IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)
e-ISSN: 2319-2402,p- ISSN: 2319-2399.Volume 15, Issue 4 Ser. I (April 2021), PP 40-51
www.iosrjournals.org

An Assessment of Ground Water Quality for Drinking and Irrigation Use in a Flood Affected Area: Chendamangalam, Ernakulam District, Kerala, India

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Abstract:
The present study mainly focuses the assessment of groundwater suitability for drinking and irrigation purpose in the flood affected area of Chendamangalam, Ernakulum district, Kerala, India. Twenty six water samples were collected from dug wells and bore wells during monsoon, post monsoon and pre monsoon seasons. The result revealed that most of the physico - chemical parameters were below the prescribed limit according to WHO standard, but the microbiological parameter total coliform count is higher than the maximum acceptance limit in the study area. Water Quality Index method is calculated by weighted arithmetic water quality index method indicate that the quality of eight ground water samples in each season was unsuitable for drinking purpose. The study reported that the wells of the study area are fall under suitable category for irrigation based on sodium percent (Na %), sodium adsorption ratio (SAR), Kelly's ratio (KR), permeability index (PI) and magnesium hazard ratio (MHR), Residual Sodium Carbonate (RSC) and Salinity diagrams (USSL & Wilcox diagrams).

Key Word*: Ground water; drinking water quality; water quality index; irrigation water quality*

Date of Submission: 14-04-2021 Date of Acceptance: 28-04-2021

I. Introduction

Groundwater is an important natural resource that is mainly used for drinking, irrigation and other industrial purposes all over the world. It occurs beneath the earth surface and it is considered as pollution free water but this valuable natural resources get deteriorated with various types of natural and anthropogenic sources[1]. A natural disaster, flood is the main sources of water pollution which enter various kinds of contaminants such as industrial, human and animal wastes into the water body through unprotected holes and surface water sources[2]. Once the contaminant enters the subsurface environment, it may remain concentrated for many years, and dispersed wide areas of groundwater aquifer and interpreting groundwater supplies unsuitable for drinking and other purposes[3]. The quality of polluted groundwater cannot be restored by stopping the contaminant from the source, therefore the regular monitoring the quality of groundwater is very important[4]. The various physio-chemical parameters play a vital role regarding the quality of groundwater for drinking and irrigation purposes. These parameters changes widely due to various type of contaminants from industrial effluents, agricultural runoff, seasonal variation and overexploitation of groundwater[5]. The main objectives of the present study are to evaluate the seasonal variation of groundwater quality parameters are collected from different locations in the Chendamangalam village and to assess its suitability for drinking and irrigation purposes. For the interpretation of the results, the all parameters used to describe the water quality of a specific area, some parameters are within the prescribed limit but others are not, then the overall quality of water is vague. Thus we suggest Water Quality Index (WQI) method, it's an important technique for evaluating the groundwater quality and its suitability for drinking purposes. It is a mathematical framework used to convert large water quality data into a single number which represent the overall water quality level. The concept of WQI was proposed by Horton[6] (1965) for drinking water assessment. This method is very useful for the communication of the quality of water for public and policy makers. The Water Quality index is calculated by using some methods such as National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Council of Ministers of the Environment Water Quality Index (CCMEWQI), Oregon Water Quality Index (OWQI) and Weighted Arithmetic Water Quality Index Method (WAWQI). WAWQI method categorized the water quality giving to the transparency by using the various water quality parameters[7]. This method has been widely used by different scientists[8, 9, 10, 11]. Like drinking water, the quality of groundwater is an important criterion to decide the water for irrigation purposes. Excessive amounts of dissolved ions in irrigation water affect plants and agricultural soil, both physically and chemically, thus decreasing the productivity[12]. The groundwater quality assessment based on different agriculture indices has been studied in different parts of world[13, 14]. The

suitability of irrigation water is verified using sodium adsorption ratio (SAR), sodium percentage (%Na), residual sodium carbonate (RSC), Kelly's ratio (KR), permeability index (PI), magnesium hazard (MH) and salinity diagrams based on primary water quality parameters[15].

II. Material And Methods

Study Area

Chendamangalam is one of the tourist destinations as well as historical places in Kerala. Chendamangalam is a rare geographical combination of rivers, seven inlets, hillocks and vast expanses of green plains situated in Ernakulum district, Kerala, India. The total area of the Panchayath is 10.83 km². The area selected for the present study lies between north latitudes 10.1741^0 and east longitudes 76.2327^0. The Chendamangalam village is consisting of ten small islands called thuruthu and a vast plain. The north of the Periyar River and Chalakkudy puzha comprises the eastern boundary. This area is surrounded by rivers on three sides and is an ancient popular heritage centre. Chendamangalam panchayath consists of 18 wards. These 18 wards of the panchayath had been severely affected in the 2018 floods except larger portion of ward 9. This disaster brought dramatic changes in the life of the local people. The flood water killed 12 people and almost 80 lakhs of damage occurs at agricultural sector. Total twenty six ground water samples from dug well and bore well sources collected in seasonal ways in the year 2019 - 2020 from different wards of Chendamangalam village to assess the suitability for drinking and irrigation purposes.

