I Research Journal of Environment Sciences _________________________________ I Res. J. Environment Sci.
Vol. 1(1), 28-33, August (2012)

Physico chemical Characterization of ground water of Anand district, Gujarat, India

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Available online at: www.isca.in
Received 23rd July 2012, revised 28th July 2012, accepted 30th July 2012

Abstract

A report of physico-chemical study of the water samples taken from the Anand district of central Gujarat is presented here. Water samples from 42 sites have been subjected to physico- chemical analysis including parameters viz. pH, TDS, conductivity, hardness, dissolved oxygen, chloride, nitrate, phosphate, fluoride, iron and boron. Observations indicated pH, nitrate and phosphate values to be within permissible limit, TDS showed variable results while conductivity was high total hardness was slightly higher in some sampling locations, otherwise within the limits. Fe and boron was significantly high in all the locations. Fluoride was also absent in all the locations except Borsad. Chloride was considerably high only in Khambhat. The results were used to calculate the water quality index to draw conclusion about the suitability of the water for drinking and other domestic applications.

Keywords: Ground water, physico-chemical analysis, water quality index.

Introduction

Groundwater is the most important source of drinking water in India. Especially it plays a vital role in the development and public health of the population in arid and semi-arid zones. Unfortunately due to injudicious and unplanned urbanization and Industrialization for the past few decades in few parts of the country, the resource is either being depleted or degraded in quality[1, 2, 3, 4, 5]. The current study area of Gujarat houses aquifers which are beset with numerous quality problems, some of which are increasing in intensity over the years [6,7] Having a longest coastline in the country, sea water intrusion into aquifers is a common problem all across Gujarat right from Kutch and Saurashtra to Vadodara and Valsad [8]. Excessive Fluoride is another problem in groundwater of North Gujarat, some parts of Saurashtra and some pockets of South Gujarat [9]. Over the years, excessive amounts of Nitrate are surfacing in groundwater in various parts of the state [10]. In addition to all this, Gujarat has various pockets of high industrial activity where large amounts of effluents are released, sometimes directly into sea. High amounts of toxic waste have been detected in aquifers of South and Central Gujarat [11]. Particularly in case of Anand, in central Gujarat, where the main supply of drinking water emanates from ground water, the existing water supply and sewerage system is characterized by non availability of chlorination plants at certain locations, intermittent water supply, and inequitable distribution of water, ageing pumps, inadequate disposal of sewerage and lack of sewage treatment. This area has been amongst the first in the country to adopt tubewell technology which has witnessed high growth in the past five decades. The lithological and hydrogeological setting of the area is characterized with the central Alluvial plains of Gujarat consist of North-South ranging aquifers which are vast deposits of rivers flowing from the Aravallis. The Mahi Right Bank Command aquifer (MRBC) encompasses Anand district and few Blocks of Kheda district. The land has a flat and monotonous topography with a gentle slope from the north east to the south west[11]. Along with these facts, as per the demographic trends, the population in the district is anticipated to increase from 2,090,276 at present[12]. Therefore the present study was undertaken to monitor the ground water quality data of Anand district. Taking into consideration, the above facts the present study was attempted to do the physicochemical characterization of groundwater in Anand district.

Material and methods

Study site*:* The study site, Anand district situated within 22° 6' to 22° 43' north ***latitude*** and 72° 2' to 73° 12' east longitude has a total area of 2941 sq. Km and total population of 18,56,872 according to Anand District Panchayet statistics, 2011.

