Groundwater Quality Investigations – A Case Study in Pallavaram area, Tamil Nadu

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Abstract: The rising salinity of groundwater used for water supply is a major problem. Indiscriminate use of fertilizers in certain areas has resulted in very high concentrations of some of the chemical constituents in groundwater. Water quality investigations of groundwater in Pallavaram area of Tamil Nadu, India have been studied during January 2019 and evaluated the suitability of water for drinking and domestic purposes. The groundwater samples were collected from 50 locations. The parameters were analyzed for pH, EC, TDS, Hardness, Calcium, Magnesium, Sodium, Potassium, Carbonate, Bicarbonate, Chloride and Sulphate with the help of standard method of APHA.

Keywords: chemical constituents, suitability, domestic purposes and APHA.

Introduction

Groundwater is becoming an important source of water supply in many regions since there has been a tremendous increase in the demand for fresh water due to growth in population. The rapid growth of urban areas has adversely affected the groundwater quality due to over exploitation of resources and improper waste disposal practices. The rising salinity of ground water used for water supply and irrigation is a major problem. Therefore, it is absolutely necessary to ascertain the potability of water before it is used for human consumption.

There are many examples of salinity increase in various parts of the country, particularly in canal command areas. Water logging is a common feature associated with many of the irrigation commands of surface water projects. Indiscriminate use of fertilizers in certain areas has resulted in very high concentrations of some of the chemical constituents in groundwater. The objective of this study is to assess the quality of groundwater and to classify the water in order to evaluate the water suitability for drinking, domestic and irrigation purposes. Hence the present study aims to conduct detailed investigations on groundwater quality in Pallavaram area of Chennai city, Tamil Nadu.

Review of Literature

Recently various authors carried out extensive studies on ground water quality and its suitability for various purposes. Application of agricultural chemicals, dumping industrial and domestic wastes at the land surface or within the unsaturated zone may have considerable impact on the groundwater quality. Rajamohan et.al. (1999) carried out the groundwater quality study of Kancheepuram district, Tamil Nadu and results shows that, the correlation among the chemical parameters, silicate weathering and source for the nutrients is mainly by agricultural activities. Varadarajan (2000) carried out study of groundwater quality of both open and bore wells in the Malaprabha sub basin in Belgaum District of Karnataka and applied one dimensional solute transport model SWIMv2.1 to predict the movement of contaminants through the unsaturated zone.

Durbude et al (2002) mapped the ground water quality parameters in Ghataprabha command area in GIS environment. Varadarajan et al (2003) have studied the hydrochemical characteristics of a Malaprabha sub basin and found the fluoride concentration along the downstream of the sub basin. Tatawat et al. (2008) investigated the quality of ground water for Jaipur city, Rajasthan and its suitability for domestic and irrigation purposes. Laluraj et al. (2005) studied the ground water quality and sea water intrusion of shallow aquifers of coastal zones of Cochin, India.

Study Area

The study was carried out in Pallavaram (Pallavapuram) region is a town and located in the suburbs of Chennai (Madras) city which is well known for tanneries. The geographic location of the area is between 80° 07'30" to 80° 10'56" East longitude and 12° 57'13" to 12° 58'56" North latitude. The area serves as a home town for lots of small scale and large-scale tanning industries. Chrome tanning is the popular method practiced in this area. The area has periya eri (big tank), once a sprawling water body covering about 189 acres, now shrunken into to small patch and used as outfall of effluent and dumping of garbage which has adversely affected the quality of the groundwater. The study area is 13 km away from the Bay of Bengal. The general topography falls from south to north and west to east. The climate of the area is with low humidity and high temperature, and the temperature is around 18ºC - 25ºC during winter and during summer has a maximum of 35ºC - 42ºC is generally hot. Temperature starts rising towards the end of February. The area receives maximum rainfall from North-West monsoon and annual rainfall is 1,124 mm. The flow of groundwater is from west to east. Most of the study area consists of barren land and the land use pattern of this area is mainly of buildings, roads, industries, schools and college. Pallavaram a satellite town for Chennai City is well connected by good network of roads and railway line, located on South Chennai

Materials and Methods

In order to assess the groundwater chemistry, groundwater samples were collected from 50 locations including bore wells, hand pumps and open wells by dip or grab sampling method. The samples were collected from wells, which are being extensively used for agriculture, drinking and other domestic purposes.