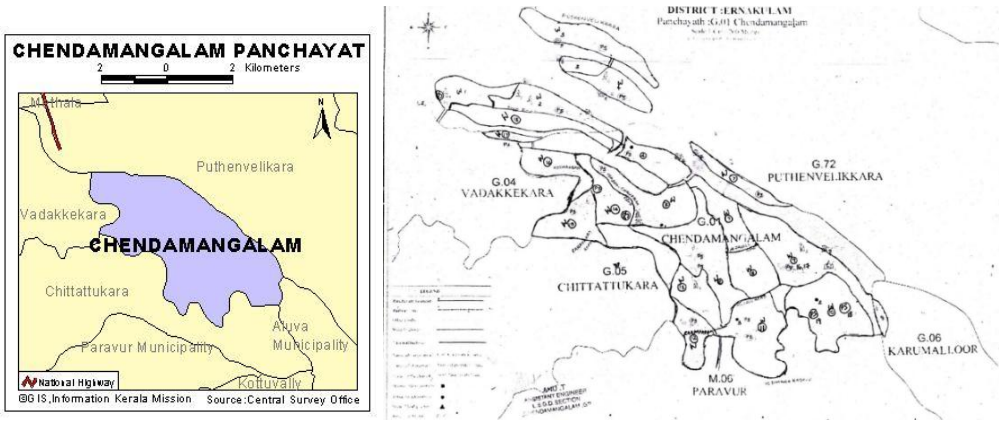


Figure 1 &2: Location map of Chendamngalam Panchayath

Table 1: Details of water sampling stations in Chendamangalam Village

Station no:	Description	Ward Name	Remarks
1	Ward 1	Gothuruthu – Vadakkethuruthu	Dug well (DW1)
2	Ward 2	Gothuruthu	Dug well (DW2)
3	Ward 3	Chathedam – Kurumbathuruthu	Dug well (DW3), Bore well (BW3)
4	Ward 4	Kurumbathuruthu – C P Thuruthu	Dug well (DW 4)
5	Ward 5	Kunjavarathururuthu	Dug well (DW 5)
6	Ward 6	Chendamangalam	Dug well (DW 6)
7	Ward 7	Valiya Pazhampillithuruthu	Dug well (DW 7), Bore well (BW7)
8	Ward 8	Kizhakkumpuram	Dug well (DW 8), Bore well (BW8)
9	Ward 9	Kottayil Kovilakom	Dug well (DW 9)
10	Ward 10	Palathuruthu	Dug well (DW 10), Bore well (BW10)
11	Ward 11	Thekkumpuram	Dug well (DW 11), Bore well (BW11)
12	Ward 12	Karimbadam	Dug well (DW 12)
13	Ward 13	Manakkodam	Dug well (DW 13)
14	Ward 14	Vadakkumpuram	Dug well (DW 14)
15	Ward 15	Kochangadi	Dug well (DW 15), Bore well (BW15)
16	Ward 16	Kootukadu	Dug well (DW 16), Bore well (BW16)
17	Ward 17	Gothuruthu – Thekkethuruthu	Dug well (DW 17)
18	Ward 18	Kadalvathuruthu	Dug well (DW 18)
19	Ward 9	Kottayil Kovilakom	Control Well (CW)

III. Methodology

Overall water quality parameters of the Chendamangalam panchayath evaluated and reported in this study during the period 2019 - 2020, obtained 3 seasonal sampling events (monsoon, post monsoon and pre monsoon) starting from July 2019 to March 2020 consisting of 19 sampling locations (Table 1). Physico-chemical parameters of groundwater were temperature, pH, EC, TA, TH, Ca^{2+}, Mg^{2+}, TDS, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-}, PO_4^{3-}, trace metals and microbiological parameter total coliform determined in the laboratory using

standard analytical procedure as recommended by APHA (2012)[16]. Water Quality Index (WQI) technique and irrigational parameters are calculated from these physio chemical and microbiological data.

Water Quality Index methods

The Water Quality Index (WQI) is employed to combination of numerous parameters and their dimensions into one score. This method is readily understandable to public as well as policy makers and it is calculated by using different methods[17,18]. In our study Water Quality Index (WQI) is calculated by using Weighted Arithmetic Water Quality Index Method (WAWQI). The parameters such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, Fe, SO_4^{2-}, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Total Coliform counts (TC) are used for this technique. This method includes following steps

1) The values of fifteen parameters for each groundwater source or mean value of the parameters is determined.

2) Quality rating scale of each parameter is calculated by using formula

$$Q_i = \left[(V_0 - V_i) / (V_s - V_i) \right] 100 \quad \text{---------- (1)}$$

Where Qi = Quality rating of the i^{th} water quality parameter, V_0 = observed value or mean value of the observed values of any parameter, V_i = ideal value of particular parameter [$V_i = 0$ for all parameter except pH and DO. Vi for pH = 7 and for DO = 14.6mg/L.], Vs = Standard permissible value of a particular parameter determined by WHO.

3). Calculation of relative unit weight (w_i)

The relative unit weight of any parameter (w_i) $\propto 1/Vs$

$$w_i = \frac{K}{V_s} \quad \text{---------- (2)}$$

$$\text{Where } K = \frac{1}{\sum_{i=1}^{n} \frac{1}{V_s}} \quad \text{---------- (3)}$$

4). Finally water quality index $(WQI) = \dfrac{\sum_{i=1}^{n} w_i Q_i}{\sum_{i=1}^{n} w_i}$ ---------- (4)

The overall quality of groundwater is assessed by using this WQI Table 2.

Table 2: Classification of groundwater on the basis of Water Quality Index, WQI [19]

WQI Level	Water Quality	Grading
0-25	Excellent (E)	A
25-50	Good (G)	B
51-75	Poor (P)	C
76-100	Very Poor (VP)	D
>100	Unfit for Drinking Purpose (UDP)	E

Assessment of Irrigation water quality

The quality of irrigation water is very important for the growth of crops, the maintenance of soil productivity and protection of environment[20]. Based on these physio chemical parameters irrigation quality in the study area is assessed by using different calculated parameters such as sodium percent (Na%), sodium adsorption ratio (SAR), Kelly's ratio (KR), permeability index (PI) and magnesium ratio (MR).

Sodium adsorption ratio (SAR)

Sodium adsorption ratio (SAR) is a measure of sodium in the water sample against calcium and magnesium ions[21]. SAR can be obtained by using the following equation[22]:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}} \quad \text{---------- (5)}$$

Sodium Percentage (Na%)

According to Wilcox, 1948[23] Na% is a common parameter in all natural water, to obtain the suitability of irrigation use. It can be determined by the following equation.

$$Na\% = \frac{Na^{+} \times 100}{Ca^{2+} + Mg^{2+} + Na^{+} + K^{+}} \quad \text{---------- (6)}$$

Residual Sodium Carbonate (RSC)

The residual sodium carbonate is a measure of the hazard involved in the use of high carbonate waters. RSC calculated by the following equation[24].

$$RSC = (CO_3^{2-} + HCO_3^{-}) - (Ca^{2+} + Mg^{2+}) \quad \text{---------- (7)}$$

Magnesium hazard ratio (MHR)

The magnesium ratio was calculated using the following equation[25].

$$MHR = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}} \quad \text{---------- (8)}$$

Kelly's ratio (KR)

Kelly's ratio was measured by sodium against calcium and magnesium[26].

$$KR = \frac{Na^{+}}{(Ca^{2+} + Mg^{2+})} \quad \text{---------- (9)}$$

Permeability Index (PI)

Doneen[27] developed a classification for water irrigation suitability based on permeability Index (PI). PI can be calculated by following equation.

$$PI = \frac{Na^{+} + \sqrt{HCO_3^{-}}}{Ca^{2+} + Mg^{2+} + Na^{+}} \times 100 \quad \text{---------- (10)}$$

The agricultural suitability was also explained by the diagrams such as USSL and Wilcox. The United States Salinity Laboratory Classification (USSL) developed by United Stated Salinity Laboratory Staff under United States Department of Agriculture[22]. The diagram is constructed by plotting sodium adsorption ratio (SAR) versus electrical conductivity (EC). Wilcox[28], 1955 classified ground water for irrigation purposes by correlating sodium percent and electrical conductivity.

