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Research paper

Groundwater Quality Assessment for Irrigation in Madhavaram

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Abstract

The study focused to assess the groundwater in Madhavaram, Chennai, Tamil Nadu, for irrigational purposes. Irrigation indices like SAR, SSP, PI and KR was determined in each groundwater sample to identify its irrigational suitability. This study further envisaged that these groundwater aquifers have low Sodium adsorption ratio and hence groundwater is fit for irrigation, while residual sodium bicarbonate and Kelly's ratio values indicated that majority of these aquifer have water of marginal to harmful quality against irrigation. The dominance pattern of cations in the studied ground water was in the order of Na > Ca > Mg > K and the sequence of anionic dominance was as follows: Cl > HCO_3 > SO_4. All 20 wells fall under the excellent category of SAR. SSP values of groundwater range from 49 to 71 and indicated that 15 wells are under permissible and 5 wells are under doubtful classification. PI value indicated that groundwater is unsuitable against irrigation. The KR indicated that groundwater quality in 18 wells is not fit for irrigation. Hence, necessary pre-treatment methodology is to be adopted for utilizing groundwater for irrigation purpose.

Keywords: *Groundwater; Urban Pollution; Physico-chemical parameters; Irrigation Indices*

1. Introduction

Water resource scarcity was observed in many part of world because of highly contamination by various industrial discharges to the land and nearby water bodies. Along with the natural surface water resources, groundwater is used to serve various purposes like domestic uses, agricultural uses and industrial uses. But due to over population demand, industrial growth, groundwater gets polluted.

Groundwater quality depends on surface water, subsurface water and geology of soil. The change in quality of groundwater affects the all living beings particularly human health. The geochemical parameters in groundwater also affect the quality of groundwater, and hence, it is necessary to assess the groundwater quality in terms of various geochemical parameters before it is used for domestic, agricultural and industrial uses.

Arshid Jehangir [1] studied the geochemistry parameters and irrigation quality indices for water along Jhelum river. Irrigation indices were calculated for irrigation purposes in Bapatla was studied by Devojee [2]. The drinking and irrigation suitability of groundwater in Pugalur, TN was studied by Jafar [3].

Krishnakumar [4] focused the groundwater in Vedaraniyam for its suitability for irrigation. The water quality parameters for surface water and groundwater in Bargarh were determined by Mahananda againt the suitability of irrigation [5]. Nag [6] used GIS to assess gruondwaer quality for both domestic and irrigation uses in Birbhum District, West Bengal, India. Sinha [7 assessed groundwater quality for irrigation in a hard rock hilly terrain using GIS and suitability of groundwater for Irrigation in Pulicat using GIS also studied by Sivakumar [8].

Groundwater quality is not only pollution by urbanization, but also polluted due to industrialization. In this aspect, suitability of groundwater around Pallavaram, tannery industry belt, Chennai was studied by Sivakumar [9, 10].

Thus, this project mainly focused to investigate the groundwater quality to suit irrigation purposes in Madhavaram, Chennai. The objectives framed for this study are assessing physico-chemical quality parameters in groundwater of Madhavaram and finding the groundwater utilization for irrigation with the help of irrigation indices viz., SAR, SSP, PI and KR.

2. Methods and Materials

2.1 Study Area

The study area is Madhavaram and it is a Taluk located between Perambur and Kodungaiyur in North Chennai, Tamil Nadu. The latitude and longitude of Madhavaram is 13.14 and 80.23 respectively. The satellite image of Madhavaram is shown in Fig. 1.

