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Assessment of the ground water quality and its suitability for drinking and irrigation purposes: A case study of Patancheru, Andhra Pradesh, India

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ABSTRACT

Ground water quality is important as it is the main factor determining its suitability for drinking, domestic, agricultural and industrial purposes. The suitability of groundwater for drinking and irrigation has been assessed in patancheru industrial area of medak district of Andra Pradesh, India. In order to assess the ground water quality forty ground water samples were collected in pre-monsoon 2008 and post-monsoon 2008 and analyzed for physical and chemical parameters. Physical and chemical parameters of groundwater such as electrical conductivity, pH, total dissolved solid, Na, K, Ca, Mg, HCO_3, Cl, and SO_4 were determined. The result shows that the groundwater of the study area is not suitable for drinking purposes and also not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances.

Keywords: groundwater, drinking, irrigation, Ground water pollution, electrical conductivity

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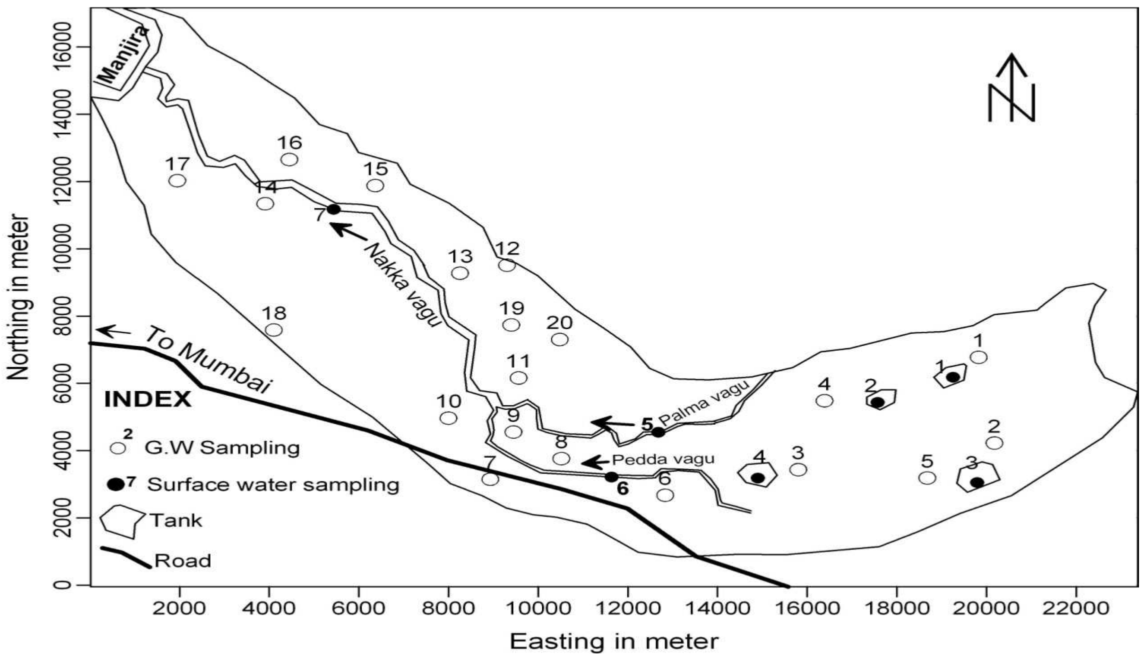
INTRODUCTION

