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Physical and Chemical Quality Boundaries of Ground Water in Kanchipuram District of Tamil Nadu, India

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Abstract: Water is fundamental for all living life forms for their living and metabolic cycles. The purpose of the current investigation is to gauge a few water quality boundaries in the Kanchipuram region of Tamil Nadu, India and dissect the information by multivariate statistical methods. So as to evaluate the ground water quality, boundaries, for example, pH, total dissolved solids (TDS), electrical conductivity (EC), chloride (Cl), sulphate (SO_4), calcium (Ca), magnesium (Mg), nitrate (NO_3), sodium (Na), potassium (K), carbonate (CO_3) and hydrogen carbonate (HCO_3) were resolved utilising distinctive systematic techniques. The after effects of physicochemical properties were contrasted and recommended limits given by WHO (2004) and BIS (2012). The acquired outcome uncovers that the decided water quality boundaries are not exactly as far as possible. Measurable methods, for example, Pearson connection, principal and cluster examinations were applied among the ground water information to consider the relation between them.

Key words: Groundwater, sulphate (SO_4), nitrate (NO_3), quality boundaries.

Introduction

Groundwater is the primary wellspring of water gracefully for drinking, modern and farming purposes in numerous parts of India. In India, practically all the surface and ground water is not suitable for direct utilisation. Drinking of such water prompts the turmoil of teeth or bones through fluorosis, which is because of the utilisation of fluoride-rich water (Shah et al., 2008). Excessive doses of fluoride more noteworthy than 1 mg L^{-1} can cause dental, skeletal, and non-skeletal types of fluorosis. Generally, ground water has been dirtied because of anthropogenic exercises, for example, home-grown sewage, mechanical waste water, and farming run-off, utilisation of composts, pesticides, and fertiliser and lime deny dumps (Venugopal et al., 2009). Groundwater with low pH esteems can cause gastrointestinal turmoil, consequently, this water cannot be utilised for drinking purposes. High TDS values are not appropriate for both agribusiness and drinking purposes (Davis and Dewiest, 1966; Fetter, 1990).

The chemical nature of groundwater relies upon the type and nature of soil and rock present along the pathway of groundwater immersion zone (Chidambaram et al., 2008; Foster et al., 2000). The variation in ground water quality happens along the course of development of water through the hydrological cycle and the activity of the accompanying cycles: dissipation, transpiration, and particular take-up by vegetation, oxidation/decrease, cation exchange, separation of minerals, precipitation of auxiliary minerals, blending of waters, draining of composts and fertilizer, contamination

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and organic cycles (Appelo and Postma, 1999). Numerous groundwater quality evaluation works have been completed in various parts of India (Durvey et al., 1997; Dasgupta and Purohit, 2001; Hem, 1991; Khurshid et al., 2002; Majumdar and Gupta, 2000; Subba Rao, 2006; Subba Rao et al., 1999; Sujatha and Reddy, 2003). The investigation region (Kanchipuram District, Tamilnadu) covers agricultural exercises and is situated close to the beach front locale. Most of the individuals here use ground water both for drinking and water system purposes. Thus, this examination forms the baseline attempt on the geochemistry of ground water reasonableness for drinking and agrarian purposes in the investigation territory. Hence, the principal goal of the current work is (i) to gauge the water quality boundaries, for example, pH, total dissolved solids (TDS), electrical conductivity (EC), chloride (Cl), sulphate (SO_4), calcium (Ca), magnesium (Mg), nitrate (NO_3), sodium (Na), potassium (K), carbonate (CO_3) and hydrogen carbonate (HCO_3) in ground water tests of Kanchipuram District of Tamilnadu, India utilising different analytical techniques, (ii) to contrast the normal estimations of boundaries and guidelines of WHO (2004) and BIS (2012) and (iii) to contemplate the relationships between water quality boundaries, by multivariate statistical methods.

Study Area

Kanchipuram region (Figure 1) is arranged on the north east shore of Tamil Nadu and lies between 11° 00’ to 12° 00’ north and 77° 28’ to 78° 50’ east.