IV. Results and Discussion

Overall water quality parameters of the Chendamangalam panchayath evaluated and reported in this study during the period 2019 - 2020. Physico-chemical and biological parameters of groundwater analyzed were temperature, pH, EC, Turbidity, Total Alkalinity (TA), Total Hardness (TH), Ca^{2+}, Mg^{2+}, TDS, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, NO_3^{-}, PO_4^{3-}, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), trace metals and total coliform are presented in Table 3. Groundwater usually maintains a fairly constant temperature, normally close to the average annual air temperature for surficial aquifers[29]. In monsoon temperature was 26.2^0C to 28.7^0C and gradually it increases in post monsoon 26.4^0C to 28.9^0C and reaches 26.7^0C to 29.2^0C in pre monsoon. It is found that the temperature of the dug wells, bore wells and control well are within the permissible limit (30^0C) as per WHO guidelines. pH has no direct impact on consumers, it remains an important quality parameter which controls water solubility and the rate of metallic reaction[30]. The pH for the analyzed samples ranges from 6.39 – 7.25 in the monsoon season, 6.45–6.86 in the post-monsoon season and 6.09–7.29 in the pre -monsoon season. The permissible pH value prescribed by WHO for drinking purpose is in the range 6.5–8.5. The sample BW10 in the study area falling out of this prescribed limit in the monsoon, post-monsoon seasons and pre-monsoon samples, BW3 falling out only in the post monsoon seasons. The conductivity was ranged 100.8 µS/cm to 466.9

µS/cm during monsoon seasons, 71.31 µS/cm to 385.7 µS/cm during post monsoon seasons and 83.84 µS/cm to 416.2 µS/cm during pre monsoon seasons. EC fluctuates throughout the seasons in dug wells and bore wells of different wards but within the permissible limit (<1500 µS/cm). The World Health Organization states that drinking water turbidity should be no more than 5 NTU and should ideally be less than 1 NTU. The monsoon and post monsoon all the samples show turbidity value less than 5 NTU except station DW5. Pre monsoon samples station DW4, DW5 and DW6 showed turbidity values are greater than 5 NTU. The presence of inorganic salts such as bicarbonates, chlorides, sulphates, phosphates and nitrates of calcium, magnesium, sodium, potassium etc. are responsible for the TDS in groundwater[31]. According to WHO permissible limit of TDS for drinking water is 500 mg/L. The TDS value ranges from 100.8 – 466.9 mg/L, 71.31 – 385.7 mg/L and 83.84 - 416.2 mg/L monsoon, post monsoon and pre monsoon seasons respectively. All the samples show TDS within the permissible limit. The highest alkalinity reported in the dug well DW3, 179.17 mg/L, 274.48 mg/L and 196 mg/L for monsoon, post monsoon and pre monsoon respectively. According to WHO the permissible limit of alkalinity in drinking water is <500 mg/L. Control well shows the lowest alkalinity 18.86 mg/L at monsoon season. Results reveal that alkalinity value is less than the permissible limit for all the samples studied. The seasonal variation of total hardness (TH) varies from 50.51 –74.36 mg/L in monsoon, 64.88 – 75.68 mg/L in post monsoon and 64.94 – 73.37 mg/L in pre monsoon. Control Well (CW) shows very low hardness in monsoon season (50 mg/L) compared to other wells. Hardness (mg/L) of water is classified into a range of extremely soft to too hard for ordinary domestic use[32]. Water with hardness 0 to 45 mg/L $CaCO_3$ is *extremely soft to soft water* (ESS). Hardness of 46 mg/L to 90 mg/L $CaCO_3$ is considered as *soft to moderately hard water* (SMH). *Moderately hard to hard water* (MHH) has hardness in the range 91 mg/L to 130 mg/L $CaCO_3$. Hardness between 131 mg/L to 170 mg/L $CaCO_3$ is categorized as *hard to very hard water* (HVH) and hardness of 171 mg/L to 250 mg/L is *very hard to excessively hard* (VHEH) water. A water sources with hardness > 250 mg/L are *too hard for ordinary domestic use*. According to this classification, water from the wells of the study area shows soft to moderately hard (SMH) class. Out of 7 bore wells BW16 shows low ca^{2+} in all the seasons (19.87 mg/L - monsoon, 18.01 mg/L - post monsoon and 18.28 mg/L – pre monsoon) and BW 3 shows higher ca^{2+} 23.53 mg/L - monsoon, 22.76 mg/L - post monsoon and 19.22 mg/L – pre monsoon. Calcium concentration of control well varies from 16.26 mg/L to 18.27 mg/L at three seasons studied. The seasonal variation of magnesium concentration is very low compared to calcium, all the wells in Chendamangalam in all seasons studied, the concentration of $Mg^{2+} < 10$. As per WHO[33], the maximum permissible limit for sodium is 200 mg/L, and the value of sodium in all the sampling stations of Chendamangalam panchayat is within the prescribed limit. Compared to 19 dug wells in the study area DW12 shows low sodium concentration in each seasons, 8.8 mg/L (monsoon), 12.6 mg/L (post monsoon) and 14.1 mg/L (pre monsoon) and DW3 shows the highest concentration and it varies from 30.4 to 36.5 in different seasons. Chloride occurs in all types of water. The permissible limit of chloride in drinking water is 250 mg/L according to BIS[34]. The ground water source DW12 shows chloride concentration is lowest (1.01mg/L in monsoon, 1.05mg/L in post monsoon and 1.33 mg/L in pre monsoon) whereas DW4 shows the highest (50.29 – 97.25 mg/L). In natural waters, chloride content was fairly low, usually less than 100 mg/L, it is clear that all the seasons in the study area the concentration of chlorine is less than 100mg/L. The maximum permissible limit of K^+ concentration in groundwater is 10 mg/L as per the WHO standards[33], and all the groundwater samples are within the permissible level. Higher phosphorus concentration in a water body is an indication of pollution through domestic sewage, detergents, agricultural runoff etc. In control well CW, there is no phosphate in post monsoon and pre monsoon season and only very little concentration (0.10 mg/L) in monsoon. All the wells (dug wells and bore wells) in the study area have shown very minute concentration of phosphate up to 1 mg/L. In bore wells phosphate is very low compared to dug wells that is because adsorption and mineralization leads to immobilization of phosphate that in turn limits its movement within or below the root zone. The main source of sulphate is industrial waste and domestic sewage. The sulphate in ground water generally occurs as soluble salts of calcium, magnesium and sodium[35]. The concentration of sulphate in the wells of Chendamangalam varies from 2.84 to 45.60 mg/L during the monsoon season, 1.32 to 28.98 mg/L during the post monsoon and 0.76 to 21.81 mg/L during the pre monsoon. The result reveals that all the samples studied the sulphate concentration falling within the desirable limit of BIS (200 mg/L) and WHO (250 mg/L). The occurrence of nitrate in high levels causes many health problems. The permissible limit of nitrate in drinking water is 10 mg/L. The nitrate content in the wells of Chendamangalam varied from 0 – 2.05 mg/L during the monsoon season, 0.01 to 2.37 mg/L during the post monsoon and 0.03 to 3.04 mg/L during the pre monsoon. Dissolved oxygen is the most important parameter in water quality studies. The DO concentration in groundwater below 3 mg/L is hazardous to human consumption[36]. The seasonal study reported that dug wells and bore wells of Chendamangalam at different seasons, the dissolved oxygen value in between 3 - 7 mg/L. Biological oxygen demand (BOD) is a measure of bacterial load in water and it is linked to the oxidation of biodegradable organic materials[37]. In unpolluted water the BOD will be comparatively less (usually less than 6 mg/L) while organically polluted water the BOD will be more than 100 mg/L[38]. The range of BOD in the dug wells of study area was 1.11 to 5.89 mg/L at different

seasons. From the 7 bore wells studied BOD varies 1.52 – 5.1 during the monsoon, 2.02– 5.52 mg/L during the post monsoon and 3.44 – 5.70 mg/L in pre monsoon.

