Hydro-Chemical Evaluation of Ground Water Quality in Meenambalam, Kollam District, Kerala, India

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Abstract— The suitability of groundwater quality for domestic and drinking purposes was assessed in Meenambalam area based on the various water quality parameters. Five groundwater samples were collected and analysed for parameters like pH, electrical conductivity, turbidity, total dissolved solids, dissolved oxygen, bio-chemical oxygen demand, acidity, alkalinity, total hardness, calcium hardness and cations (Ca^{2+}, Mg^{2+}).

Index Terms— Acidity, Alkalinity, Bio-chemical oxygen demand, Dissolved oxygen, Electrical conductivity, Groundwater quality, Meenambalam area, Suitability for drinking purposes, Total dissolved solids, Total hardness, Water quality parameters

1. INTRODUCTION

Quality of water is an important factor when human health is considered. As the quality of water decreases, the effects on human health will increase. So it is essential to evaluate the groundwater quality in a region. Water quality determines the suitability of water for a particular purpose [1]. The main source of water resource for drinking and agricultural purposes is groundwater. So importance of the groundwater quality in an area should not be underestimated [2].

Hydro-chemical characteristics of groundwater of Meenambalam region, Kollam district, Kerala, India was selected to evaluate the suitability of groundwater for drinking and domestic purposes and to estimate the Water quality Index (WQI). The co-ordinate of the region is 8°48'41''N 76°44'16''E. Water quality index is a very useful tool for communicating the information on general quality of water to the citizens in the study area [3]. Hydro-chemical characteristics and contamination of groundwater in rural areas as well as in urban areas that caused due to the anthropogenic intervention like agricultural activities, industrial and domestic waste water were the main focus area of many researchers [4]

Fig.1. Location map

2. OBJECTIVES

The objectives of this study were

1. To evaluate the ground water quality in Meenambalam area, Kollam district, Kerala, India.
2. To determine the quantity of various physical and chemical parameters of groundwater in the study area.
3. To evaluate the suitability of groundwater for drinking purpose and to estimate the Water Quality Index.

3. MATERIALS AND METHODS

The current study was done to investigate the conditions of groundwater contamination in the

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study area. The hydro-chemical evaluation was done by collecting 5 groundwater samples from the wells in Meenabalam area during February – March, 2016. Prior to sampling, the sampling containers (prewashed plastic polythene bottles) were cleaned and rinsed with the groundwater. The electrical conductivity and pH was measured immediately after the sampling was completed. The pH values were measured with the help of digital pH meter and the electrical conductivity values were measured with the help of conductivity meter. Turbidity was determined using Nephelometer and all other chemical analysis was completed within the sampling day itself. Titration method was used to determine the concentration of various constituents in the groundwater.

In this study the water quality index is calculated based on the standards of drinking water quality recommended by the Bureau of Indian Standards (BIS) [15], Indian Council of Medical Research (ICMR) [16] and World Health Organisation (WHO) has been used for the calculation of WQI of the water body.

The overall Water Quality Index calculated by aggregating the quality rating with the unit weight linearly.

$$\text{Water Quality Index} = \Sigma q_n W_n / \Sigma W_n$$

Where quality rating or sub index (q_n) was calculated using the following expression.

$$q_n = 100 \times (V_n - V_{io}) / (S_n - V_{io})$$

Let there be n water quality parameters and quality rating or sub index (q_n) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value

q_n=Quality rating for the n^{th} Water quality parameter.

V_n=Estimated value of the n^{th} parameter at a given sampling station.

S_n=Standard permissible value of the n^{th} parameter.

V_{io}=Ideal value of n^{th} parameter in pure water, (i.e.,0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/L respectively).

Unit weight was calculated by a value inversely proportional to the recommended standard value S_n of the corresponding parameter.

$$W_n = K / S_n$$

W_n=Unit weight for the nth parameters.

S_n=Standard value for n^{th} parameters.

K=Constant for proportionality.

