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Suitability of groundwater in and around Tannery industrial belt

D.Sivakumar*, A.N.Kandaswamy, V. Kalpana Priya, S.Hemalatha
Department of Civil Engineering, Vel Tech High Tech Dr.Rangarajan Dr.Sakunthala Engineering College, Avadi, Chennai, Tamil Nadu, India
Corresponding Author: Email: shri.sivakumar1974@gmail.com

ABSTRACT

Quality of water is an important criterion for evaluating the suitability of water for drinking and industrial purposes. This paper evaluated groundwater quality classification in accordance with the current law regulations in Pallavaram, Chennai, Tamil Nadu. Water samples were collected during the month of December 2014 from 20 wells and were analyzed for the concentrations of various physico-chemical parameters. The selected physico-chemical parameters were pH, TDS, total hardness (TH), anions like Ca, Mg, Na and K, and cations like SO_4, NO_3, Cl_2, HCO_3, and F. The physico-chemical study of the groundwater systems of selected in and around the study area showed that groundwater is nearly acidic and mostly oxidizing in nature. The groundwater contamination is due to the recharge of effluent discharged by tanning industries into open drains and lakes. On comparing the results against drinking quality standards laid by BIS, it was found that most of the water quality parameters were above the permissible limit and some were not, but it can be used for drinking purpose after treatment. These results help the Government to take some initiative for checking the deterioration of groundwater quality and to treat groundwater by various treatment options to meet the GIS drinking water quality standard before being supplied for various uses.

Keywords: Groundwater quality parameters, Water quality index, Bureau of Indian standard

INTRODUCTION

Groundwater is the primary source of water for human consumption, and industrial uses in many regions all over the world. In India, most of the population depends on groundwater as the only source of drinking water supply. Protection of water resources, fresh and salt water ecosystems and of the water we drink and bath in is therefore one of the cornerstones of environmental protection. The groundwater consumption rate is increasing day by day in the areas where surface water sources are not enough to meet the demands. The resources in several locations become contaminated from numerous human activities or natural sources (Milovanovic, 2007). Industrial, residential, municipal and agricultural activities affect groundwater quality (Sivakumar, 2011). Contaminations of the groundwater result in the poor quality of drinking water, loss of water supply and potential health problems. Drinking water has no alternatives; therefore, it is very important to cleverly manage the available surface water resources (Ravikumar, et al., 2013) and monitor the quality of ground water (Chatham, et al., 2010), which is used as a raw material for drinking. The tanning industries are the major consumers of fresh water and the used of the water is discharged as wastewater. The various chemicals used in tanning industries in and around Pallavaram area are lime, sodium carbonate, sodium bi-carbonate, common salt, sodium sulphate, chrome sulphate, fats, liquors, vegetable oils and dyes pollute the water resources particularly groundwater resource. The main objectives of this study are to assess the groundwater quality of 20 selected sites, nearby places of Pallavaram, Chennai, Tamil Nadu, India. As similar to previous researchers (Sahu and Sikdar, 2008; Sivakumar and Swaminathan, 2008; Sivakumar, et al., 2014), to know the suitability of groundwater for drinking purposes, various physico-chemical parameters like pH, electrical conductivity (EC), total dissolved solids (TDS), total hardness (TH), calcium(Ca) magnesium (Mg), sodium (Na), potassium (K), Bicarbonate (HCO_3), chloride (Cl_2), nitrate (NO_3), sulphate (SO_4) and fluoride were analyzed. Compared all physico-chemical parameters of five selected areas with BIS drinking water quality and determined water quality indices to suit groundwater for drinking purpose.

MATERIALS AND METHODS

Study Area: Pallavaram is a town and a second-grade municipality located in the suburbs of Chennai. It forms a part of theTambaram taluk of Kanchipuram district, Tamil Nadu, India with 12.57 latitude and 80.09 longitude. The groundwater of Pallavaram was polluted by untreated sewage and wastewater from tannery industry.

