Research Article

Assessment of Groundwater Quality along the Cooum River, Chennai, Tamil Nadu, India

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Groundwater quality in Chennai city along the Cooum river, during the premonsoon (June–July) and postmonsoon (Dec–Jan) for three years, from 2009 to 2011, was analyzed. Groundwater samples were collected from 20 bore wells on either side of the river. The analysis focused on the determination of seven specific water quality parameters, namely, pH, EC, TDS, BOD, COD, Na and Pb, using standard procedures. The statistical analysis, like the mean and standard deviation, coefficient of variance, and correlation, and multilinear regression analysis of the obtained data were carried out. The analysis of the collected samples reveals that the stated water quality parameters have not complied with the WHO standards, and the water is not fit for drinking and domestic purposes. The correlation and multilinear regression analyses suggest that the conductivity has a significant correlation with the other six considered water quality parameters.

1. Introduction

Groundwater is a natural precious resource that sustains the basic needs of all living creatures. It cannot be created or supplemented electronically or hydrologically or by any other means [1, 2]. People living on earth suffer without potable water, though the earth is covered by 75% of water. Groundwater serves as a vital source for domestic, agricultural, and industrial uses [3, 4]. In Chennai city, the growing urbanization and rapid industrialization lead to the generation of huge quantities of waste water. The uncontrolled discharge of sewage, garbage, and industrial effluents into the downstream of the Cooum river, percolates through the soil and contaminates the Groundwater sources. As per the WHO [5], about 80% of all the diseases in human beings are caused by impure water. The Cooum river originates in Tiruvallur district, traversing about 70 km and ends in Chennai city, draining into the Bay of Bengal. Of this 16 km, the study area falls within Chennai city. In Chennai district, the river flows through three corporation zones, namely, Kilpauk, Nungambakkam, and Triplicane.

The Cooum river is 80% more polluted than the treated sewage [6]. Hence, a periodic assessment of the Groundwater becomes necessary to ensure the suitability of water for drinking. Considering these aspects, the present study focuses on analyzing the specific water quality parameters of some groundwater samples on either side of the Cooum river within the city limits as shown in Figure 1.

2. Experimental

2.1. Study Area. The study area, along the Cooum river in Chennai district of Tamil Nadu, India, lies between latitude 13° 4' 5.18" north and longitude 80° 17' 9.06" east. The Cooum river is the starting point where the municipalities and town Panchayats that lie on either side of the river discharge both treated and untreated industrial effluents and domestic sewage in addition to the bathing of animals, human activities, washing of vehicles directly or by feeder drains into the 16 km length of the Cooum river [7]. People living near this area depend on bore wells for their daily requirement. The literature survey reveals that no Groundwater studies on bore

TABLE 1: Detail of sample sites along the left side (SL) of the Cooum river.

Site no.	Area	Latitude/longitude	Depth of bore well (m)	Apparent water quality
SL1	Arumbakkam	13° 4' 30.8'' N 80° 12' 29.43'' E	33	Odorless, colorless
SL2	Nungambakkam	13° 3' 57.27'' N 80° 13' 56.37'' E	34	Odorless, colorless
SL3	Chintadripet	13° 80' 14' 55'' N 42° 3' 59.60'' E	34	Odorless, colorless
SL4	Chintadripet	13° 4' 20.64'' N 80° 16' 11.27'' E	35	Odorless, colorless
SL5	Nungambakkam,	13° 3' 32.72'' N 80° 14' 15.82'' E	33	Odorless, colorless
SL6	MMDA Colony	13° 3' 59.42'' N 80° 12' 49.54'' E	35	Odorless, colorless
SL7	Choolaimedu	13° 3' 34.67'' N 80° 13' 32.62'' E	33	Odorless, colorless
SL8	Chinmaya Nagar	13° 3' 42.89'' N 80° 11' 44.15'' E	34	Odorless, colorless
SL9	Vadapalani	13° 3' 23.42'' N 80° 12' 20.09'' E	33	Odorless, colorless
SL10	Gopalapuram	13° 3' 2.11'' N 80° 15' 22.76'' E	32	Turns yellowish

TABLE 2: Detail of sample sites along the right side (SR) of the Cooum river.