The pH, temperature and EC were measured at the time of sample collection using portable kits (NPC 361-D). Total hardness, Calcium, Magnesium, Carbonate, Bicarbonate, Chloride and Sulphate were analyzed in the laboratory by volumetric titration methods; while sodium and potassium by Flame Photometry (Systronics). The chemical parameters were analyzed in the laboratory by standard methods (APHA, 1985). The chemical parameters analyzed were presented in the Table 1.

Table 1 Analyzed Chemical Parameters of the Study Area

S.No	pH	HCO3	CO3	Cl	SO4	Ca	Mg	Na	K	TDS	EC
1	7.41	573.40	0.00	163.07	81.54	128.13	36.46	156.00	14.00	1170.23	1648.21
2	8.42	603.90	0.00	286.24	143.12	64.07	24.31	68.00	6.00	1210.12	1704.39
3	7.82	555.10	0.00	310.46	155.23	48.05	38.89	110.00	9.00	1256.45	1769.65
4	7.35	347.70	0.00	262.46	131.23	304.32	102.08	179.00	24.00	1367.43	1925.96
5	7.65	463.60	0.00	347.41	173.71	96.10	38.89	77.00	11.00	1245.23	1753.85
6	7.26	335.50	0.00	212.70	106.35	240.25	189.58	120.00	14.00	1267.32	1784.96
7	7.70	408.70	0.00	311.96	155.98	160.17	75.35	137.00	12.00	1280.43	1803.42
8	7.34	634.40	0.00	490.04	245.02	128.13	26.74	167.00	15.00	1750.67	2465.73
9	7.37	420.90	0.00	184.34	92.17	128.13	24.31	177.00	23.00	1089.56	1534.59
10	8.18	402.60	0.00	148.89	74.44	48.05	29.17	132.00	11.00	900.09	1267.73
11	7.49	390.40	0.00	290.69	145.35	96.10	29.17	257.00	18.00	1276.56	1797.97
12	7.48	542.90	0.00	198.52	99.26	176.18	26.74	176.00	12.00	1255.66	1768.54
13	7.53	664.90	0.00	448.90	224.45	128.13	24.30	166.00	22.00	1987.56	2799.38
14	7.82	579.50	0.00	354.50	177.25	160.17	36.46	144.00	19.00	1540.66	2169.94
15	7.56	524.60	0.00	510.48	255.24	160.17	43.75	167.00	18.00	1810.54	2550.06
16	6.93	128.10	0.00	68.90	34.45	208.22	2.43	177.00	10.00	650.23	915.82
17	7.25	530.70	0.00	382.86	191.43	32.03	2.43	66.00	18.00	1220.98	1719.69
18	7.28	305.00	0.00	176.46	88.23	80.08	7.29	110.00	9.00	780.97	1099.96
19	7.25	597.80	0.00	332.90	166.45	48.05	17.01	81.00	7.00	1289.09	1815.62
20	7.72	170.80	0.00	91.74	45.87	64.07	51.04	110.00	9.00	555.09	781.82
21	7.86	597.80	0.00	177.25	88.63	80.08	24.31	78.00	6.00	1090.09	1535.34
22	7.50	494.10	0.00	416.24	208.12	208.22	65.62	177.00	18.00	1699.00	2392.96
23	7.64	317.20	0.00	219.79	109.90	208.22	29.17	187.00	20.00	1100.09	1549.42
24	7.63	622.20	0.00	453.76	226.88	80.08	24.31	137.00	14.00	1698.88	2392.79
25	7.65	396.50	0.00	333.23	166.62	48.05	24.31	246.00	26.00	1290.90	1818.17
26	7.93	683.20	0.00	304.87	152.44	16.02	26.74	147.00	12.00	1355.09	1908.58
27	7.53	366.00	0.00	276.51	138.26	48.05	36.46	155.00	12.00	1100.09	1549.42
28	8.42	433.10	0.00	170.16	85.08	16.02	85.07	58.00	9.00	890.09	1253.65
29	7.67	610.00	0.00	313.34	156.67	160.17	26.74	134.00	6.00	1510.88	2128.00
30	7.56	683.20	0.00	319.05	159.53	224.23	85.07	180.00	11.00	1680.09	2366.32
31	7.23	109.80	0.00	49.10	24.55	80.08	51.04	142.00	14.00	502.09	707.17
32	8.24	933.30	0.00	624.26	312.13	80.08	87.50	110.00	11.00	2200.87	3099.82
33	7.84	994.30	0.00	710.92	355.46	144.15	31.60	146.00	11.00	2400.56	3381.07
34	7.54	1134.60	0.00	602.68	301.34	96.10	82.64	143.00	12.00	2435.87	3430.80
35	7.78	219.60	0.00	113.44	56.72	112.12	148.26	174.00	12.00	850.09	1197.31
36	7.36	658.80	0.00	399.70	199.85	176.18	41.32	184.00	14.00	1700.45	2395.00
37	7.60	658.80	0.00	258.14	129.07	208.22	140.97	187.00	14.00	1600.34	2254.00
38	7.30	414.80	0.00	297.80	148.90	96.10	29.17	79.00	10.00	1100.53	1550.04
39	7.21	732.00	0.00	389.95	194.98	112.12	41.32	114.00	9.00	1563.97	2202.77
40	7.47	542.90	0.00	333.23	166.62	96.10	34.03	191.00	8.00	1400.08	1971.94
41	8.01	646.60	0.00	398.16	199.08	80.08	9.72	132.00	10.00	1512.12	2129.75
42	8.52	646.60	0.00	433.78	216.89	32.03	17.01	39.00	11.00	1409.00	1984.51