Collection of Water Samples and Analysis: To know the exact conditions of the groundwater it is very much essential to go for water sampling and testing for the various parameters such as like pH was measured with the help of pH meter, electrical conductivity (EC) was measured with the help of an electrical conductivity meter which in turn used to calculate the TDS, anions like Ca, Mg, Na and K and cations like HCO_3, Cl_2, SO_4, and NO_3 and F were measured as per the standard procedure stipulated by APHA, AWWA, WEF (2005).The values of these physico-chemical parameters obtained from groundwater of different areas are used to determine the suitability of groundwater for drinking purpose. The drinking water standard is used for checking the groundwater suitability for drinking purposes.

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Water Quality Index: Water quality is the condition of the water body or water resource in relation to its designated uses (Mangukiya, et al., 2012). It can be defined in qualitative and/or quantitative terms. The need for expressing water quality in a format that is simple and easily understood by common people has been recognized and experts have designed the term Water Quality Index (WQI). The WQI takes the complex scientific information and synthesizes into a single number between zero and 100, by normalizing the observed values to subjective rating curves. It summarizes the relative changes in the underlying group of the water-quality variable. A number of algorithms (models) for calculating WQI have been developed and reported in the literature (Reza Rizwan and Gurdeep Singh, 2010; Sivakumar et al., 2014).

In the first step, each of the parameters has been assigned a weight (wi) according to its relative importance in the overall quality of water for drinking purposes. The maximum weight of 5 has-beens assigned to the parameter nitrate due to its major importance in water quality assessment. Magnesium, which gives a weight of 1 as magnesium by itself may not be that harmful**.**

In the Second step, relative weight (We) is computed from the following equation:

$$Wi=wi/\sum wi \tag{1}$$

In the third step, a quality rating scale (qi) for each parameter is assigned by dividing its concentration in each water sample by its respective standard according to the guidelines laid down in the WHO and the result is multiplied by 100:

$$qi= (Ci/ Si) x100 \tag{2}$$

where, qi is the quality rating, Ci is the concentration of each chemical parameter in each water sample in mg/l, and Si is the water standard for each chemical parameter in mg/l.

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

$$Si= Wi \times qi \tag{3}$$

$$WQI = \Sigma Si \tag{4}$$

RESULTS AND DISCUSSIONS

Various physico-chemical parameters in a groundwater were analyzed for the parameters pH, TDS, total hardness (TH), anions like Ca, Mg, Na and K, and cations like SO_4, NO_3, Cl_2, HCO_3, and F and the results are discussed below. The experimental results are presented in Table 1 and results were compared with drinking water quality standard (Table 2). Further the statistical analyses were presented in Table 3.

Table.1.The Experimental Results of Physico-Chemical Parameters

Parameters	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**
pH	6.9	6.5	7.1	7.1	7.3	7.1	7.2	6.9	6.8	6.9
Ca	144	70	48	240	86	176	78	96	98	66
Mg	74	26	35	51	16	185	57	49	69	50
Na	115	343	303	439	154	941	138	152	173	150
K	7	7	1	36	13	23	8	7	12	7
HCO_3	470	153	659	421	250	458	494	525	494	366
SO_4	98	142	93	192	109	225	107	85	92	87
Cl	266	493	163	844	188	1886	128	160	216	149
NO_3	99	92	56	104	39	24	27	52	141	132
F	0.32	0.08	1.17	0.37	0.34	0.46	0.31	0.32	0.61	0.67
TDS	1038	1250	1030	2117	730	3689	790	864	1049	825
TH	665	280	265	810	280	1200	430	440	530	370
Parameters	**W11**	**W12**	**W13**	**W14**	**W15**	**W16**	**W17**	**W18**	**W19**	**W20**
pH	6.6	6.6	6.8	6.8	6.6	6.9	6.8	6.9	6.8	7
Ca	88	124	98	70	112	78	72	60	66	76
Mg	131	124	74	43	56	52	47	85	101	129
Na	312	122	157	76	233	171	163	140	138	199
K	5	15	7	7	26	6	86	235	5	2
HCO_3	403	476	329	275	427	311	317	683	622	427
SO_4	201	102	110	62	131	119	91	119	24	38
Cl	525	340	241	138	312	238	195	209	195	418
NO_3	162	131	193	55	57	34	166	78	51	125
F	0.7	0.37	0.46	0.5	1.57	1.73	1.93	2.03	1.52	1.75
TDS	1626	1196	1045	589	1142	855	980	1270	893	1202
TH	760	820	550	350	510	410	375	500	580	720