Where $K = 1/\Sigma (1 / S_n)$

Table 1: Status and Index level (WQI) of water quality [13][14]

Water quality status	Water Quality Index Level
Excellent water quality	0 – 25
Good water quality	26 – 50
Poor water quality	51 – 75
Very Poor water quality	76 – 100
Unsuitable for drinking	>100

Table 2: Instrumental and Volumetric methods used for the hydro-chemical analysis of groundwater in Meenambalam area, Kollam district, Kerala, India

Parameter	Method	Unit
pH	Electrometric	-
EC	Electrometric	µS/cm
Turbidity	Nephelometric	NTU
TDS	EC x Conversion factor	mg/l
DO	Azide modification	mg/l
BOD	5 day BOD test	mg/l
Hardness	EDTA titrimetric	mg/l
Ca^{2+}	EDTA titrimetric	mg/l
Mg^{2+}	Calculation	mg/l
Acidity	Titration	mg/l
Alkalinity	Titration	mg/l

4. RESULTS AND DISCUSSION

The analytical results of hydro-chemical analysis of groundwater samples collected from different

sampling sites of Meenambalam area, Kollam district, Kerala, India. Table 2 presents the hydro-chemical characteristics of groundwater in the study area.

Table 3: Hydro-chemical characteristics of groundwater in Meenambalam area, Kollam district, Kerala, India

Sample	Electrical Conductivity (µS/cm)	pH
1	115.4	3.93
2	69.9	6.84
3	132.9	5.32
4	128.7	4.78
5	143.7	5.52
6	151.9	6.88
7	169.3	6.70
8	145.4	6.96
9	172.3	7.13
10	144.1	6.91
Sample	Turbidty (NTU)	TDS (mg/l)
1	5	73.86
2	3	44.74
3	5	85.06
4	3	82.37
5	4	91.97
6	1	97.22
7	2	108.35
8	1	93.06
9	2	110.27
10	2	92.22
Sample	Total Hardness (mg/l)	Calcium Hardness (mg/l)
1	16	12
2	24	22
3	24	12
4	28	20
5	24	12
6	22	16
7	16	12
8	26	22
9	20	14
10	28	20
Sample	Calcium (mg/l)	Magnesium (mg/l)
1	4.810	0.972
2	8.818	0.486
3	4.810	2.916
4	8.016	1.944
5	4.810	2.916
6	6.413	1.458
7	4.810	0.972
8	8.818	0.972
9	5.611	1.458
10	8.016	1.944
Sample	DO (mg/l)	BOD (mg/l)
1	3.24	0.81
2	5.67	1.62
3	6.08	1.22
4	3.24	1.03
5	6.48	2.43
6	4.86	1.13
7	4.03	1.08
8	5.67	1.32
9	6.68	2.47
10	5.25	1.22
Sample	Alkalinity (mg/l)	Acidity (mg/l)
1	8	36
2	18	16
3	16	30
4	12	32
5	10	28
6	18	14
7	20	16
8	24	12
9	28	10
10	24	12

Table 4: Average, Maximum and Minimum values of the parameters

Parameter	Avg.	Max.	Min.
Electrical Conductivity (µS/cm)	137.36	172.3	69.9
pH	6.10	7.13	3.93

Parameter	Avg.	Max.	Min.
Turbidity (NTU)	2.8	5	1
TDS (mg/l)	87.91	110.27	44.74
Alkalinity (mg/l)	17.80	28.00	8.00
Acidity (mg/l)	20.60	36.00	10.00
Total Hardness (mg/l)	22.80	28.00	16.00
Calcium Hardness (mg/l)	16.20	22.00	12.00
Calcium (mg/l)	6.49	8.82	4.81
Magnesium (mg/l)	1.60	2.92	0.97
DO (mg/l)	5.12	6.68	3.24
BOD (mg/l)	1.43	2.47	0.81

pH is a measure of the balance between the concentration of hydrogen ions and hydroxyl ions in water. The pH of water provides vital information in many geochemical equilibrium or solubility calculations [5]. For drinking water the limit of pH is specified as 6.5-8.5 [6]. The pH value of the groundwater samples varies from 3.93 to 7.13, which clearly shows that most of the groundwater samples in the study area are slightly acidic in nature. Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation. On the opposite end of the scale, pH values below 4 also cause irritation due to the corrosive effects of low pH levels. Extreme pH levels can worsen existing skin condition [7].