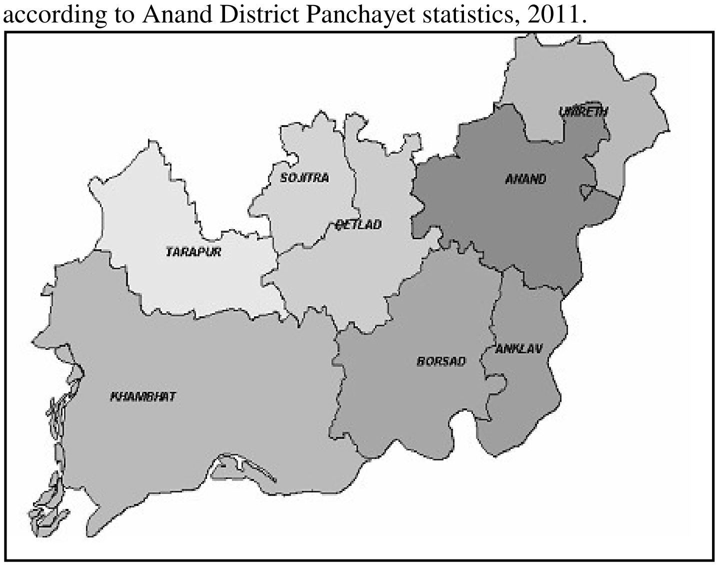

Figure-1
Image showing district map of Anand (study area)

Sample collection and Analysis: In Anand district the groundwater samples were collected from the villages of seven tehsils viz. Petlad, Umreth, Ankalav, Borsad, Khambhat, Sojitra, Tarapur. Sampling sites were chosen representative of different coverage areas in and around Anand district. Within the tehsils total 42 sites were selected. For the drinking water sampling, from one site 3 samples were collected from different utilization perspective areas like main market, residential area or school of the villages. Samples were collected by grab sampling method. Some of the parameters like DO, pH, TDS, Conductivity, of the samples were done onsite with the help of multi parameter analyser (Eutech Cyberscan 660). For further analysis samples were collected in polyethylene bottles having capacity of 1 liter and stored in the laboratory at 4^oC. Physical and chemical analysis was done in the laboratory following the methods of APHA [13]. The reagents used for the analysis were AR grade and double distilled water was used for preparation of solutions. The simple linear correlation analysis has been carried out to find out correlation between any two tested parameters. The significance of correlation was also tested. For statistical analysis SPSS version 11 was used. Apart from this water quality index was calculated to identify the quality of water in the respective tehsils and assigning them to be fit for drinking.

For computing WQI three steps were followed. In the first step, each of the parameters has been assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purpose. In the second step, the relative weight is computed [14].

$$W_i = (w_i / \text{sum } w_i) \quad (1)$$

Where, W_i is relative weight, w_i is the weight of each parameter and n is the number of parameter. In the third step, a quality rating scale (q_i) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down by BSI and the result multiplied by 100

$$q_i = (C_i / S_i) \times 100 \quad (2)$$

Where q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in mg/L, and S_i is the Indian drinking water standards for each chemical parameter in mg/L according to the guidelines of the BSI 10500 [15].

For computing the WQI, the SI is first determined for each chemical parameter, which is then used to determine the WQI as per the following equation:

$$SI_i = W_i \times q_i \quad (3)$$

Where, WQI = summation SI_i

SI_i is the subindex of i^{th} parameter; q_i is the rating based on concentration of i^{th} parameter and n is the number of parameters.

The computed WQI values are classified into five types, “excellent water” to “water, unsuitable for drinking, i.e. very poor."

Table-1
Table showing Water quality index value and its interpretation.

Water Quality Index (WQI) Value	Water Quality
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor

Results and Discussion

Hydrochemistry: The average value of the different physicochemical parameters of groundwater of Anand district is presented in table 2 and figure 2. All the groundwater samples showed slightly alkaline to alkaline pH due to the presence of carbonates and bicarbonates. Values averaged 7.40 to 8.30, which meets compliance with prescribed BSI and WHO standards. This bears resemblance with studies of pH in Jalgaon district, Maharashtra[16]. Highest pH was observed in khambat groundwater followed by Ankalav. Salinity ingress from coastal area might be the causative factor for high pH in Khambat.