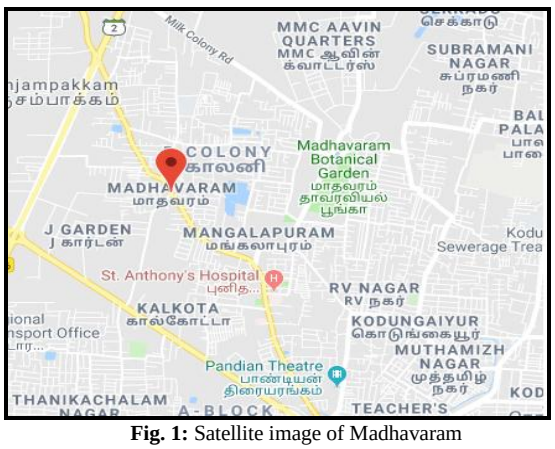

Fig. 1: Satellite image of Madhavaram

2.2 Collection of Groundwater Samples

The sterilized bottles used for collecting bore well water samples. The 20 bore well water samples collected and were analyzed against basic water quality parameters as per APHA, 2005. The latitude and longitude of 20 bore wells are presented in Table 1.

Table 1: Latitude and longitude details of the sites

Well No	Latitude	Longitude
w1	13.11783	80.20350
w2	13.11800	80.19600
w3	13.14305	80.24019
w4	13.15250	80.24789
w5	13.15654	80.23410
w6	13.14122	80.19848
w7	13.15141	80.20490
w8	13.14908	80.21990
w9	13.14780	80.24650
w10	13.13481	80.20840
w11	13.13655	80.21983
w12	13.13624	80.22776
w13	13.13833	80.23559
w14	13.13893	80.24511
w15	13.12822	80.20347
w16	13.12399	80.20936
w17	13.12981	80.21848
w18	13.12762	80.22518
w19	13.11930	80.21210
w20	13.12019	80.22251

3 Results and Discussion

The parameters pH, total dissolved solids, total hardness, calcium, magnesium, chloride, sulphate, nitrate, fluoride, sodium, total alkalinity, bicarbonate and potassium were analysed in the 20 bore wells water around Madhavaram. Table 2 represents the various parameters in groundwater samples from 20 sites.

Table 2: Physico-chemical parameters of 20 bore well samples

Wells	EC	pH	Ca	Mg	Na	K	HCO_3	SO_4	Chloride	Nitrate	Fluoride	TDS	TH ($CaCO_3$)	Total Alkalinity
1	3830	7.1	88	182	433	3	580	10	922	9	1	2032	970	475
2	850	7.2	38	22	110	0	275	40	121	4	1	473	185	225
3	2520	6.4	74	41	413	5	336	151	549	35	0	1436	355	275
4	1040	5.9	68	16	131	0	195	69	149	102	0	633	235	160
5	1560	6.4	86	39	177	16	122	66	340	169	0	949	375	100
6	2138	6.9	67	79	217	4	959	48	467	38	0	1175	495	293
7	2007	6.6	72	63	255	6	298	65	433	69	0	1131	441	244
8	1883	6.5	77	48	248	9	240	81	402	99	0	1091	390	196
9	1448	6.1	71	25	204	2	227	88	263	89	0	864	279	187
10	2356	6.9	70	91	287	4	383	46	525	35	0	1287	550	314
11	2158	6.6	74	65	285	6	314	75	470	63	0	1214	452	257
12	2123	6.5	75	50	304	6	292	99	456	68	0	1212	393	239
13	2286	6.4	74	41	358	5	306	130	492	53	0	1311	357	251
14	2217	6.3	74	39	348	5	301	129	471	55	0	1270	344	246
15	2553	7.1	69	110	299	2	435	29	578	16	1	1373	624	356
16	2969	7.1	75	132	344	3	479	25	690	16	1	1588	733	392
17	2377	6.8	73	85	299	4	369	58	529	44	0	1309	532	301
18	2263	6.6	73	71	299	5	338	74	496	53	0	1262	472	276
19	3040	7.0	77	136	352	3	486	25	709	16	1	1626	751	398
20	2473	6.8	73	93	307	4	389	53	554	38	0	1354	564	318

3.1 Physico-Chemical Analysis

From Table 2, it may be noted that the pH values of the groundwater varied from 5.9 to 7.1 indicates that neutral quality of groundwater, and hence, it may be used for all purposes.

