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Evaluation of the seasonal variation in the hydrogeochemical parameters and quality assessment of the groundwater in the proximity of Parli Thermal power plant, Beed, Maharashtra, India

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ABSTRACT

Combustion of coals in thermal power plants is one of the major sources of environmental pollution due to generation of huge amounts of ashes, which are disposed off in large ponds in the vicinity of the thermal power plant. Objective of this paper is to study hydrogeochemical parameters to see pollution transport in the area of Parli Thermal Power Plant (TPP) and to understand effect of thermal power plant waste on the quality of groundwater and suitability of groundwater for domestic and irrigation purposes. In the present study, hydrogeochemical investigation is carried out in the basaltic terrain. The bore wells and dug well water samples were collected from the study area for two seasons i.e. pre monsoon and post monsoon in May 2012 and December 2012. Comparison of the groundwater quality in relation to drinking water quality standards proves that most of the water samples surrounding to power plant are not suitable for drinking purpose. Some of the samples fall under very high salinity and sodium hazard zone which are not suitable for irrigation purpose. Studies revealed that the high concentration of total dissolved solid, chloride, magnesium and sodium are may be attributed to the anthropogenic or industrial activities, ash residues dump and weathering of basalt rocks.

Keywords: Parli Thermal Power Plant (P.T.P.P.), Groundwater, Hydrogeochemical, Irrigation, Water quality, Beed, Maharashtra.

INTRODUCTION

During last few years, the utilization of surface and groundwater for drinking, industrial and agricultural purposes has increased manifolds but consequently it is observed that the water is polluted and affecting the human health, soil nutrients, livestock, biomass and environment in certain areas [4]. Groundwater pollution has become a major subject of public concern the world over. Despite the large volume of water that covers the surface of the earth, only 1% is inland fresh and easily available for human use. The qualities of groundwater resources vary naturally and widely depending on climate, season, and geology of bedrock as well as anthropogenic activities [16]. In addition to the natural sources of constituents acquired by water during its interaction with atmosphere and rocks, various human activities such as industrial, sewage and domestic waste disposal, fertilisers, pesticides etc. also contribute chemical constituents to water. Therefore, a regular check of its chemical quality is required for assessing its suitability for different purposes and for quantitatively monitoring any future change [5]. Over pumping of aquifers, discharge of toxic chemicals and contamination of water bodies with substance that promote algae growth are major cause for water quality degradation [7] and also the pollution of the groundwater happens mostly due to percolation of pluvial water and the infiltration of contaminants through the soil under waste disposal site [18]. The use of lignite in the power plants as well as the fly ash is burned residue of coal which has alarming dimensions, open dumping of fly ash can creates and led to increasing environmental problems associated not only with gaseous emissions but also with the disposal of ash residues, because not paying the necessary attention to effectively create disposal sites and techniques to deposit wastes before and during the construction of the power plants.[1][11].The effluent discharged by thermal power plant require treatment before they are discharge into the fresh water streams

[15]. Fly ash from Parli Thermal Power Station of the Maharashtra State Power Generation Co. Ltd. has been dumped in check dam constructed by PTPS. This is main source of leaching of different pollutants in the surrounding area and it contaminates groundwater and surface water resources. Groundwater samples are taken mostly from dug wells and few from Bore wells in the study area, an attempt has been made to understand the spatial distribution of hydrogeochemical constituents and also interpret chemical variations in groundwater under various natural and anthropogenic influences.

MATERIALS AND METHODS

Study area

Parli is one of the taluka of Beed in Marathwada area of Maharashtra. Beed is situated Flanked by Aurangabad and Jalna districts in the north, Parbhani in the east, Latur in the south east, Osmanabad in south and Ahmadnagar district in the west and southwest. The study area is bounded by latitude 18°45’ to 19° and longitude 76°25’ to 76°40’ (Fig.1). The area receives an annual average rainfall ranging between 650 to 750 mm. The maximum temperature ranges between 40°C and 42°C and minimum temperature ranges between 12°C and 13°C throughout year respectively. Parli has a big Sugar factory, Cement factory and Thermal Power Plant of 500 MW capacities. Parli thermal power project is at 2nd position in Maharashtra for producing electricity after Chandrapur.

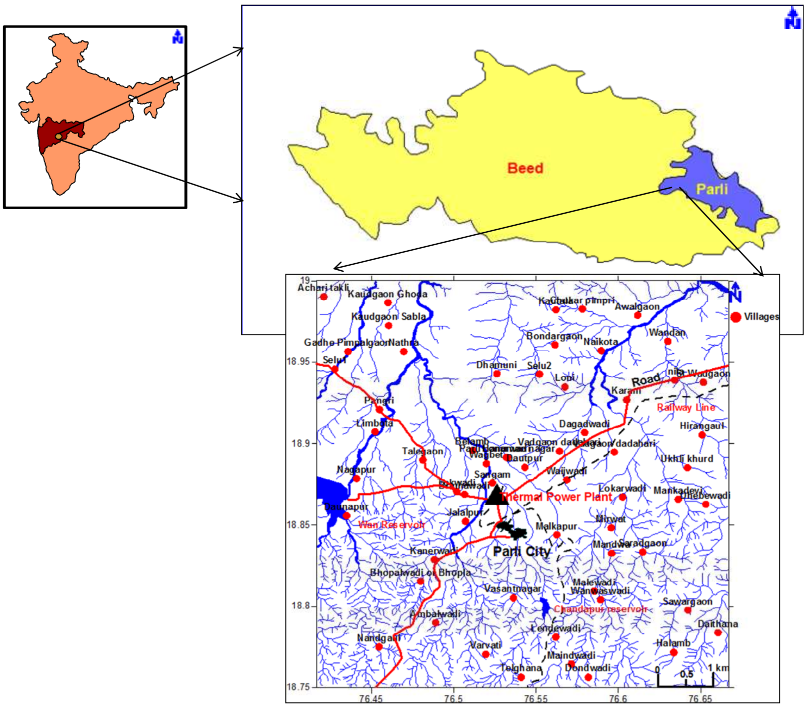

Fig 1. Location map of study area

Geology and Hydrogeology

The major part of the district is covered by Basaltic flows commonly known as Deccan Traps of Upper Cretaceous-Lower Eocene age. The Deccan Trap includes several flows of Basalt which are supposed to have extruded from fissure volcanoes. Groundwater in Deccan Trap Basalt occurs mostly in the upper weathered and fractured parts down to 20 to 25 m depth. At places potential zones are encountered at deeper levels in the form of fractures and inter to flow zones. The upper weathered and fractured parts form phreatic aquifer and groundwater occurs under water table (unconfined) conditions. Hydrogeologically, the Deccan basalts have been regarded as low-permeability rocks, but the crux of the problem of finding groundwater in the basalts is their high degree of inhomogeneity [6]. Rocky and thin layered soils are observed in major part of the study area. In order to assess the level of pollution and to conduct a geochemical study 60 groundwater samples were collected surrounding Thermal Power Plant at various locations (Fig.2a).