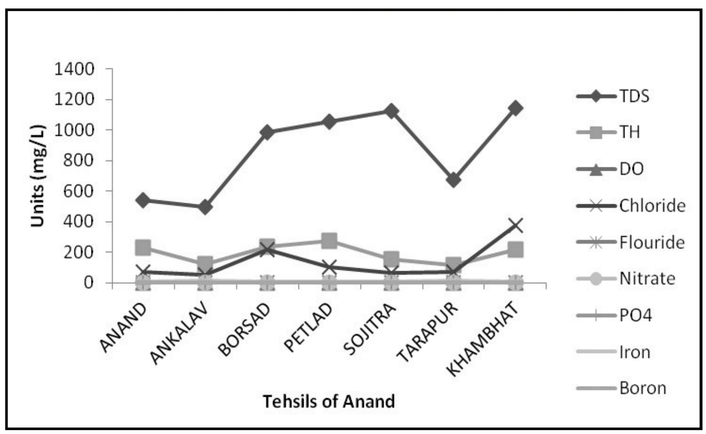

Figure-2
Physicochemical parameters of groundwater in Anand district

Electrical conductivity indicates the total dissolved solids in water. Electrical conductivity in waterways is affected by different factors like geology and soils, land use, flow, run-off, groundwater inflows, temperature, evaporation and dilution. In our study EC varied between 608 to 1251 ms/cm. Highest value was recorded in Khambat Groundwater, the reason for which can be attributed towards saline soil, which increases EC. Petlad and Sojitra also showed higher values of EC (1164 and 1153 ms/cm) indicating the presence of high amount of dissolved inorganic substances in ionized form. This can be addition of heavy metals from industries, which also increases the electrical conductivity of water. Results are at par with studies of Patil and Patil[16]. Observation hints at overall high EC values in the entire district.

TDS has a direct relation with EC and thus as expected TDS was also higher in the groundwater samples exhibiting high EC. TDS ranged between 498 and 1145 mg/L. Lowest mean value was recorded at Ankalav a highest at Khambat. In water, total dissolved solids are composed mainly of carbonates, bicarbonates, chlorides, phosphates and nitrates of calcium, magnesium, sodium, potassium and manganese, organic matter, salt and other particles. This reflects high values at Khambat. TDS was found to be considerably elevated in all the sampling locations of Anand district. The values are higher than groundwater of Champaran border Bihar[17].

Total hardness was found to vary between 115.20 to 271 mg/L. Minimum hardness was observed at Tarapur followed by Ankalav (120.83mg/L) and highest at Petlad. Water hardness is the traditional measure of the capacity of water to react with soap. It is not caused by a single substance but by a variety of dissolved polyvalent metallic ions, predominantly calcium and magnesium cat ions, although other cat ions (e.g. aluminium, barium, iron, manganese, strontium and zinc) also contribute. Although hardness is caused by cat ions, it may also be discussed in terms of carbonate (temporary) and non-carbonate (permanent) hardness. Recorded values were lower than study by Sivakumar etal in Amravati river basin at Tamil Nadu. But none of the samples cross the maximum permissible limits of 500 and 600 ppm of WHO and CPHEEO standards.

DO ranged from 2.58 to 3.52 mg/L. Low values of DO indicate high rate of oxygen consumption by oxidisable mater, which in turn indicates high concentration of organic matter. DO concentration in ground water has a relative significance since they control the valence state of trace metals and constrain the bacterial metabolism of organic matter [18]. It also hints at the rate of inorganic ferrous silicate oxidation rates, which is a significant low temperature weathering mechanism. Lower DO values can be corroborated with the presence of high organic matter in the geochemical nature of the sediments and soil profile of the areas.