Despite some awareness regarding groundwater pollution in the industrial parts of Medak, a great deal still remains to be done to document the extent of the problem. About 400 (large and small) industries are in the area, and since 1977 these have been engaged in the manufacture, production, and processing of pharmaceuticals, paints and pigments, metal treatment and steel rolling, cotton and synthetic yarn, and engineering products. Most of them use various inorganic and organic chemicals as raw materials. Apart from discharging waste effluents into the streams, semi-solids are burned in the open. The leachate from these wastes, combined with precipitation, infiltrates to the shallow water table. Water pollution not only affects ground water quality but also threats human health, economic development, and social prosperity. The quality of water is equally important to its quantity owing to the suitability of water for various purposes. The groundwater is one of the most contaminated natural resources, in the study area, due to unplanned and random industrial growth and urbanization without following basic pollution control norms. The rapid industrialization initiated in early 1970 has started showing up its after effects few years later in the form of physicochemical contamination of the both surface and groundwater bodies of the area. Poor people cannot able to drink safe water as well as plant and aquatic life has also affected throughout the years, in spite of some preventive and remedial measures being initiated. Water quality data is essential for the implementation of responsible water quality regulations for charactering and remediating contamination and for the protection of the health of humans and the ecosystem. Regular monitoring of ground water resources thus plays a key role in sustainable management of water resources. The aim of the study is to investigate the effects of the industrial activities on ground water quality and its suitability for drinking and irrigation purposes.

MATERIALS AND METHODS

The Study Area

The Patancheru and Bolaram Industrial Development Areas (IDAs) (78°08′–78°23′ east longitude and 17°30′–17°42′ north latitude) of the Medak district are located about 35 km from Hyderabad, Andhra Pradesh (AP), India; the location is shown in Fig. 1.



Ground water sampling
1. Kazipally 2. Mallampet 3.Kistareddy pet 4. Sultan pur 5. Balaram
6. Patancheru 7. Muthangi 8. Pocharam 9. Ganapathigudam 10. Chitkul
11.Bacheguda 12.Pedda kanjerla 13.Chinna kanjerla 14.Bithole 15.cheduruppa
16. Arutla 17. Ismail khan pet 18. Rudraram 19. Inderesham 20.Inole

Surface water sampling
1. Kazipally lake 2. Gandigudem lake 3. Asanikunta 4. Kistareddy pet lake 5. Palma vagu 6.Pedda vagu 7. Nakka vagu

3.1 Hydrogeochemical sampling procedure

The objective of sampling is to collect a portion of material small enough in volume to be transported conveniently and handled in the laboratory while still accurately representing the material being sampled [1] (APHA, 1992). Samples, however, have to be handled in such a way that no significant change in composition occurs before the tests are made.

A total number of 40 groundwater samples were collected for physico-chemical analysis in two successive pre-and post-monsoon seasons corresponding to Pre-monsoon 2008 and Post-monsoon 2008.

The water samples were collected and stored in 1 liter capacity clean plastic bottles. Before collection of samples, the bottles were properly washed. Prior to collecting the samples, the containers were rinsed by the water to be sampled. The wells were duly pumped before collecting their sample so that the stagnant water, if any, is completely removed from storage within the well assembly. The major ion analyses were carried out at National Geophysical Research Institute, Hyderabad.

3.2 Analytical techniques for major ions

The water samples were analyzed as per the standard methods of APHA (1992). Values of pH were measured by a portable digital water analyses kit with electrodes. The instrument was calibrated with buffer solutions having pH values of 4 and 9. Total dissolved solids (TDS) were calculated by summing up the concentrations of all the major cations and anions. The values of electrical conductivity (EC) were measured by portable kit with electrodes in the lab.

The concentrations of Ca^{++}, Mg^{++}, Cl^{-}, HCO_3^{-} and total hardness were determined by volumetric method. Ca^{++} and Mg^{++} were determined by EDTA titration. For HCO_3^{-}, HCl titration to a methyl orange point was used. Chloride was determined by titration with $AgNO_3$ solution. Flame emission photometry has been used for the determination of Na^{+} and K^{+}. In this method water sample is atomized and sprayed into a burner. The intensity of the light emitted by a particular spectral line is measured with the help of a photoelectric cell and a galvanometer. Sulphate was determined by gravimetric method.

RESULTS AND DISCUSSION

The analytical data of successive pre-and post-monsoon seasons for groundwater sample corresponding to June 2008 and November 2008 are given mg/l is in table 1a &1b. Equivalents per million (epm) values are also calculated and given in table 2a and 2b for above periods.

