Hydrogeochemistry of subsurface and surface water from bank of Jayanti stream, Kolhapur area, Maharashtra (India)

Golekar R B [1], Salokhe Abhay [1], Kamble Nirmal [1], Baride M V[2], Patil S N [1], Pathare S V [3]
1- Department of Applied Geology, School of Environmental and Earth Sciences,
North Maharashtra University Jalgaon, 425001 (India)
2- Department of Geology, Z B Patil College Dhule, India
3- Department of Geology, Rajaram College, Kolhapur (India)
rbgolekar@gmail.com

ABSTRACT

Jayanti stream chosen for hydrogeochemical analysis which is tributary of Panchganga River and Panchganga is a major tributary of Krishna River in part of Maharashtra state, India. In order to assess the physicochemical parameters, a total 17 water samples were collected from bank of Jayanti stream. Obtained results of hydrogeochemical parameters of groundwater from study area compared with the prescribed limit by Bureau of Indian Standards and World Health Organization. The result shows that the contamination of groundwater system through network of subsidiary streams. Analyzed water samples anion - cation balance within the acceptable limit except few samples. Trace elements result shows that the most of water samples beyond their permissible limits except Fe, Mn and Zn. The correlation matrices show that good positive correlation with EC and Cl, EC and Ca, EC and HCO_3. TDS and Cl also reveal high positive correlation. However, Mg and K, K and CO_3 were the negative correlation pairs.

Keywords: Groundwater geochemistry, irrigation hazards, graphical representation, Kolhapur urban area, Maharashtra, India

1. Introduction

Groundwater plays a fundamental role in human life and development. The Safe portable water is absolutely essential for healthy living. About 80% diseases of the world population and more than one-third of the deaths in the developing countries are due to contamination of water (WHO 1993). Man can control the some undesirable chemical constituents in water before it enters the ground. But, once the water enters the ground, man's control over the chemical quality of water of percolating water is very limited (Johnson C.C. 1979). Groundwater is ultimate and most suitable fresh water resource for human consumption in both urban as well as rural areas. Recent year water pollution is an important issue for the environmental aspects especially in urban areas (Golekar R. B., et al 2013). Jayanti River chosen for hydro geochemical analysis which is tributary of Panchganga River and Panchganga is a major tributary of Krishna River in Kolhapur district, Maharashtra state, India. The industrial establishments in and Kolhapur and the industrial township of Jawaharnagar and Kondawal as well as sugar factories/leather industries are responsible for disposing treated and untreated effluents in the natural drainage system. This has lead to widespread groundwater contamination. Thus, it is very essential to check levels of pollution and protect this valuable resource so considering this aspect seventeen water sampling from in and around Kolhapur urban area was carried out and analyze various physicochemical parameters and trace elements. The study area which is bounded by 15 ° 45´ N to 17 ° 11´ N latitude and 73 ° 40´ E to 74° 42´ E longitude. Location map of study area shows in figure 1. The Kolhapur area receives its

major rainfall from the South West monsoon winds; it also gets some rainfall from thunderstorms during the month of April and May. The rainy season is from June to October. The study area receives annual rainfall about 1800 mm.
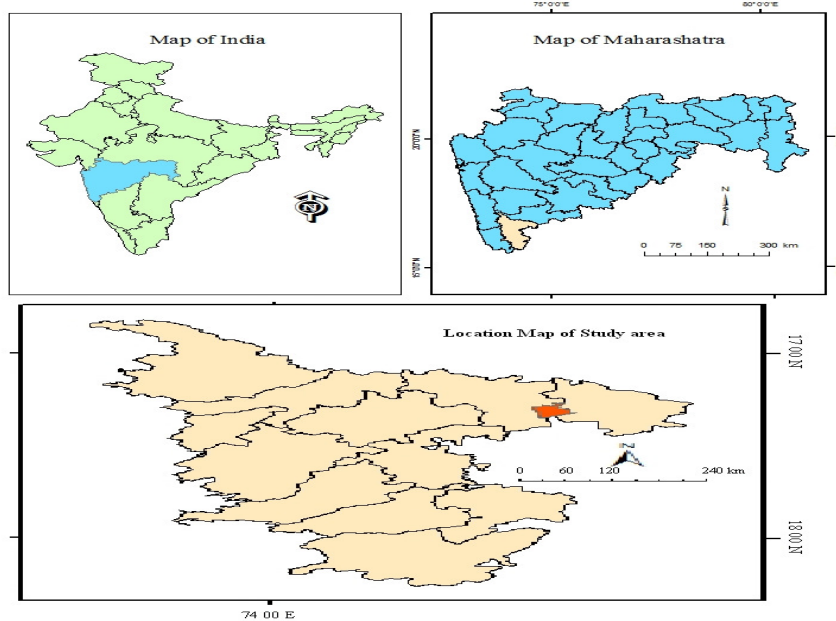