S.No	pH	HCO3	CO3	Cl	SO4	Ca	Mg	Na	K	TDS	EC
43	8.56	591.70	0.00	372.68	186.34	16.02	9.72	79.00	6.00	1312.00	1847.89
44	8.62	561.20	0.00	333.23	166.62	128.13	29.17	99.00	5.00	1409.56	1985.30
45	7.88	433.10	0.00	330.90	165.45	96.10	82.64	110.00	11.00	1265.09	1781.82
46	8.01	54.90	0.00	24.86	12.43	64.07	19.44	114.00	12.00	310.06	436.70
47	7.95	390.40	0.00	155.98	77.99	48.05	46.18	134.00	14.00	866.56	1220.51
48	7.77	524.60	0.00	177.25	88.63	96.10	9.72	146.00	27.00	1100.09	1549.42
49	7.54	542.90	0.00	181.92	90.96	176.18	31.60	120.00	14.00	1213.89	1709.70
50	7.52	683.20	0.00	306.90	153.45	256.27	26.74	159.00	16.00	1610.75	2268.66

Groundwater Quality for drinking purposes

Groundwater quality assessment was carried to determine its suitability in terms of drinking purposes. The groundwater samples were collected in and around the Pallavaram suburbs town, Chennai. The concentration with the limits recommended by BIS is discussed (Table 2). GIS is used to understand the spatial distribution and variation of the ions with respect to the location.

Table 2. Various Recommended limit for Groundwater Quality

S.No.	Parameters	WHO 2003	ICMR 1975	BIS 1999
1	pH	6.5 – 9.5	7.0 – 8.5	6.5 – 8.5
2	Electrical Conductance	1400	-	-
3	Total Dissolved Solids	600	500	2000
4	Sodium	-	-	-
5	Potassium	-	-	-
6	Calcium	100	200	200
7	Magnesium	150	200	100
8	Chloride	250	200	1000
9	Carbonate	-	-	-
10	Bicarbonate	-	-	-
11	Sulphate	250	200	400
12	Nitrate	50	50	100
13	Total Hardness	500	600	600