Table.2.Drinking Water Quality Standards

Parameters	Standards (IS:10500, revision 2003)
pH	6.5-8
Calcium (Ca)	75
Magnesium (Mg)	30
Sodium (Na)	200
Potassium (K)	10
Bicarbonate (HCO_3)	200
Sulphate (SO_4)	200
Chloride (Cl)	250
Nitrate (NO_3)	50
Fluoride (F)	1.5
Total dissolved solids (TDS)	600
Total hardness as $CaCO_3$	200

Table.3.Statistical Analyses for the Selected Samples

Parameters	Min.	Max.	Mean	S.D.
pH	6.5	7.3	6.88	0.38
Calcium (Ca)	48	240	97.3	49.3
Magnesium (Mg)	16	185	72.7	56.7
Sodium (Na)	76	941	230.95	154.95
Potassium (K)	1	235	25.75	24.75
Bicarbonate (HCO_3)	153	683	428	275
Sulphate (SO_4)	24	225	111.35	87.35
Chloride (Cl)	128	1886	365.2	237.2
Nitrate (NO_3)	24	193	90.9	66.9
Fluoride (F)	0.08	2.03	0.8605	0.7805
Total dissolved solids (TDS)	589	3689	1209	620
Total hardness as $CaCO_3$	265	1200	542.25	277.25

pH: Quantitative measure strength of the acidity or alkalinity of a solution is defined as the negative common logarithm of the concentration of hydrogen ions [H+] in moles/l pH = log [H+]. The pH value was measured by a pH meter. The pH is now defined in electrochemical terms. The pH value observed from the samples collected ranges between 6.5 and 7.3 for all selected wells of the study area. The results indicated that which falls within the BIS drinking water quality standard limit.

Total dissolved solids (TDS): TDS is a measure of the combined content of all inorganic and organic substances contained in a liquid in molecular, ionized or micro-granular (colloidal sol) suspended form. Total dissolved solids are normally discussed only for freshwater systems, as salinity includes some of the ions constituting the definition of TDS. TDS is not generally considered a primary pollutant, but it is used as an indication of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants. In this study, the TDS of selected wells ranged from589 to 3689 mg/l (Table 1), and the average value of 1209 mg/l (Table 3), which exceeds the standard value of 600 mg/l (Table 2).

Total Hardness: The total hardness in water samples ranges between 265 to 1200 mg/l (Table 1) and the average value is 542.3 mg/l (Table 3), indicate that the values are higher than the desirable limits as per the BIS standard (Table 2) and the water types is hard in nature. This hardness is as the result of the dissolution of limestone deposit, which may be present underneath the study areas produce calcium carbonate ($CaCO_3$), yields excess concentration of hardness. Therefore, it may probably conclude that this limestone deposit is considered responsible for this.

Calcium: The calcium in groundwater samples of 5 selected places varied from 48 to 240 mg/l (Table 1) and the average value is 97.3 mg/l (Table 3), indicates, the calcium value is exceeding the desirable range as per the standard (Table 2). The above variation of calcium is due to the presence of higher concentration of gypsum / limestone beneath the good point and due to mixing of tannery industry wastewater into the groundwater storage reservoir.

Magnesium: Magnesium is one of the most common elements in the earth’s crust. It is present in all natural waters. It is an important contributor to water hardness. All study area has more magnesium concentration varied from 16 to 185 mg/l (Table 1) and the average value is 72.7 mg/l (Table 3), indicates the magnesium concentration is not higher than the desirable limits (Table 2). The presence of dolomites and mafic minerals (amphibole) in rocks beneath the groundwater also produce the excess magnesium in groundwater.