The TDS values were ranged between 473 and 1626 mg/l indicated that the TDS was contributed by sewage discharges. The EC values were varied between 850 and 3830 µS/cm. The average value of EC found in this study area is 2204.5 µS/cm, indicated that more dispersible ions are presented in the groundwater because of geology of earth crust along with improper disposal of wastewater on land. The total hardness value ranged between 185 and 970 mg/l. The average total hardness value found to be 74.82 mg/l. Calcium concentration varied from 38 mg/l to 88 mg/l. The concentration of magnesium in 20 bore well water ranged between 22 and 182 mg/l. The concentration of sodium in groundwater varied from 110 to 433 mg/l. Potassium values reached to 16 from 0 mg/l. Bicarbonate values in 20 bore wells varied from 122 to 959 mg/l. The average value of bicarbonate found in the study area is 366.18 mg/l. The concentration of sulphate varied between 10 and 151 mg/l with an average of 68.02 mg/l. The chloride concentration were found between 121 and 922 mg/l with an average of 480.82 mg/l. Nitrate concentration is found from 4 to 169 mg/l with an average of 53.45 mg/l. Fluoride concentration was established from 0 to 1 mg/l. Total alkalinity ranged from 100 to 475 mg/l. The average alkalinity of this study area is 275.262 mg/l. All values are indicating the quality of groundwater collected from 20 wells.

3.2 Irrigation Water Quality Indices

Various irrigation indices like sodium adsorption ratio (SAR), soluble sodium percentage (SSP), and permeability index (PI) are important indices along with Kelley's ratio (KR) to judge the groundwater against irrigation. The results of SAR, SSP, PI and KR are presented in Table 3.

Table 3: The results of SAR, SSP, PI and KR for 20 bore wells of groundwater in Madhavaram

Well No.	SAR	SSP	PI	KR
1	6.02	49.14	101.00	0.96
2	3.50	56.16	111.30	1.28
3	9.52	71.76	102.67	2.52
4	3.70	54.61	106.80	1.2
5	3.96	51.78	101.89	1.02
6	4.22	48.82	109.25	0.94
7	5.26	55.85	103.18	1.25
8	5.45	58.39	102.97	1.38
9	5.31	61.54	104.52	1.59
10	5.30	53.13	102.85	1.13
11	5.81	57.97	102.94	1.36
12	6.64	62.82	102.94	1.67
13	8.23	68.69	102.83	2.17
14	8.15	68.86	102.94	2.19
15	5.18	50.92	102.66	1.03

16	5.50	50.40	101.98	1.01
17	5.61	54.96	102.73	1.21
18	5.95	57.89	102.86	1.36
19	5.56	50.36	101.88	1.01
20	5.60	54.17	102.63	1.17

3.2.1 Sodium Adsorption Ratio (SAR)

SAR determines the cation exchange property of soil with water. It affects the soil structure when sodium is replace with calcium and magnesium. SAR by calculated by

$$SAR = Na^{+} / [(Ca^{2+} + Mg^{2+})/2]^{0.5} \quad (1)$$

SAR value is unit less however, the parameter values are substituted in meq/l. Classification of 20 bore wells water sample against SAR is presented in Table 4.

Table 4: SAR values classification of groundwater (Todd 1959; Richards 1954)

Water Quality Type	SAR Values	No of Samples
Excellent	< 10	20
Good	10 - 18	0
Doubtful	18 – 26	0
Unsuitable	> 26	0

3.2.2 Soluble Sodium Percentage (SSP)

SSP indicates the availability of sodium in groundwater which increases the hardness and permeability of soil for plants growth. It can be calculated by

$$\mathbf{SSP} = [(Na + K) / (Ca + Mg + Na + K)] \times 100 \quad (2)$$

where, all parameters are expressed in meq/l.
The water quality classification of 20 bore wells water based on SSP is presented in Table 5.