Electrical conductivity (EC) is a measure of water capacity to convey electric current. The desirable limit of electrical conductivity in drinking water is 1500 µS/cm [6]. The electrical conductivity of samples in this area varies from 69.9 to 172.3µS/cm. The electrical conductivity of all samples is below the desirable limit and the value depends on the temperature, concentration and type of ions present in it [5]. The relative difference in water quality between different aquifers can be identified with the help of electrical conductivity values [8].

The total dissolved solids in the groundwater samples vary between 44.74 to 110.27mg/l, with an average value of 87.91mg/l. According to World Health Organisation (WHO) the maximum permissible limit of the total dissolved solids (TDS) is 1500mg/l and the desirable value is 500mg/l [9]. From the values obtained the groundwater in Meenambalam area contains TDS which is below to the desired value specified by the WHO.

Water that has high mineral content can be considered as hard water and the threshold limit of total hardness is 300mg/l [10]. The groundwater samples from the study area contain no hardness and the values of both total hardness and calcium hardness are well below the threshold limit. Since the concentration of total hardness is low the groundwater in this region will not cause any gall bladder issues, urinary stones and arthritis [11].

Calcium is one of the essential nutritional elements for humans and it is required to prevent cardiac disorders and for the proper functioning of metabolic processes. Calcium concentration varies from 4.81 to 8.82mg/l and the calcium concentration for drinking water is specified as 75mg/l [12]. From this we can conclude that the samples fall well below the required concentration. Similarly magnesium content in samples varies from 0.97 to 2.92mg/l. The maximum permissible limit of magnesium concentration of drinking water is specified as 100mg/l [12] and the groundwater in the study area contains magnesium concentration less than the permissible limit.

Amount of oxygen that is present in the water is the dissolved oxygen content and it is measured in milligrams per litre (mg/l), or the number of

milligrams of oxygen dissolved in a litre of water. A dissolved oxygen level that is too high or too low can harm aquatic life and affect water quality. Biochemical oxygen demand (BOD) also called biological oxygen demand is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. BOD of safe drinking water must be 0mg/l and most pristine rivers will have a 5-day carbonaceous BOD below 1 mg/l. The samples have BOD values that lie in the range of 0.81 to 2.47mg/l.

Table 5: Drinking Water standards recommending Agencies and unit weights

Sl. No.	Parameters	Standards	Unit	Recommended
1	pH	6.5-8.5	-	ICMR/BIS
2	Electrical Conductivity	300	µS/cm	ICMR
3	Total Dissolved Solids	500	mg/l	ICMR/BIS
4	Total Alkalinity	200	mg/l	ICMR
5	Total hardness	300	mg/l	ICMR/BIS
6	Calcium	75	mg/l	ICMR/BIS
7	Magnesium	30	mg/l	ICMR/BIS
8	Dissolved Oxygen	5	mg/l	ICMR/BIS
9	Biochemical Oxygen Demand	5	mg/l	ICMR
10	Turbidity	5	NTU	BIS

Table 6: Water Quality Index Calculation of S1

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	3.93	6.5-8.5	0.1512	204.67	30.950
2	Electrical Conductivity	115.40	300	0.0043	38.47	0.165
3	Total Dissolved Solids	73.86	500	0.0026	14.77	0.038
4	Total Alkalinity	8.00	200	0.0064	4.00	0.026
5	Total hardness	16.00	300	0.0043	5.33	0.023
6	Calcium	4.81	75	0.0171	6.41	0.110
7	Magnesium	0.97	30	0.0428	3.24	0.139
8	Dissolved Oxygen	3.24	5	0.2571	118.33	30.419
9	Biochemical Oxygen Demand	0.81	5	0.2571	16.19	4.163
10	Turbidity	5.00	5	0.2571	100.00	25.708
Water Quality Index =Σ qnWn ΣWn			91.74	ΣWn	Σqn	ΣWnqn
				1.00	511.41	91.74

Table 7: Water Quality Index Calculation of S2

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	6.84	6.5-8.5	0.1512	10.67	1.613
2	Electrical Conductivity	69.9	300	0.0043	23.30	0.100
3	Total Dissolved Solids	44.74	500	0.0026	8.95	0.023
4	Total Alkalinity	18	200	0.0064	9.00	0.058
5	Total hardness	24	300	0.0043	8.00	0.034
6	Calcium	8.82	75	0.0171	11.76	0.201
7	Magnesium	0.486	30	0.0428	1.62	0.069
8	Dissolved Oxygen	5.67	5	0.2571	93.01	23.911
9	Biochemical Oxygen Demand	1.62	5	0.2571	32.40	8.329
10	Turbidity	3	5	0.2571	60.00	15.425
Water Quality Index =Σ qnWn ΣWn			49.76	ΣWn	Σqn	ΣWnqn
				1.00	258.70	49.76