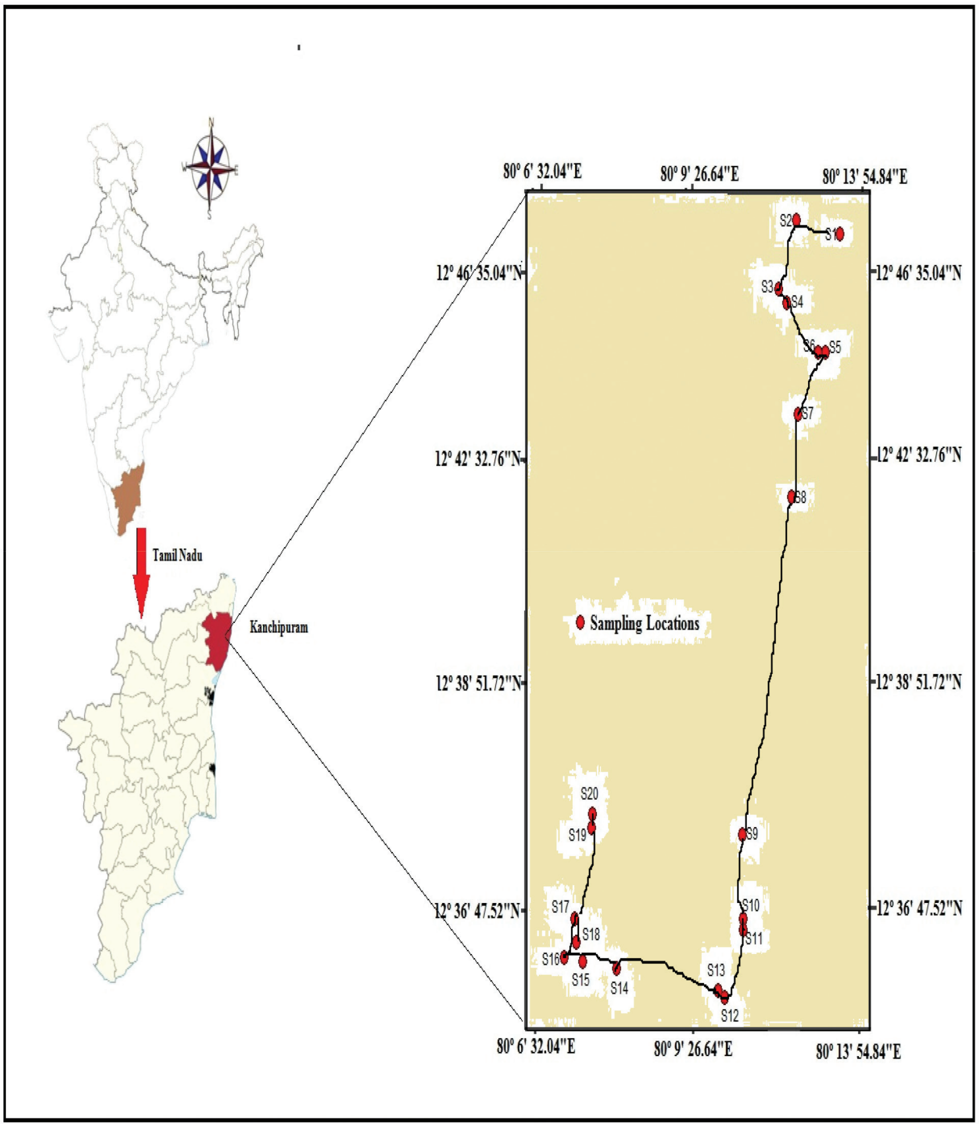

Figure 1: Ground water sampling locations, Kanchipuram district, Tamilnadu.

The region covers a complete geological zone of 4393.37 Km^2 and a coastline of 57 Km. The pre-storm precipitation is practically uniform all through the locale. The seaside taluks get a bigger number of downpours instead of the inside locales. This area is for the most part contingent upon the occasional downpours; the miserable conditions win in case of the disappointment of downpours. Northeast and southwest rainstorm contribute individually to the all-out yearly precipitation. The typical precipitation of the locale has been 1213.3 mm and real precipitation has been 1133 mm. The months between April and June are commonly hot with temperatures going up to a normal limit of 36.6ºC. In winter (December-January) the normal least temperature is 19.8ºC. Granite rock, stone quarry, sand quarry, silica sand and mud are the minerals accessible in the Kanchipuram locale.

Material and Methods

Sample Collection and Preparation

A groundwater test was gathered from 20 areas in Kanchipuram locale, Tamilnadu from physically worked hand-siphons during the long stretch of March-April (Pre storm PRM) of the year 2017 in cleaned and screw topped polyethylene bottles. The ground water tests from the gathered areas is shown in Figure 1 and Table 1 and gives the topographical data of different areas in the Kanchipuram District, Tamilnadu.