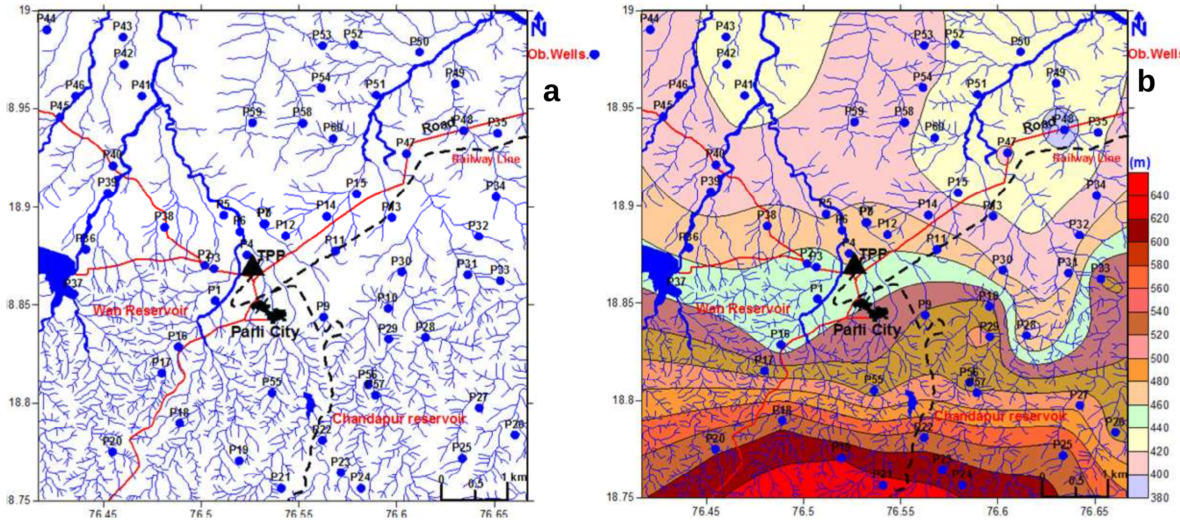

Fig 2. a) Location of Observation wells and Drainage map of study area b) Elevation map of study area.

In the present work, an attempt has been made on the evaluation of interrelated hydrogeochemical processes and the various factors that contribute to the chemistry of water. The role of various factors in groundwater can be understood better by applying statistical analysis on the chemical parameters. In the study area, the highest elevation is towards the southern part (636 m) while minimum elevation is towards the northern part (396 m). This indicates the general slope is from southwest to northeast (Fig. 2b). One of the main imperative approaches for the identification of groundwater flow directions is the water level contour map, [12] The well inventory data shows the maximum depth to groundwater level varies from 3m (P27 Dug well Sawargaon) to 23 m (P20 Dug well Nandgaul) in bellow ground level (bgl) during Pre monsoon, 0 m (P18, P23 Dug wells from Ambalwadi and Maindwadi) to 17 m bgl during Post monsoon as shown in figure 3a and 3b. But the present pre monsoon water levels in southwest and post monsoon water levels in southwest and North West area have gone deeper, due to increasing need for agricultural activities and domestic purposes causing overexploitation of groundwater.

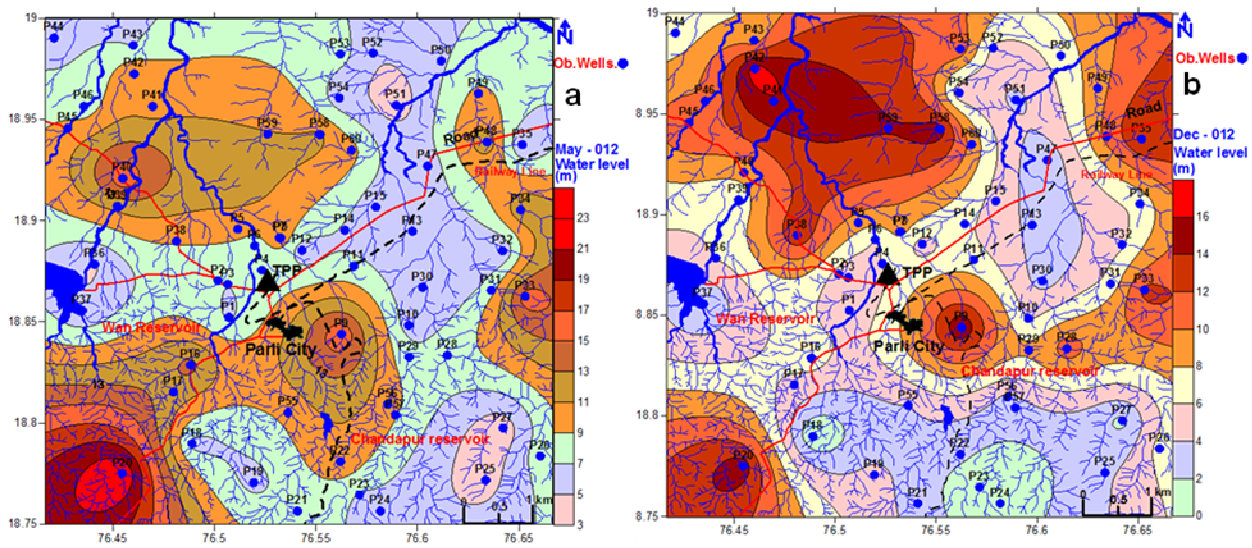

Fig 3. a) Pre monsoon Water level in study area b) Post monsoon Water level in study area

The water table and quality are influenced by recharge and excessive withdrawal of groundwater. Therefore, groundwater levels were measured with reference to ground elevation [17] and Ground water samples were collected during May 2012 and December 2012 representing pre- and post-monsoon seasons to evaluate the seasonal variations in chemical compositions. Groundwater samples were collected in HDPE bottles pre-washed with dilute hydrochloric acid and then labelled each one, during May 2012. The samples were stored bellow 5°C temperature to analysis in the laboratory. For collection, preservation and analysis of the samples, the standard methods [2][20]were followed. pH and EC of groundwater samples were measured by using pH and Conductivity meters. Na and K were measured by using a Flame Photometer (Model: Elico-Cl 161 Flame Photometer). Ca, Mg, TH, Cl, HCO3 and Acidity were determined Titrimetric methods. (Trivedy and Goel 1986). Sulphate was analysed using UV- Spectrophotometer (Model: Shimadzu UV-1800). The results of chemical analysis are given in Table 1 and 2 the chemical analysis data have been interpreted using various plots such as Piper's trilinear diagram (1944), Gibbs (1970) and Wilcox (1955) diagrams, to assess the groundwater quality and also used to compare the similarities and dissimilarities of the ions simultaneously for pre- and post-monsoon groundwater samples.

