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Groundwater Quality Assessment around Nagalkeni Tannery Industrial Belt

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***Abstract*—**The groundwater quality was assessed nearby places of Nagalkeni, Chennai, Tamil Nadu, India. The selected physico-chemical parameters were pH, EC, TDS, total hardness (TH), anions like Ca, Mg, Na and K, and cations like SO_4, NO_3, Cl_2, HCO_3, and CO_3, and Cr(VI). In order to suit the groundwater for drinking and irrigation purposes, compared the value of selected parameters with the value of selected parameters from BIS drinking water quality standard and irrigation water quality indices. The physico-chemical study of the groundwater systems of selected sites of nearby places of Nagalkeni showed that the groundwater is nearly acidic and mostly oxidizing in nature and hence, water is not suitable for drinking purpose directly. The results of the irrigation indices indicated that the groundwater samples in the study area found to be brackish water, results, groundwater from the study area is also not suitable for irrigation purpose directly, but the groundwater may be used after implementing some suitable treatment techniques.

***Keywords*—**Physico-Chemical Parameters, Tannery Industry Effluent, Groundwater Quality Indices.

I. Introduction

GROUNDWATER is ultimate, most suitable fresh water resource used for domestic, industrial and agricultural purposes. Groundwater is the major source, particularly used as drinking water in both urban and rural areas [2].Nowadays, the use of groundwater has gradually increased due to the increase of water demand and the shortage of surface water [3], which has led to its over exploitation and subsequently the quantity of groundwater becomes scarce [3]-[5]. The quality of groundwater gets deteriorated due to improper treatment and disposal of domestic sewage, industry wastewater on the land, results, developing countries is facing the groundwater quality reduction problems [6].Further, the agricultural runoff on land can overload chemicals, wastes and nutrients on groundwater and make the groundwater is toxic, as a result, the groundwater is not fit for any uses [7].

In addition, by considering the effects of groundwater contamination due to physico-chemical changes [8], sea water intrusion [9], heavy metal contamination and industrial pollution [10]-[12], and solid waste contamination [13]-[15],long-term conservation of groundwater are to be required for maintaining the quality of groundwater resources for its various uses. The domestic sewage and treated industrial wastewater has been widely used for irrigation, particularly, in developing countries like India, where the requirement of water for irrigation is more [16].

Though various treatment methods and remedial measures adopted for removing the contaminants in the wastewater of various sources and the polluted groundwater resources, the human being, plant and aquatic life has affected throughout the years [17].Therefore, basic monitoring of groundwater quality is important to check the pollution level of groundwater before being consumed for various needs. Different groups of chemists and biologists regularly conducted a good number of groundwater quality analysis across the country.

The main objective of this case study is to assess the groundwater quality of 5 selected sites, nearby places of Nagalkeni, Chennai, Tamil Nadu, India. As similar to previous researchers [16]-[20], the suitability of groundwater for domestic and agricultural purposes were analyzed by assessing various physico-chemical parameters like pH, EC, TDS, TH, Ca, Mg, Na, K, SO_4, NO_3, Cl_2, HCO_3, CO_3 and Cr(VI). To suit groundwater in the nearby Nagalkeni area for drinking and irrigation purposes, all physico-chemical parameters in groundwater of nearby 5 selected places of Nagalkeni were compared with BIS drinking water quality standard and irrigation indices.

II. Materials and Methods

A. Study Area

The selected study area of this present study is Nagalkeni, situated in Kanchipuram District, Tamil Nadu with 12.96 Latitude and 80.14 Longitude (Fig.1).The groundwater of Nagalkeni was polluted by untreated sewage and wastewater from tannery industry. Tannery industry wastewater contains particularly, lime, sodium-carbonate, sodium bicarbonate, common salt, sodium sulphate and chrome sulphate [6]. Chromium present in wastewater is in the form of Cr^{3+} but when tannery wastewater is discharged onto the land (soil), Cr^{3+} is in the oxidized form of Cr^{6+}, which is more toxic in nature [18]. The Cr(VI) is carcinogenic to human beings when the concentration of Cr(VI) exceeds the tolerance limit of 0.05 mg/L (BIS drinking water quality standard - IS 10500:1991). Thus, untreated sewage and untreated wastewater disposal of tannery industry on the land in Nagalkeni is leading to contaminate both soil and water environment.