4.1 Physico-chemical attributes of groundwater

The properties of groundwater of the area under study, in terms of fundamental parameters, such as, pH, hardness, total dissolved solids and EC are given below.

4.1.1 Electrical Conductivity

The electrical conductivity with 400 µmhos/cm at 25^{o} C is considered suitable for human consumption (WHO, 1984), while more than 1500 µmhos/cm at 25^{o} C may cause corrosion of iron structures.

On the basis of electrical conductance, groundwater is classified as given by Sarma and Narayanaswamy (1981) [2]. In the study area, Electrical Conductivity values ranges between 3800-11800µS/cm during June 2008. The EC values during November 2008 ranges between 3600-11600 µS/cm.

4.1.2 Hydrogen Ion Concentration (pH)

Values of pH were measured at well sites, which range between 7.24 to 8.6 and 7.15 to 8.64 during pre-monsoon 2008 and post-monsoon 2008, respectively (Table-1a and b). The groundwater thus is mildly acidic to slightly alkaline in nature.

4.1.3 Hardness

In the area of study the hardness value varies from 693 to 3560 mg/l and 652 to 3800 mg/l in pre-and post-monsoon 2008 and he average value for above period is 1480.9 mg/l& 1400 mg/l, respectively. It was found that all samples are higher than desirable limit for drinking purposes of >300 mg/l in above periods. So, all the sample are not fit for drinking purpose within the permissible limit of drinking water standard (BIS, 1991).

4.1.4 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) have been calculated by summing up all the major cations and anions (Table-1a and 1b) and the correlation between TDS and instrumentally determined EC excellent. TDS values for June, 2008 samples range from 2410 to 7500 mg/l, the average value for the samples being 4018 mg/l. The TDS values during November 2008 range between 2301 to 7484 mg/l with an average value of 4077 mg/l. The TDS concentration was found to be above the permissible limit may be due to the leaching of various pollutants in to the ground water which can decrease the pot ability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly up on transits [3].

Drinking water becomes significantly unpalatable at TDS value >1000 mg/l. From this point of view, therefore, groundwater in the study area is not really ideal.

4.2 Drinking Water Quality

The groundwater samples for both the seasons i.e. pre-and post-monsoons 2008 shows the high TDS concentration and are above the permissible limit of 2000 mg/L WHO 1997 & BIS 1991 and making the water unsuitable for various domestic activities. Based on TDS values Davies and DeWiest (1996) [4]propose a threefold classification of groundwater. (1) Domestic (<500 mg/L) (2) Irrigation (500-1,000 mg/l) and (3) Industry (>1,000 mg/L). According to this classification all the samples of both seasons are in category (3). The SO_4 concentration is also above the highest desirable limit of 400mg/l. The SO_4 concentration of eight & nine samples in both the seasons cross the maximum permissible limit of drinking standards (BIS 1991). The high intake of SO_4 may result in gastrointestinal irritation and respiratory problems to the human system (Subramani et al 2005, Maiti 1982, Subba Rao 1993) [5] [6] [7]. Fourteen samples of Pre-monsoon 2008 & seven samples of post-monsoon 2008 have nitrate concentration more than highest desirable limit of 45 mg/l (BIS). The high concentration of nitrate in drinking water is toxic and cause blue baby disease / metaemoglobinaemia in children and gastric carcinomas. In both pre-and post-monsoon of samples of 2008, fluoride concentration exceeds the maximum permissible limit of 1.5mg/l which is hazardous for human consumption (BIS 1991) [8].