pH is a term to express the intensity of acidic or alkaline conditions. pH is an important parameter in assessing the water quality. The pH of the groundwater samples ranges from 6.93 to 8.62. The groundwater samples of the study area show faintly alkaline in nature. High pH causes a bitter taste; water pipes and water-using appliances becomes encruste; depresses the effectiveness of the disinfection of chlorine. The factors like air temperature also bring about changes the pH of water. If the pH is found beyond the permissible limit, it affects the mucous membrane of cells. The spatial distribution map of pH shows, maximum groundwater samples of the study fall within the BIS permissible limit of 6.5 – 8.5 and locations 42, 43 and 44 exceeds the maximum permissible limit (Fig. 1). Electrical Conductivity (EC) or salinity value is a manifestation to signify the total concentration of soluble salts in water. This property is called electrical conductivity. It is a useful tool to assess the purity of water. A sudden rise in EC in the water indicates addition of some pollutants to it. The depth of dug wells range from 10 m to 26 m bgl while that of tube wells extend beyond 40 m. The EC of tube well and dug well samples did not show much variation. The spatial distribution of EC in well samples as shown in the fig. 2, reveals that groundwater salinity increases toward the southern part of the study area. However, some heterogeneity in salinity distribution is observed. The EC recorded disturbances in the groundwater quality of the study area which as per field observation is due to industries and dumping site. The increase in conductivity indicates that there must be an increase in number of ions which is supported by salinity values. Salinity of samples in the study area ranges from 436.70 to 3430.80 μScm^{-1}. Most of the waters in the study area shows good for domestic uses sample location 44 shows high salinity due to the influence of industrial effluent and solid waste dumping site on groundwater quality. Calcium (Ca^{2+}) is the next dominant cation found in groundwater. The calcium and magnesium are the most abundant elements in the groundwater. In groundwater the calcium content generally exceeds the magnesium content. Ca^{2+} may dissolve readily from carbonate rocks and limestone's or is leached from soils. However, dissolved magnesium concentration is lower than Ca^{2+} in the groundwater. Other sources are primarily industrial and municipal discharges. Ca^{2+} is an essential nutritional element for human being, plant cells and soils. It is found in alkaline in nature. The concentration of Ca^{2+} ranges from 16.02 to 304.32 mg/l. The desirable limit of calcium in drinking water is 75 mg/l, maximum groundwater samples exceeded the desirable limit (Fig. 3). The rapid industrialization and urbanization in the area contributed to the high concentration of Ca^{2+} in the groundwater of the area.