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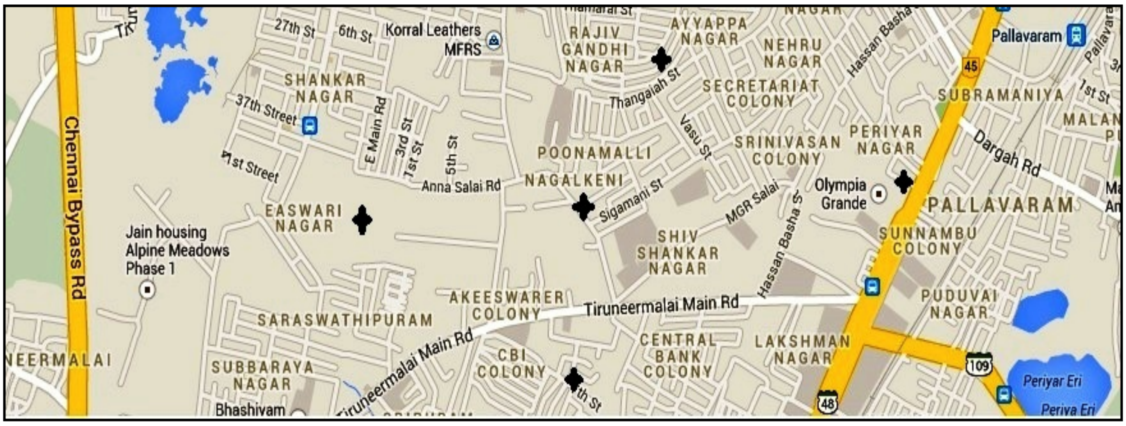

Fig. 1 Study Area of Nagalkeni for Groundwater Quality Analysis

B. *Collection of Water Samples*

The selected sites for the investigations are Nagalkeni (L1), Rajiv Gandhi Nagar (L2), Periyar Nagar (L3), CBI Colony (L4), and Easwari Nagar (L5). Totally, 15 groundwater samples were collected such a way 3 groundwater samples (both open and bore wells) from each site within the vicinity of Nagalkeni. The water samples were collected from the wells without the presence of bubbles using cleaned air tight plastic bottles. The collected groundwater samples were immediately stored in a refrigerator to avoid contaminations at 5°C. The groundwater samples collected in the month of July 2013. The various physico-chemical analyses were carried out for the collected samples in the Environmental Engineering Laboratory.

C. *Experimental Analysis*

Analyzed the collected groundwater samples for various physico-chemical parameters like pH was measured with the help of pH meter, electrical conductivity (EC) was measured with the help of an electrical conductivity meter, anions like Ca, Mg, Na and K, and cations like SO_4, $NO_{3,}$ and$Cl_{2,}$ were measured as per the standard procedures stipulated by APHA [1]. The Cr(VI) was measured with the help of UV spectrophotometer.

The values of these physico-chemical parameters in a groundwater of different areas are used to determine the suitability of groundwater for drinking and irrigation purposes. The BIS drinking water standard is used for checking the groundwater suitability for drinking purposes. Irrigation water quality indices such as a sodium adsorption ratio (SAR), soluble sodium percentage (SSP) and residual sodium carbonate (RSC) along with BIS water quality standard used to check the groundwater from selected areas are suitable for irrigation purposes.

D. *Sodium Adsorption Ratio*

The sodium adsorption ratio gives a clear idea about the adsorption of sodium by soil. It is the proportion of sodium to calcium and magnesium, which affects the availability of the water to the crop. The Sodium Adsorption Ratio (SAR) can be calculated by the following equation:

$$\mathrm{SAR} = \frac{\mathrm{Na}}{\sqrt{(\mathrm{Ca+Mg})/2}} \tag{1}$$

where, all the ions are expressed in meq/L.

E. *Soluble Sodium Percentage*

Sodium percent is an important factor for studying sodium hazard. It is also used for adjudging the quality of water for agricultural purposes. High percentage sodium water for irrigation purpose may stunt the plant growth and reduces soil permeability. The Soluble Sodium Percentage (SSP) can be calculated by the following equation:

$$\mathrm{SSP} = \frac{(\mathrm{Na+K})\times 100}{\mathrm{Ca+Mg+Na+K}} \tag{2}$$

where, all the ions are expressed in meq/L.