Table- 1a: Results of Chemical analysis in mg/l (pre-monsoon 2008)

S.No.	Location	pH	EC (μseimens)	TDS	Hardness	HCO_3	Cl	SO_4	Na	K	Ca	Mg
1	KAZIPALLY	7.24	11700	7500	1030	563	3100	1040	2300	80	222.4	116.4
2	MALLAMPET	7.34	6200	3960	1600	548	1436	487	645	81.9	332	189
3	KISTAREDDYPET	7.95	4300	2725	801	702	798	325.1	603	25	201.5	72.4
4	SULTANPUR	8.01	4800	3010	1110	715.3	1002	255	529.1	12.1	288	95.4
5	BOLARAM	7.81	11800	7500	1650	736	3412.4	687.4	2104.4	10.9	389.1	164.5
6	PATANCHERU	8.22	7200	4660	1800	745	1745	578	880	25.3	484	144
7	MUTHANGI	7.98	5400	3432	769	704	1004.1	554	855	12	201	65
8	POCHARAM	7.95	8700	5500	2740	711.4	2194	764	705	21.1	765.9	201.5
9	GANAPATHIGUDEM	7.95	10200	6500	3560	841	2801	642	705	45	1045	230
10	CHITKUL	7.68	5000	3210	867	689	1260	191.3	745	21	201	89
11	BACHUGUDA	7.67	10800	6900	3100	714	3150	640	1900	36	321.4	180
12	PEDDA KANJERLA	7.85	4400	2800	777	704.5	936	222	603	8	209	62
13	CHINNA KANJERLA	8.6	4400	2841	1050	568	1010	261	553	15.1	265	95
14	BITHOLE	7.62	3800	2410	757	551	880	203	521	9	175	78
15	CHUDURUPPA	7.94	4500	2885	943	678	962	251	645	9.1	256	74
16	ARUTLA	8.01	3800	2445	1040	698	645	285	426	7.3	287	78
17	ISMAIL KHAN PET	8.2	4000	2550	693	731.9	721	312	564	9.4	136	86
18	RUDRARAM	7.79	4200	2689	1070	680	865	455	460	1.2	290	85
19	INDERESHAM	7.32	7200	4440	2180	789	1725	556	687	37	501	225
20	INOLE	8.02	5200	3300	790	1390	1225	275	621	16	245	245

Table- 1b: Results of Chemical analysis in mg/l (post-monsoon 2008)

S.No.	Location	pH	EC (μseimens)	TDS	Hardness	HCO_3	CL	SO_4	Na	K	Ca	Mg
1	KAZIPALLY	7.15	11400	7310	1100	521	3091	1089	2219	45	201	145
2	MALLAMPET	7.35	4600	2950	1160	558	957	412	403	98	282.1	112
3	KISTAREDDYPET	7.42	4500	2810	763	660	885	314	585	32	198.4	65.2
4	SULTANPUR	7.41	4100	2610	979	689	902	198.2	481	15	267	76
5	BOLARAM	7.17	11600	7484	1560	765	3210	888.1	2045.2	10.1	387	145.2
6	PATANCHERU	8.05	6900	4443	1910	706.9	1574	647	697	45	561	123
7	MUTHANGI	7.54	5600	3561	652	698	1100	521	898	35	187	45
8	POCHARAM	7.56	8700	5532	2950	756	2069	701	765	31.5	801.4	231
9	GANAPATHIGUDEM	7.43	9900	6310	3800	789.5	2775	651.9	711.9	21	1125.6	214
10	CHITKUL	8.64	4900	3159	960	678	1198	220.9	699	30.1	251	81.4
11	BACHUGUDA	7.89	10600	6750	1400	842	2900	615	1850	19.1	324	145
12	PEDDA KANJERLA	8.25	4300	2732	845	659	918	265	587	17	210.5	83
13	CHINNA KANJERLA	7.88	4700	3100	977	628	1125	235	610	10.2	245	89
14	BITHOLE	7.95	3800	2453	822	587	845	216	516	14	186	87
15	CHUDURUPPA	8.3	4800	3050	933	785	1014	214	610	17.5	278	58
16	ARUTLA	8.23	3600	2301	770	711	601	254	457	5	231	47
17	ISMAIL KHAN PET	8.3	4100	2660	886	742	702	365	545	10.9	233	74.1
18	RUDRARAM	7.76	4180	2663	1220	712	775	351	385	1.5	365	75
19	INDERESHAM	7.55	6600	4200	1940	755	1641	500	680	35	445	201
20	INOLE	7.36	6000	3838	725	1390	1200	241	554	10	268	175