RESULTS AND DISCUSSION

Chemistry of groundwater

The analytical results of the chemical analysis and the statistical parameters such as minimum, maximum, average and correlation matrix of groundwater data are presented in Table 3, Table 4 and 5 for both pre monsoon and post monsoon season. The pH indicates the acidic or alkaline nature of the water. The pH of groundwater samples of the study area ranges from 7.12 to 9 .0 and 7.9 to 9.5 during pre and post-monsoon season respectively. The groundwater is generally alkaline in nature due to presence of bicarbonates ions. The pH value in eastern part was found to be 9.0 which are beyond the permissible limit as per WHO guidelines (1984) and Bureau of Indian Standards [3], due to the seepage of effluent. Total hardness (TH) is caused primarily by the presence of cations such as calcium and magnesium and anions such as carbonate, bicarbonate, chloride and sulphate in water. Hard water is unsuitable for domestic use. The total hardness varies between 40 to 1174 mg/l and 60 to 1384 mg/l during pre and post monsoon season respectively. In pre monsoon season highest hardness is observed from sample number P5 (Belamb) and during post monsoon season from sample number P42 (Kaudgaon sabla).

Table 1 Major cations and anions for pre-monsoon season May-12 (mg/l), Parli

Sr.No.	pH	EC	TDS	Ca	Mg	TH	Na	K	Cl	SO_4	HCO_3	Acidity
P1	8.07	2968	1899.52	41.68	68.71	386	80.9	4.6	164.72	274.0	215	10
P2	7.68	56000	35840	92.18	96.97	628	314.6	4.9	498.42	59.1	185	12.5
P3	7.81	41400	26496	9.62	130.11	558	155.6	10	353.58	25.8	205	10
P4	8.22	54600	34944	72.14	86.74	536	318.4	3.5	600.66	75.8	205	10
P5	7.73	72800	46592	134.67	204.18	1174	269.3	6.5	860.52	163.2	165	10
P6	7.96	52200	33408	48.90	99.90	532	190.9	4	556.64	89.3	245	5
P7	7.88	50600	32384	56.11	127.18	662	141.2	5.4	556.64	121.8	130	5
P8	8.03	1740	1113.6	45.69	16.57	182	421.8	6.4	36.92	59.3	255	10
P9	8.34	1796	1149.44	29.66	19.49	154	70.1	3.6	22.72	60.8	250	10
P10	7.97	1618	1035.52	14.43	18.03	110	63.7	7.1	35.5	66.2	225	7.5
P11	8.73	2158	1381.12	10.42	6.33	52	162.9	3.4	107.92	107.0	125	5
P12	8.04	68200	43648	87.37	114.51	688	243.5	43	690.12	144.7	305	12.5
P13	7.88	47000	30080	35.27	109.64	538	163.8	4.8	457.24	127.6	140	7.5
P14	8.14	3912	2503.68	40.88	33.62	240	180.3	4.4	325.18	89.1	130	5
P15	7.63	3052	1953.28	88.18	154.47	854	86.7	4	434.52	99.9	155	10
P16	7.9	1576	1008.64	6.41	44.83	200	18.9	3.5	24.14	44.8	250	5
P17	8.32	1026	656.64	14.43	0.97	40	45.6	4.1	25.56	48.3	140	7.5
P18	8.26	1020	652.8	23.25	1.46	64	14.5	4.2	18.46	42.1	125	5
P19	8.07	2446	1565.44	17.64	74.07	348	30.9	3.3	123.54	71.4	200	7.5
P20	8.24	1596	1021.44	26.45	39.96	230	18.7	4.3	78.1	57.7	145	5
P21	8.14	1364	872.96	28.06	19.49	150	42.9	3.1	45.44	62.5	165	2.5
P22	8.48	1588	1016.32	9.62	6.82	52	98.7	3.4	117.86	92.0	50	5
P23	8.2	1094	700.16	24.85	25.34	166	12.2	3	19.88	26.4	180	7.5
P24	8.03	2234	1429.76	13.63	6.82	62	132.9	4.5	214.42	62.5	50	2.5
P25	7.95	1840	1177.6	11.22	55.55	256	14.6	4.4	49.7	50.6	240	10
P26	8.22	1538	984.32	24.05	31.67	190	13.6	3	38.34	57.9	185	5
P27	9.03	1584	1013.76	39.28	5.85	122	22	3.2	51.12	57.7	245	10
P28	7.87	1658	1061.12	32.06	35.09	224	19.6	3.2	29.82	51.8	265	7.5
P29	8.07	1928	1233.92	33.67	35.09	228	61.2	11	66.74	89.5	190	7.5
P30	8.09	1722	1102.08	7.21	54.09	240	37	3.1	42.6	55.4	260	12.5
P31	7.92	1762	1127.68	15.23	49.70	242	35.5	4	36.92	60.6	210	7.5
P32	8.15	1952	1249.28	5.61	12.67	66	152.4	4.4	59.64	73.5	215	5
P33	8.29	1026	656.64	24.85	15.59	126	14.7	3.6	18.46	49.8	160	2.5
P34	7.95	1748	1118.72	32.06	39.47	242	41.9	2.9	41.18	86.2	215	7.5
P35	8.17	1346	861.44	12.83	30.70	158	28.4	3.5	59.64	57.7	125	5
P36	8.05	1682	1076.48	22.44	34.11	196	37	2.9	51.12	60.8	255	7.5
P37	8.1	2018	1291.52	12.02	65.78	300	39.4	3.4	63.9	87.2	300	7.5
P38	8.11	3738	2392.32	97.80	71.15	536	117.3	5.3	330.86	92.9	115	7.5
P39	7.69	43600	27904	72.95	129.13	712	115.3	3.9	312.4	181.3	200	5
P40	8.02	2008	1285.12	34.47	39.96	250	63.9	4	78.1	89.1	205	12.5
P41	8.04	3594	2300.16	28.86	67.73	350	172.6	3.7	85.2	201.3	305	7.5
P42	8.11	3274	2095.36	7.21	71.63	312	187.9	4.5	93.72	143.0	355	10
P43	7.8	2012	1287.68	12.02	33.62	168	86.8	3.6	86.62	96.6	235	7.5

Continued...

Table 1 Major cations and anions for pre-monsoon season May-12 (mg/l), Parli

Sr.No.	pH	EC	TDS	Ca	Mg	TH	Na	K	Cl	SO_4	HCO_3	Acidity
P44	8.52	2570	1644.8	28.06	19.98	152	115.5	3.3	110.76	113.3	175	7.5
P45	7.88	3638	2328.32	29.66	94.54	462	136.2	41	232.88	167.4	245	7.5
P46	8.21	1924	1231.36	24.05	34.11	200	77.8	3.5	66.74	103.7	230	6.25
P47	7.87	2320	1484.8	44.09	50.19	316	44	3.1	89.46	126.2	240	7.5
P48	8.13	1644	1052.16	12.83	10.23	74	117.6	3.6	69.58	88.9	170	5
P49	7.8	3572	2286.08	101.00	53.12	470	77.4	4.9	167.56	194.3	215	10
P50	7.87	3152	2017.28	27.25	18.52	144	224.6	4.4	183.18	209.9	195	7.5
P51	7.84	3226	2064.64	35.27	87.23	446	107.7	3.7	252.76	160.7	200	5
P52	8.04	1312	839.68	14.43	35.57	182	21.4	3.3	49.7	72.7	175	7.5
P53	7.92	2174	1391.36	52.91	51.65	344	29.9	3.7	80.94	185.7	140	7.5
P54	7.12	2872	1838.08	27.25	59.94	314	152.8	5.6	187.44	67.0	290	10
P55	8.32	1438	920.32	12.83	5.36	54	89.2	3.3	61.06	88.7	140	7.5
P56	8.03	1214	776.96	28.86	18.52	148	28.3	3.1	24.14	61.4	205	7.5
P57	8.2	1188	760.32	14.43	5.36	58	91.1	3.7	46.86	76.2	130	5
P58	8.4	1246	797.44	23.25	13.16	112	60.7	3.1	32.66	66.6	180	7.5
P59	7.98	2222	1422.08	56.11	35.57	286	33.9	3.5	73.84	110.6	210	7.5
P60	8	1814	1160.96	16.83	44.34	224	41.8	3.8	75.26	98.5	210	10