Site no.	Area	Latitude/longitude	Depth of bore well (m)	Apparent water quality
SR1	Aayiram Vilakku	13° 3' 59.72'' N 80° 15' 28.38'' E	34	Odorless, colorless
SR2	Anna Salai	13° 4' 27.13'' N 80° 16' 51.48'' E	33	Odorless, colorless
SR3	Anna Nagar	13° 4' 49.15'' N 80° 12' 16.12'' E	33	Odorless, colorless
SR4	Anna Nagar East	13° 5' 9.70'' N 80° 13' 13.17'' E	33	Odorless, colorless
SR5	Periamet	13° 4' 55.95'' N 80° 16' 8.52'' E	34	Odorless, colorless
SR6	Anna Nagar	13° 5' 13.13'' N 80° 12' 12.63'' E	33	Odorless, colorless
SR7	Kilpauk	13° 4' 53.24'' N 80° 14' 3.17'' E	33	Odorless, colorless
SR8	Egmore	13° 4' 30.59'' N 80° 15' 1.62'' E	32	Odorless, colorless
SR9	Periamet	13° 4' 52.49'' N 80° 15' 33.47'' E	33	Odorless, colorless
SR10	Purasavakkam	13° 5' 15.12'' N 80° 14' 50.71'' E	32	Odorless, colorless

FIGURE 1: A map showing sampling locations along the Cooum river.

wells close to the river were done so far. Hence, the study has been carried out on 20 different sites that cover the area of 16×2 km, which includes 10 sites on the left side of the river and 10 sites on the right side of the river, to assess the impact of the percolation of the river water flow on the Groundwater. The location of the sample sites was given in Tables 1 and 2.

2.2. Collection of Samples. Water samples were collected from the bore wells at a depth of 32–35 m below the ground level at 20 locations along the Cooum river. Two water samples were collected per year per sampling station covering both pre- and postmonsoon seasons. A total of 120 samples were tested and analyzed for a period of three years (2009–2011).

The collected samples were stored in cleaned and well-dried brown polythene glass bottles (2.5 L), with necessary precautions (APHA, 1995) [8]. These bottles were labeled with respect to the collecting points, date, and time in order to avoid any error between collection and analysis. All the sample collections were immediately preserved in an icebox and brought to the laboratory for determining the specific water quality parameters.

2.3. Sample Analysis. The collected samples were analyzed for specific water quality parameters such as pH, electrical conductivity (EC), total dissolved solids (TDS), biochemical oxygen demand (BOD), chemical oxygen demand (COD),

TABLE 3: Methods used for analysis of quality parameters for the water samples.

Quality parameters studied	Methods used
pH	pH meter
Electrical conductivity	Conductivity meter
Total dissolved solids	Evaporation method
Biochemical oxygen demand	Modified Winkler's method
Chemical oxygen demand	Titrated with an excess of $K_2Cr_2O_7$
Sodium	Flame photometry
Lead	Atomic absorption spectrometry

sodium (Na), and lead (Pb) using standard methods as tabulated in Table 3. The World Health Organisation (WHO) permissible limit of drinking water quality parameters were specified in Table 4. The observed values of the above specified water quality parameters along the left and right sides of the river were shown in Figures 2(a)–8(a) and 2(b)–8(b) for the pre- and postmonsoon seasons. Tables 5 and 6 summarize the maximum, minimum, mean, and standard deviations and coefficient of variance (CV%) found in the different Groundwater samples for the pre- and postmonsoon seasons respectively. The correlation and multi linear regression analyses have also been carried out to find the correlation between the water quality parameters and are listed in Tables 7 and 8.