Figure 1: Location map of study area

1.1 Geology

The geological formations of study area given in table 1 and geological map of the study are shown in figure 2.
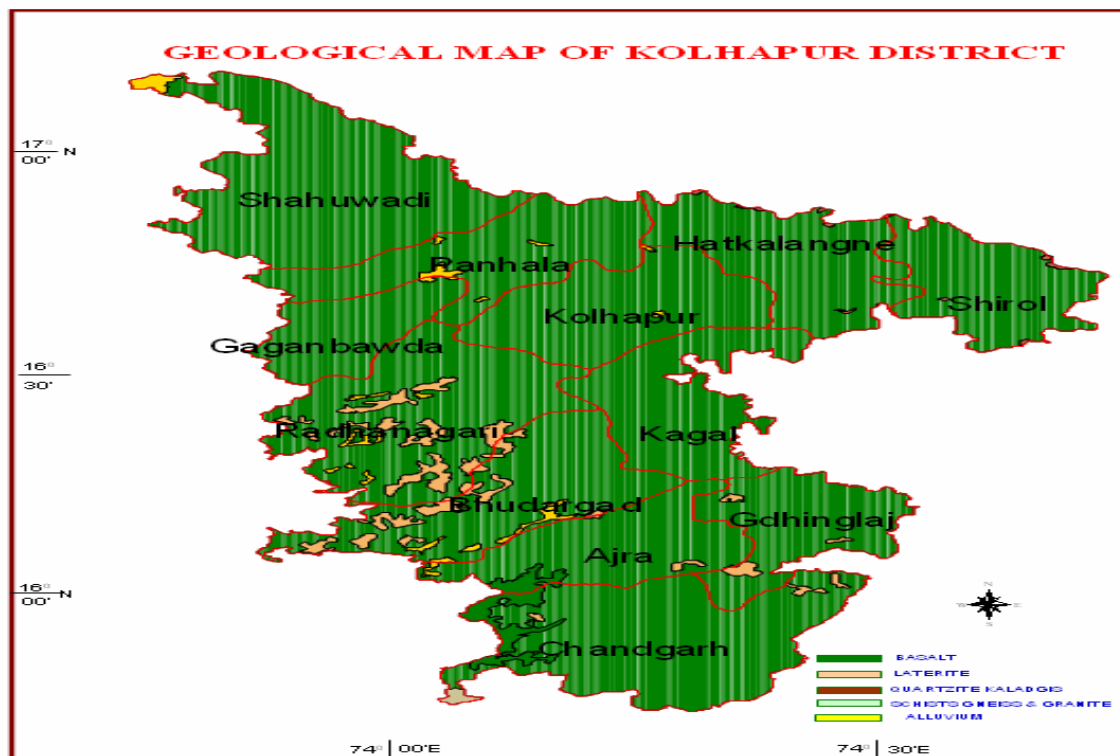

Figure 2: Geological map of Kolhapur district (Source: Geological Survey of India)

Table 1: Geology of the study area

Soil and Laterite	Recent and Sub-Recent
Deccan trap	Upper Cretaceous to Lower Eocene

2. Materials and methodology

In order to assess the physicochemical parameters, a total of 17 water samples were collected from bank of Jayanti River. Sampling locations given in table 2. Samples were collected in polyethylene bottles of one-liter capacity and prior to sampling all the sampling containers were washed and rinsed with the groundwater. The chemical parameters like pH and electrical conductivity (EC) were measured, using digital instruments immediately after sampling.

The groundwater sampled bottles were labeled, tightly packed, the collected groundwater samples were analyzed for total hardness (TH), Total dissolved solids (TDS) calcium (Ca^{++}), magnesium (Mg^{++}), sodium (Na^+), potassium (K^+), carbonate (Co_3^-), bicarbonate (HCO_3^-), chloride (Cl^-) and sulphate (SO_4^-). The chemical characteristics were determined as per the standard methods for examination of groundwater and wastewater (APHA, 2002), (Trivedi R K and Goel P K, 1984) and all results are compared with standard limit recommended by the Bureau of Indian Standards (BIS, 1991), and (World Health Organization, 1993). Six representative samples were analyzed their trace elements (Cd, Co, Cu, Fe, Mn, Ni, Pb, and Zn) by using double beam atomic absorption spectrophotometer.