All the concentrations are in mg/l, except pH. EC is measured in µS/cm

Table 2 Major cations and anions for post-monsoon season Dec-12 (mg/l), Parli

Sr.No.	pH	EC	TDS	Ca	Mg	TH	Na	K	Cl	SO_4	HCO_3	Acidity
P1	8.4	2046	1309.4	44.89	68.22	392	185	2.0	119.28	182.00	275	17.5
P2	7.9	53800	34432	181.16	171.53	1156	238	1.0	452.98	217.07	185	5
P3	8.6	3492	2234.9	23.25	147.16	662	243	7.9	320.92	254.43	285	7.5
P4	8.2	186400	119296	37.68	153.01	722	373	0.5	600.66	320.21	200	10
P5	8.9	77200	49408	167.53	194.92	1218	324	3.0	839.22	289.29	230	7.5
P6	9.3	49800	31872	71.34	77.48	496	366	0.5	532.5	225.17	285	7.5
P7	9	36000	23040	33.67	97.95	486	338	1.0	525.4	188.43	325	15
P8	8.6	1156	739.84	21.64	25.83	160	134	4.5	41.18	105.42	305	10
P9	8.4	1978	1265.9	12.02	59.45	274	166	4.4	83.78	186.57	365	12.5
P10	8.6	11600	7424	36.07	26.80	200	88.1	0.5	42.6	111.23	255	10
P11	8.4	2118	1355.5	12.02	7.31	60	304	1.0	115.02	206.49	200	7.5
P12	8.8	57000	36480	62.52	89.17	522	366	50.8	602.08	259.20	320	7.5
P13	8.4	3616	2314.2	51.30	40.45	294	362	2.4	355	166.02	135	5
P14	8.2	3256	2083.8	23.25	40.45	224	348	1.9	315.24	215.00	145	5
P15	8.9	46400	29696	169.14	99.90	832	220	1.5	109.34	144.65	255	7.5
P16	8.9	1026	656.64	28.86	22.42	164	108	0.5	24.14	69.52	295	5
P17	8.6	666	426.24	11.22	36.06	176	58.6	0.5	15.62	63.50	215	7.5
P18	8.6	708	453.12	18.44	35.57	192	108	1.5	18.46	59.14	180	7.5
P19	8.3	1948	1246.7	55.31	73.58	440	85.7	0.5	112.18	112.69	235	7.5
P20	8.4	1460	934.4	28.86	68.22	352	85.9	0.5	83.78	111.03	150	10
P21	8.3	1176	752.64	26.45	50.68	274	104	0.1	29.82	96.50	335	7.5
P22	8.4	864	552.96	28.06	28.26	186	70.4	3.0	28.4	83.63	230	5
P23	8.6	648	414.72	25.65	25.83	170	57.9	0.5	15.62	60.18	200	7.5
P24	8.4	2230	1427.2	16.03	22.42	132	297	2.2	187.44	115.80	210	2.5
P25	8.5	1060	678.4	36.87	38.01	248	68.3	0.1	44.02	97.74	205	5
P26	9.1	1556	995.84	16.03	85.76	392	85.9	0.3	83.78	107.08	215	5
P27	9.5	1426	912.64	26.45	60.91	316	127	0.1	69.58	103.97	250	5
P28	9	936	599.04	22.44	42.39	230	86.6	0.1	25.56	75.95	265	5
P29	9.3	1948	1246.7	44.09	68.22	390	137	12.8	95.14	95.05	285	5
P30	9	1126	720.64	21.64	44.83	238	110	0.5	46.86	104.80	300	5
P31	8.8	1374	879.36	60.12	35.09	294	133	2.1	45.44	58.52	305	7.5
P32	8.7	1534	981.76	31.26	12.18	128	241	1.5	52.54	89.03	225	10
P33	8.6	1134	725.76	26.45	46.78	258	100	4.4	53.96	102.52	105	5
P34	8.6	1144	732.16	24.85	43.86	242	111	0.6	41.18	79.27	280	5
P35	9.5	1336	855.04	12.83	55.55	260	128	1.1	59.64	72.22	95	7.5
P36	9	1378	881.92	33.67	53.12	302	150	0.1	78.1	80.73	250	10
P37	8.9	1422	910.08	16.03	65.30	308	134	0.6	63.9	74.09	285	5
P38	8.2	3762	2407.7	113.03	125.72	798	212	1.2	345.06	37.77	135	5
P39	8.2	3462	2215.7	60.92	143.26	740	244	1.1	258.44	74.71	210	7.5
P40	8.5	1516	970.24	36.87	52.63	308	171	1.6	69.58	90.48	300	7.5
P41	8.6	2536	1623	18.44	84.79	394	287	1.0	92.3	82.18	230	17.5
P42	8	62200	39808	80.16	288.48	1384	376	1.5	188.86	79.48	355	15

Continued...

Table 2 Major cations and anions for post-monsoon season Dec-12 (mg/l), Parli

Sr.No.	pH	EC	TDS	Ca	Mg	TH	Na	K	Cl	SO_4	HCO_3	Acidity
P43	8.4	1524	975.36	41.68	60.91	354	150	2.6	62.48	95.67	290	10
P44	8.6	1912	1223.7	35.27	46.78	280	241	1.0	105.08	64.54	260	7.5
P45	8.2	3350	2144	12.02	132.06	572	262	51.5	241.4	57.69	295	7.5
P46	8.8	1926	1232.6	36.87	58.48	332	211	1.5	102.24	69.31	250	7.5
P47	8.4	2072	1326.1	53.71	71.15	426	168	0.5	142	96.29	245	12.5
P48	9.3	1364	872.96	19.24	14.62	108	238	1.6	65.32	63.92	185	7.5
P49	8.5	2752	1761.3	60.12	115.98	626	159	2.0	161.88	101.69	210	10
P50	8.3	2526	1616.6	29.66	37.03	226	324	1.6	181.76	108.33	210	2.5
P51	8	2754	1762.6	49.70	95.02	514	211	1.0	191.7	113.93	205	17.5
P52	8.2	1232	788.48	28.06	54.09	292	97.1	0.6	46.86	69.52	250	7.5
P53	8.4	1686	1079	54.51	65.78	406	103	1.0	69.58	85.92	155	7.5
P54	9	1600	1024	28.86	67.73	350	111	2.0	134.9	76.37	160	2.5
P55	9	700	448	22.44	23.88	154	65.2	0.5	21.3	63.71	190	5
P56	8.8	792	506.88	22.44	28.26	172	89.3	0.4	18.46	77.41	235	7.5
P57	8.6	680	435.2	19.24	27.78	162	57.1	1.2	19.88	64.13	170	5
P58	8.9	1980	1267.2	32.06	63.35	340	205	1.0	69.58	106.67	205	5
P59	8.5	1288	824.32	39.28	42.88	274	107	1.5	45.44	87.58	200	10
P60	9.3	456	291.84	49.70	47.75	320	159	3.0	115.02	78.65	195	5

All the concentrations are in mg/l, except pH. EC is measured in µS/cm.