3. Results and Discussion

3.1. pH. pH is a measure of the concentration of hydrogen ions (H^+) in water. Water with a pH value below 7 is said to be acidic, and water with a pH value above 7 is basic or alkaline in nature [9, 10]. For fish and aquatic life, the protection limit of the pH ranges from 6.0 to 9.0. The experimental values of the water samples were found to be between 6.71 and 8.31 during the premonsoon and between 6.6 and 7.7 during postmonsoon which are within the prescribed limit as suggested by WHO (Figures 2(a) and 2(b)). This shows that the pH of the water samples would not affect the domestic and aquatic system. The high pH value during the premonsoon indicates the surface water contamination resulting from the penetration into the Groundwater. The mean value of pH up to 7.548 ± 0.36026 and 7.2545 ± 0.284225 during the pre- and postmonsoon seasons indicates slight alkalinity nature, presumably due to the seepage of waste water from domestic use and industries. The maximum variance value during the premonsoon $CV\% = 5.948777$ was found to be higher than that of the postmonsoon season, that is, $CV\% = 4.050786$.

3.2. EC. Electrical conductivity is a measure of concentration of ionized substances that convey electric current in water [11]. The higher EC indicates how strong is current flow based on the amount of total dissolved salts. In the present study EC values were found within the range of $498\text{--}2371\ \mu S/cm$

TABLE 4: Water quality parameters with respect to the WHO standards.

S. no	Parameter	WHO
1	pH	7.0–8.5
2	Electrical conductivity (EC) ($\mu S/cm$)	1400
3	Total dissolved solids (mg/L)	1000
4	Bio chemical oxygen demand (BOD) (mg/L)	5
5	Chemical oxygen demand (COD) (mg/L)	10
6	Sodium (mg/L)	200
7	Lead	0.01

and $508\text{--}2207\ \mu S/cm$ during pre- and postmonsoon seasons (Figures 3(a) and 3(b)). The mean $SR1\text{--}SR10$ for the pre- and postmonsoon of 2009–2011 value of EC upto $1523.75 \pm 559.89\ \mu S/cm$ and $1490.05 \pm 465.66\ \mu S/cm$ during pre- and postmonsoon shows that the higher concentration of EC was due to the higher amount of TDS. The analysis of the study period from 2009 to 2011 shows the increasing level of EC that enhances the level of the ionized substances of the water. The maximum variance value during premonsoon $CV\% = 42.11$ was found to be higher than that of the postmonsoon season, that is, $CV\% = 33.3672$.

3.3. TDS. TDS is a measure of the combined concentration of cations and anions [12]. The major components of TDS include bicarbonate (HCO_3^-), sulphate (SO_4^{2-}), hydrogen (H^+), silica (SiO_4), chlorine (Cl^-), calcium (Ca^{+2}), magnesium (Mg^{+2}), sodium (Na^+), potassium (K^+), nitrates (NO_3^-), and phosphate (PO_4^{3-}). The TDS of the Groundwater is mainly due to the vegetable decay and the disposal of effluents from industries. The TDS values of the sampling sites varied from 987 to 2892 mg/L and 905 to 2716 mg/L during the pre- and postmonsoon seasons. The present investigation shows that all the samples exceeded the limit prescribed by WHO, except the sample of the site $SR10$ (Figures 4(a) and 4(b)). The mean values of the TDS were found to be $2073.5 \pm 585.85\ mg/L$ and $2007.3 \pm 581.92\ mg/L$ during the pre- and postmonsoon seasons. This reveals the high concentration of the TDS value during the premonsoon due to the evaporation of water. The Maximum variance value during the premonsoon $CV\% = 30.38904$ was found to be higher than that of the postmonsoon season that is, $CV\% = 30.64991$.