Sample Analysis

The water tests are examined for different physicochemical boundaries as per the principal strategies suggested by American Public Health Association (APHA). Field boundaries, for example, electrical conductivity (EC), pH and temperature were estimated in the field utilising convenient meters. Total dissolved solids (TDS) were controlled by the evaporation method (Rowell, 1994). Sulphate (SO_4) examinations of the water tests were done utilizing a spectrophotometer (Fetter, 1990). Carbonate (CO_3), bicarbonate (HCO_3), calcium (Ca) and magnesium (Mg) were detected by volumetric strategies. Sodium (Na) and potassium (K) were resolved by utilising a flame photometer.

Table 1: Geographical information of ground water locations, Kanchipuram District, Tamilnadu

Sample Id	*Locations*	*Latitude*	*Longitude*
WS-1	Thaiyur-I	12˚46’22.6776”N	80˚12’25.4988”E
WS-2	Thaiyur-II	12˚46’32.736”N	80˚11’29.1084”E
WS-3	Koman Nagar-I	12˚45’42.1452”N	80˚11’5.7012”E
WS-4	Koman Nagar-II	12˚45’31.41”N	80˚11’16.0944”E
WS-5	Kalavakkam-I	12˚44’55.0356”N	80˚12’6.5916”E
WS-6	Kalavakkam-II	12˚44’54.924”N	80˚11’56.4144”E
WS-7	Kannagapattu	12˚44’8.9448”N	80˚11’31.2144”E
WS-8	Tiruporur	12˚43’7.7988”N	80˚11’22.6392”E
WS-9	Paiyanoor	12˚38’58.3656”N	80˚10’18.3324”E
WS-10	Koothavakkam-I	12˚37’57.0648”N	80˚10’19.9524”E
WS-11	Koothavakkam-II	12˚37’48.4176”N	80˚10’20.2332”E
WS-12	Poonjeri-I	12˚36’58.7772”N	80˚9’55.2996”E
WS-13	Poonjeri-II	12˚36’59.9292”N	80˚9’54.306”E
WS-14	Vadakadampadi	12˚37’20.082”N	80˚7’35.832”E
WS -15	Kuzhipanthandalam	12˚37’25.4064”N	80˚6’52.3512”E
WS-16	Eitchur	12˚37’28.1676”N	80˚6’27.5328”E
WS-17	Azhagunattham-I	12˚37’56.4996”N	80˚6’41.4396”E
WS-18	Azhagunattham-II	12˚37’39.376”N	80˚6’43.6032”E
WS-19	Amayapattu	12˚39’4.266”N	80˚7’3.9576”E
WS-20	Siruthavoor	12˚39’14.292”N	80˚7’4.4184”E

Statistical Analysis

The statistical investigation was performed by SPSS version 16.0. The correlation coefficient is normally used to gauge the connection between two factors. It is a measure to show how well one variable predicts the conduct of the other. Principal component and cluster analyses uphold the presence of the after-effects of relationship investigation.

Results and Discussion

Water Quality Boundaries

Concentration of Calcium (Ca^{2+}) and Magnesium (Mg^{2+})

Calcium (Ca^{2+}) ion concentration in the post-storm changes from 40 to 208 mg L^{-1} with a normal of 87.20 while magnesium (Mg^{2+}) ion concentration in the post-rainstorm shifts from 2.4 to 51.6 mg/L with a normal of 15.48. This shows a normal estimation of Ca^{2+} and Mg^{2+} exists similar to the suggested mandate of WHO (2004) and BIS (2012). In accordance with the local standards and regulations, the ground water in this region has been protected and maintained for human utilisation. The significant wellspring of Ca^{2+} in the groundwater is because of the ion exchange of minerals from rocks of this territory. Further, this may likewise be because of the presence of $CaCO_3$, $CaSO_4$, CaMg $(CO_3)_2$ minerals and soils in water (Annapurna and Janardhana, 2015).