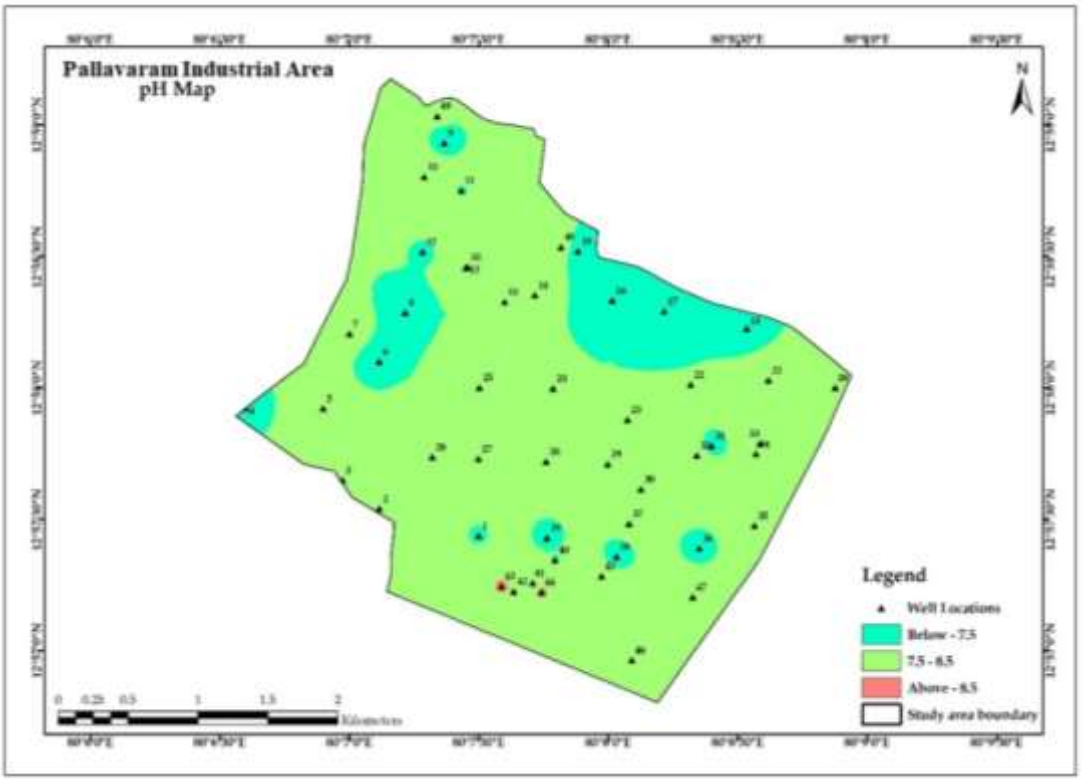

Fig.1 Spatial distribution of pH

Fig.2 Spatial distribution of Electrical Conductivity

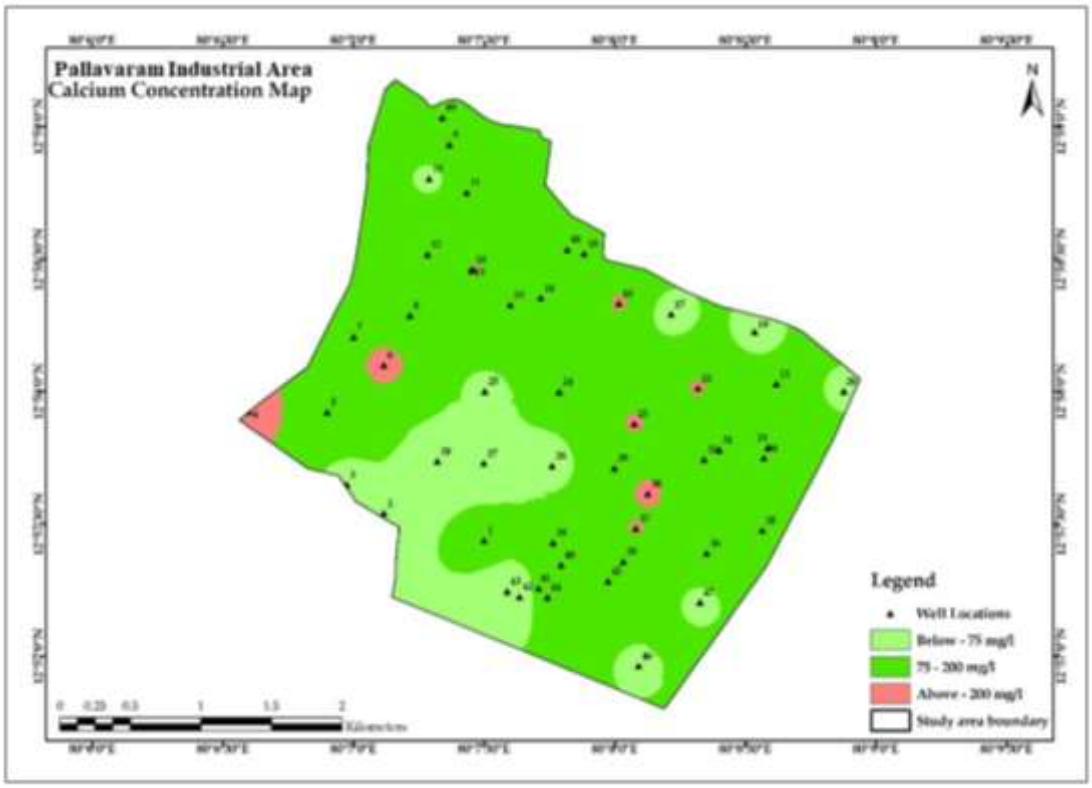

Fig.3 Spatial distribution of Calcium

Magnesium usually occurs in lesser concentration than calcium due to the fact that the dissolution of magnesium rich minerals is slow process and that of calcium is more abundant in the earth's crust. If the concentration of magnesium in drinking water is more than the permissible limit (30 mg/l), it causes unpleasant taste to the water. Magnesium concentration is found between 2.43 and 189.58 mg/l. Most of the location's magnesium ranges fall within the maximum permissible limit of 100 mg/l and groundwater samples 4, 6, 35 and 37 shows above the maximum permissible limit (Fig.4). The Cl ion was never preponderant in these waters with very high mineral contents and the high concentrations were always combined with high Na and Ca levels giving the water of mixed calcium-sodium-chloride type. Chloride is an anion found in variable amount in groundwater. The high chloride in groundwater may probably be come from the raw material used for the processing of the leather. The spatial variation map shown in fig. 5. The value of chloride (Cl^-) for the groundwater samples is ranged from 24.86 to 710.92 mg/l. The values are high in and around the residential area and also in those where tanneries are located. Most of the groundwater samples show above the acceptable limit (250 mg/l). Because of improper drainage systems the industrial wastes enter into the groundwater systems and contaminate the fresh groundwater. It produces salty taste at 250 to 500 mg/l also, chloride remains in the wastewater resulting from tanning processes. Chloride imparts a salty taste and some times higher consumption causes for the development of essential hypertension, risk for stroke, osteroporosis, renal stones and asthma in human beings. Increase of chloride kevel in water is injurious to people suffering due to heart and kidney diseases. Mostly, the chlorides are found in the form of sodium chloride in the groundwater. The possible source of sulphate from the tanneries is from ammonium sulphate, sodium sulphate, chrome sulphates which are among the chief chemicals used in the tanning process and leaching of the effluents into the groundwater could have led to contamination of groundwater. The sulphate concentration ranges from 12.43 to 355.46 mg/l. The sulphate ion is one of the important anions present in natural water which produces catharsis, dehydration and gastrointestinal irritation effect upon human beings when it is present in excess of 150 mg/l. In the study area the SO4 2- concentration are exceed the permissible limit of 200 mg/l.