3.4. BOD. The BOD values indicate the amount of organic waste present in the water [13]. The analyzed BOD values varied from 4.24 to 8.56 mg/L and from 4.3 to 8.97 mg/L during the pre- and postmonssoons, indicating that the value of BOD is higher during the postmonsoon season, presumably due to the percolation of industrial effluents and domestic wastes into the Groundwater. The sampling sites $SL1$, $SL3$, $SL4$, $SR1\text{--}SR3$, $SR8$ showed higher BOD values than those permitted by WHO (Figures 5(a) and 5(b)). The mean

FIGURE 2: (a) Observations of pH in water from the sites SL1–SL10 for the pre- and postmonsoon of 2009–2011. (b) Observations of pH in water from the sites SR1–SR10 for the pre- and postmonsoon of 2009–2011.

FIGURE 3: (a) Observations of EC in water from the sites SL1–SL10 for the pre- and postmonsoon of 2009–2011. (b) Observations of EC in water from the sites SR1–SR10 for the pre- and postmonsoon of 2009–2011.

value of BOD was 6.8995 ± 1.34 mg/L and 6.755 ± 1.27 mg/L during the pre- and postmonssoons which shows the presence of soluble salts in the sampling sites. The maximum variance value during the premonsoon of CV% = 20.38 was found to be higher than the postmonsoon seasons CV% = 19.32.

3.5. COD. The COD level indicates the amount of toxicity in water [14]. The observed values of the COD in both the seasons from all the sampling sites were found to exceed the permissible limit (Figures 6(a) and 6(b)). The analyzed COD values of the sampling sites varied from 11.1 to 24.8 mg/L and from 10.3 to 24.6 mg/L for the pre- and postmonsoon seasons. The observed COD value was higher during premonsoon the season, presumably due to the decreased flow of water during this period. The mean value of 19.72 ± 3.9 mg/L and 18.645 ± 3.99 mg/L indicates that the COD values were above the desirable limit during the pre- and postmonsoon seasons. The maximum variance value during the premonsoon CV% = 20.3865 was found to be higher than the postmonsoon seasons CV% = 19.32. The analyzed COD values were found to be higher than the BOD values. This indicates the ample

presence of chemically oxidizable substances of which the majority are nonbiodegradable [15].

3.6. Na. The higher concentration of sodium in the Ground-water causes cardiovascular diseases and toxemia in pregnant women [16]. The sodium of the water samples collected lies in the range of 130–313 mg/L and 120–313 mg/L during the pre- and postmonsoon seasons. The mean values of 230 ± 57.54 mg/L and 216.3 ± 58.22 mg/L during the pre- and postmonsoon seasons show that domestic discharge may contribute to increase the sodium content through leaching [17]. The present analysis shows that the sampling points SL1–SL4, SR1–SR5, SR8, SR9 (Figures 7(a) and 7(b)) exceed the permissible value. The maximum variance value during the premonsoon of CV% = 25.01 was found lower than that of the postmonsoon season, that is, CV% = 28.14.

3.7. Pb. Lead (Pb) is a heavy metal gets into the environment through waste water or solid waste disposal. High concentration of lead causes kidney damage, bone damage, and nervous disorder [18]. The lead concentrations in

FIGURE 4: (a) Observations of TDS in water from the sites SL1–SL10 for the pre- and postmonsoons of 2009–2011. (b) Observations of TDS in water from the sites SR1–SR10 for the pre- and postmonsoon of 2009–2011.

FIGURE 5: (a) Observations of BOD in water from the sites SL1–SL10 for the pre- and postmonsoon of 2009–2011. (b) Observations of BOD in water from the sites SR1–SR10 for the pre- and postmonsoon of 2009–2011.

FIGURE 6: (a) Observations of COD in water from the sites SL1–SL10 for the pre- and postmonsoon of 2009–2011. (b) Observations of COD in water from the sites SR1–SR10 for the pre- and postmonsoon of 2009–2011.

the samples were found to be between 0.025 and 0.087 mg/L and between 0.03 and 0.083 mg/L for the pre- and postmonsoon seasons, respectively (Figures 8(a) and 8(b)). The present study shows that all the samples obtained from the adjoining bore wells were above the permissible limit;

the mean value of Pb is above the limit due to the seepage of the Cooum water into the Groundwater and indicates its toxicity during the pre- and postmonsoon of seasons (0.0642 ± 0.014 mg/L and 0.0578 ± 0.014 mg/L). The maximum variance found during the postmonsoon of CV% = 26.80

TABLE 5: Statistics of three years (2009–2011) groundwater quality data—premonsoon.