Sodium: The sodium present in the water samples of the selected area is varied from 76 to 941 mg/l (Table 1) and the average value is 230.95 mg/l (Table 3). Sodium salts (e.g., sodium chloride) are found in virtually all food (the main source of daily exposure) and drinking water. Although concentrations of sodium in potable water are typically less than 200 mg/l, they can greatly exceed this in some countries. The levels of sodium salts in air are normally low in relation to those in food or water. It should be noted that some water softeners can add significantly to the sodium content of drinking-water. No firm conclusions can be drawn concerning the possible association between sodium in drinking water and the occurrence of hypertension. Therefore, no health based guideline value is proposed. However, concentrations in excess of 200 mg/l may give rise to unacceptable taste.

Nitrate: The nitrate concentration in the study area varied from 24 to 193 mg/l (Table 1). The mean concentration of nitrate is 90.9 mg/l (Table 3), which is not greater than the permissible limit of 50 mg/l (Table 2)**.** Sources of nitrate in water include human activities such as application of fertilizer in farming practices, human and animal waste.

Chloride: The chloride concentration in the study area varies from 128 to 1886 mg/l (Table 1). The mean concentration of chloride is 365.2 mg/l (Table 3), which is greater than the permissible limit (Table 2). Chloride in drinking-water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion. Excessive chloride concentrations increase rates of corrosion of metals in the distribution system depending on the alkalinity of the water. This can lead to increased concentrations of metals in the supply No health-base guideline value is proposed for chloride in drinking-water. However, chloride concentrations in excess of about 250 mg/l can give rise to detectable taste in water.

Sulphate: Sulphate occurs in water as the inorganic sulphate salts as well as dissolved gas (H_2S). Sulphate is not a noxious substance although the high sulphate concentration in the water may have a laxative effect. The water samples taken from the study area varied from 24 to 225 mg/l (Table 1) and the average value is 111.35 mg/l (Table 3), which is lesser than the permissible limit of 200 mg/l as per the standard (Table 2). The variation signifies the differential dissolution of gypsum, which is predicted to be underneath the wells.

Fluoride: Fluoride in drinking-water will be an invaluable reference source for all those concerned with the management of drinking-water containing fluoride and the health effects arising from its consumption, including water sector managers and practitioners as well as health sector staff at policy and implementation levels. The water samples taken from the study area varied from 0.08 to 2.03 mg/l (Table 1) and the average value is 0.86 mg/l (Table 3), which is lesser than the permissible limit of1.5 mg/l as per the standard (Table 2).

Water Quality Index: The standard ranges of water quality index are given in Table 4. The water quality index of the study area selected is determined by using the weighted arithmetic mean method. In the first step, the selected 10 parameters pH, total dissolved solids (TDS), total hardness (TH), calcium (Ca^{2+}) magnesium (Mg^{2+}), sodium (Na^+), Chloride (Cl_2^-), nitrate (NO_3^-), sulphate (SO_4^{2-}) and fluoride (F) have been assigned a weight (wi) value, based on their perceived effects on primary health (Table 1). The maximum weight of 5 has been assigned to parameters like pH, nitrate and total dissolved solids due to their major importance in water quality assessment. Least value of 1 has been assigned to the parameter magnesium and the range between 1 and 5 is assigned to the rest of the parameters. Water quality index is calculated based on the standard values (Table 2), average values (Table 3) and weight factors of water quality parameters (Table 4). In the second step, relative weight (Wi) is computed using the Eqn.1, in the third step, the quality rating qi is calculated using the Eqn.2, then, the water quality sub index Si is calculated using the Eqn.3, are presented in Table 4. Finally, the WQI is calculated using the Eqn.4, the results are also presented in Table 4. The important point is to note that Table 4 represents the overall quality of groundwater around the Nagalkeni industrial estate. The detailed calculation on WQI for each selected are (W1W2,W3,W4,W5,W6,W7,W8,W9,W10,W11,W12,W13,W14,W15,W16,W17,W18,W19,W20) are not presented for this present study, but the final value of WQI is presented in Table 6.