The trace elements Zn, Cu, Ni, Co, Fe, Mn, Cr, Pb, Cd & As were analyzed by Inductive Couple Plasma Optical Emission Spectroscopy (ICPOES). Total 26 ground water samples (19 dug wells and 7 bore wells) were taken from the study area at different seasons (monsoon, post monsoon and pre monsoon) were analyzed. In the water sample the trace elements Zn, Cu, Ni, Co, Cr, Pb, Cd & As reported as below detectable limit. The higher concentration of Fe may cause toxic effect to human health. In this study area all the bore wells shows high level of Fe concentrations except BW 10 & BW11 in all the seasons. The Fe concentration is higher in dug wells DW5 & DW6. The station DW5 reported Fe concentration 3.117 mg/L during monsoon, 2.980 mg/L during post monsoon and 1.892 mg/L during the pre monsoon. Entire season studied, the sampling station DW6 reported Fe concentration 0.835 mg/L, 0.645 mg/L and 0.351 mg/L in monsoon, post monsoon and pre monsoon period respectively. The element manganese was one of the most abundant metals in the earth's crust and usually occurs together with iron. In drinking water the permissible limit of Mn is 0.05 mg/L. Four sampling stations BW3, DW4, DW5 & BW10 shows manganese concentration higher than the permissible limit. Other 22 samples show manganese value is less than the permissible limit. In monsoon it ranges from 0.014 mg/L to 0.409 mg/L, post monsoon concentration ranges from 0.014 mg/L to 0.354 mg/L and pre monsoon it varies from 0.012 mg/L to 0.317 mg/L.

Table 3: Seasonal variation of various water quality parameters of Chendamangalam Panchayath

Sl NO:	Parameters	Monsoon Range	Post monsoon Range	Pre monsoon Range	WHO Permissible limit
1	Temperature ^{0}C	26.2-28.7	26.4-28.9	26.7-29.2	-
2	pH	6.39-7.25	6.45-6.86	6.07-7.29	6.5-8.5
3	Conductivity	100.8-466.9	71.31-385.7	83.84-416.20	1500
4	Turbidity (NTU)	0 - 8.9	0 -9.8	1.1 - 9.6	5
5	TDS (mg/L)	100.80 - 466.90	71.31 - 378.80	83.84 - 416.20	500
6	Alkalinity (mg/L)	18.86-179.17	49.02-274.48	29.40-196	-
7	TH (mg/L)	50.51 - 74.36	64.88 - 75.68	64.94 -73.37	100
8	Ca2+ (mg/L)	16.27 - 23.54	17.67 - 22.76	16.87 - 20.71	75
9	Mg2+ (mg/L)	1.55 -5.72	4.66 - 7.42	4.99 - 6.42	50
10	Na+ (mg/L)	8.8 -30.4	12.6 -36	14.1 - 36.5	200
11	Chloride (mg/L)	1.01-97.25	1.05 -78.25	1.33 - 50.29	250
12	K+ (mg/L)	5 - 8.4	5.9 - 9.5	7.2 - 10.8	10
13	Phosphorus (mg/L)	0 -0.36	0 - 0.82	0 - 0.93	-
14	Sulphate (mg/L)	2.84 - 45.60	1.32 - 28.98	0.76 – 21.81	250
15	Nitrate (mg/L)	0 - 2.05	0.01 - 2.37	0.03 - 3.04	10
16	DO (mg/L)	3.63 - 6.83	3.33 -6.99	3.04 - 6.91	-
17	BOD (mg/L)	1.91 -5.89	1.61 -4.98	1.11 - 5.64	-
18	Fe (mg/L)	0.028-10.696	0.020-8.235	0.008-7.240	0.1
19	Zn (ppb)	BDL	BDL	BDL	5000
20	Cu(ppb)	BDL	BDL	BDL	1000
21	Ni (ppb)	BDL	BDL	BDL	-
22	Co(ppb)	BDL	BDL	BDL	-
23	Cr (ppb)	BDL	BDL	BDL	100
24	Pb(ppb)	BDL	BDL	BDL	15
25	cd (ppb)	BDL	BDL	BDL	5
26	As (ppb)	BDL	BDL	BDL	10
27	Mn (ppb)	14 – 409	14 -354	12 -317	50
28	Total coliform (per 100ml)	6.2 - >1100	6.1 - >1100	6.1 - >1100	0

The total coliform analysis done by MPN method. All the sampling stations, the total coliform is present in monsoon, post monsoon and pre monsoon season. Water samples studied DW13, DW14 and CW in all the seasons shows that the total bacterial count is less than 10/100ml of MPN coliforms. Well water samples DW1, DW4, DW6, DW9, DW12 and DW18 shows higher amount of total coliform (>1100/100ml). The seasonal study shows that the bacterial count is higher in monsoon season compared to post monsoon and pre monsoon period. The microbial load is increases in ground water tremendously due to the accumulation of human and animal excreta.

Assessment of Drinking Water Quality Using Water Quality Index

Seasonal variation of water quality index (WQI) of the drinking water sources of Chendamangalam area are shown in the Table 4. The water quality index level of control well (CW), DW3& DW16 in all the seasons shows in the range 0-25 that means water is excellent quality and Grade A. In the case of water sample DW13 monsoon and post monsoon excellent category and pre monsoon sample shows good (27.65). Samples DW14 and DW17 water quality is good in all the season studied. WQI of DW8 reveals that poor in monsoon

season and pre monsoon and post monsoon season it is Good. DW7, DW10 and DW11 shows the WQI level is greater than 100 for monsoon season and pre monsoon and post monsoon in the range 50 to 100 and DW15 shows WQI in monsoon in between 75-100 (Grade D) and pre monsoon and post monsoon 50-75 (Grade C). Other eight seasonal samples based on WQI water is unfit for drinking purpose, WQI level is higher than 100 and Grade E. These eight samples WQI is higher than 100 in all the seasons studied because the total coliform count is higher in these samples. This drinking water source is only used after any disinfection treatment (chlorination).