4.3 Groundwater suitability for Irrigational Usages

The suitability of groundwater for irrigation is dependent on the effects of the mineral constituents of water of both the plant and soil. Salt may harm plant growth physically by limiting the uptake of water through modification of osmotic processes, or chemically by metabolic reactions effected by toxic constituents. Effects of salts on soils in causing changes in soil structure, permeability and aeration directly affect the plant growth [9].

The irrigation water containing a high proportion of sodium will increases the exchange of sodium content of the soil, affecting the soil permeability, and texture making the soil hard to plough and unsuitable for seeding emergence [10] [11]. If the percentage of Na with respect to Ca + Mg + Na is considerably above 50% in irrigation waters, soils containing calcium and magnesium take up sodium in exchange for calcium and magnesium causing deflocculation and impairment of the quality and permeability of soils [12]. The addition of gypsum or lime may correct the situation of the soil.

The total dissolved solids, measured in terms of specific electrical conductance gives the salinity hazard of irrigation water. The electrical conductivity is a measure of salinity hazard to crop as it reflects the TDS in the groundwater.

Based on analytical results, irrigational quality parameters like sodium adsorption ratio (SAR), electrical conductivity (EC) were estimated to assess the suitability of groundwater for irrigation. The salt present in the water, besides affecting the growth of plants directly, also affects soil structure permeability and aeration, which indirectly affect the plant growth [13] [14] [15].

Table- 2a: Results of Chemical analysis in meq/l (pre-monsoon 2008)

SNO	Location	HCO_3	Cl	SO_4	Na	K	Ca	Mg
1	KAZIPALLY	9.23	87.3	21.6	100	2.05	11.1	9.58
2	MALLAMPET	40.5	8.98	10.1	28	2.09	16.6	15.6
3	KISTAREDDYPET	22.5	11.5	6.77	26.2	0.63	5.96	10
4	SULTANPUR	28.2	11.7	5.31	23	0.3	7.85	14.4
5	BOLARAM	12.1	96.1	14.3	91.5	0.279	19.4	13.5
6	PATANCHERU	12.2	49.2	12	38.3	0.647	24.1	11.9
7	MUTHANGI	11.5	28.3	11.5	37.2	0.307	10	5.35
8	POCHARAM	11.5	61.8	15.9	30.7	0.54	38.2	16.6
9	GANAPATHIGUDEM	13.8	78.9	13.4	30.7	1.15	52.1	18.9
10	CHITKUL	11.3	35.5	3.98	32.4	0.537	10	7.33
11	BACHUGUDA	11.7	88.7	13.3	82.6	0.921	16	14.8
12	PEDDA KANJERLA	11.5	26.4	4.62	26.2	0.205	10.4	5.1
13	CHINNA KANJERLA	9.31	28.5	5.43	24	0.386	13.2	7.82
14	BITHOLE	9.03	24.8	4.22	22.7	0.23	8.73	6.42
15	CHUDURUPPA	11.1	27.1	5.22	28	0.233	12.8	6.09
16	ARUTLA	11.4	18.2	5.93	18.5	0.187	14.3	6.42
17	ISMAIL KHAN PET	12	20.3	6.49	24.5	0.24	6.78	7.08
18	RUDRARAM	11.1	24.4	9.47	20	0.0307	14.5	7
19	INDERESHAM	12.9	48.6	11.6	29.9	0.946	25	18.5
20	INOLE	22.8	34.5	5.72	27	0.409	12.2	20.2

Table- 2b: Results of Chemical analysis in meq/l (post-monsoon 2008)