The maximum allowable limit of TH for drinking purpose is 500 mg/l and the most desirable limit is 100 mg/l as per WHO (1998) guidelines. The groundwater samples in the vicinity of Thermal Power Plant shows more hardness. The distribution of TH in groundwater of the study area is demonstrated in figure 4a and b. The concentration of TDS ranges from 652 to 46592 mg/l and from 291 to 119296 mg/l for pre- and post-monsoon season respectively. In pre monsoon season highest TDS is observed from sample number P5 (Belamb) and in post monsoon sample number P4 (Sangam) showing highest TDS. The maximum allowable limit of TDS for drinking purpose is 500 mg/l and the most desirable limit is 1500 mg/l as per WHO (1998) guidelines. EC ranges 1020 to 2800 uS/cm and 456 to 186400 uS/cm in Pre and Post monsoon season respectively (Fig. 5a and b). TDS and EC are relatively high in groundwater samples in the vicinity of Thermal Power Plant. The permissible limit of calcium in drinking water is 75 to 200 mg/l as per WHO (1998) guidelines. The calcium concentration of groundwater samples collected from the study area ranges from 5.61 to 134 mg/l and 11.22 to 181 mg/l in pre and post monsoon season respectively. None of the samples exceeds the permissible limit.

Table 3 Concentration of major ions in groundwater, Parli

		Pre monsoon May-2012			Post monsoon Dec-2012		
Parameter	Unit	Min	Max	Average	Min	Max	Average
pH		7.12	9.03	7.96976	7.9	9.5	8.50024
Cond	uS/cm	1020	72800	9859.066	456	186400	11133.87
TDS	mg/l	652.8	46592	6309.803	291.84	119296	7125.675
Ca	mg/l	5.61	134.67	34.10817	11.22	181.16	41.72283
Mg	mg/l	0.97	204.18	50.36967	7.31	288.48	67.718
Na	mg/l	12.2	421.8	99.83334	57.1	375.9	181.4917
Cl	mg/l	18.46	860.52	162.8267	15.62	839.22	151.3247
SO4	mg/l	25.8	274	95.1	37.77	320.21	113.8348
HCO3	mg/l	50	355	197.8333	95	365	233.6667

Table 4 Correlation matrix for pre-monsoon season May-12 (mg/l), Parli

	pH	TDS	Ca	Mg	Na	K	Cl	SO4
pH	1	-0.28	-0.32	-0.56	-0.21	-0.128	-0.349	-0.23
TDS		1	0.605	0.745	0.593	0.318	0.9	0.173
Ca			1	0.641	0.433	0.205	0.725	0.392
Mg				1	0.382	0.302	0.819	0.37
Na					1	0.263	0.637	0.255
K						1	0.353	0.223
Cl							1	0.302
SO4								1

Table 5 Correlation matrix for post-monsoon season Dec-12 (mg/l), Parli

	pH	TDS	Ca	Mg	Na	K	Cl	SO4
pH	1	-0.127	-0.2	-0.31	-0.19	-4.50E-02	-0.1	-0.12
TDS		1	0.44	0.574	0.536	0.105	0.7	0.68
Ca			1	0.583	0.307	-1.90E-02	0.5	0.34
Mg				1	0.473	0.18	0.6	0.37
Na					1	0.267	0.8	0.62
K						1	0.3	0.17
Cl							1	0.79
SO4								1

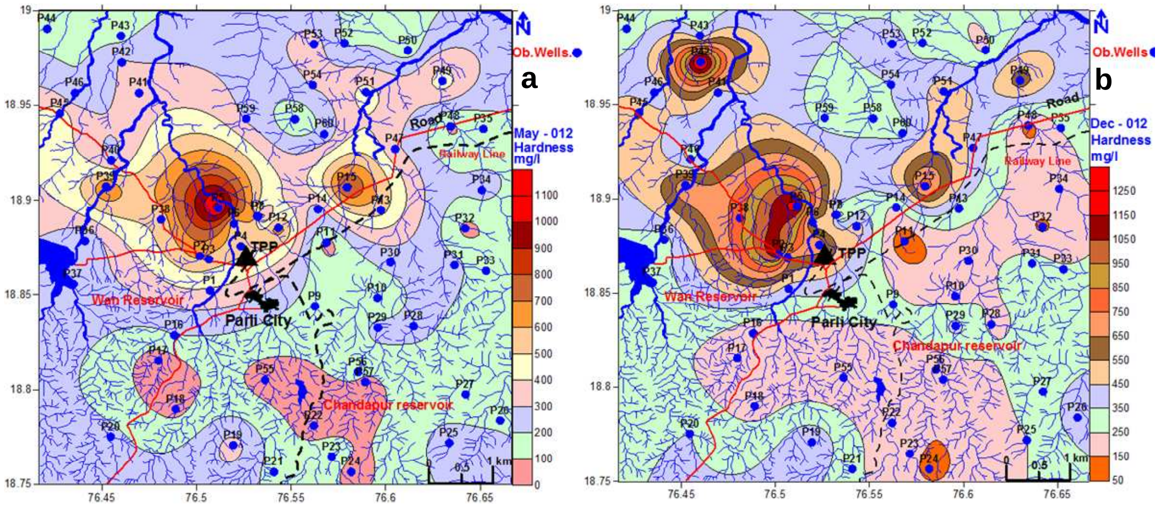

Fig 4. Distribution of Total Hardness in and around Parli, May2012 (a) and December 2012 (b)