F. *Residual Sodium Carbonate*

If groundwater having high concentration of bicarbonate, there is a tendency for calcium, magnesium and sodium to precipitate as a result, the relative proportion of calcium, magnesium and sodium in the water is increased in the form of calcium, magnesium and sodium carbonate. RSC is calculated as

$$\mathrm{RSC} = (\mathrm{HCO_3} + \mathrm{CO_3}) - (\mathrm{Ca} + \mathrm{Mg}) \tag{3}$$

where, all ionic concentrations are expressed in meq/L.

III. Results And Discussions

The physical and chemical parameters exhibit considerable variations from sample to sample. All the analyses were carried out near the temperature of 30°C. Groundwater quality variation at sample sites (from L1 to L5) for the parameters pH, EC, TDS, total hardness (TH), anions like Ca, Mg, Na and K, and cations like SO_4, $NO_{3,}$ $Cl_{2,}$ HCO_3, and CO_3,and Cr(VI) are presented in Table I. The experimental results are compared with BIS drinking water quality standard (Table II). The statistical analysis includes minimum, maximum, mean, standard deviation was done using SPSS 15.0 (Table III).

TABLE I
THE EXPERIMENTAL RESULTS OF ALL PHYSICO-CHEMICAL PARAMETERS

Sample No. / Parameters	L1	L2	L3	L4	L5
pH	6.86	6.35	6.04	6.16	5.47
EC	3152.02	2960.99	2272.76	2631.39	1822.3
TDS	2017.29	1895.03	1454.57	1684.09	1166.27
TH	605.35	512.95	386.12	419.75	271.70
Ca	148.21	125.61	65.38	88.18	53.99
Mg	39.05	35.00	28.85	32.14	25.99
Na	457.18	386.38	237.31	287.25	197.21
K	26.03	23.33	19.23	21.43	17.33
HCO_3	165.25	145.23	108.5	128.52	93.62
CO_3	132.25	118.52	104.25	91.45	72.53
Cl_2	585.89	460.36	415.25	345.20	312.65
SO_4	624.36	586.82	356.25	454.80	260.85
NO_3	41.50	39.18	27.20	35.20	26.03
Cr(VI)	0.19	0.16	0.12	0.14	0.09

All parameters are expressed as mg/l except pH and EC is expressed as µmhos/cm

TABLE II
BIS DRINKING WATER QUALITY STANDARD

Parameters	BIS Standards(IS : 10500, 91 revision, 2003)
pH	6.5-8.5
EC,	-
TDS, mg/l	500
TH, mg/l	300
Ca, mg/l	75
Mg mg/l	30
Na, mg/l	200*
K, mg/l	-
HCO_3, mg/l	-
CO_3, mg/l	-
Cl_2, mg/l	250
SO_4, mg/l	200
NO_3, mg/l	45
Cr(VI), mg/l	0.05

*Standard of WHO

TABLE III
STATISTICAL ANALYSIS FOR THE SELECTED WELL SAMPLES

Sample No. / Parameters	MIN.	MAX.	MEAN	S.D.
pH	5.47	6.86	6.18	0.50
EC	1822.30	3152.02	2567.89	534.50
TDS	1166.27	2017.29	1643.45	342.08
TH	271.70	605.35	439.17	126.78
Ca	53.99	148.21	96.27	39.89
Mg	25.99	39.05	32.21	5.11
Na	197.21	457.18	313.07	107.21
K	17.33	26.03	21.47	3.41
HCO_3	93.62	165.25	128.22	28.49
CO_3	72.53	132.25	103.80	23.22
Cl_2	312.65	585.89	423.87	107.49
SO_4	260.85	624.36	456.62	152.88
NO_3	26.03	41.50	33.82	6.97
Cr(VI)	0.09	0.19	0.14	0.04

From Table I, it may be observed that the pH value of all sites is within the BIS limit and groundwater is in acidic condition. The identified all parameters are not within the prescribed limits as mentioned in the BIS except the nitrate, whose value in all sites is within the prescribed limits as mentioned in the BIS. From the results mentioned in the Table I, it was found that the groundwater from the selected sites (L1 to L5) is not suitable for drinking purposes directly, but it can be used for drinking purpose after adopting suitable treatment processes. Further, to know the suitability for irrigation purposes, the quality parameters are compared with irrigation water quality indices.