Table 2: Locations of water sampling points

Sample ID	Latitude	Longitude	Elevation (in meter)
1	16.66 N	74.23 E	612
2	16.67 N	74.22 E	573
3	16.68 N	74.23 E	565
4	16.69 N	74.23 E	553
5	16.69 N	74.23 E	557
6	16.70 N	74.23 E	571
7	16.70 N	74.23 E	550
8	16.71 N	74.23 E	533
9	16.71 N	72.22 E	533
10	16.71 N	72.22 E	538
11	16.71 N	72.22 E	545
12	16.71 N	72.22 E	538
13	16.71 N	72.22 E	546
14	16.70 N	74.23 E	571
15	16.70 N	72.22 E	538
16	16.71 N	72.22 E	533
17	16.69 N	74.23 E	553

3. Results and discussions

Groundwater quality assessment was carried to determine its suitability in terms of drinking purposes, the results of physicochemical parameter presented in table 3 and 4. Equivalent per million values along with summation of cations and anions is presented in Table.5. Hydrogeochemical parameters of groundwater in the study area compared with the prescribed Bureau of Indian Standards (BIS, 1991) and World Health Organization (WHO, 1993).

3.1 Physicochemical parameters

pH of water sample measures it's hydrogen ion concentration and indicates whether the sample is acidic, neutral or basic. The pH value of absolute pure water is 7. If the pH value is less than 7, the water is said to be acidic in nature and if it is more than 7 the water is called as alkaline. The pH value in analysed water samples varies from 6.5 to 7.6 with an average value 7.0. This shows that the groundwater of the study area is mostly alkaline in nature.

The electrical conductivity is directly related to the concentration of ionized substance in water and may also be related to problems of excessive hardness and other mineral contamination (Johnson C. C., 1979). The value of EC in analysed water samples varies from 207.2 µmhos /cm to 854.0 µmhos /cm with an average value of 596.3µmhos/cm.

The total dissolves solids (TDS) indicate the general nature of salinity of water. TDS is a direct measurement of the interaction between ground water and subsurface minerals. The total dissolved solids (TDS) are the concentrations of all dissolved minerals in water indicate the general nature of salinity of water. The TDS value in analysed water samples varies from 136.0 to 555.7 ppm with a mean of 596.3 ppm. The BIS specifies a desirable total dissolved solids limit of 500 ppm and a maximum permissible limit of 2000 ppm, and in study area all samples are within the permissible limit as prescribed by Bureau of Indian standards (BIS, 1991). High values of TDS could be due to intensive irrigation. Sources for TDS include agricultural run-off, urban run-off, industrial wastewater, sewage, and natural sources such as leaves, silt, plankton, and rocks. Piping or plumbing may also release metals into the water.

Calcium is naturally present in water, Ca element is essential for the life of plants and animals. The presence of calcium in drinking water is natural geological source, industrial waste, mining by products and agricultural wastes. Calcium (Ca^{2+}) values in analysed water samples varies from 90 to 318 ppm with an average value of 199.1 ppm, the desirable limit of calcium for drinking water is specified by Bureau of Indian standards (BIS, 1991) as 75 ppm and a maximum permissible limit of 200 ppm. It is observed that all the samples were beyond the maximum permissible limit. The relatively higher concentration of bicarbonate with respect to chloride suggests the intense chemical weathering taking place in the area (Golekar R. B, et al 2013).

In natural water magnesium occurs with calcium, but it concentration generally lower than the calcium. The present area water samples shows that magnesium (Mg^{2+}) concentration varies from 13.7 to 23.7 ppm with mean values of 18.5 ppm. According to Bureau of Indian standards (BIS, 1991) the desirable values of Mg^{2+} are 30 ppm and a maximum permissible limit of 100 ppm, all samples of the study area mg is significant.