Table 5: SSP classification of groundwater

Water Quality Type	SSP Values	No of Samples
Excellent	< 20	0
Good	20 - 40	0
Permissible	40 - 60	15
Doubtful	60 - 80	5
Unsuitable	> 80	0

All 20 wells are excellent category according to SAR Values. From all the study sites had very low SAR values, which ranged between 5 and 10, indicating that groundwater samples had excellent quality against irrigation. The SSP values found for the groundwater collected in Madhavaram study area varied from 49 to 72, of which, SSP values in 15 sites found between 40 and 60. According to Todd, all 15 sites belong to permissible category except 5 sites (3, 9, 12, 13, and 14) which belong to doubtful category. Low SAR and SSP seemed to be due to significant quantities of divalent calcium and magnesium.

3.2.3 Wilcox Diagram

Wilcox diagram was arrived using the values of SSP and EC. The Wilcox diagram is shown in Fig. 2. Wilcox diagram specified that groundwater samples fell under the "Good to permissible" and "doubtful to unsuitable" categories. The Wilcox classification for the groundwater of 20 bore wells is presented in Table 6.

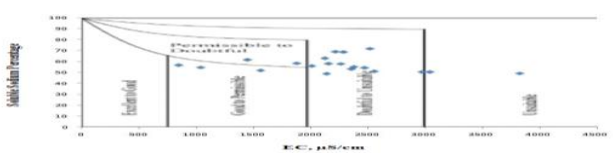

Fig. 2: Wilcox diagram for Irrigation Classification

Table 6: Wilcox diagram observation

Water Quality	SSP Values	No of Samples (Wilcox Observations)
Excellent	< 20	0
Good	20 - 40	3 (W2, W4, W5)
Permissible	40 - 60	2 (W9, W8)
Doubtful	60 - 80	13 (W3, W6, W7, W10, W11, W12, W13, W14, W15, W16, W17, W18, W20)
Unsuitable	> 80	2 (W1, W19)

3.2.3 Permeability Index (PI)

Permeability of soil is affected by occurrence of various ions like Na^{+}, Ca^{2+}, Mg^{2+} and HCO_3 contents. Hence, it is necessity to calculate permeability index against irrigation. It can be determined by

$$PI = (Na^{+} + \sqrt{HCO_3}) \times 100 / (Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}) \quad (3)$$

The PI values ranged between 101 and 105 (Table 3). The values of PI indicated that all 20 groundwater bore wells come under the category of class III and indicted groundwater is not suited for irrigation (Table 7).

Table 7: PI classification of groundwater (Gupta and Gupta, 1987)

Water Quality Type	PI Values	No of Samples
Suitable for irrigation	< 80	0
Moderate for irrigation	80 - 100	0
Unsuitable for irrigation	> 100	20

3.2.4 Kelly's Ratio (KR)

Kelly's Ratio (KR) used to know the availability of calcium and magnesium against sodium. If KR < 1, water is used for irrigation and > 1 indicates not suitable for irrigation. KR is determined by

$$KR = Na / (Ca+Mg) \quad (4)$$

where, all parameters in meq/l.

Table 8: KR classification of groundwater

Water Quality Type	KR Values	No of Samples
Suitable for Irrigation	< 1	2
Not Suitable for Irrigation	> 1	18

The KR showed that water quality in 18 bore well samples are not suitable and only 2 bore wells are suitable for irrigation (Table 8).

4 Conclusions

The groundwater quality of Madhavaram, Chennai, Tamil Nadu was assessed for irrigation. The irrigation quality indices were calculated based on calcium, magnesium, potassium, sodium and bicarbonate. Groundwater from most of the bore wells was found very hard in nature, because of availability of more calcium, magnesium and sodium. All the 20 wells fall under the excellent category of SAR. The SSP values of groundwater indicated that most of bore wells were not suited for irrigation. The Wilcox diagram indicated that the groundwater quality fell under "Good to permissible" and "doubtful to unsuitable" categories. PI values represented that groundwater in Madhavaram can be labeled as a class III (100-120%) and showed that water from bore wells are unsuited against irrigation. The Kelly's ratio showed that water quality in 18 wells is not suitable for irrigation. Hence, it is necessary to adopt some pre-treatment methodology for utilizing groundwater for irrigation purpose.

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