Table 8: Water Quality Index Calculation of S3

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	5.32	6.5-8.5	0.1512	112.00	16.937
2	Electrical Conductivity	132.9	300	0.0043	44.30	0.190
3	Total Dissolved Solids	85.06	500	0.0026	17.01	0.044
4	Total Alkalinity	16	200	0.0064	8.00	0.051
5	Total hardness	24	300	0.0043	8.00	0.034
6	Calcium	4.81	75	0.0171	6.41	0.110
7	Magnesium	2.916	30	0.0428	9.72	0.416
8	Dissolved Oxygen	6.08	5	0.2571	88.79	22.826
9	Biochemical Oxygen Demand	1.22	5	0.2571	24.30	6.247
10	Turbidity	5	5	0.2571	100.00	25.708
Water Quality Index =Σ qnWn ΣWn			72.56	ΣWn	Σqn	ΣWnqn
				1.00	418.54	72.56

Table 9: Water Quality Index Calculation of S4

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	4.78	6.5-8.5	0.1512	148.00	22.381
2	Electrical Conductivity	128.7	300	0.0043	42.90	0.184
3	Total Dissolved Solids	82.37	500	0.0026	16.47	0.042
4	Total Alkalinity	12	200	0.0064	6.00	0.039
5	Total hardness	28	300	0.0043	9.33	0.040
6	Calcium	8.02	75	0.0171	10.69	0.183
7	Magnesium	1.944	30	0.0428	6.48	0.278
8	Dissolved Oxygen	3.24	5	0.2571	118.33	30.421
9	Biochemical Oxygen Demand	1.03	5	0.2571	20.60	5.296
10	Turbidity	3	5	0.2571	60.00	15.425
Water Quality Index =Σ qnWn ΣWn			74.29	ΣWn	Σqn	ΣWnqn
				1.00	438.81	74.29

Table 10: Water Quality Index Calculation of S5

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	5.52	6.5-8.5	0.1512	98.67	14.920
2	Electrical Conductivity	143.7	300	0.0043	47.90	0.205
3	Total Dissolved Solids	91.97	500	0.0026	18.39	0.047
4	Total Alkalinity	10	200	0.0064	5.00	0.032
5	Total hardness	24	300	0.0043	8.00	0.034
6	Calcium	4.81	75	0.0171	6.41	0.110
7	Magnesium	2.916	30	0.0428	9.72	0.416
8	Dissolved Oxygen	6.48	5	0.2571	84.57	21.742
9	Biochemical Oxygen Demand	2.43	5	0.2571	48.60	12.494
10	Turbidity	4	5	0.2571	80.00	20.566
Water Quality Index =Σ qnWn ΣWn			70.57	ΣWn	Σqn	ΣWnqn
				1.00	407.27	70.57

Table 11: Water Quality Index Calculation of S6

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	6.88	6.5-8.5	0.1512	8.00	1.210
2	Electrical Conductivity	151.9	300	0.0043	50.63	0.217
3	Total Dissolved Solids	97.22	500	0.0026	19.44	0.050
4	Total Alkalinity	18	200	0.0064	9.00	0.058
5	Total hardness	22	300	0.0043	7.33	0.031
6	Calcium	6.41	75	0.0171	8.55	0.147
7	Magnesium	1.458	30	0.0428	4.86	0.208
8	Dissolved Oxygen	4.86	5	0.2571	101.45	26.080
9	Biochemical Oxygen Demand	1.13	5	0.2571	22.52	5.789
10	Turbidity	1	5	0.2571	20.00	5.142
Water Quality Index =Σ qnWn ΣWn			38.93	ΣWn	Σqn	ΣWnqn
				1.00	251.79	38.93