Concentration of Sodium (Na^+) and Potassium (K^+)

Excess of Na^+ causes hypertension, amicable ailments, kidney issues and nerve issues in the human body (Ramesh and Elango, 2011). As indicated by Hem (1985), high estimations of Na+ in groundwater may either be because of the compound enduring of feldspars or over misuse of groundwater assets (Hem, 1985). In the current examination, all the groundwater tests show a grouping of Na^+ beneath reasonable breaking points (WHO, 2004). K^+ concentration in groundwater ranges from 1.2 to 15 mg L^{-1} with a normal estimation of 6.40 mg/L and there is no danger from K^+ in groundwater (Annapurna and Janardhana, 2015).

Concentration of Chlorine (Cl^-)

A concentration of Cl^- in groundwater changes from 70.9 to 363.3 mg/L with an average of 249.73 mg L^{-1}. The alluring furthest reaches of Cl^- for drinking water is determined as 200 mg L^{-1} according to WHO (2004) and tests WS3, WS4, WS6, WS7, WS8, WS11, WS12, WS13, WS16, WS17, and WS18 are over this cut-off. Chlorides are innocuous at low levels, however, at levels higher than 200 mg L^{-1}, it causes smell and pungent taste may lead to irritating heart issues also adding to hypertension. The concentration of Cl^- in groundwater is high because of home-grown wastages or potentially filtering from upper soil layers in dry atmospheres (Srinivasamoorthy et al., 2008).

Concentration of CO_3^{2-} and HCO_3^{2-}

The CO_3^{2-} content is found to be fluctuating from 0 to 84 mg/L whereas HCO_3^{2-} is the prevailing anion and the concentration shift from 21.4 to 244 mg L^{-1} with an average of 110.12 mg L^{-1}. The most extreme admissible cut-off for HCO_3^{2-} the focus is discovered to be 125-350 mg L^{-1}, thus the groundwater from the examination territory is reasonable for drinking purposes (WHO, 2004).

Concentration of SO_4^{2-} and NO_3^-

As observed from Table 2, SO_4^{2-} ions range from 0.65 to 33.77 mg L^{-1} with an average of 9.66 mg/L, and all examples are underneath the most permissible limit of 200 mg/L (WHO, 2004). Tests with higher concentrations of SO_4^{2-}in drinking water are related to respiratory issues (Subramani et al., 2010). NO^{3-} concentration in the examination zone ranges from 55.29 to 135.7 mg L^{-1} with an average of 83.53 mg L^{-1}. All examples are over the allowable furthest reaches of 50 mg L^{-1} according to WHO (2004). The concentration of NO^{3-} is high because of the decaying organic issue, sewage and compost from rural spill over (Karnath, 1987). Higher concentration of NO^{3-} can cause methaemoglobinaemia, gastric malignancy, goitre, birth deformity and hypertension.

Concentration of pH, TDS and EC

Table 2 gives the measured water quality boundaries in tests which shows that the pH esteem went from 6.8 to 8.2 with an average estimation of 7.41. This demonstrates that water tests are soluble in nature and inside the endorsed furthest reaches of WHO (2004) and BIS (2012). Alkalinity is regularly identified with hardness because the fundamental wellspring of alkalinity is carbonate rocks (limestone) which are generally formed from $CaCo_3$.

TDS ranges from 759.2 to 1748.38 µS cm^{-1} with an average of 1351.12 µS cm^{-1} and EC shifts from 418.69 to 1051.76 mg L^{-1} with an average of 797.5 mg L^{-1}. These average estimations of EC and TDS were less than the limits mentioned by WHO (2004) and BIS (2012). Water with high TDS is of substandard acceptability and may actuate a horrible physiological response in the transient consumers and gastrointestinal

Table 2: Determined ground water quality boundaries of Kanchipuram district, *Tamilnadu*