Hardness of water is related to presence of Ca^{2+} and Mg^{2+} in water basically depending on soil type of that area. The hardness of natural waters depends mainly on the presence of dissolved calcium and magnesium salts. Total Hardness is considered as a major character of drinking water. A total hardness value in analysed water samples varies from 340 to 1830 ppm with a mean values 938.1 ppm. The maximum permissible limit of total hardness (TH) for drinking water is specified by Bureau of Indian standards (BIS, 1991) as 600 ppm. It is observed that except two samples, all samples are within maximum permissible limit. The high concentration of hardness may occur locally in groundwater from chemical and industry effluent as well as excessive application of lime to the soil in agricultural areas.

Chloride ions are generally present in natural waters and its presence can be attributed to dissolution of salts. Soil porosity and permeability can build up chloride ions in water. The chloride (Cl^-) ion concentration in analysed water samples varies from 127.8 to 573.7 ppm with a mean values 364.4 ppm. The desirable limit of chloride for drinking water is specified by Bureau of Indian standards (BIS, 1991) as 250 ppm and a maximum permissible limit of 1000 ppm. It is observed that all the samples were within the maximum permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

The primary source of carbonate and bicarbonate ions in groundwater is the dissolves carbon dioxide in rain and snow which, as it enters the soil, dissolves more carbon dioxide. The carbonate concentration in analysed water samples varies from to 0.0 ppm to 48 ppm with an average value of 5.3 ppm. The bicarbonate varies from to 135 ppm to 370 ppm with an average value of 238 ppm.

Sodium concentration in analysed water samples value varies from 48.0 to 125 ppm. The permissible limit of sodium for drinking water is specified by Bureau of Indian standards (BIS, 1991) as 200 ppm and only one sample is crosses the permissible limit. The European Economic Community (EEC, 1980) has prescribed the guideline level of potassium at 10 ppm in drinking water.

Potassium concentration in analysed water samples varies from 2.5 to 11.3 ppm and as per European Economic Community (EEC, 1980) criteria, only one sample is crosses the permissible limit and remaining samples of the study area fall within the guideline level of 10 ppm.

Sulphate can be found in almost all natural water. Sulphate (SO_4^-) content in groundwater is made possible through oxidation, precipitation, solution and concentration, as the water traverses through rocks (Karanth K.R., 1987). The sulphate values in analysed water samples varies from 12 to 42 ppm with an average value 25 ppm, this show that the all the sample were within the maximum permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

The Nitrate values in analysed water samples varies from 24 to 97 ppm with an average value 59 ppm, this show that the all the sample were beyond the maximum permissible limit prescribed by Bureau of Indian standards (BIS, 1991). Nitrate contamination in ground water and surface water they may be cause of urban waste and leaching of nitrogenous fertilizer from agricultural waste. Kolhapur district is one of the leading for sugarcane cultivation since this area use of nitrogenous fertilizers for better yields, this is one of the main reason of nitrate contamination into ground water by leaching processes.

Table 3: Analytical results of physicochemical parameter of water samples

Sample ID	pH	EC	TDS	TH	TA	Ca	Mg	Na
1	7.6	312.8	199.3	558	180	90	20.38	58.83
2	6.7	693	443.5	1026	280	289	21.62	48
3	6.7	571.6	368.3	748	220	147	17.66	125
4	6.8	562.3	360.4	708	205	165	20.35	101.02
5	6.9	751.1	484.4	742	205	280	16.62	110
6	7	677.2	425	888	200	241	22	76.5
7	6.8	579.5	372.2	624	270	187	17.92	108.05
8	6.5	570.2	367	802	240	174	18.65	125
9	6.9	576.8	360.4	886	245	149	17.94	88.91
10	6.5	343.2	223.1	460	175	139	15.66	92.6
11	6.9	570.2	372.2	846	175	125	13.65	98.66
12	7	571.6	369.6	834	260	198	14.6	54.66
13	6.8	207.2	136	340	135	134	15.12	56.09
14	7.3	831.6	520.1	1830	370	318	17.6	58.62
15	7.2	814.4	524	1804	350	232	18.15	116.07
16	7.5	650.8	421.1	1040	330	226	22.52	122
17	7.3	854	555.7	1812	300	290	23.65	114.66
Maximum	7.6	854	555.7	1830	370	318	23.7	125
Minimum	6.5	207.2	136	340	135	90	13.7	48
Average	7	596.3	382.5	938.1	243.5	199.1	18.5	91.5
BIS limits	6.5 - 8.0	1400	500	500	400	75	30	250