Table 12: Water Quality Index Calculation of S7

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	6.70	6.5-8.5	0.1512	20.00	3.024
2	Electrical Conductivity	169.3	300	0.0043	56.43	0.242
3	Total Dissolved Solids	108.35	500	0.0026	21.67	0.056
4	Total Alkalinity	20	200	0.0064	10.00	0.064
5	Total hardness	16	300	0.0043	5.33	0.023
6	Calcium	4.81	75	0.0171	6.41	0.110
7	Magnesium	0.972	30	0.0428	3.24	0.139
8	Dissolved Oxygen	4.03	5	0.2571	110.09	28.302
9	Biochemical Oxygen Demand	1.08	5	0.2571	21.50	5.527
10	Turbidity	2	5	0.2571	40.00	10.283
Water Quality Index =Σ qnWn ΣWn			47.77	ΣWn	Σqn	ΣWnqn
				1.00	294.68	47.77

Table 13: Water Quality Index Calculation of S8

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	6.96	6.5-8.5	0.1512	2.67	0.403
2	Electrical Conductivity	145.4	300	0.0043	48.47	0.208
3	Total Dissolved Solids	93.06	500	0.0026	18.61	0.048
4	Total Alkalinity	24	200	0.0064	12.00	0.077
5	Total hardness	26	300	0.0043	8.67	0.037
6	Calcium	8.82	75	0.0171	11.76	0.201
7	Magnesium	0.972	30	0.0428	3.24	0.139
8	Dissolved Oxygen	5.67	5	0.2571	93.01	23.911
9	Biochemical Oxygen Demand	1.32	5	0.2571	26.42	6.792
10	Turbidity	1	5	0.2571	20.00	5.142
Water Quality Index =Σ qnWn ΣWn			36.96	ΣWn	Σqn	ΣWnqn
				1.00	244.84	36.96

Table 14: Water Quality Index Calculation of S9

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	7.13	6.5-8.5	0.1512	8.67	1.311
2	Electrical Conductivity	172.3	300	0.0043	57.43	0.246
3	Total Dissolved Solids	110.27	500	0.0026	22.05	0.057
4	Total Alkalinity	28	200	0.0064	14.00	0.090
5	Total hardness	20	300	0.0043	6.67	0.029
6	Calcium	5.61	75	0.0171	7.48	0.128
7	Magnesium	1.458	30	0.0428	4.86	0.208
8	Dissolved Oxygen	6.68	5	0.2571	82.49	21.206
9	Biochemical Oxygen Demand	2.47	5	0.2571	49.42	12.705
10	Turbidity	2	5	0.2571	40.00	10.283
Water Quality Index =Σ qnWn ΣWn			46.26	ΣWn	Σqn	ΣWnqn
				1.00	293.07	46.26

Table 15: Water Quality Index Calculation of S10

Sl. No.	Parameters	Observed Values	Standard Values (Sn)	Unit Weight (Wn)	Quality Rating (qn)	Wn.qn
1	pH	6.91	6.5-8.5	0.1512	6.00	0.907
2	Electrical Conductivity	144.1	300	0.0043	48.03	0.206
3	Total Dissolved Solids	92.22	500	0.0026	18.44	0.047
4	Total Alkalinity	24	200	0.0064	12.00	0.077
5	Total hardness	28	300	0.0043	9.33	0.040
6	Calcium	8.02	75	0.0171	10.69	0.183
7	Magnesium	1.944	30	0.0428	6.48	0.278
8	Dissolved Oxygen	5.25	5	0.2571	97.43	25.046
9	Biochemical Oxygen Demand	1.22	5	0.2571	24.46	6.288
10	Turbidity	2	5	0.2571	40.00	10.283
Water Quality Index =Σ qnWn ΣWn			43.36	ΣWn	Σqn	ΣWnqn
				1.00	272.87	43.36

From the water quality index calculations, the samples S2, S6, S7, S8, S9 and S10 are of good quality. Samples S1, S3, S4 and S5 are of poor quality and require some treatment before consumption.

5. CONCLUSION

Analysis reveals that the groundwater of the study area needs certain degree of treatment before consumption. Also the groundwater needs to be protected from the perils of contamination. The groundwater in the study region i.e. Meenambalam, Kollam district, Kerala, India is slightly acidic and lacks the required quantity of calcium, which is essential nutritional element for humans and it is required to prevent cardiac disorders and for the proper functioning of metabolic processes.

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