SNO	**Location**	**HCO_3**	**CL**	**SO_4**	**Na**	**K**	**Ca**	**Mg**
1	KAZIPALLY	8.54	87.1	22.7	96.5	1.15	10	11.9
2	MALLAMPET	9.15	27	8.57	17.5	2.51	14.1	9.22
3	KISTAREDDYPET	10.8	24.9	6.53	25.4	0.818	9.9	5.37
4	SULTANPUR	11.3	25.4	4.12	20.9	0.384	13.3	6.26
5	BOLARAM	12.5	90.4	18.5	88.9	0.256	19.3	11.9
6	PATANCHERU	11.6	44.3	13.5	30.3	1.15	28	10.1
7	MUTHANGI	11.4	31	15.8	39	1.41	9.3	3.7
8	POCHARAM	12.4	58.3	14.6	33.3	0.806	40	19
9	GANAPATHIGUDEM	12.9	78.2	13.5	30.9	0.537	56.1	17.56
10	CHITKUL	11.1	33.7	4.58	30.4	0.77	12.5	6.6
11	BACHUGUDA	13.8	81.7	12.8	80.4	0.488	16.2	11.9
12	PEDDA KANJERLA	10.8	25.9	5.52	25.5	0.435	10.5	6.83
13	CHINNA KANJERLA	10.3	31.7	4.89	26.5	0.261	12.2	7.33
14	BITHOLE	9.62	23.8	4.5	22.4	0.358	9.28	7.16
15	CHUDURUPPA	12.9	28.6	4.45	26.5	0.448	13.9	4.77
16	ARUTLA	11.7	16.9	5.29	19.9	0.128	11.5	3.87
17	ISMAIL KHAN PET	12.2	19.8	7.6	23.7	0.279	11.6	6.1
18	RUDRARAM	11.7	21.8	7.3	16.7	0.038	18.2	6.17
19	INDERESHAM	12.4	46.2	10.4	29.6	0.895	22.2	16.5
20	INOLE	22.8	33.8	5.02	24.1	0.256	13.4	14.4

4.3.1 Sodium Adsorption Ratio (SAR) Criterion

The interpretation of water quality suitable for the irrigation purposes are given by Richard (1954) [16] in the form of EC versus SAR values. Electrical Conductivity (E.C.) has been treated as index of salinity hazards and sodium adsorption (SAR) as index of sodium hazards. SAR is calculated from the ionic concentration (in meq) of sodium, calcium and magnesium according to following relationship (Karanth, 1987).

$$SAR = \frac{Na}{\sqrt{\frac{Ca+Mg}{2}}}$$

The SAR values of the groundwater samples of the area are given in Table-. The data has been plotted using US Salinity diagram into observe the suitability of water for irrigation purposes. The SAR value ranges from 5.15 to 29.1 with an average value of 11.05 in the samples collected during pre-monsoon 2008. The analytical data of pre-monsoon 2008 plotted on the US salinity diagram (Richards 1954) show that 70% of samples fall in C_4S_2 region, 15% in region and 15% fall in C_4S_4 region. Very high salinity water (C_4S_4) is not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances. The irrigation water must be applied in excess to provide considerable leaching and very salt-tolerant crops should be selected.

During post-monsoon of 2008, the SAR values range from 4.78 to 29.16 with an average value of 10.82. Therefore the possibility of sodium hazard may be high in this area. The analytical data show that 80% of the groundwater samples fall in the field of C_4S_2. The ground water having high salinity and medium sodium hazard is not suitable for irrigation under ordinary conditions 15% of the samples belong to C_4S_4 region. These very high salinity and very high is generally unsatisfactory for irrigation unless special action is taken, such as addition of gypsum to soil.