A. Hardness

Hardness is the sum of Ca and Mg concentrations expressed in terms of mg/l of calcium carbonate. The degree of hardness in water is commonly based on the classification listed in Table IV and hardness of groundwater of selected sites is given in Table V.

TABLE IV
CLASSIFICATION OF WATER HARDNESS

Hardness range(mg/l of $CaCO_3$)	Water Classification
0 – 75	Soft
75 – 150	Moderately hard
150 – 300	Hard
>300	Very Hard

TABLE V
GROUNDWATER QUALITY BASED ON HARDNESS

Sample locations	EC value	Remark
L1	605.35	Very Hard
L2	512.95	Very Hard
L3	386.12	Very Hard
L4	419.75	Very Hard
L5	271.70	Hard

From Table V, it may be observed that hardness from the selected sites is within the range of 271.70 to 605.35 mg/l.The groundwater quality of the selected sites can be classified as very hard for the sites L1, L2, L3 and L4 and hard for the site L5 and the quality of groundwater are unsuitable for irrigation.

B. Salinity Hazards

Electrical Conductivity: Electrical conductivity is a measure of water's capacity to conduct electric current. As most of the salts in the water are present in the ionic form, so they are responsible to conduct electric current. Generally, groundwater tends to have high electrical conductivity due to the presence of high amount of dissolved salts. In order to classify the type of groundwater based on the salinity hazard, the total concentration of soluble salts in groundwater can be expressed in terms of specific conductance. Salinity hazard classification is presented in Table VI and the salinity hazard of groundwater of selected sites is given in Table VII.

TABLE VI
SALINITY HAZARD CLASSES

Salinity Hazard Class	EC,(μmhos/cm)	Remark on quality
C1	100-250	Excellent
C2	250-750	Good
C3	750-2250	Doubtful
C4	>2250	Unsuitable

TABLE VII
GROUNDWATER QUALITY BASED ON EC

Sample locations	EC value	Class	Remark
L1	3152.02	C4	Unsuitable
L2	2906.99	C4	Unsuitable
L3	2072.76	C3	Doubtful
L4	2631.39	C4	Unsuitable
L5	1822.30	C3	Doubtful

From Table VII, it may be observed that EC from the selected sites are within the range of 1822.30 to 3152.02 μmhos/cm, and hence, the groundwater quality of the selected sites can be classified as C4 (L1, L2 and L4) and C3 (L3 and L5) group and the quality of groundwater is doubtful and unsuitable for irrigation.

Total Dissolved Solids: Total dissolved solids in a water sample include all solid materials in solution, whether ionized or not. It does not include suspended sediments, colloids or dissolved gases. TDS is the numerical sum of all dissolved solids determined accurately by chemical analyses. Its general acceptance level is 500 mg/L according to BIS standard (Table II). But, WHO has set an allowable limit of 1500 mg/L. In the study area, the TDS varies from 1166.27 to 2017.29 mg/L. It is exceeding the BIS limit. Salinity hazard classification of groundwater based on TDS is presented in Table VIII and the salinity hazard based on TDS on groundwater of selected sites is given in Table IX. From Table IX, it can be stated that, the water of the study area (L1 to L5) belongs to brackish water.

TABLE VIII
SALINITY HAZARD CLASSES [21]

SalinityHazard Class	TDS,(mg/L)	Remark onquality
C1	0-1000	Fresh Water
C2	1000-10000	Brackish Water
C3	10000-100000	Saline Water
C4	>100000	Brine

TABLE IX
GROUNDWATER QUALITY BASED ON TDS

Sample locations	TDS value	Class	Remark
L1	2017.29	C2	Brackish water
L2	1895.03	C2	Brackish water
L3	1454.57	C2	Brackish water
L4	1684.09	C2	Brackish water
L5	1166.27	C2	Brackish water

C. Sodium Hazards

Sodium Adsorption Ratio: The SAR classification of groundwater samples from the study area is presented in Table X and the sodium hazard based on SAR of groundwater of selected sites is given in Table XI. From Table XI, it may be observed that SAR from the selected sites is between 10.43 and 20.60, and hence, the groundwater quality of the selected sites (L1 and L2) can be classified as S3 group, may be doubtful for irrigation. The sites L3, L4 and L5 can be classified as S2 group may be used for irrigation.