Table 4: Seasonal variation of water quality index (WQI) of Dug wells (DW) and control well (CW) of Chendamangalam Panchayath

Well No:	Monsoon			Post monsoon			Pre monsoon		
	WQI	Water Quality	Grade	WQI	Water Quality	Grade	WQI	Water Quality	Grade
DW1	346.26	Unfit for Drinking Purpose (UDP)	E	309.63	Unfit for Drinking Purpose (UDP)	E	289.46	Unfit for Drinking Purpose(UDP)	E
DW2	187.19	Unfit for Drinking Purpose(UDP)	E	129.97	Unfit for Drinking Purpose(UDP)	E	115.13	Unfit for Drinking Purpose(UDP)	E
DW3	16.31	Excellent	A	16.67	Excellent	A	18.27	Excellent	A
DW4	336.84	Unfit for Drinking Purpose(UDP)	E	335.82	Unfit for Drinking Purpose(UDP)	E	345.21	Unfit for Drinking Purpose(UDP)	E
DW5	861.58	Unfit for Drinking Purpose(UDP)	E	803.39	Unfit for Drinking Purpose(UDP)	E	521.22	Unfit for Drinking Purpose(UDP)	E
DW6	485.78	Unfit for Drinking Purpose(UDP)	E	436.81	Unfit for Drinking Purpose(UDP)	E	363.01	Unfit for Drinking Purpose(UDP)	E
DW7	126.55	Unfit for Drinking Purpose(UDP)	E	92.57	Very Poor(P)	D	87.61	Very Poor(P)	D
DW8	58.74	Poor (P)	D	43.05	Good	B	33.50	Good	B
DW9	283.80	Unfit for Drinking Purpose(UDP)	E	130.30	Unfit for Drinking Purpose(UDP)	E	128.58	Unfit for Drinking Purpose(UDP)	E
DW10	123.52	Unfit for Drinking Purpose(UDP)	E	93.72	Very Poor (VP)	D	92.44	Very Poor (VP)	D
DW11	157.03	Unfit for Drinking Purpose(UDP)	E	84.00	Very Poor (VP)	D	81.61	Very Poor (VP)	D
DW12	289.92	Unfit for Drinking Purpose(UDP)	E	292.90	Unfit for Drinking Purpose(UDP)	E	287.57	Unfit for Drinking Purpose(UDP)	E
DW13	21.10	Excellent	A	25.77	Excellent	A	27.65	Good	B
DW14	36.07	Good	B	37.15	Good	B	37.43	Good	B
DW15	85.05	Very Poor (VP)	D	56.53	Poor(P)	C	60.84	Poor(P)	C
DW16	23.22	Excellent	A	24.01	Excellent	A	15.11	Excellent	A
DW17	32.38	Good	B	27.15	Good	B	28.59	Good	B
DW18	296.65	Unfit for Drinking Purpose(UDP)	E	293.34	Unfit for Drinking Purpose(UDP)	E	142.65	Unfit for Drinking Purpose(UDP)	E
CW	19.04	Excellent	A	20.58	Excellent	A	23.18	Excellent	A

Assessment of Groundwater for Irrigation

Water used for irrigation can vary greatly in quality depending upon type and quantity of dissolved salts. Salts are present in irrigation water in relatively small amounts but their effects are significant. The soil problems most commonly encountered and used as a basis to evaluate water quality are those related to salinity, water infiltration rate, toxicity and a group of other miscellaneous problems[39]. Therefore, knowledge of irrigation water quality is critical to understanding what management changes are necessary for long-term productivity.

Sodium adsorption ratio (SAR)

The suitability of irrigation quality of groundwater samples was evaluated by determining the Sodium adsorption ratio (SAR). It can be used to find out the degree to which irrigation water tends to enter into cation exchange reactions, undergo within the soil. If high amount of sodium present in the groundwater can have the tendency to replace the adsorbed calcium or magnesium in the aquifer, causes damage to soil structure and the soil becomes compact and impermeable[40]. The calculated SAR values range from 0.6718 to 2.64 in monsoon season, 0.8625 to 2.61 in post monsoon and 1.05 to 3.05 in pre monsoon season. Richard[22] has classified ground water based on SAR and the classification criteria are presented in Table 5. Compared to the table value it's clear that all the water samples studied in all season's falls the low sodium class. Figure 3 shows that all the water samples studied in the study area fall under the excellent category for irrigation quality.

Sodium Percentage (%Na)

Sodium in irrigation water usually expressed as percent sodium and it's an important parameter to compute to evaluate the suitability for irrigation[23]. Irrigation water classified based on in terms of Na%, the

irrigation water is excellent the percentage of sodium is less than 20, good is between 20-40, permissible between 40-60, doubtful in between 60-80 and unsuitable is greater than 80. Percentage sodium is observed in the range 21.10 – 49.70%, 24.99 – 48.71% and 28.16 – 46.75% during the three seasons respectively (Figure 4). In monsoon and pre monsoon season 14 samples are in good quality and 5 samples comes in permissible limit and Post monsoon 15 samples are in good quality (20-40%) and 4 samples comes in permissible limit (40-60%).

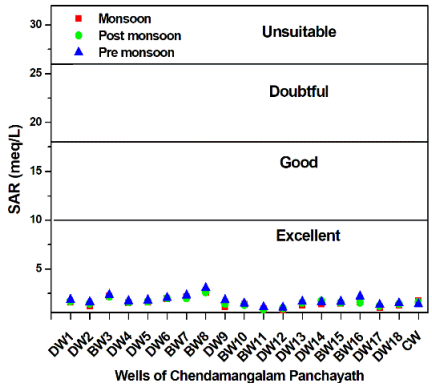


Figure 3: Seasonal variation of sodium adsorption ratio (SAR) of ground water sources along the Chendamangalam Panchayath during the year 2019 -2020

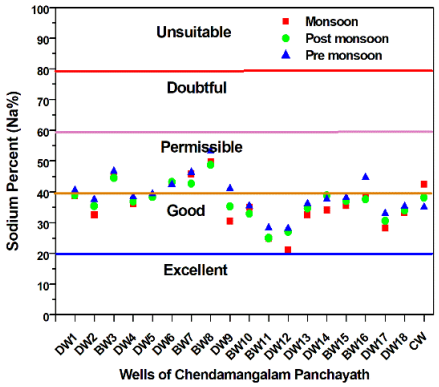


Figure 4: Seasonal variation of sodium percent (Na%) of ground water sources along the Chendamangalam Panchayath during the year 2019 -2020

Table 5: Classification of ground water on the basis of irrigation water quality parameters

Parameters	Range	Water type
Sodium Adsorption Ratio (SAR)	< 10	Excellent
	10-18	Good
	18-26	Doubtful
	>26	Unsuitable
Sodium Percentage (%Na)	<20	Excellent(E)
	20-40	Good(G)
	40-60	Permissible(P)
	60-80	Doubtful(D)
Residual Sodium Carbonate (RSC)	<1.25	Good(G)
	1.25-2.50	Doubtful(D)
	>2.5	Unsuitable(US)
Magnesium Hazard Ratio (MHR)	<50	Suitable (S)
	>50	Unsuitable (US)
Kelly Ratio (KR)	<1	Suitable(S)
	>1	Unsuitable (US)
Permeability Index (PI)	>75% (Class I)	Good for irrigation (G)
	25-75% (Class II)	Good for irrigation(G)
	<25% (Class III)	Unsuitable for irrigation (US)

Residual Sodium Carbonate (RSC)

The excess sum of carbonate and bicarbonate in groundwater over the sum of calcium and magnesium also influences the suitability of water for irrigation because in waters having high concentration of bicarbonate, there is tendency for calcium and magnesium to precipitate as the water in the soil becomes more concentrated. An excess quantity of sodium bicarbonate and carbonate is considered to be detrimental to the physical properties of soils, as it causes dissolution of organic matter in the soil, which in turn leaves a black stain on the soil surface on drying. As a result, the relative proportion of sodium in the water is increased in the form of sodium carbonate, and this excess, denoted by Residual Sodium Carbonate (RSC). According to the U.S. Salinity laboratory[22], an RSC < 1.25 meq/l means water is suitable for irrigation purposes whereas RSC value ranges from 1.25 to 2.5 meq/l is considered as marginally suitable and RSC > 2.5 meq/L indicated as unsuitable for irrigation purpose. In the present study, the water samples in all seasons shows RSC is less than 1.25 meq/L (Figure 5), it indicates water is suitable category for irrigation purpose.