All parameter expressed in ppm Except EC in µmohs/cm and pH

Table 4: Analytical results of physicochemical parameter and facies of water samples

Sample ID	K	Cl	SO₄	CO₃	HCO₃	NO₃	Water Type
1	2.54	127.8	14	30	150	55	Ca-Na-Cl-HCO3
2	2.78	443.04	26	0	280	58	Ca-Cl-HCO3
3	2.97	350.74	22	0	220	85	Ca-Na-Cl-HCO3
4	7.96	330.86	14	0	205	65	Ca-Na-Cl-HCO3
5	8.46	546.7	28	0	205	68	Ca-Na-Cl
6	7.45	481.38	36	0	200	60	Ca-Cl
7	9.75	349.32	32	0	270	55	Ca-Na-Cl-HCO3
8	9.16	332.28	41	0	240	56	Ca-Na-Cl-HCO3
9	9.56	355	19	0	245	24	Ca-Na-Cl-HCO3
10	10.25	262.7	17	0	175	32	Ca-Na-Cl-HCO3
11	11.25	346.48	26	0	175	36	Ca-Na-Cl-HCO3
12	10.55	329.44	21	0	260	49	Ca-Cl-HCO3

13	4.17	164.72	12	0	135	54	Ca-Na-Cl-HCO3
14	3.66	450.14	16	0	370	66	Ca-Cl-HCO3
15	3.49	404.7	23	40	310	97	Ca-Na-Cl-HCO3
16	4.65	345.06	36	20	310	65	Ca-Na-Cl-HCO3
17	5.61	573.68	42	0	300	81	Ca-Na-Cl-HCO3
Maximum	11.3	573.7	42	40	370	97	Water Type
Minimum	2.5	127.8	12	0	135	24	Ca-Na-Cl-HCO3
Average	6.7	364.4	25	5.3	238.2	59.2	Ca-Cl-HCO3
BIS limits	10	250	250	NA	500	45	Ca-Na-Cl-HCO3

Table 5: Equivalent per millions values of water samples

Sample ID	Ca	Mg	Na	K	Cl	SO_4	CO_3	HCO_3	NO_3	Σ Cations	Σ Anions
1	4.5	0.2	2.6	0.1	3.6	0.3	1.0	2.5	0.9	7.3	8.3
2	14.5	0.2	2.1	0.1	12.5	0.5	0.0	4.7	1.0	16.8	18.6
3	7.4	0.1	5.4	0.1	9.9	0.5	0.0	3.7	1.4	13.0	15.4
4	8.3	0.2	4.4	0.2	9.3	0.3	0.0	3.4	1.1	13.0	14.1
5	14.0	0.1	4.8	0.2	15.4	0.6	0.0	3.4	1.1	19.1	20.5
6	12.1	0.2	3.3	0.2	13.6	0.8	0.0	3.3	1.0	15.7	18.6
7	9.4	0.1	4.7	0.3	9.8	0.7	0.0	4.5	0.9	14.4	15.9
8	8.7	0.2	5.4	0.2	9.4	0.9	0.0	4.0	0.9	14.5	15.1
9	7.5	0.1	3.9	0.2	10.0	0.4	0.0	4.1	0.4	11.7	14.9
10	7.0	0.1	4.0	0.3	7.4	0.4	0.0	2.9	0.5	11.4	11.2
11	6.3	0.1	4.3	0.3	9.8	0.5	0.0	2.9	0.6	10.9	13.8
12	9.9	0.1	2.4	0.3	9.3	0.4	0.0	4.3	0.8	12.7	14.9
13	6.7	0.1	2.4	0.1	4.6	0.3	0.0	2.3	0.9	9.4	8.0
14	15.9	0.1	2.5	0.1	12.7	0.3	0.0	6.2	1.1	18.7	20.3
15	11.6	0.1	5.0	0.1	11.4	0.5	1.3	5.2	1.6	16.9	20.0
16	11.3	0.2	5.3	0.1	9.7	0.8	0.7	5.2	1.1	16.9	17.4
17	14.5	0.2	5.0	0.1	16.2	0.9	0.0	5.0	1.3	19.8	23.4