Parameter	Year	Premonsoon						
		pH	EC ($\mu\text{S}/\text{cm}$)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Na (mg/L)	Pb (mg/L)
Max	2009	8.31	2173	2677	8.34	24.2	287	0.081
	2010	8.26	2296	2713	8.35	24.6	303	0.083
	2011	8.3	2371	2892	8.56	24.8	313	0.087
Min	2009	6.85	498	987	4.39	13.3	130	0.025
	2010	6.71	631	1048	4.24	11.1	137	0.03
	2011	7.04	583	1010	4.64	11.8	150	0.036
Mean	2009	7.51	1355	1894.15	6.8135	18.73	219.75	0.0585
	2010	7.4185	1515.95	2029	6.74	18.755	226.55	0.055
	2011	7.548	1523.75	2073.5	6.8995	19.72	230	0.0642
Std.	2009	0.41391	570.724	575.614	1.27868	3.4278	53.18	0.01494
	2010	0.44131	536.77	577.915	1.37405	4.0111	55.006	0.014567
	2011	0.36026	559.887	585.852	1.34849	3.9107	57.544	0.014468
CV%	2009	5.51145	42.11985	30.38904	18.76686	18.30112	24.20023	25.53846
	2010	5.9487	35.40816	28.48275	20.3865	21.38683	25.40013	26.48545
	2011	4.7729	36.74402	28.25426	19.54475	19.83114	25.01913	22.53583

FIGURE 7: (a) Observations of Na in water from the sites SL1–SL10 for the pre- and postmonsoon of 2009–2011. (b) Observations of Na in water from the sites SL1–SL10 for the pre- and postmonsoon of 2009–2011.

FIGURE 8: (a) Observations of Pb in water from the sites SL1–SL10 for the pre- and postmonsoon of 2009–2011. (b) Observations of Pb in water from the sites SR1–SR10 for the pre- and postmonsoon of 2009–2011.

TABLE 6: Statistics of three years (2009–2011) groundwater quality data—postmonsoon.

Postmonsoon								
Parameter	Year	pH	EC ($\mu\text{S}/\text{cm}$)	TDS (mg/L)	BOD (mg/L)	COD (mg/L)	Na (mg/L)	Pb (mg/L)
Max	2009	7.7	2004	2605	8.97	23.7	313	0.081
	2010	7.7	2073	2673	8.39	24.3	300	0.08
	2011	7.75	2207	2716	8.25	24.6	310	0.083
Min	2009	6.7	508	905	4.3	10.3	120	0.03
	2010	6.6	557	981	4.37	10.9	127	0.03
	2011	6.7	567	993	4.46	11.3	133	0.03
Mean	2009	7.222	1358.1	1873.35	6.6555	17.365	207.45	0.0528
	2010	7.187	1422.35	1944.08	6.644	18.072	207.7	0.055
	2011	7.2545	1490.05	2007.3	6.755	18.645	216.3	0.0578
Std.	2009	0.2658	453.16	574.18	1.25741	3.9141	56.049	0.014152
	2010	0.29113	455.259	570.488	1.28389	3.987	58.448	0.01407
	2011	0.284225	465.6663	581.9234	1.268574	3.997562	58.22199	0.014413
CV%	2009	3.680421	33.3672	30.64991	18.8928	22.54017	27.01808	26.80303
	2010	4.050786	32.00752	29.34488	19.32405	22.06175	28.14059	25.58182
	2011	3.917913	31.25172	28.99036	18.77978	21.4404	26.91724	24.93599

TABLE 7: Correlation coefficient (r) for different water quality parameters—premonsoon.