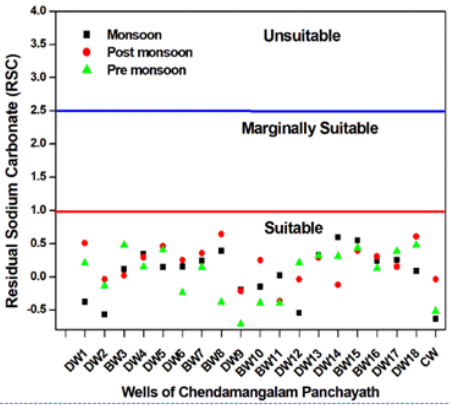


Figure 5: Seasonal variation of residual sodium carbonate (RSC) of ground water sources along the Chendamangalam Panchayath during the year 2019 -2020

Table 6: Seasonala variation of MHR of ground water sources from Chendamangalam Panchayath

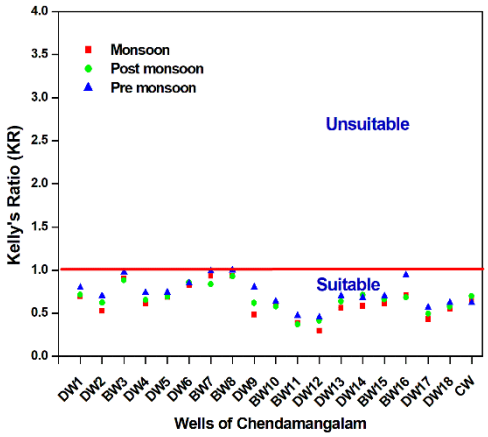
Wells	MHR (Monsoon)	MH R (Post monsoon)	MH R (Pre monsoon)	Inference
DW1	21.74	35.03	34.69	Suitable
DW2	20.77	33.21	34.37	Suitable
BW3	19.59	23.91	34.50	Suitable
DW4	30.89	38.37	34.57	Suitable
DW5	18.88	26.92	31.91	Suitable
DW6	20.25	30.91	36.75	Suitable
BW7	20.07	36.25	33.73	Suitable
BW8	29.75	35.95	34.59	Suitable
DW9	21.67	33.21	34.45	Suitable
BW10	21.77	33.10	34.82	Suitable
BW11	21.84	33.00	34.42	Suitable
DW12	19.48	32.25	34.50	Suitable
DW13	19.07	32.96	33.62	Suitable
DW14	25.14	34.34	33.34	Suitable
BW15	24.81	31.98	34.84	Suitable
BW16	21.35	30.59	33.44	Suitable
DW17	20.83	33.22	32.49	Suitable
DW18	18.39	33.21	34.09	Suitable
CW	19.50	30.97	33.54	Suitable

Magnesium hazard ratio (MHR)

In water the concentration of magnesium exceeds over calcium, creates adverse effects on crop yield. Excess magnesium enhances the soil pH and affects its quality. Magnesium Hazard Ratio (MHR) < 50 means water is suitable for irrigation and the MHR > 50, water is unsuitable for irrigation[41]. Seasonal variations of the MHR values of different locations are shown in the Table 6. The results reveals that all the water samples in all seasons, MHR is in the range of 20 to 40 that means water is suitable for irrigation purpose.

Kelly's ratio (KR)

Kelly's ratio was measured by sodium against calcium and magnesium. The Kelly's ratio is less than one indicates water is suitable for irrigation and more than one indicates an excess level of sodium in water and that is unsuitable. From the Figure 6 it is clear that all the groundwater sources are suitable for irrigation purposes in all the seasons, being KR < 1.



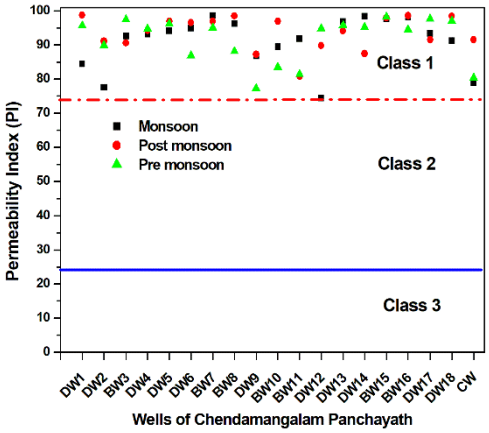


Figure 6 & 7: Seasonal variation of KR & PI of ground water sources along the Chendamangalam Panchayath during the year 2019 -2020 respectively

Permeability Index (PI)

The soil permeability is affected by long term use of irrigation water. Permeability Index (PI) is also used to determine the suitability of water for irrigation purpose. Table 1 shows the classification of Irrigation water based on permeability index (PI). According to PI water is classified as three classes, class I hold 75 % or more of maximum permeability, class II is greater than 25% permeability and these two categories suitable for irrigation. Class III is less than 25% permeability and it considered as unsuitable for irrigation. Figure 7

illustrates that all the water samples tested in all seasons show class I category and PI is greater than 75% and is good for irrigation purpose.

Wilcox diagram

Wilcox, 1948[23] classified ground water for irrigation purposes by correlating sodium percent and electrical conductivity. It is divided into five classes-*excellent to good, good-permissible, permissible to doubtful, doubtful to unsuitable and unsuitable* quality of water[28]. From the Figure 8 it shows that all the samples belongs to excellent to good category.