3.2 Graphical representation of data

The most common methods of graphical representation of the hydrogeochemical analytical data are tabular form. The determination of ionic concentration of groundwater recorded in different units. However certain chemical aspects are not covered by tabular representation and therefore the use of different diagram has been adopted for this purpose. Different methods of graphic representation such as piper plot, Wilcox and ternary diagrams. Several workers namely Piper (Piper A M, 1944) have used triangular diagram. The importance of piper's Trilinear diagram has been widely recognized in ground water studies. The diagram consisting three distinct fields - two triangular fields and one diamond shaped fields. The percent epm values of different constituents of water are represented by three points in which cation and anions grouped separately and are plotted in lower left and right triangles respectively then the anions and cation are combined to show a single point diamond shape fields, which throws

height on the hydro chemical facies classification. Piper Trilinear diagram (Figure 2) shows that the ground water of the study area in majority of Ca-Na-Cl-HCO3 type. Wilcox plot (Figure 3) shows that the ground water of the study area belonging to low sodium hazard but medium to high salinity hazards zones. Ternary plot (Figure 4) of the ground water geochemistry shows that the ca is most abundant compared to Na and mg. The analytical data plotted on an anion – cation balance control chart for assessing the data quality, as shown in Figure 5.The control chart of anion–cation balance (Figure 5) is a graphic representation of data quality. The anionic sum in mill equivalents per liter should equal the cationic sum in mill equivalents per liter, although they are rarely equal in practice. This inequality increases as the ion concentration increases. The difference between anion and cation sum in mill equivalents is acceptable within +- 1 as expressed by the equation: Σ Anions – Σ Cation = +-1 (Chadha, 1999). Analyzed water samples anion – cation balance within the acceptable limit except few samples.

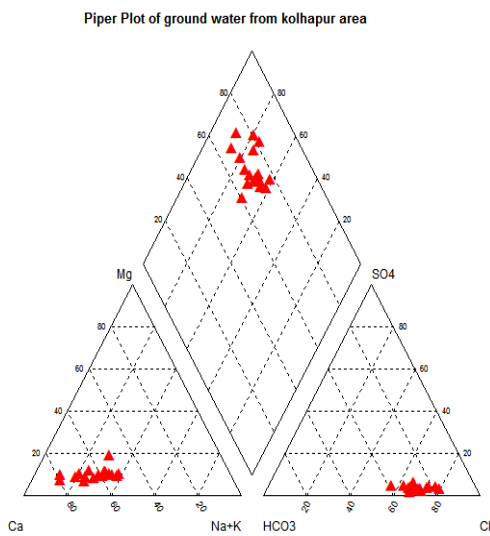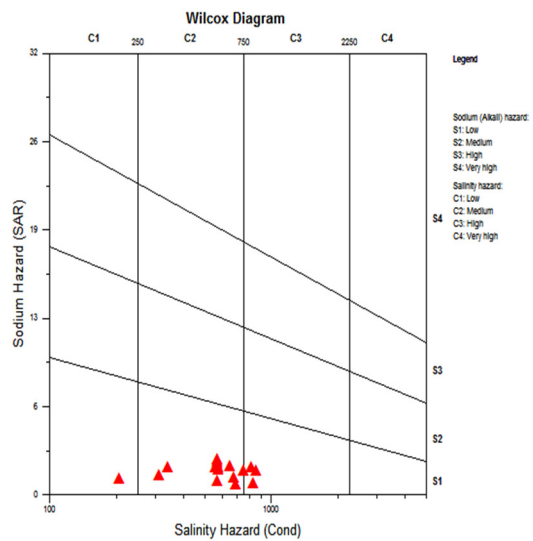**Figure 3:** Piper Trilinear diagram of water

Figure 4: Wilcox plot of water

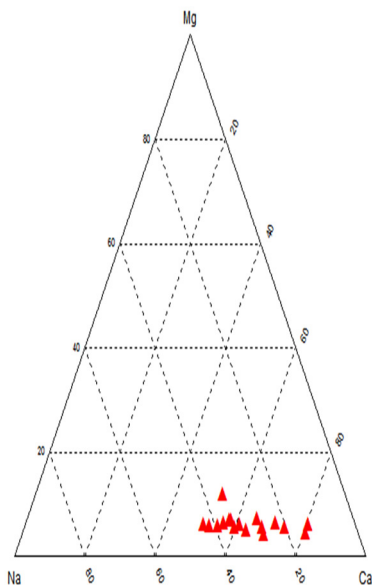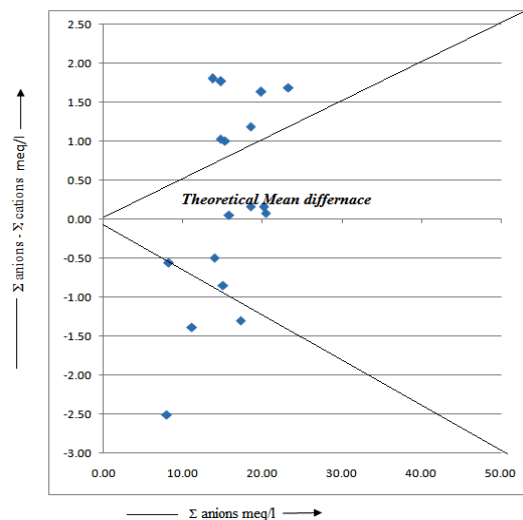**Figure 5:** Ternary plot of water