Parameter	pH	EC	TDS	BOD	COD	Na	Pb
2009 premonsoon							
pH	1						
EC	0.251	1					
TDS	0.331	0.96	1				
BOD	0.217	0.831	0.785	1			
COD	0.226	0.867	0.884	0.668	1		
Na	0.449	0.926	0.895	0.878	0.768	1	
Pb	0.103	0.761	0.819	0.829	0.709	0.821	1
2010 premonsoon							
pH	1						
EC	0.437	1					
TDS	0.447	0.896	1				
BOD	0.192	0.782	0.900	1			
COD	0.442	0.911	0.863	0.762	1		
Na	0.238	0.811	0.941	0.932	0.731	1	
Pb	0.420	0.846	0.816	0.758	0.835	0.750	1
2011 premonsoon							
pH	1						
EC	0.191	1					
TDS	0.352	0.950	1				
BOD	0.185	0.876	0.859	1			
COD	0.229	0.896	0.873	0.764	1		
Na	0.370	0.896	0.947	0.888	0.767	1	
Pb	0.186	0.856	0.855	0.694	0.874	0.766	1

TABLE 8: Correlation coefficient (r) for different water quality parameters—postmonsoon.

Parameter	pH	EC	TDS	BOD	COD	Na	Pb
2009 postmonsoon							
pH	1						
EC	0.3	1					
TDS	0.412	0.975	1				
BOD	0.348	0.88	0.899	1			
COD	0.182	0.935	0.89	0.811	1		
Na	0.399	0.915	0.948	0.909	0.808	1	
Pb	0.084	0.832	0.78	0.676	0.827	0.748	1
2010 postmonsoon							
pH	1						
EC	0.363	1					
TDS	0.445	0.972	1				
BOD	0.405	0.884	0.921	1			
COD	0.244	0.933	0.893	0.829	1		
Na	0.333	0.846	0.886	0.809	0.762	1	
Pb	0.186	0.849	0.808	0.747	0.857	0.781	1
2011 postmonsoon							
pH	1						
EC	0.392	1					
TDS	0.325	0.974	1				
BOD	0.310	0.914	0.892	1			
COD	0.164	0.895	0.935	0.812	1		
Na	0.363	0.879	0.843	0.818	0.730	1	
Pb	0.167	0.821	0.846	0.723	0.853	0.734	1

was higher than that of the premonsoon season, that is, $CV\% = 26.48$.

3.8. Statistical Analysis. The statistical relationship between the water quality parameters was examined, through the analysis of the linear correlation method [19, 20]. The correlation coefficient r between two parameters, x and y , is determined using the following equation:

$$r = \frac{n \sum xy - \sum x \sum y}{\sqrt{[n \sum x^2 - (\sum x)^2] [n \sum y^2 - (\sum y)^2]}}, \quad (1)$$

where x = values of the x -variable; y = values of the y -variable; n = number of data points.

A positive correlation exists when an increase in the value of one parameter is associated with a corresponding increase in the value of another parameter. The correlation matrices for all the samples of three years during pre- and postmonsoon seasons are listed in Tables 7 and 8. According to the guidelines, the correlation is good if $r > 0.6$ and marginal if $0.47 < r < 0.6$. The conductivity shows a significant correlation with the other parameters, like TDS, BOD, COD, Na, Pb with ($r > 0.7610$) and ($r > 0.821$) during the pre- and postmonsoon seasons except the pH. The correlation between the pH and Na ($r > 0.278$) and ($r > 0.333$) during the pre- and postmonssoons indicates the level of bicarbonate and carbonate of sodium in the Groundwater

samples, and hence, the presence of alkalinity of the water [21]. The BOD and COD shows a good correlation with ($r > 0.668$) and ($r > 0.676$) during pre- and postmonssoons. The high degree of association between the TDS and Na ($r > 0.926$ & $r > 0.843$) during the pre- and postmonsoon seasons indicates the anthropogenic activities such as discharge of sewage, which percolates and mixes with Groundwater [22].