From Table 6, it may be observed that the WQI for selected area is exceeding the standard values of 100 (Table 5) except Tambaram (Table 6) and overall average of WQI in Pallavaram industrial belt is also exceeding the value of 100 (Table 4). The variation is mainly due to the dissolved constituents, which exists as ions, molecules or solid particles, these constituents not only undergo chemical and physical reactions but also redistribution take place among the various ionic species. Hence groundwater cannot be consumed as drinking water directly but it can be used after undergoing some treatment processes.

Table.4.The Average Values and Weight Factor, Relative Weight Factor, Quality Rating, Water Quality Sub Index of Water Quality Parameters

S.No.	Parameters	Values	Weight Factor (Wi)	Relative Weight Factor (Wi)	Quality Rating (qi)	Water quality Sub index (Si)
1	pH	6.88	5	0.14	98.2	13.76
2	Calcium (Ca)	97.30	2	0.05	129.7	6.48
3	Magnesium (Mg)	72.70	1	0.03	242.3	7.27
4	Sodium (Na)	230.95	3	0.08	115.4	9.23
5	Potassium (K)	25.75	2	0.05	257.5	12.87
6	Bicarbonate (HCO_3)	428.00	2	0.05	214	10.7
7	Sulphate (SO_4)	111.35	4	0.11	55.6	6.12
8	Chloride (Cl)	365.20	3	0.08	146.1	11.6
9	Nitrate (NO_3)	90.90	5	0.13	181.8	23.6
10	Fluoride (F)	0.86	2	0.05	57.3	2.86
11	TDS	1209.00	5	0.13	201.5	26.19
12	Total Hardness	542.25	4	0.11	271.1	29.82
WQI						**160.5**

Table.5.The Standard Ranges Of WQI

WQI Value	Water Quality
<50	Excellent
50-100	Good
100-200	Poor
200-300	Very poor
>300	Not fit for drinking

Table.6.Water Quality Index for the Selected Water Samples

Sample No.	Name of Place	WQI	Water Type
W1	Medavakkam	148.65	Poor
W2	Solinganallur	130.34	Poor
W3	Kelambakkam	115.03	Poor
W4	Perunkudi	236.4	Very Poor
W5	Velachery	274.53	Very Poor
W6	Velachery	326.61	Not Fit for Drinking
W7	Palavanthangal	104.48	Poor
W8	Meenambakkam	113.94	Poor
W9	Pallavaram	153.6	Poor
W10	Pallavaram	125.16	Poor
W11	Nagalkeni	202.7	Very Poor
W12	Thiruneermalai	177.4	Poor
W13	Chrompet	161.6	Poor
W14	Tambaram	90.35	Good
W15	Mangadu	147.0	Poor
W16	Kundrathur	109.61	Poor
W17	Pammal	181.825	Poor
W18	Mudichur	259.1	Poor
W19	Old Perungalathur	126.02	Poor
W20	Old Perungalathur	167.77	Poor

CONCLUSION

The groundwater quality was accessed nearby the places of Pallavaram, Chennai, Tamil Nadu, and India. In order to suit the groundwater for drinking purpose, compared the value of selected parameters like pH, TDS, total hardness (TH), anions like Ca, Mg, Na and K, and cations like SO_4, $NO_{3,}$ $Cl_{2,}$ HCO_3, and F with the value of corresponding parameters in BIS drinking water quality standard. Water quality index (WQI) rating was obtained to quantify the overall groundwater quality status of the area. The physico-chemical study of the groundwater systems, selected in aroundPallavaramindustrial estate showed that groundwater is nearly acidic and mostly oxidizing innature. The results of WQI indicated that the groundwater is not fit for drinking purpose directly, but it can be used after proper treatments.

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