Figure 6: Chart for anion–cation balances

3.3 Trace elements

Analytical results of trace elements (representative water samples) presented in table 6.

Table 6: Analytical results of trace elements in representative water samples

Sample ID	Cd	Co	Cu	Fe	Mn	Ni	Pb	Zn
1	0.007	0.053	0.106	0.099	0.036	0.041	0.003	0.529
4	0.078	0.013	0.13	0.238	0.023	0.562	0.373	0.723
7	0.007	BDL	0.207	0.081	0.046	BDL	0.018	0.178
9	0.007	0.08	0.456	0.088	0.045	BDL	0.007	0.873
13	0.068	0.037	0.091	0.162	0.056	BDL	0.323	BDL
15	0.089	0.082	0.091	0.16	0.069	0.025	0.161	0.401
Maximum	0.089	0.082	0.456	0.238	0.069	0.562	0.373	0.873
Minimum	0.007	0.013	0.091	0.081	0.023	0.025	0.003	0.178
Average	0.043	0.053	0.180	0.138	0.046	0.209	0.148	0.541
BIS limits	0.001	NA	0.05	0.3	0.07	0.1	0.005	5

where, NA = Not available, BDL Below detected level

Cadmium value in analysed water samples varies from 0.007 to 0.089 with an average value 0.043 ppm, this show that the all the sample were beyond the maximum permissible limit prescribed by Bureau of Indian standards (BIS, 1991). The Cd occurs due to the natural and anthropogenic sources in the environment (Baride M V, et al 2012).

Cobalt value in analysed water samples varies from 0.013 to 0.082 with an average value 0.053 ppm, this show that the all the sample were beyond the maximum permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

Cu value in analysed water samples from 0.091 to 0.456 with an average value 0.180 ppm, this show that the all the sample were beyond the maximum permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

Fe value in analysed water samples from 0.081 to 0.238 with an average value 0.138 ppm, this show that the all the sample were within the permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

Pb value in analysed water samples from 0.003 to 0.373 ppm with an average value 0.148 ppm, this show that most of the sample were beyond the maximum permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

Mn value in analysed water samples from 0.023 to 0.049 ppm with an average value 0.046 ppm, this show that the all the sample were within the permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

Ni value in analysed water samples from 0.025 to 0.562 ppm with an average value 0.209 ppm, this show that the all the sample were beyond the maximum permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

Zn value in analysed water samples from 0.178 to 0.873 ppm with an average value 0.541 ppm, this show that the all the sample were within the permissible limit prescribed by Bureau of Indian standards (BIS, 1991).

3.3 Irrigation quality parameters

Analytical results of different irrigation quality parameters presented in table 7.

Table 7: Analytical results of irrigation water quality parameter

Sample ID	SAR	RSC	Na %	SSP
1	1.46	-2.71	41.45	29.31
2	0.73	-11.63	12.87	11.40
3	2.59	-5.19	61.78	38.19
4	1.97	-6.56	44.29	30.69
5	1.73	-12.00	31.13	23.74
6	1.26	-10.57	24.01	19.36
7	2.02	-6.39	43.42	30.28
8	2.40	-6.29	53.13	34.70
9	1.83	-4.90	43.34	30.23
10	1.98	-5.36	48.90	32.84
11	2.23	-4.50	58.21	36.79
12	1.01	-6.83	21.42	17.64
13	1.22	-5.73	30.72	23.50
14	0.87	-11.28	14.70	12.81
15	1.97	-6.67	38.56	27.83
16	2.07	-7.40	40.35	28.75
17	1.74	-11.52	30.33	23.27
Maximum	2.59	-2.71	61.78	38.19
Minimum	0.73	-12.00	12.87	11.40
Average	1.71	-7.38	37.56	26.55

Where, SAR = Sodium absorption ratio, RSC = Residual Sodium Carbonate, Na % = Percentage of sodium, SSP = Soluble sodium percentage

SAR is express as (Richard, 1954), $SAR = Na/\dfrac{Na}{\sqrt{(Ca+mg)/2}}$

Classification of water with reference to the SAR values is less than 10 it is indicate the excellent for irrigation. All analysed water sample SAR value less than 10 it is indicates excellent for irrigation purpose.