Table 2
Table showing physicochemical parameters of Anand district groundwater ± SD (n ≥ 3)

Location	**pH**	**Cond.**	**TDS**	**TH**	**DO**	**Cl**	**F**	**NO_3**	**PO_4**	**Iron**	**Boron**
		Mili Siemens/cm	**All units in mg/L**								
ANAND	7.70 ± 1.20	693 ± 38	542.64 ± 171	230.14 ± 138	2.58 ± 0.38	71.93 ± 26.08	0.00 ± 0.00	0.49 ± 0.53	0.06 ± 0.09	5.04 ± 1.95	2.33 ± 0.24
ANKALAV	8.20 ± 0.40	608 ± 411.58	498.98 ± 89.52	120.83 ± 71.08	3.49 ± 0.23	53.67 ± 8.96	0.00 ± 0.00	0.22 ± 0.08	0.00 ± 0.00	12.91 ± 14.16	1.81 ± 0.99
BORSAD	8.00 ± 1.20	837 ± 12.04	986.48 ± 20.11	237.00 ± 91.75	3.51 ± 0.71	214.60 ± 115.29	2.15 ± 1.82	0.34 ± 0.25	0.32 ± 0.34	9.12 ± 3.47	2.65 ± 0.08
PETLAD	7.60 ± 1.00	1164 ± 46.76	1056.00 ± 123.63	272.00 ± 133.39	2.73 ± 0.51	99.98 ± 29.40	0.00 ± 0.00	0.41 ± 0.26	0.05 ± 0.01	4.91 ± 0.80	1.70 ± 0.31
SOJITRA	7.40 ± 1.20	1153 ± 35.36	1129.00 ± 67.53	151.50 ± 94.21	2.58 ± 0.29	62.18 ± 15.29	0.00 ± 0.00	0.43 ± 0.66	0.10 ± 0.08	6.43 ± 1.54	1.85 ± 0.04
TARAPUR	7.90 ± 0.40	780 ± 60.18	673.02 ± 29.81	115.20 ± 105.72	3.52 ± 0.82	74.54 ± 35.44	0.00 ± 0.00	0.10 ± 0.9	0.00 ± 0.01	11.2 ± 4.20	1.94 ± 0.03
KHAMBAT	8.30 ± 0.20	1251 ± 97.72	1145.00 ± 151.43	217.50 ± 114.71	3.40 ± 0.79	374.50 ± 193.76	0.31 ± 0.13	0.23 ± 0.20	0.30 ± 0.57	10.29 ± 3.85	3.89 ± 0.61

Chlorides are widely distributed in nature as salts of sodium (NaCl), potassium (KCl), and calcium (CaCl2). Chloride in water may be considerably increased by treatment processes in which chlorine or chloride is used. BIS (Bureau of Indian Standard) have recommended a desirable limit of 250 mg /l of chloride in drinking water; this concentration limit can be extended to 1000 mg/l of chloride in case no alternative source of water with desirable concentration is available. However ground water having concentration of chloride more than 1000 mg /l are not suitable for drinking purposes (In our study chloride was found to be elevated in all the sites with the highest value at Khambat (374.50 mg/L), which can be obviously linked to the sodicity of the soil and saline ingress. Range of chloride content was within 53.67 and 374.50 mg/L. Borsad also exhibited high chloride content. There can be two reasons for high chloride values in the other sites. Either it can be leached from various rocks into soil and water by weathering or dumping of various chloride salts used in industries. Potassium chloride is used in the production of fertilizers and Sodium chloride is widely used in the production of industrial chemicals such as caustic soda, chlorine, sodium chlorite, and sodium hypochlorite [19].

Exposure to fluoride in drinking water has a number of adverse effects on human health including crippling skeletal fluorosis that is a significant cause of morbidity in a number of regions of the world[20]. Fluoride pollution in groundwater in North Gujarat is an alarming one[9]. However in our observation of Anand district, except Borsad (2.15 mg/L) fluoride was below detectable range in all the other tehsils. Most of the fluoride found in groundwater is naturally occurring from the breakdown of rocks and soils or runoff and infiltration of chemical fertilizers in agricultural areas. The significance of measuring fluoride lies in its health consequences. At low concentrations fluoride can reduce the risk of dental cavities. Exposure to somewhat higher amounts of fluoride can cause dental fluorosis. Results are similar to previous observations[18, 19].

