). Accordingly, all the water samples form the study area is excellent quality for irrigation because of its RSC concentration < 1.25.

Permeability Index (PI): In the present study, the permeability index (PI) values for post monsoon in shallow aquifer range from 18.23 to 50.99 and in deep aquifer 16.88 to 42.66. The value of pre monsoon is in shallow aquifer 11.04 to 26.98 ppm and deep aquifer 12.70 to 29.81. According to Raghunath (1987), the PI values are included between 25 and 75, showing that the water belongs to the good class and has suitable quality for irrigation[18].

CONCLUSION

In the study area, elevated levels of physicochemical parameters were observed in drinking water. Shallow aquifer water showed significantly higher levels of contaminations as compared to deep aquifers water sources. This study concluded that majority physicochemical parameters have surpassed their respective safe drinking water guidelines set by the BIS except hardness, calcium, magnesium, potassium and boron. Higher contaminations were observed in bore well as compared to the dug wells. This study recommends the regular monitoring of drinking water and strict enforcement the environmental rules and regulations on industrial and exploration activities that could contaminate water and pose potential threats to human health. This study recommends stopping the use of bore well water for drinking and other domestic purposes and emphasis on deep boring tube wells installation and regular monitoring and treatment of drinking water.

ACKNOWLEDGEMENTS

Author has dedicated this paper to late Dr. A. S. Yadav who is inspiring the idea of this research work. Author officially acknowledged to the Principal, Khare-Dhere-Bhosale College, Guhagar, Ratnagiri (M.S.) India. Sincere thanks to Dr. Golekar R. B., Department of Geology, Khare-Dhere-Bhosale College, Guhagar, Ratnagiri (M.S.) India for his constructive suggestions.

REFERENCES

1. Appelo CAJ, Postma D (2005) Geochemistry, Groundwater and Pollution. Second edition. A. A. Balkema, Rotterdam
2. Kamyotra J. S. and Bhardwaj R. M., (2011) Municipal Wastewater Management in India, India Infrastructure Report
3. Mvungi, A., Mashauri, D. and N.F. Madulu (2005) Management of water for irrigation agriculture in semi-arid areas: Problems and prospects. Physics and Chemistry of the Earth 30: 809–817.
4. UN (2006) Water, a shared responsibility. The United Nations World Water Development.Report - 2. UNESCO and Berghahn Books, Paris and London.
5. Golekar R. B., Patil S. N. and Baride M. V. (2013) Human health risk due to trace elements contamination in groundwater from Anjani and Jhiri river catchment of Northern Maharashtra, India Earth Sciences Research Journal v. 17 (1) pp 17-23
6. Golekar R. B., Baride M. V., Patil S. N. (2014) Geomedical health hazard due to groundwater quality from Anjani - Jhiri River Basin, Northern Maharashtra (India) International Research Journal of Earth Sciences v. 2 (1) pp 1-14
7. Baride M.V., Patil S. N., Golekar R B (2014) Groundwater geochemistry of shallow and deep aquifers from Jalgaon district, northern Maharashtra (India) International Journal of Advanced Geosciences v. 2 (2) pp 97-104 doi: 10.14419/ijag.v2i2.3348
8. Golekar R.B., Baride M.V., Patil S.N. (2017) STUDY THE STATUS OF GEOMEDICAL HEALTH HAZARDS DUE TO QUALITY OF WATER IN JALGAON DISTRICT, MAHARASHTRA (INDIA) Bulletin of Pure and Applied Sciences. Vol.36 F (Geology), No.2, 2017: P.103-121 DOI 10.5958/2320-3234.2017.00004.X
9. Kumbhar K. S., Baride M. V., Golekar R. B. (2017) Evaluation of Groundwater Quality and Its Suitability for Drinking and Agriculture Use: A Case Study of 06 Quality Affected Watersheds in Kolhapur District, Maharashtra, India Bulletin of Pure and Applied

Sciences. F (Geology), Vol. 36 Issue (No.1) 2017: P.44-59 DOI 10.5958/2320-3234.2017.00004.X
10. APHA AWWA, (2005) Standard methods for the examination of water and waste water, American Public Health Association, Washington, DC, 21st ed.
11. Richards L. A (1954) (US Salinity Laboratory) Diagnosis and improvement of saline and alkaline soils, US Department of Agriculture hand book, 60p
12. Eaton F. M (1950) SIGNIFICANCE OF CARBONATES IN IRRIGATION WATERS. Soil science, 69(2), 123-134
13. Lloyd J.W. and Heathcote J.A. (1985). Natural Inorganic Hydrochemistry in Relation to Groundwater Claredon Press, Oxford 294 pp
14. Doneen L. D (1964) Notes on water quality in agriculture. Department of Water Science and Engineering, University of California, Davis
15. BIS (2003). Bureau of Indian Standards Specification for drinking water. IS: 10500:91. Revised 2003, Bureau of Indian Standards, New Delhi.
16. Paranjpe S C (2007) Development and Augmentation of groundwater resources with emphasis on deep aquifers, Pune metropolitan region, Maharashtra. Ph. D. thesis, University of Pune, India. 186p.
17. Pawar N J, Pawar J B, Suyash Kumar, Supekar A. (2008) Geochemical eccentricity of groundwater allied to weathering of basalts from the Deccan Volcanic Province, India: Insinuation on CO2 consumption. Aquat Geochem 14: 41-71.
18. Raghunath, H.M. (1987) Groundwater 2nd (ed) New age International Pvt. Ltd. New Delhi Publication.

Source of Support: None Declared
Conflict of Interest: None Declared