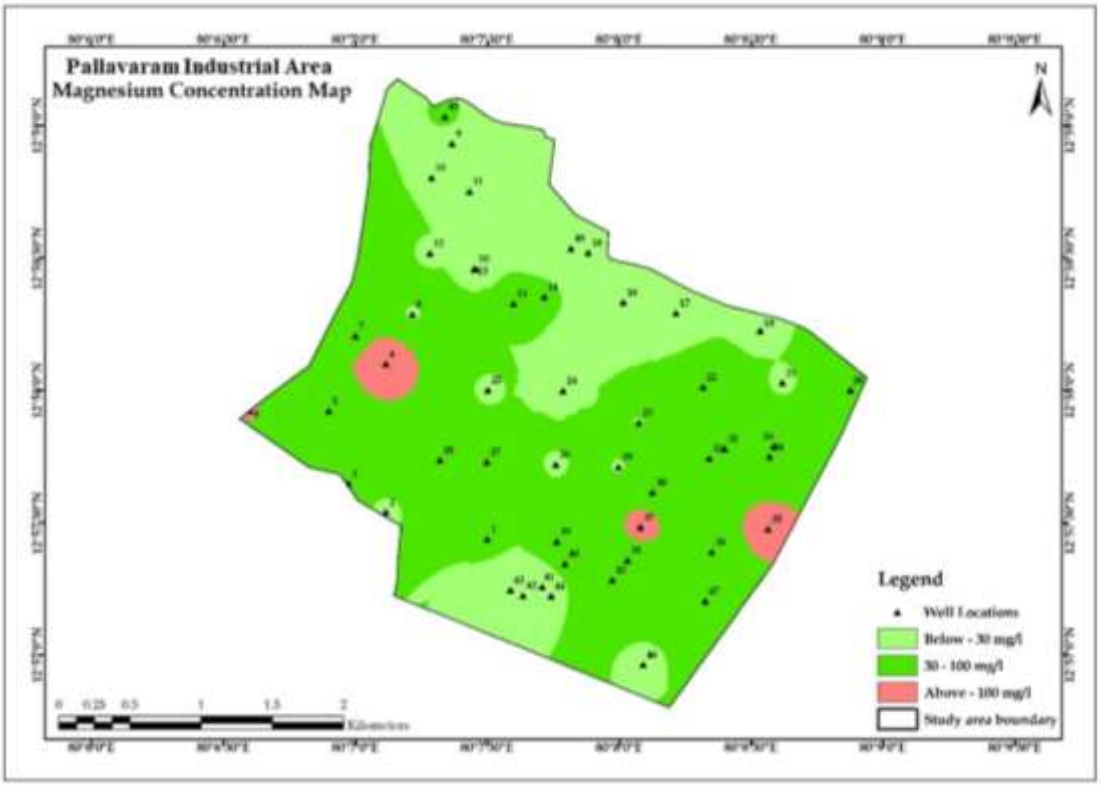

Fig. 4 Spatial distribution of Magnesium

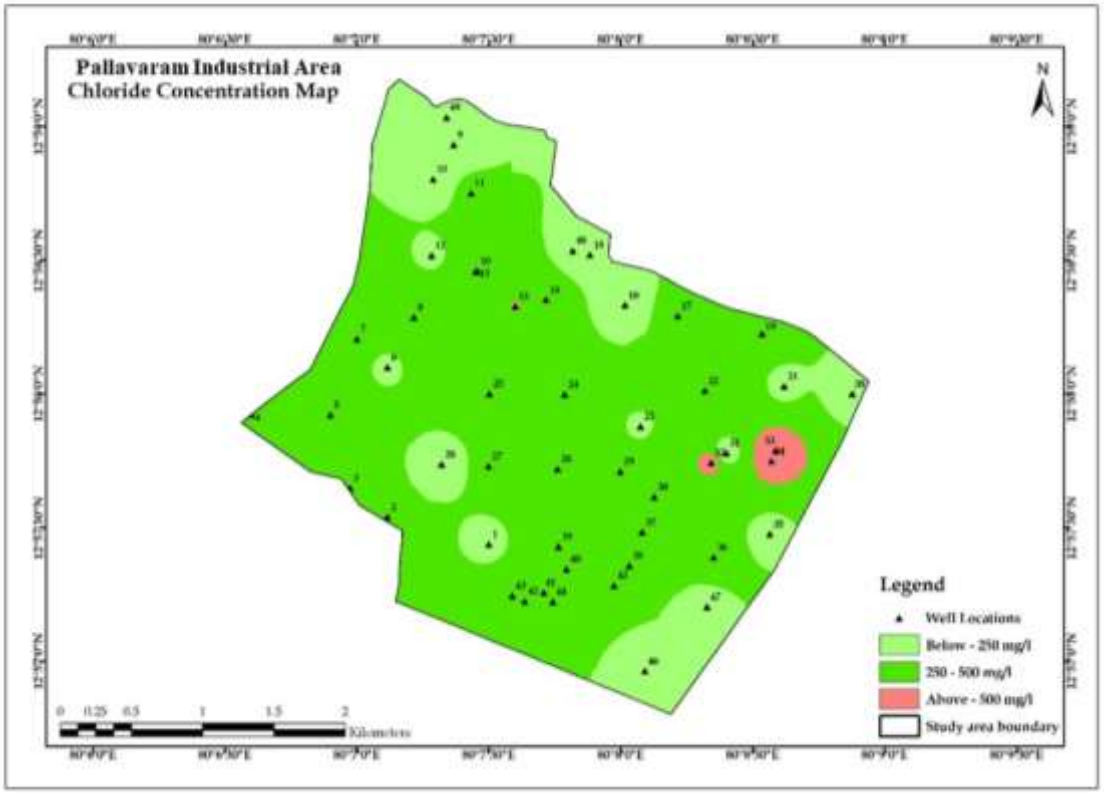

Fig. 5 Spatial distribution of Chloride

The groundwater is further evaluated to determine its facies by plotting the percentages of select chemical constituents in Piper diagram. The plots indicated scattered distribution with minor or negligible variations in their chemical (Fig.6). The groundwater samples of Pallavaram show significant changes in percentage of samples belonging to different water types, but for the variations in the number of samples, the groundwater in general was of Na–Cl, Ca-Na–HCO_3 and Ca–Mg-Cl types. Few samples (one in each) fall in two or three sub-blocks of the diagram i.e., Ca-HCO_3 and Ca-Cl types. It can be inferred from plots that the groundwater was of mixed type with multiple processes involved in its evolution. The piper plots further strengthen that the fact that the anthropogenic factors predominate the mineralogy process taking place in the study area in determining the water chemistry. The plots also suggest that among cations Na followed by Ca and Mg and in anions Cl

dominate the ionic concentration in groundwater. Aquifer parameters seem to play minimum role in the determination of the water facies as no seasonal changes were evident. Change in storage of aquifer between seasons did not influence the major geochemical makeup of groundwater quality of the area due to continuous dumping of waste. The major source of all these ions is sodium chloride and sodium sulphate, which are used in large amounts in the tanneries during different stages of the process for bringing out fine quality leather from skins and hides. The groundwater type of the study area was distinguished and grouped by their position on a Piper diagram. In most of the sample Na-Cl dominated facies was clearly observed.