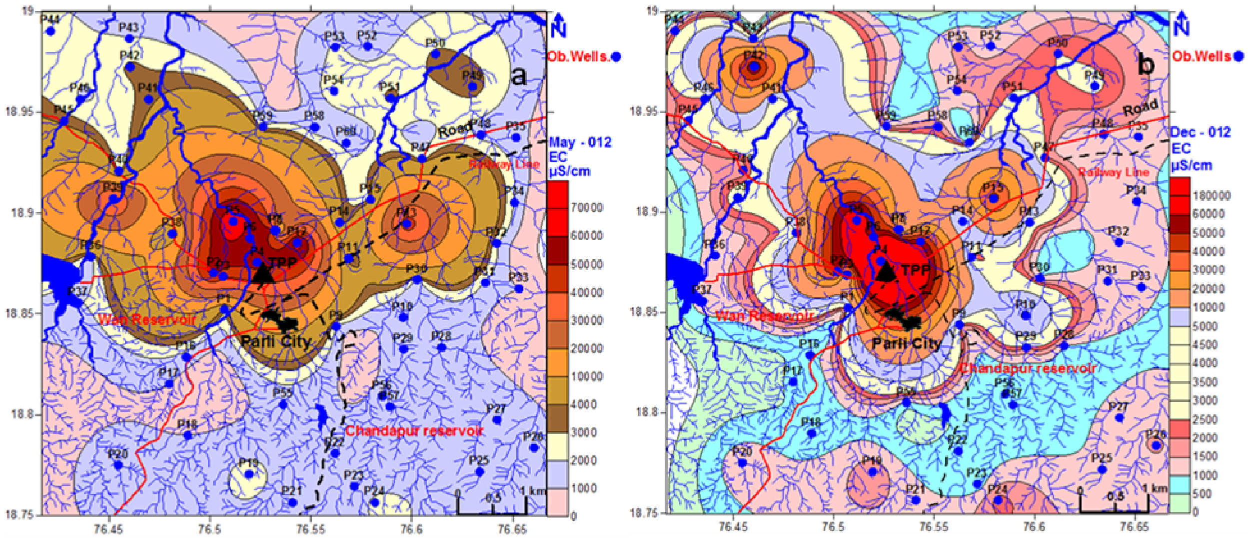

Fig 5. Distribution of Electrical Conductivity in and around Parli, May2012 (a) and December 2012 (b)

Magnesium (Mg^{2+}) usually occurs in lesser concentration than calcium due to the fact that the dissolution of magnesium rich minerals is a slow process and that of calcium is more abundant in the earth's crust. The acceptable limit is 30 mg/l as per Indian standards[3]. The magnesium level in the groundwater samples ranged from 0.97 to 204 mg/l and 7.3 to 288 mg/l in pre and post monsoon season respectively. The highest Mg in pre monsoon season is observed from sample number P5 (Belamb) and in post monsoon season from sample number P4 (Sangam). Most of the locations near Thermal Power Plant exceed the permissible limit given by WHO (1995). Distribution of magnesium in study area is shown in figure 6a and b. The primary source of sodium in natural water is from the release of the soluble products during the weathering of minerals. The concentration of sodium in the area varies from 12 to 421 mg/l in pre monsoon season and from 57.1 to 375.9 mg/l in post monsoon season. The distribution of sodium and potassium in groundwater of the study area is revealed in figure 7a and b. The highest Na in pre monsoon season is observed in sample number P8 (Parli) and in post monsoon season sample from number P42 (Kaudgaon sable).

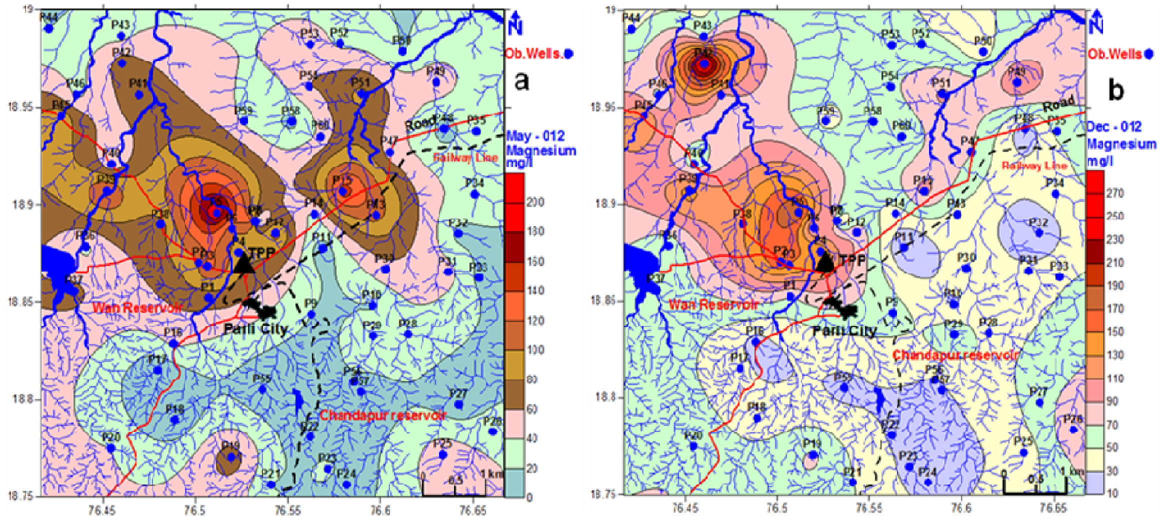

Fig 6. Distribution of Magnesium in and around Parli, May2012 (a) and December 2012 (b)

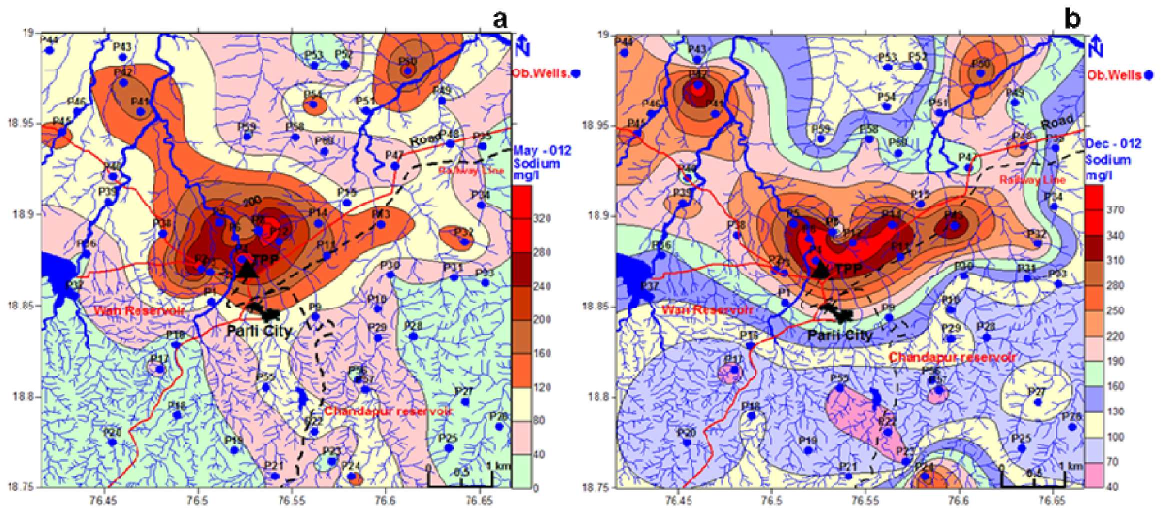

Fig 7. Distribution of Sodium in and around Parli, May2012 (a) and December 2012 (b)

The sodium concentration more than 50 mg/l makes the water unsuitable for domestic use. Groundwater in the vicinity of Thermal Power Plant area which comes under the non-safe zone for drinking with reference to the concentration of sodium, which is more than 250 mg/l. The potassium level in the groundwater samples ranged from 2.9 to 43.4 mg/l and 0.1 to 51.5 mg/l in pre and post monsoon season respectively.