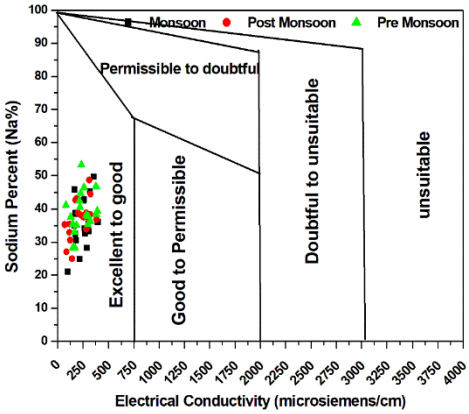


Figure 8: Wilcox diagram of ground water samples

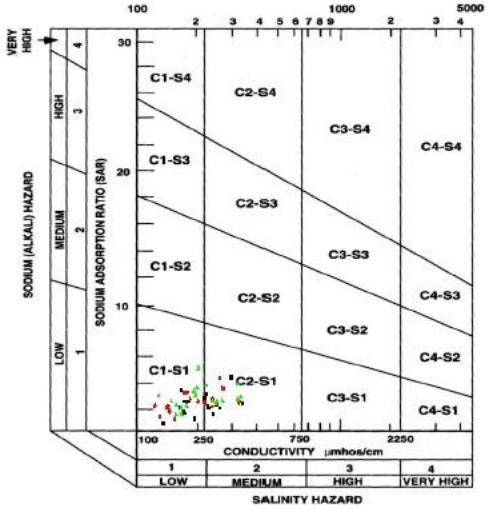


Figure 9: USSL diagram of water samples

USSL Diagram

USSL diagram is used in water quality studies related to irrigation purposes. This diagram was developed by United States Department of Agriculture [22] (1954). The diagram is constructed by plotting sodium adsorption ratio (SAR) versus electrical conductivity (EC). The salinity hazard divides the plot in 250, 750 and 2250 µmhos, resulting in four categories. They are EC < 250 µmho – low salinity water (C1), EC in the range 250 - 750 µmho – medium salinity water (C2), EC in the range 750 -2250 µmho – high salinity water (C3) and EC > 2250 µmho – very high salinity water (C4). The sodium adsorption ratio (SAR) is also divided into four categories - low sodium water (S1), medium sodium water (S2), high sodium water (S3) and very high sodium water (S4). Figure 9 shows that all the seasons studies 10 samples including control well shows C2S1 category that means medium sodium hazard and low salinity hazard and other 9 samples low sodium water and low salinity hazard (C1S1 category). It indicated that this groundwater samples studied in 3 season's good quality for irrigation based on the USSL diagram.

V. Conclusion

The present work mainly comprises the major results of physico-chemical and biological parameters of the flood affected water samples from the dug well (DW) and bore well (BW) sources for the assessment of drinking and irrigation purposes. The control well (CW) is considered as not affected by the 2018 flood. The water samples studied in all season's shows that most of the physico chemical parameters are in the permissible level according to WHO standard. According to the hardness classification, water from the wells of the study area shows soft to moderately hard (SMH) class. In the water sample the trace elements Zn, Cu, Ni, Co, Cr, Pb, Cd & As reported as below detectable limit. In this study area all the bore wells shows high level of Fe concentrations except BW 10 & BW11 in all the seasons. In our study period, most of the well water samples at different seasons come under unsafe for drinking purpose with reference to total coliform count. The total coliform bacterial count in monsoon, post monsoon and pre monsoon season found to be higher than the permissible limit of WHO (0/100mL of MPN coliforms). The water quality index level of control well (CW), DW3& DW16 in all the seasons reveals excellent quality drinking water. The flood affected wells DW1, DW2, DW4, DW5, DW6, DW9, DW12 and DW18 shows water quality index value higher than 100 that indicates water is unsafe for drinking purpose. This well water is only used after conventional treatment and disinfection.

Water suitability for irrigation purpose was measured by different parameters like sodium adsorption ratio (SAR), sodium percentage (Na%), residual sodium carbonate (RSC), magnesium hazard ratio (MHR), Kelly's ratio (KR) and permeability index (PI). Seasonal ways study with respect to SAR and Na% shows that water is excellent for irrigation purpose. RSC < 1.25 meq/L in Monsoon, post monsoon and pre monsoon seasons in the study area reveals that water is suitable for irrigation. Magnesium hazard ratio is in between 20 to 40 indicate water is suitable for irrigation. On the basis of PI and KR all the ground water samples should be suitable for irrigation. Wilcox diagram shows that seasonal ways samples are excellent to good category for irrigation and USSL diagram shows that water is good for irrigation. The concentration of heavy metals in irrigation water is very low. The result reveals that natural disaster like flood not affect the irrigational quality of groundwater but it affect drinking water quality at Chendamangalam. Groundwater is a precious resource so we need to preserve and protect this valuable resource.

Acknowledgements

The first author is thankful to Kerala State council for Science, Technology and Environment for the financial support in the form of Post-Doctoral Fellowship. The authors are thankful to Sacred Heart College, Thevara for providing the facilities for this study.

References

[1]. Howari, F. M., Abu-rukah, Y., & Shinaq, R. (2005). Hydrochemical Analyses and Evaluation of Groundwater Resources of North Jordan, Water Resources, *1*. *32*(5), 607–616.

[2]. Sarfraz, M. (2016). Investigation of Portable Groundwater Quality and Health Risk Assessment of Selected Trace Metals in Flood Affected Areas of District Rajanpur, Pakistan. *Journal of Environmental Analytical Chemistry*, *3*(2). https://doi.org/10.4172/2380-2391.1000183

[3]. Nagarajan, R., Rajmohan, N., Mahendran, U., & Senthamilkumar, S. (2010). Evaluation of groundwater quality and its suitability for drinking and agricultural use in Thanjavur city, Tamil Nadu, India. *Environ Monit Assess*, 289–308. https://doi.org/10.1007/s10661-009-1279-9

[4]. Ramakrishnaiah, C. R., Sadashivaiah, C., & Ranganna, G. (2009). Assessment of Water Quality Index for the Groundwater in Tumkur Taluk , Karnataka State , India. *E-Journal of Chemistry*, *6*(2), 523–530.

[5]. Tiwari, R. N. (2011). Assessment of groundwater quality and pollution potential of Jawa Block Rewa District , Madhya Pradesh , India. *Proceedings International Academy Ecology Environmental Sciences*, *1*, 202–212.

[6]. Horton, R.K. (1965) An Index Number System for Rating Water Quality. *Journal of the Water Pollution Control Federation*, 37, 300-306.

[7]. Tyagi, S., Sharma, B., Singh, P., & Dobhal, R. (2013). Water Quality Assessment in Terms of Water Quality Index. *American Journal of Water Resources,1.3, 34-38* https://doi.org/10.12691/ajwr-1-3-3

[8]. Balan, I. N., Shivakumar, M., & Kumar, P. D. M. (2012). An assessment of groundwater quality using water quality index in Chennai, Tamil Nadu, India. *Chronicles of Young Scientists*, *3*(2), 146 - 150. https://doi.org/10.4103/2229-5186.98688

[9]. Chandra, D. S., Asadi S.S., & Raju M. V. S. (2017). Estimation of water quality index by weighted arithmetic water quality index method : a model study. *International Joural of Civil Engineering and Technology 8*(4), 1215–1222.

[10]. Agarwal, M., Singh, M., & Hussain, J. (2020). Evaluation of Groundwater Quality for Drinking Purpose using Different Water Quality Indices in Parts of Gautam Budh Nagar District, India. *Asian Journal of Chemistry*, *26*(12), 70–73.

[11]. Achari, V. S., George, T. R., Deepa, P., Ambili, M. S., Jayasree, S., Rajalakshmi, A. S., & Lopez, R. M. (2017). Hydrogeochemistry of groundwater along a tsunami devastated coastal segment of Kerala: Arattupuzha village, Alappuzha, India. *Indian Journal of Geo-Marine Sciences*, *46*(9), 1765–1779.