Sample Id	*Locations*	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	CO_3^{-}	HCO_3^{-}	NO_3^{-}	SO_4^{2-}	*pH*	*EC*	*TDS*
		mg/L	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*	*mg/L*		*mg/L*	*µS/cm*
WS-1	Thaiyur-I	102	2.4	50.5	5.7	124.08	24	46.1	105.92	11.04	7.9	574.74	1003.02
WS-2	Thaiyur-II	78	37.2	69.5	2.2	179.76	24	146	55.29	5.79	7.6	700.74	1199.91
WS-3	Koman Nagar-I	208	4.8	67.3	4.5	330.19	18	31.1	74.08	17.34	7.3	858.31	1446.11
WS-4	Koman Nagar-II	88	20.4	184.7	2.9	310.19	84	163	56.23	18.58	8.2	1031.00	1715.93
WS-5	Kalavakkam-I	40	6	100.6	4.1	194.98	48	93.6	75.03	12.82	7.5	678.13	1164.57
WS-6	Kalavakkam-II	52	3.6	185.3	1.2	363.36	0	134.2	62.78	3.05	7.2	908.49	1524.52
WS-7	Kannagapattu	68	15.6	199.4	10.1	327.91	0	231.8	85.46	10.49	6.9	1051.76	1748.38
WS-8	Tiruporur	46	8.4	193.5	4.6	298.81	0	170.8	110.39	16.91	7.1	952.41	1593.14
WS-9	Paiyanoor	170	4.8	79.3	8.8	198.81	72	134.4	106.53	29.16	8.1	906.80	1521.88
WS-10	Koothavakkam-I	60	20.4	68	4.2	138.63	24	45.6	113.29	0.65	7.2	577.77	1007.76
WS-11	Koothavakkam-II	168	28.8	84	11.8	362.04	30	57.4	73.14	2.32	7.8	920.50	1543.28
WS-12	Poonjeri-I	128	20.4	92.7	9.1	336.78	0	122	112.32	6.47	7.1	930.77	1559.32
WS-13	Poonjeri-II	134	51.6	51.7	10.8	315.21	0	134.2	82.61	4.03	6.9	887.15	1491.18
WS-14	Vadakadampadi	40	13.2	87.8	12.9	124.08	0	244	63.72	1	7.4	689.70	1182.65
WS- 15	Kuzhipanthandalam	50	12	79.4	5.6	186.35	48	94.2	72.2	3.16	7.6	653.91	1126.73
WS-16	Eitchur	102	37.2	68.7	4.4	299.53	12	21.4	66.54	5.84	7.4	720.61	1230.95
WS-17	Azhagunattham-I	52	9.6	188.4	5.4	301.33	0	97.6	135.7	5.2	6.8	898.23	1508.48
WS-18	Azhagunattham-II	68	6	192.3	2.2	354.50	0	122	71.25	3.68	7.1	922.93	1547.08
WS-19	Amayapattu	50	3.6	114	15	177.25	36	67.6	67.48	33.77	7.7	667.70	1148.28
WS-20	Siruthavoor	40	3.6	46.7	2.5	70.90	24	45.4	80.71	1.88	7.3	418.69	759.20
Mean		87.20	15.48	110.19	6.40	249.73	22.20	110.12	83.53	9.66	7.41	797.52	1351.12

disturbance. Normally happening absolute broken up solids emerge from the enduring and disintegration of rocks and soils. In this examination, a comparison of the determined ground water quality boundaries of Kanchipuram area, Tamilnadu was performed with the reasonable restriction guidelines provided by WHO (2004) and BIS (2012), which has been listed in Tables 2 and 3.

Pearson Correlation Analysis

Pearson correlation analysis is a bivariate technique applied to depict the level of relation between hydro compound boundaries. The correlation coefficient is a proportion of the direct relationship between two factors. The coefficient ranges from −1 to 1 where −1 depicts a relationship where an expansion in one variable is joined by an anticipated and reliable reduction in the other, 0 portrays an irregular or non-existent relationship and +1 depicts a relationship where an expansion in one variable is joined by an anticipated and predictable increment in the other. If one variable will in general increase and the other decrease the correlation coefficient is negative. On the other hand, if the two factors will in general increase together, the correlation coefficient is positive. Connection estimations of −1 or 1 infer a definite direct relationship among the factors (Oorkavalan et al., 2016). Table 4 gives the correlation coefficients between the groundwater quality boundaries. As observed from Table 4, a great positive relationship exists between Cl–Na, HCO^{3-}Na, HCO^{3-}Na, TDS-Na, EC-Na, TDS-Cl, EC-Cl,

Table 3: Comparison of average water quality boundaries with permissible limit of WHO (2004) and BIS (2012)