Mostly, the chlorides are found in the form of sodium chloride in the groundwater. The chloride concentration varied from 18.46 to 860 mg/l and 15 to 839 mg/l in P5 (Belamb) during pre and post monsoon season respectively. The high chloride may be attributed to industrial, domestic wastes, leaching from upper soil layers in dry climates and natural geochemical activities in this area. The sulphate concentration was ranged from 8 to 274 mg/l and 7 to 320 mg/l during pre and post monsoon season respectively. In the study area the sulphate level is within the permissible limit of 200 to 400 mg/l given by WHO (1998). Bicarbonate was ranged from 50 to 355 mg/l during pre monsoon season from sample number P42 (Kaudgaon sable) and 95 to 365 mg/l in post monsoon season from sample number P9 (Malkapur).The Bicarbonate level is within the permissible limit of 500 mg/l given by BIS (1991).

Hydrogeochemical facies

As water flows through an aquifer it assumes a characteristic chemical composition as a result of interaction with the lithologic framework. The term hydrochemical facies is used to describe the bodies of groundwater in an aquifer, that differ in their chemical composition. The facies are a function of the lithology, solution kinetics, and flow patterns of the aquifer. Hydrochemical facies can be classified on the basis of dominant ions using the Piper's trilinear diagram [8].

In order to understand the role of various cations and anions in the groundwater chemistry during pre- and post-monsoon period, the data were plotted on the trilinear diagram (Piper 1944). From figure 8 it is seen that in pre-monsoon season 36 samples (66%) and post-monsoon season 31 samples (55.6%) belongs to Ca+Mg > Na+K (alkaline earths exceeds alkalies) hydrochemical facies. Similarly in pre-monsoon season 19 samples (31.6%) and in post-monsoon season 28 samples (56.6%) represent Na+K > Ca+Mg hydrochemical facies.

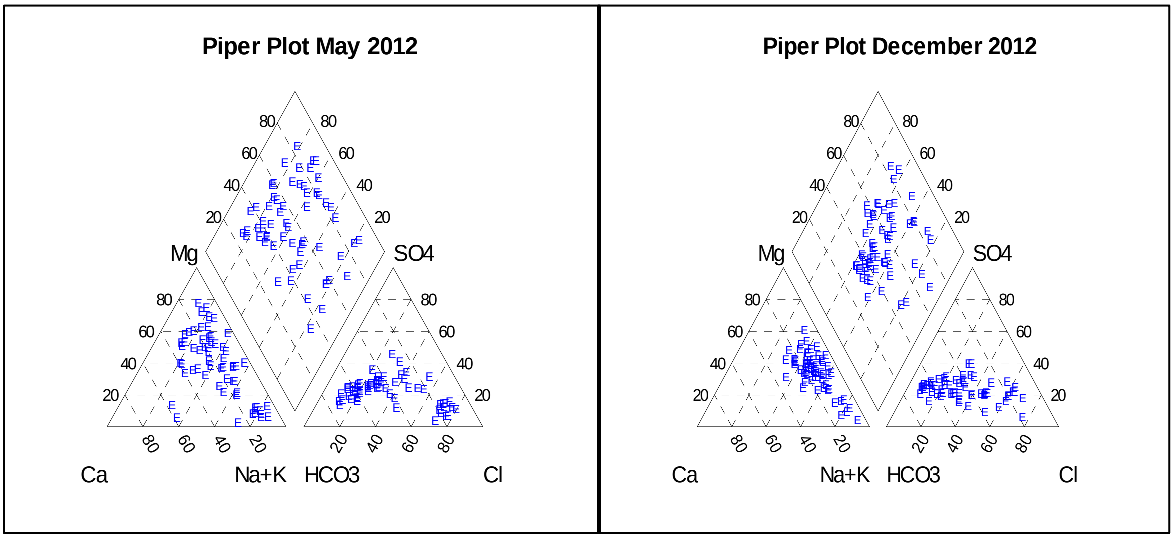

Fig 8. Distribution of water samples on Piper's Trilinear Diagram

It is also observed that in pre-monsoon season 21 samples (35%) and post-monsoon season 22 samples (36.3%) belongs to HCO_3+CO_3 > CL+SO_4 (weak acid exceeds strong acid) hydrochemical facies. Similarly in pre-monsoon season 34 samples (56.6%) and in post-monsoon season 36 samples (60%) CL+SO_4 > HCO_3+CO_3 (strong acid exceeds weak acid) hydrochemical facies **(**Table 6).

Groundwater for Irrigation Purpose

Groundwater is valuable only when its quality is suitable for a variety of purposes.

Table 6 Distribution of groundwater according to water types with reference to the Piper's Trilinear Diagram

Sr. No.	Type of Facies	Pre-Monsoon	Post-Monsoon
1	Ca+Mg > Na+K	36 (66%)	31 (55.6%)
2	Na+K > Ca+Mg	19 (31.6%)	28 (56.6%)
3	Na+K	-	1 (1.6%)
4	HCO_3+CO_3 > CL+SO_4	21 (35%)	22 (36.3%)
5	CL+SO_4 > HCO_3+CO_3	34 (56.6%)	36 (60%)
6	Cl+SO_4	3 (5%)	-

Water for irrigation should satisfy the needs of soil and the crop as the liquid phase in soil water plant growth and crop production. EC and Na+ play a vital role in the suitability of water for irrigation. The high salt content in irrigation water causes an increase in soil solution osmotic pressure. The salts, besides affecting the growth of plants directly, also affect soil structure, permeability and aeration, which indirectly affect plant growth [9]. The suitability of water for irrigation can be estimated by both salinity and sodium hazard with the help of Wilcox diagram.

Both salinity and sodium hazard are classified as low, medium, high and very high, they are represented by C1, C2, C3, C4 and S1, S2, S3, S4, respectively [21] as shown in figure 9. Majority of the pre monsoon samples fall in low sodium hazard and high salinity hazard, while few samples are fall in to high sodium hazard and high salinity hazard zones indicating non-suitability of groundwater for agricultural purposes. The post-monsoon samples fall in the range of low to very high sodium hazard and medium to very high salinity hazard zone indicating limited use for agricultural purposes. Gibbs (1970) proposed a diagram to understand the relationship of the chemical components of waters from their respective aquifer lithologies [10], various factors controlling groundwater chemistry are analyzed by the diagram [14].