Multivariate methods like cluster analysis, factor analysis, principal component analysis, discriminant analysis, neuron net classification, and multiple regression analysis have been successfully used in water quality analysis without much loss of information to a reasonably manageable data set [23–25]. In the present study, the statistical multiple regression models have been used for predicting the correlation between the independent variables and the dependent variable. However, multiple regression is very sensitive to outliers, and models developed for one area may not be suitable for different area [26]. Despite its limitations, the multiple regression is used to evaluate Groundwater samples, since, it generates minimum data set of indicators and is also easy to implement and interpret [27]. The six selected independent variables pH, TDS, BOD, COD, Na, and Pb and a dependent variable EC were used as input data in the following multiple linear regression equation [28, 29]. Electrical conductivity is selected as a dependent variable based on the correlation analysis studies. The following equation predicts whether

TABLE 9: Regression equations based on analyzed parameters.

Year	Regression equation	R^2 value	F value
Premonsoon			
2009	$EC = 36.358 * pH + 0.807 * TDS + 107.888 * BOD + 24.851 * COD - 3.528 * Na + 6124.594 * Pb - 1231.212$	0.958	49.555
2010	$EC = 2.818 * pH + 0.211 * TDS - 94.336 * BOD + 71.715 * COD + 2.966 * Na + 6154.062 * Pb - 671.780$	0.892	17.981
2011	$EC = -184.985 * pH + 0.571 * TDS + 66.079 * BOD + 31.193 * COD + 0.332 * Na + 1575.589 * Pb + 487.066$	0.945	37.07
Postmonsoon			
2009	$EC = -86.422 * pH + 0.594 * TDS + 4.994 * BOD + 25.715 * COD - 0.229 * Na + 2456.061 * Pb + 306.783$	0.977	91.861
2010	$EC = -45.855 * pH + 0.683 * TDS - 30.021 * BOD + 25.132 * COD - 0.619 * Na + 3254.098 * Pb + 119.508$	0.969	67.6
2011	$EC = -17.058 * pH + 0.495 * TDS - 10.607 * BOD + 36.501 * COD - 0.134 * Na + 1181.900 * Pb - 476.028$	0.969	68.523

the dependent variable EC is related to more than one independent variable. Consider the following:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots \beta_n X_n, \quad (2)$$

where X_1 , X_2 , and X_n denotes the independent variable, Y stands for the dependent variable, β_0 represents the intercept β_1 , and β_n represents the regression coefficients of the variables.

The multilinear regression analysis was carried out by using the IBM Statistical Package for Social Science (SPSS) software. The estimated R^2 value and F values of this model are represented in Table 9. The high R^2 ($R^2 > 0.892$ & $R^2 > 0.969$) during the pre- and postmonsoon seasons indicates that the conductivity has a very good correlation with the other chosen parameters. The variance ratio of the F values is high indicating a significant correlation of EC with the other parameters.

4. Conclusion

The results of the study indicate that the bore wells in the adjoining areas of the Cooum river are highly polluted, and hence the groundwater of the study area is unfit for domestic use. The analysis in respect of seven parameters, namely, pH, EC, TDS, BOD, COD, Na, and Pb, reveals that more than 90% of the water samples have exceeded the drinking water permissible limit prescribed by the WHO, except the pH. The result of the correlation and multilinear regression analysis shows that the conductivity has high significant correlation with the other parameters. The concentrations of EC, TDS, COD, Na and Pb increased every consecutive year, compared to the first year of the study period. This indicates the increase in the pollution load due to the intrusion of domestic sewage and industrial effluents into the Groundwater. Hence, consistent monitoring measures are essential to assess the impact of the percolation of the wastewater, causing contamination of the groundwater

in the study area, and a preventive mechanism coupled with remedial measures is necessary for the benefit of mankind.

Conflict of Interests

The authors declare no conflict of interests or financial disclosures relevant to this paper.

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