The values of SSP less than 50 indicates good quality of water and higher values shows that the unacceptable quality of water for irrigation (USDA, 1954). It is observed from obtained data of SSP of all water samples are suitable for irrigation purpose because of SSP values less than 50. SSP calculated by using following formula, $SSP = \dfrac{Na \times 100}{Ca + Mg + Na}$

The values for RSC is calculated as per Eaton formulae, RSC= (CO3 + HCO3) - (Ca+ Mg) meq/l. Accordingly the all ground water is suitable for irrigation because of RSC value > 2.5.

The suitability of the groundwater for irrigation depends on the mineralization of the water and its effect on plant and soil. Sodium concentration is an important criterion for defining the type of irrigation. The sodium percentage (Doneen, 1962) is calculated by using following formula,

Na % = $\frac{Na \times 100}{ca+mg}$ Where all ionic concentration expressed in meq/l.

All water samples suitable to irrigation purpose except sample ID 3, 8 and 11 as per Na % values less than 50 %.

3.4 Coefficient correlation of major elements in water

Relationship of physicochemical parameters of groundwater Correlation coefficient is a normally use measurement of recognized the correlation between two variables. It is simply a measure to exhibit how well one variable predicts the other. The correlation matrices for 12 variables were prepared and presented in Table 8 and illustrate that show good positive correlation with EC and Cl, EC and Ca, EC and HCO_3. TDS and Cl also exhibit high positive correlation. However Mg and K, K and CO_3 were the negative correlation pairs.

Table 8: Coefficient correlation matrix of water samples

	pH	EC	TDS	Ca	Mg	Na	K	Cl	SO₄	CO₃	HCO₃	NO₃
pH	1.0											
EC	0.3	1.0										
TDS	0.3	1.0	1.0									
Ca	0.2	0.8	0.8	1.0								
Mg	0.4	0.4	0.4	0.4	1.0							
Na	-0.1	0.3	0.3	0.0	0.2	1.0						
K	-0.5	-0.1	-0.1	-0.3	-0.5	0.2	1.0					
Cl	0.0	0.9	0.9	0.9	0.4	0.3	0.1	1.0				
So₄	0.0	0.5	0.5	0.4	0.5	0.5	0.2	0.6	1.0			
CO₃	0.6	0.0	0.0	-0.1	0.2	0.1	-0.5	-0.3	-0.1	1.0		
HCO₃	0.3	0.8	0.8	0.7	0.4	0.1	-0.2	0.6	0.3	0.1	1.0	
NO₃	0.3	0.5	0.5	0.5	0.4	0.4	-0.6	0.4	0.2	0.4	0.4	1.0

4. Conclusions

The study gives a detailed hydrochemistry of the area adjacent to the Panchganga and Jayanti stream and groundwater quality in shallow aquifers along the Jayanti stream. It establishes contamination of groundwater system in exposed stretches by wastewater flowing through the stream. It has been established that originally the groundwater in the aquifers had evolved to chloride facies, where the total dissolved solutes in groundwater was contributed mainly by geogenic sources.

The groundwater recharge to shallow aquifers along the stream caused dilution of the chloride facies water leading to re-evolution of the groundwater facies towards bicarbonate type. In this process, the groundwater quality was degraded by anthropogenic contaminants from wastewater flowing through the stream. Thus, recharge through stream water led to entry of trace elements in groundwater.

This establishes the fact that anthropogenic contamination of the groundwater simultaneously leads to changes in the hydro chemical facies of the groundwater. The entry of contaminants into groundwater system through network of subsidiary streams is also evident from the pattern of spatial variation in the concentration of the groundwater contaminants.

Hence, the study on anthropogenic contamination of groundwater system should be coupled with hydro chemical facies analysis for broad assessment of groundwater quality.

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