TABLE X
SODIUM ADSORPTION RATIO SAR CLASS

Sodium hazard class	SAR(meq/L)	Remark on quality
S1	>10	Excellent
S2	10-18	Good
S3	18-26	Doubtful
S4	>26	Unsuitable

TABLE XI
GROUNDWATER QUALITY FROM SELECTED SITES FOR SAR

Sample locations	SAR Value	Class	Remark
L1	20.60	S3	Doubtful
L2	18.75	S3	Doubtful
L3	12.15	S2	Good
L4	12.91	S2	Good
L5	10.43	S2	Good

Soluble Sodium Percentage: Sodium percent is an important factor for studying sodium hazard. It is also used for adjudging the quality of water for agricultural purposes. High percentage sodium water for irrigation purpose may stunt the plant growth and reduces soil permeability. The SSP classification of groundwater samples from the study area is presented in Table XII and the sodium hazard based on SSP of groundwater of selected sites is given in Table XIII.

TABLE XII
SOLUBLE SODIUM PERCENTAGE (SSP) CLASS [22]

Sodium hazard class	SSP(meq/L)	Remark on quality
S1	<20	Excellent
S2	20-40	Good
S3	40-80	Doubtful
S4	>80	Unsuitable

TABLE XIII
GROUNDWATER QUALITY FROM SELECTED SITES FOR SSP

Sample locations	SSP Value	Class	Remark
L1	95.30	S4	Unsuitable
L2	94.39	S4	Unsuitable
L3	90.17	S4	Unsuitable
L4	92.24	S4	Unsuitable
L5	86.75	S4	Unsuitable

From Table XIII, it may be observed that the soluble sodium percentage values of shallow groundwater in the study area range between 86.75 and 95.30, indicating very high alkali hazards and hence, the groundwater quality of the selected sites (from L1 to L5) can be classified as S4 group and the quality of groundwater is unsuitable for irrigation. Thus, the water has to be treated before it is used for the purpose of irrigation otherwise; there is a serious possibility of crop failure, which may lead to huge economic loss for the farmers.

D. Residual Sodium Carbonate

The classification of RSC is presented in Table XIV and the groundwater of the study area is classified based on RSC is presented in the Table XV. From the Table XV, it may be observed that the RSC value that were obtained for 5 places were found to be > 2.25 and thus they are not suitable for irrigation purposes.

TABLE XIV
RESIDUAL SODIUM CARBONATE (RSC) CLASS

RSC(meq/L)	Remark on quality
<1.25	Good
1.25-2.25	Doubtful
>2.25	Unsuitable

TABLE XV
GROUNDWATER QUALITY FROM SELECTED SITES FOR RSC

Sample locations	RSC(meq/L)	Remark
L1	5.02	Unsuitable
L2	4.44	Unsuitable
L3	3.62	Unsuitable
L4	3.36	Unsuitable
L5	2.53	Unsuitable

The above variations are mainly due to more wastewater generated from the tannery industry sectors left in the land and the same infiltrated through porous soil media, reached the groundwater system and finally groundwater get contaminated. In addition, the above variations are due to anthropogenic impact of processes carried out in tannery industry; all quality parameters of groundwater were also contaminated. Further, due to municipal wastewater, leachate from all dumping places also contaminated the groundwater. The wastewater contains toxic / non-toxic, organic and inorganic substances and many of which were not readily susceptible to biodegradation. Finally, these pollutants in the form of dissolved materials carried cause irreversible groundwater contamination.

IV. CONCLUSION

In order to assess the groundwater suitability for drinking and irrigation purposes, experimental investigations have been performed on various parameters like pH, EC, TDS, TH, Ca, Mg, Na, K, SO_4, $NO_{3,}$ $Cl_{2,}$ $HCO_{3,}$ CO_3 and Cr(VI) in the groundwater and those parameters have also been compared with BIS water quality standard and irrigation quality indices. From the results of this study, it may be concluded that the groundwater is not suitable for drinking and irrigation purposes directly, but it can be used for both purposes after adopting proper treatment techniques. In addition to the groundwater quality parameter analysis, other factors like soil types, soil engineering properties, crop types, cropping patterns, frequency of rainfall, frequency of irrigation, climate, etc. have important factors in determining the suitability of groundwater for irrigation purposes.

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