[12]. Ravikumar, P., & Somashekar, R. K. (2011). Geochemistry of groundwater, Markandeya River Basin, Belgaum district, Karnataka State, India. *Chinese Journal of Geochemistry*, *30*(1), 51–74. https://doi.org/10.1007/s11631-011-0486-6

[13]. Raihanand, F., Alam, J B. (2008). Assessment of groundwater quality in Sunamganj Bangladesh, *Iran. J. Environ. Health. Sci. Eng*, 5 (3) 155–166.

[14]. Sarkar, A. A., & Hassan, A. A., (2006). Water Quality Assessment of a Groundwater Basin in Bangladesh for Irrigation Use. *Pakistan Journal of Biological Sciences, 9, 1677-1684.*

[15]. Gautam, S. K., Maharana, C., Sharma, D., Singh, A. K., Tripathi, J. K., & Singh, S. K. (2015). Evaluation of groundwater quality in the Chotanagpur plateau region of the Subarnarekha river basin, Jharkhand State, India. *Sustainability of Water Quality and Ecology*, 6. https://doi.org/10.1016/j.swaqe.2015.06.001.

[16]. APHA; Rice, E.W., R. B., Eaton, A. D., and Clesceri, L.S. (2012) Standard method for the examination of water and wastewater, 22nd edition, *American Public Health Association,*Washington, ISBN 978-0-87553—13-0.

[17]. Bordalo, A. A., Teixeira, R., & Wiebe, W. J. (2006). A water quality index applied to an international shared river basin: The case of the Douro River. *Environmental Management*, *38*(6), 910–920. https://doi.org/10.1007/s00267-004-0037-6

[18]. *Deepa, P.* (2018) Hydrochemistry and groundwater quality of coastal phreatic aquifers of Alappuzha and Ernakulam regions of Kerala, India. *PhD Thesis*, Cochin University of Science and Technology.

[19]. Brown, R. M., McClelland, N. I., Deininger, R. A., & O'Connor, M. F. (1972). A Water Quality Index -Crashing the Psychological Barrier. *Indicators of Environmental Quality*, 173–182. https://doi.org/10.1007/978-1-4684-1698-5_15.

[20]. Achari, V. S., Ambili, M. S., & Deepa, P. (2018). Irrigation Water Quality and Corrosion Indices of Groundwater Sources of Tsunami Affected Alappad Coast, Kollam, Kerala, India. *Indian Journal of Scientific Research*. *18(2)*, 102-108.

[21]. Li, P., He, X., Li, Y., & Xiang, G. (2019). Occurrence and Health Implication of Fluoride in Groundwater of Loess Aquifer in the Chinese Loess Plateau: A Case Study of Tongchuan, Northwest China. *Exposure and Health*, *11*(2), 95–107. https://doi.org/10.1007/s12403-018-0278-x.

[22]. Richards, L., A. (1954). Diagnosis and Improvement of Saline and Alkaline Soils. *Soil Science Society of America Journal*, *18*(3), 348. https://doi.org/10.2136/sssaj1954.03615995001800030032x

[23]. Wilcox, L. V. (1948). The quality of water for irrigation use. *US Department of Agriculture Technology Bulletin*, Washington D C, 962.

[24]. Singh, V. K., Bikundia, D. S., Sarswat, A., & Mohan, D. (2012). Groundwater quality assessment in the village of Lutfullapur Nawada, Loni, District Ghaziabad, Uttar Pradesh, India. *Environmental Monitoring and Assessment*, *184*(7), 4473–4488. https://doi.org/10.1007/s10661-011-2279-0

[25]. Naseem, S., Hamza, S., & Bashir, E. (2010). Groundwater Geochemistry of Winder Agricultural Farms, Balochistan, Pakistan and Assessment for Irrigation Water Quality. *European Water*, *31*, 21–32.

[26]. Kelley, W. P. (1951). Alkali soils—their formation, properties and reclamation, Reinhold, New York.

[27]. Doneen, L., D. (1964) Notes on Water Quality in Agriculture. *Water Science and Engineering*, 4001.

[28]. Wilcox, L. V. (1955). Classification and Use of Irrigation Waters. *Department of Agriculture, United States*. *969* (Circular No. 696), 21. https://www.ars.usda.gov/arsuserfiles/20360500/pdf_pubs/P0192.pdf

[29]. Chapman, D., (1996) Water Quality Assessments - A guide to use of biota, sediments and water in enviromental monitoring. *Univ. Press. Cambridge ISBN* 0 419 21590 5 (HB) 0 419 21600 6 (PB) **2,** 609.

[30]. USEPA. (1983) United State Environmental Protection Agency EPA-600/4-79-020 USEPA Cincinnati.

[31]. Ravikumar, P., Mehmood, M. A., & Somashekar, R. K. (2013). Water quality index to determine the surface water quality of Sankey tank and Mallathahalli lake, Bangalore urban district, Karnataka, India. *Applied Water Science*, *3*(1), 247–261. https://doi.org/10.1007/s13201-013-0077-2

[32]. Vesilind, P. A.; Morgan S. M.; Heine L.G. (2004). Introduction to Environmental Engineering *Singapore Thomson Asia Pte. Ltd*. 479.

[33]. WHO. (2008) Guidelines for Drinking-Water Quality. *Eisei Kagaku*, *35*(5), 307–312. https://doi.org/10.1248/jhs1956.35.307

[34]. WHO. (2011) Guideline for Drinking Water Quality Recommendations, Switzerland, Geneva.

[35]. Jain, C. K., Bandyopadhyay, A., & Bhadra, A. (2010). Assessment of ground water quality for drinking purpose, District Nainital, Uttarakhand, India. *Environmental Monitoring and Assessment*, *166*(1–4), 663–676. https://doi.org/10.1007/s10661-009-1031-5

[36]. Radhakrishnan, R., Dharmaraj, K., Renjithakumari, B.D. (2007). A Comparative Study on the Physicochemical and Bacterial Analysis of Drinking, bore well and sewage water in the three different places of Sivakasi, *Journal of Environmental Biol*ogy, 28(1), 105-108.

[37]. Togue, F. K., Kuate, G. L. O., & Oben, L. M. (2017). Physico-chemical characterization of the surface water of Nkam river using the principal component analysis. *Journal of Materials and Environmental Science*, *8*(6), 1910–1920.

[38]. BIS. (1983) Drinking water quality standards, Bureau of Indian Standards, New Delhi.

[39]. Ayers, R. S. and Westcot, D. W. (1985). *Water Quality for Agricultura FAO 29*.

[40]. Achari, V. S., Deepa, P., Ambili, M. S. (2018) Groundwater Quality of Andhakaranazhy Coast, Alappuzha, Kerala, *Indian Journal of Scientiific Research*, 18 (2), 119–125.

[41]. Paliwal, K. V. (1972). Irrigation with saline water. New Delhi: *IARI*, Monogram no. 2 (New series) 198.

S. Jayasree, et. al. "An Assessment of Ground Water Quality for Drinking and Irrigation Use in a Flood Affected Area: Chendamangalam, Ernakulam District, Kerala, India." *IOSR Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT)*, 14(4), (2020): pp 40-51.