Sample No.	*Water quality parameters*	*WHO (2004)*	*BIS (2012)*	*Minimum*	*Maximum*	*Average*
1	Ca^{2+} (mg/L)	75	75-200	40	208	87.20
2	Mg^{2+} (mg/L)	30	30-100	2.4	51.6	15.48
3	Na^{+} (mg/L)	200	200	46.7	199.4	110.19
4	K^{+} (mg/L)	20	-	1.2	15	6.40
5	Cl^{-} (mg/L)	200	250-1000	70.9	363.3	249.73
6	CO_3 (mg/L)	-	-	0	84	22.20
7	HCO_3^- (mg/L)	125-350	-	21.4	244	110.12
8	NO_3^- (mg/L)	50	45	55.2	135.7	83.53
9	SO_4^{2-} (mg/L)	200	200-400	0.65	33.77	9.66
10	pH	6.5-8.5	6.5-8.5	6.8	8.2	7.41
11	TDS (mg/L)	500-1000	500-2000	418.6	1051.7	797.52
12	EC (µS/cm)	1400	-	759.2	1748.3	1351.12

Table 4: Pearson correlation analysis of ground water quality boundaries

Variables	*Ca^{2+}*	*Mg^{2+}*	*Na^{+}*	*K^{+}*	*Cl^{+}*	*CO_3^-*	*HCO_3^-*	*NO_3^-*	*SO_4^{2-}*	*pH*	*TDS*	*EC*
Ca^{2+}	1											
Mg^{2+}	0.258	1										
Na^{+}	-0.370	-0.295	1									
K^{+}	0.204	0.153	-0.178	1								
Cl^{+}	0.386	0.242	**0.555**	-0.039	1							
CO_3^-	0.158	-0.137	-0.177	-0.063	-0.293	1						
HCO_3^-	-0.282	0.054	**0.513**	0.226	0.145	-0.159	1					
NO_3^-	0.048	-0.200	0.069	0.056	-0.036	-0.218	-0.113	1				
SO_4^{2-}	0.223	-0.355	0.122	0.288	-0.037	**0.511**	-0.002	0.022	1			
pH	0.245	-0.127	-0.282	0.055	-0.320	**0.854**	-0.155	-0.342	0.470	1		
TDS	0.346	0.149	**0.675**	0.112	**0.865**	-0.098	0.502	0.062	0.194	-0.156	1	
EC	0.346	0.149	**0.675**	0.112	**0.865**	-0.098	0.502	0.062	0.194	-0.156	1	1

particularly, Cl shows a great positive connection with Na demonstrating disintegration, filtering of optional salts alongside anthropogenic exercises (Thilagavathi, et al., 2012). Poor positive connection of Ca^{2+} with all different ions shows the lesser chance of anthropogenic influence in the water bodies.

Principal Component Analysis

The principal component examinations which incorporate the rotated component matrix, and the percent and total percent of difference clarified by every component of ground water information are given in Table 5. The arrangement of components controls the extent of difference of every factor. From Table 5 and Figure 2, it is very well seen that the initial two principal together record for 44.33% of the complete change in the informational collection, in which the primary head principal clarifies 26.77% of the all-out variance, and the second head principal displays 17.56% of the all-out variance. Since the estimations of mutuality are seen to be high (0.551–0.841) for all the 12 chemical factors and the eigenvalues of the initial two principal parts are more than unity, these two components can be utilised to evaluate the predominant hydro geochemical measures, without losing any noteworthy attributes. The concentrations of Na^+, Cl^-, HCO_3^-, TDS and EC show high sure loadings (0.551–0.841), on the primary head part. On the second head component, Ca^{2+} concentrations have high certain loadings (0.831). The blends of TDS, EC and Cl^- ions affecting the high certain loadings seen on the first and second head component (Table 5), propose that the main principal component is related with a mix of different hydro geochemical measures that add to improve more mineralized water (TDS). For example, a high certain stacking of Na^+ ions proposes a level of ion exchange on the clay materials present in the zone, which is started by the invading waters through the dirt zone, as is recommended by Hem (1991). The relationship of principal component scores between the first and second principal components is represented in Figure 2.

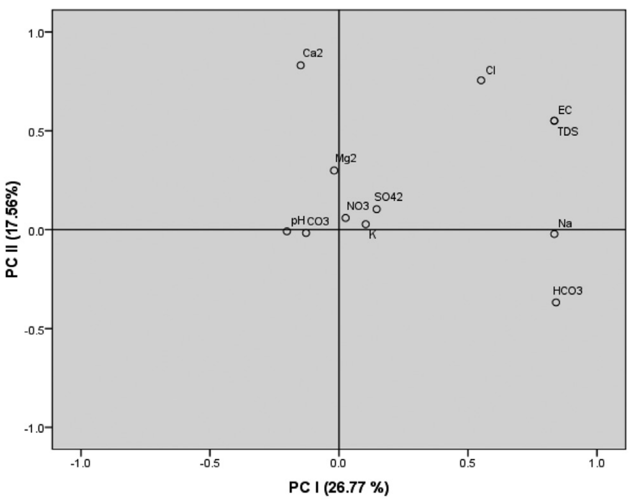

Figure 2: Rotated principal components of ground water quality boundaries.