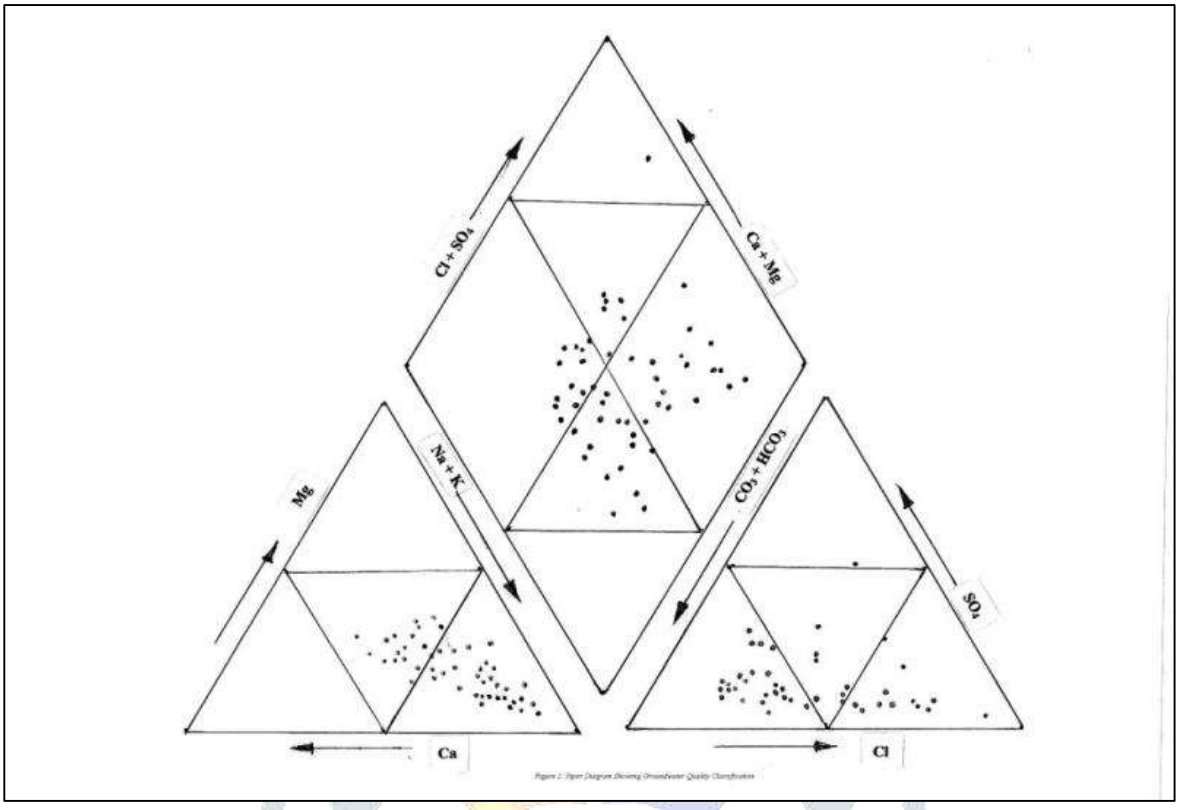

Fig. 6 Piper Diagram

Conclusion

The groundwater in most of the area is highly polluted and in few sites it was moderately polluted in comparison with drinking water standards. Groundwater types of Ca-Mg-Cl type along with NaCl domination both the seasons occurring in the region. TH falls under hard to very hard categories and is not suitable for drinking purposes. Further, the water quality parameters found for the region suggest profound human interference. It was found that the quality of groundwater in this area has deteriorated mainly due to extensive use of chemical in the tannery industries and solid waste dumpsite seriously affected due to the combined effect of industrialization and urbanization. As there is no natural or other possible reason for high concentration of these pollutants, it can be concluded that tannery effluent and landfill site have significant impact on groundwater quality in the area. It is high time that the suffering of the people had to be relieved by taking proper policy action. Further, the stagnating water mixed with outfall of industrial effluent and domestic sewage percolating into the groundwater medium and thereby polluting the groundwater resources.

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