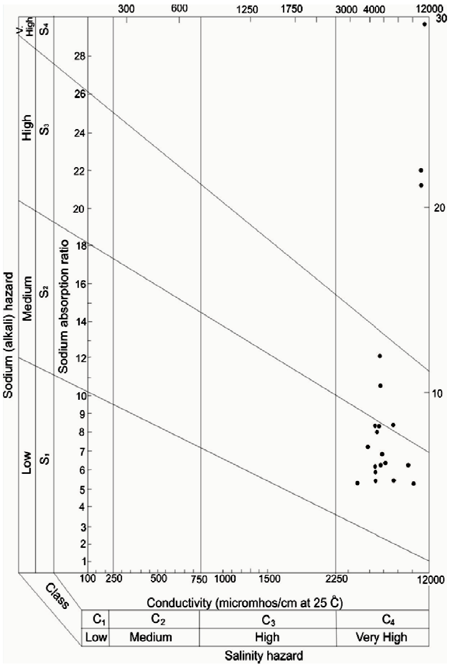


Figure 2: SAR Vs E.C. (Pre-monsoon 2008)

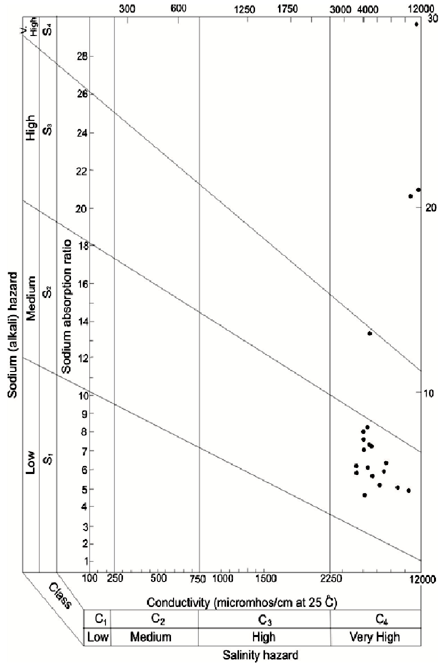


Figure3: SAR Vs E.C. (Post-monsoon 2008)

CONCLUSION

The ground water with in industrial area has very high content of TDS, EC, TH, Ca, Mg, Cl, SO4, and NO3 proving that the industrial effluents are not only causing direct contamination of water, but are also responsible for ion enrichment by enhancing the release of dissolved species in solution. The higher concentration of cations and anions in ground water is an indication of manmade source. Higher concentration of chloride and sulphate, nitrate in samples indicates anthropogenic impact on water quality. Large quantities of acids and $caco_3$ material are used by pharmaceutical, paints, rubber industries which are released out in the form of effluents without proper treatment into open channels leading to accumulations of these elements in ground water in and around industrial areas which prove to be potential pollutants as point source.

Inferior ground water quality may cause water born diseases and crop damage. About 80% of water born diseases in the world (WHO 1984) [17] and over one third of the total deaths in the developing countries are caused by consumption of polluted water and lack of knowledge of water quality of assessment. Overall, groundwater of the study area is not suitable for drinking purposes. Groundwater of the study area are also not suitable for irrigation under ordinary conditions, but may be used occasionally under very special circumstances.

Remediation measures should be adopted to restore the already highly contaminated aquifers. In view of deteriorating quality of groundwater and degradation of soil cover, it is recommended

1. To have a constant monitoring of the quality of ground water in this area and necessary preventive measures have to be adopted to avoid further deterioration.
2. Industries should monitor their air emissions regularly and take measures to ensure compliance with the prescribed emission standards.
3. Industries should strictly follow applicable government regulations on pollution control.

4. Organic waste should be dumped in places far from residential areas.
5. New industrial wastewater collection and treatment facilities must be constructed and existing facilities modernized and upgraded.
6. Industrial wastewater facilities must be more effectively operated.
7. Discharges of industrial wastewater into municipal sewer systems must be pre-treated, especially with regard to hazardous substances.
8. Environmentally sound techniques should be universally applied. Hazardous substances should be properly stored, treated and disposed of.

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