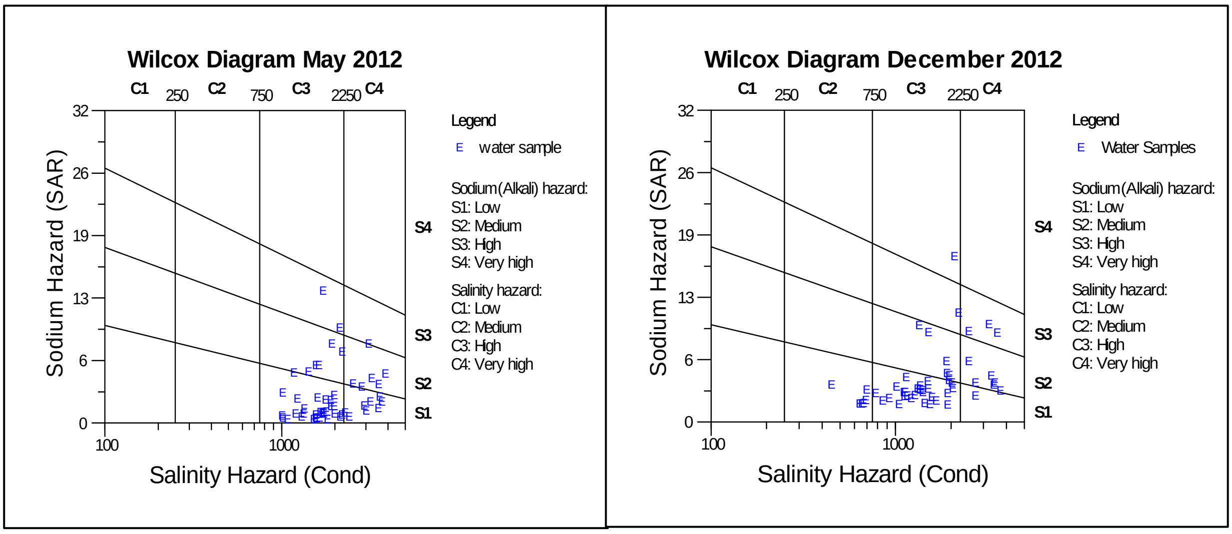

Fig 9. Distribution of water samples on Wilcox Diagram

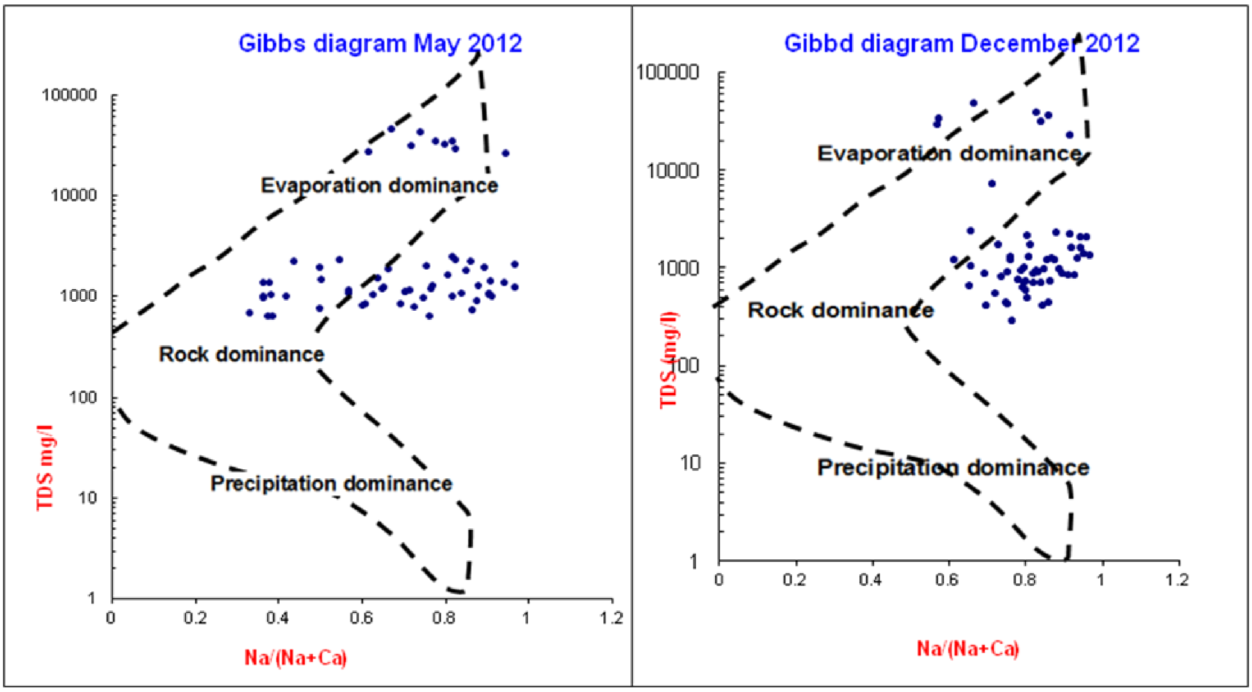

Fig.10 Distribution of water samples on Gibb's diagram

The groundwater samples are scattered between the rock and evaporation dominance fields (Fig. 10). This suggests that the majority of the groundwater samples of both the season fall in the rock dominance field while very few groundwater samples of both the season fall in evaporation field. Lithology of the area may be controlling the groundwater chemistry of post monsoon and the pre monsoon samples.

Interrelations of chemical parameters

The interrelations among the chemical parameters are evaluated, using a correlation coefficient (r) model, to assess the sources of dissolved salts in the groundwater [19] Table 4 and 5. The pH shows negative correlation with TDS (r= -0.28), Na (r= -0.21),Mg (r= -0.56), Ca (r= -0.32), Cl (r= -0.34), K (r= -0.12), SO_4 (r= -0.23) in pre monsoon and TDS (r= -0.12), Na (r= -0.19),Mg (r= -0.30), Ca (r= -0.16), Cl (r= -0.11), SO_4 (r= -0.11) in post monsoon season. In pre monsoon groundwater samples Ca shows good positive correlation with Cl (r= 0.72) and Mg (r= 0.64). Mg shows good positive correlation with Cl (r= 0.81). Na shows good positive correlation with Cl (r= 0.6). In Post monsoon samples Mg shows good positive correlation with Cl (r= 0.6), C (r= 0.6). Na shows good positive correlation with Cl (r= 0.8), SO_4 (r= 0.6). Cl shows good positive correlation with SO_4 (r= 0.7).

CONCLUSION

Groundwater quality in and around Parli Thermal Power Plant (PTPP) area has been analyzed in the present work. The groundwater is alkaline in nature and total hardness is observed in all samples near to PTPP fall under hard to very hard category. The TDS in the north region and surrounding region of PTPP exceeds the permissible limit. The concentration of Calcium, Bicarbonate and Sulphate is below the desirable limit. In most of groundwater samples the concentration of Mg, Na, Cl, is very high and above the permissible limit which are in the vicinity of Thermal Power Plant. Major hydro chemical facies identified using piper trilinear diagram were Ca+Mg > Na+K and $CL+SO_4 > HCO_3+CO_3$ in pre and post- monsoon season. The concentrations of physiochemical constituents in the water samples are compared with the Bureau of Indian Standards WHO (1998) and BIS (1983) to know the suitability of water for drinking purpose. Based on the analysis, most of the area at many locations near to PTPP falls in moderately polluted to severely polluted leading the water is unsuitable for drinking purpose. According to the quality classification of irrigation water proposed by Wilcox and US salinity classification some of the water samples fall in the suitable range for irrigation purpose but samples near to PTPP are not suitable for irrigation. It was observed that the quality of groundwater was not suitable for drinking and irrigation purpose in surrounding area of Parli Thermal Power Plant which is very near to Parli city. These sampling sites have become unsuitable by the influences of urban and Thermal power plant and other industrial waste discharge, aquifer material mineralogy together with semiarid climate, other anthropogenic activities and increased human interventions in the groundwater quality in the study area. Based on the findings of the present multi-disciplinary study, the following follow-up actions are recommended. Avoide to use water from polluted wells which are in proximity of PTPP. Develop a drinking-water monitoring network, increase public awareness of water quality and health aspects. Continue the introduction of sustainable household practices and good agricultural practices with the communities.

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