Table 5: Principal component analysis of ground water quality boundaries

Variables	*PC I*	*PC II*
Ca^{2+}	-0.148	0.831
Mg^{2+}	-0.019	0.299
Na^+	0.835	-0.022
K^+	0.104	0.028
Cl^+	0.551	0.755
CO_3^-	-0.128	-0.017
HCO_3^-	0.841	-0.368
NO_3^-	0.026	0.059
SO_4^{2-}	0.146	0.103
pH	-0.202	-0.008
TDS	0.834	0.551
EC	0.834	0.551
% of variance explained	26.77	17.56

Cluster Analysis

Cluster analysis is utilised for gathering the factors dependent on the comparability of the reactions to a few factors. Based on the interfacing separations among boundaries and their situations on the dendrogram, unmistakable clusters of the factors were characterised. Cluster analysis is a helpful strategy for consolidating groundwater wells into homogenous gatherings as per their water quality (Venkatramanan et al., 2013). Cluster analysis manages to partition the information into clusters dependent on the data found on the information. Additionally, Johnson (1967) presented the strategy for hierarchical clustering which helps in recognising gatherings or clusters in the enormous gathering of information. In this technique, the groups are shaped by utilising various parameters dependent on the similitudes found on the information. The comparability is analysed by the "Euclidean separation" between the parameters.

In this investigation, two clusters were shaped by the ground water quality boundaries and shown in Figure 3. Cluster I shapes because of concentration of pH, chloride (Cl), sulphate (SO_4), calcium (Ca), magnesium (Mg), nitrate (NO_3), sodium (Na), potassium

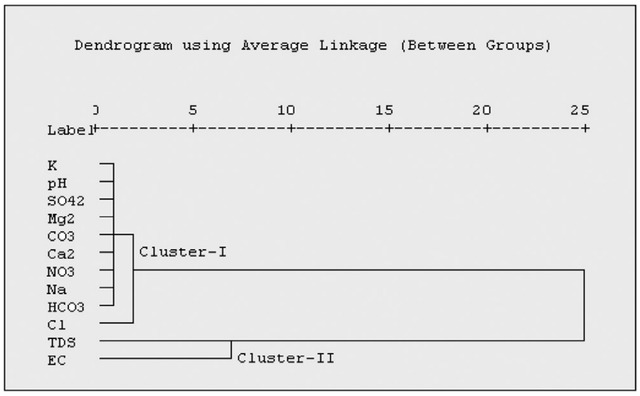

Figure 3: Clustering of ground water quality boundaries.

(K), carbonate (CO_3), hydrogen carbonate (HCO_3) and Cluster II frames just because of total dissolved solids (TDS), and electrical conductivity (EC). This concludes that all the significant boundaries could be shaped in different groups depending upon the similar nature of the water tests obtained.

Conclusion

In the Kanchipuram region of Tamil Nadu, the ground water quality was investigated utilising different boundaries. The average estimations of these boundaries show that nature of the ground water is acceptable and reasonable for drinking and agricultural exercises. Although there are few water quality boundaries, it was noted that ground water could not be utilised directly. Particularly, the examples WS3, WS4, WS6, WS7, WS8, WS11, WS12, WS13, WS16, WS17, and WS18 show marginally more noteworthy Cl^- content which is because of home-grown wastages and additionally filtering from upper soil layers in dry atmospheres. Additionally, NO^{3-} concentration in the investigation zone were found to be greater than the maximum allowed limit of 50 mg L^{-1} according to WHO (2004). This somewhat high concentration of NO_3^- is because of the decaying organic issue, sewage and manure from the farming overflow in the examination zone. From the Pearson correlation, it is realised that Cl^- shows a great positive correlation with Na demonstrating dissolution, draining of optional salts alongside anthropogenic exercises. Cluster investigation shows that, nature of ground water is practically same in the examination region.

Conflict of Interests

No conflict of interest was reported by the authors.

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