Inorganic chemical nitrate is a major contaminant in groundwater due to its serious health concern. If ingested in considerable amount can produce methemoglobinemia in infants and children. The major source of nitrate in ground water emanates from nitrates fixed by plants from atmospheric nitrogen or additional use of nitrate containing fertilizers, which are partially used by plants and the rest infiltrates with rainfall into groundwater. Nitrate levels of Anand district however does not seem to pose any risk due to their low concentrations. Range of nitrate concentration varied between 0.10 to 0.49 mg/L of average concentration in the seven tehsils of Anand. Nitrate levels are similar to studies by Seher[22] in Pakistan, Rao[23] in Krishna district, Andhra Pradesh.

The main source of phosphorus in the environment is from soil and rock weathering. In nature, phosphorus usually exists as part of a phosphate molecule. Phosphorus in aquatic systems occurs as organic and inorganic phosphate. In this study total phosphate was measured which is a combination of organic and inorganic forms. Phosphate values were quite low in all the tehsils of Anand district with concentrations ranging from below detection range to 0.32 mg/L. Highest value was recorded at Borsad followed by 0.30mg/L at Khambhat.

Iron is a common constituent in soil and ground water. It is present in water either as soluble ferrous iron or the insoluble ferric iron. In high concentration it causes scaling in plumbing fixtures. In the present study Iron was found to be varying widely between locations. The range was between 4.91 and 8192 mg/L. Tarapur showed exceedingly high Fe concentration compared to all the other sites. The Fe concentrations in all the sites were higher than permissible limits. High Fe contamination at Ankalav and Tarapur can have several causes like either it can either be due to anoxic condition of the underlying soil, or it can be microbial dissolution of Fe. The authors are also not sure about the depth of the groundwater source, which can be a crucial investigation because depth of the groundwater is linked to redox potential of the subsurface which can influence the Fe concentration of the site. Results show that the entire district is highly contaminated with Fe levels in groundwater.

Boron naturally occurs mainly as boric acid and as boric acid salts. It is released from rocks and soils through weathering, and subsequently ends up in water. It also gets added to soil and groundwater through domestic landfills, when these are inadequately sealed. It serves as a typical indicator compound that indicates the presence of other hazardous substances. Boron was also present in notably high concentrations in all the sampling sites. Range was between 1.70 and 3.89 mg/L and is far beyond permissible limits. Not much literature is found on boron monitoring of groundwater. Boron also has a direct influence of seawater since seawater contains higher concentration of Boron than ordinary groundwater. This accounts for high Boron level in Khambhat following the seawater intrusion model.

Correlation between the different parameters: Correlation between the different parameters of groundwater of Anand in all the tehsils showed both positive and inverse relations between the parameters, some moderately correlated and some well correlated (Table 3). Highest positive correlation was observed between Chloride and boron (0.94) followed by conductivity and TDS indicating strong dependence between them. DO and pH also showed a positive correlation, which suggests that with more oxygenation of water, the alkalinity of water increases. Nitrate was also negatively correlated with DO and moderately with pH. Phosphate showed good positive correlation with Boron and Fluoride. Apart from this there were other moderate correlations were seen between parameters.

Table 3
Table showing Correlation matrix between the different physico chemical parameters of groundwater of Anand

	pH	Cond	TDS	TH	DO	Cl^-	F	NO_3	PO_4	Iron	Boron
pH	1	-	-	-	-	-	-	-	-	-	-
Cond.	-0.22375	1	-	-	-	-	-	-	-	-	-
TDS	-0.20275	0.932209	1	-	-	-	-	-	-	-	-
TH	-0.1488	0.407125	0.436366	1	-	-	-	-	-	-	-
DO	0.844955	-0.29514	-0.16743	-0.36446	1	-	-	-	-	-	-
Chloride	0.600839	0.51931	0.562464	0.404095	0.400817	1	-	-	-	-	-
Flouride	0.261772	-0.07425	0.263668	0.350292	0.424243	0.426131	1	-	-	-	-
Nitrate	-0.66586	0.184621	0.202313	0.614935	-0.85934	-0.20608	0.033103	1	-	-	-
PO4	0.37357	0.425743	0.623008	0.480896	0.285549	0.868467	0.751211	0.066133	1	-	-
Iron	0.80064	-0.36745	-0.31487	-0.6677	0.90525	0.201023	0.115437	-0.88428	0.036694	1	-
Boron	0.613587	0.369926	0.378567	0.313245	0.337342	0.949055	0.328519	-0.16462	0.808067	0.19924442	1

Water Quality indices: The water quality index (WQi) calculation based on all the parameters of the groundwater of Anand showed variable results in the seven tehsils (Figure 3). Anand showed 14.29% of good water and 85.71% of poor water. Ankalav showed 66.66 % good water and 33.33% poor water. Petlad exhibited 100% poor water while Borsad showed 50% poor water and 50% very poor water. Sojitra also recorded a result of 50% of poor water and 50% of good water. Tarapur had 60% poor water and 40% very poor water. Khambhat yielded 12.5% poor water and 87.5% very poor water. Overall observation indicates a dominance of poor and very poor water except in Anand, Ankalav and Sojitra.

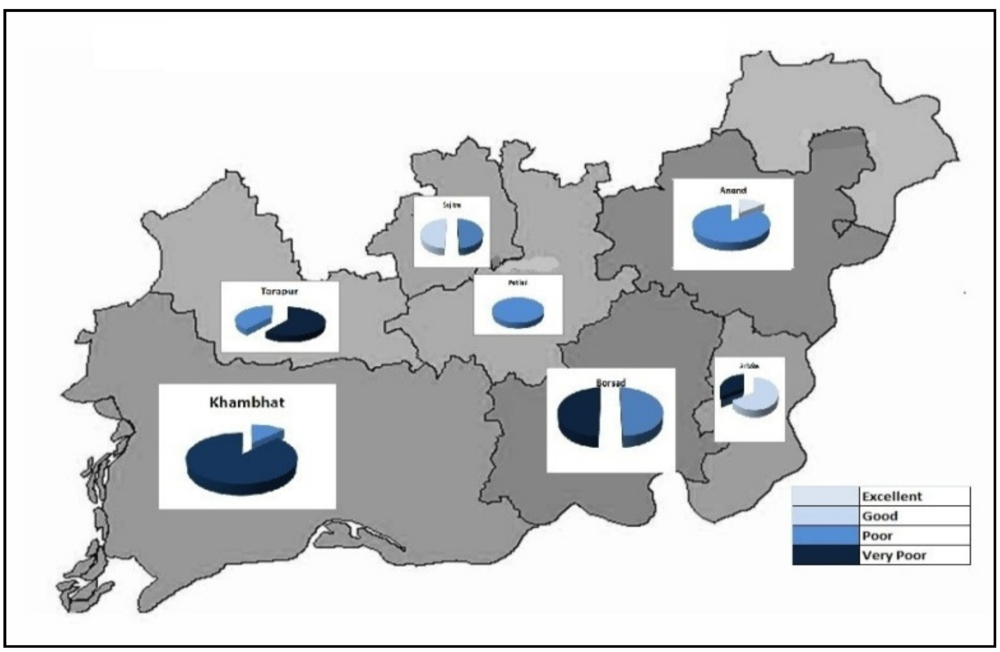

Figure 3
Water quality indices shown as pie charts in each Taluka of Anand district

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Conclusion

The physico chemical parameters of the groundwater from 42 sites in seven Tehsils of Anand district revealed that pH value was within permissible limit, TDS was quite high than limits, total hardness was slightly higher in some sampling locations , otherwise within the limits. Fe was found to be notably high in all the sampling locations, Boron was also present in significantly higher concentrations in all the locations; however nitrate and phosphate pollution did not exist in the entire district. Fluoride was also absent in all the locations except Borsad. Chloride was considerably high only in Khambhat. Drinking water quality analysis showed dominance of poor and very poor water with good water in some locations.

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